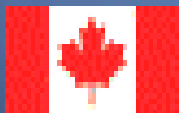


# *Simulating Water-borne Disease Transmission Among Salmon Farms in the Discovery Islands, Canada*

*Mike Foreman<sup>1</sup>, Kyle Garver<sup>2</sup>, Dario Stucchi<sup>1</sup>,  
Ming Guo<sup>1</sup>, Peter Chandler<sup>1</sup>,  
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*<sup>1</sup>Institute of Ocean Sciences, Sidney, BC*

*<sup>2</sup>Pacific Biological Station, Nanaimo, BC*

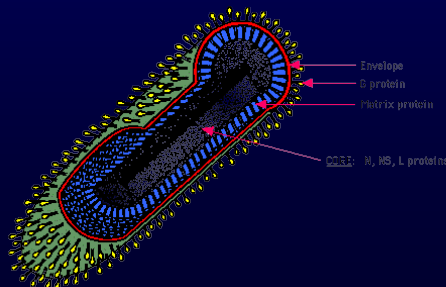


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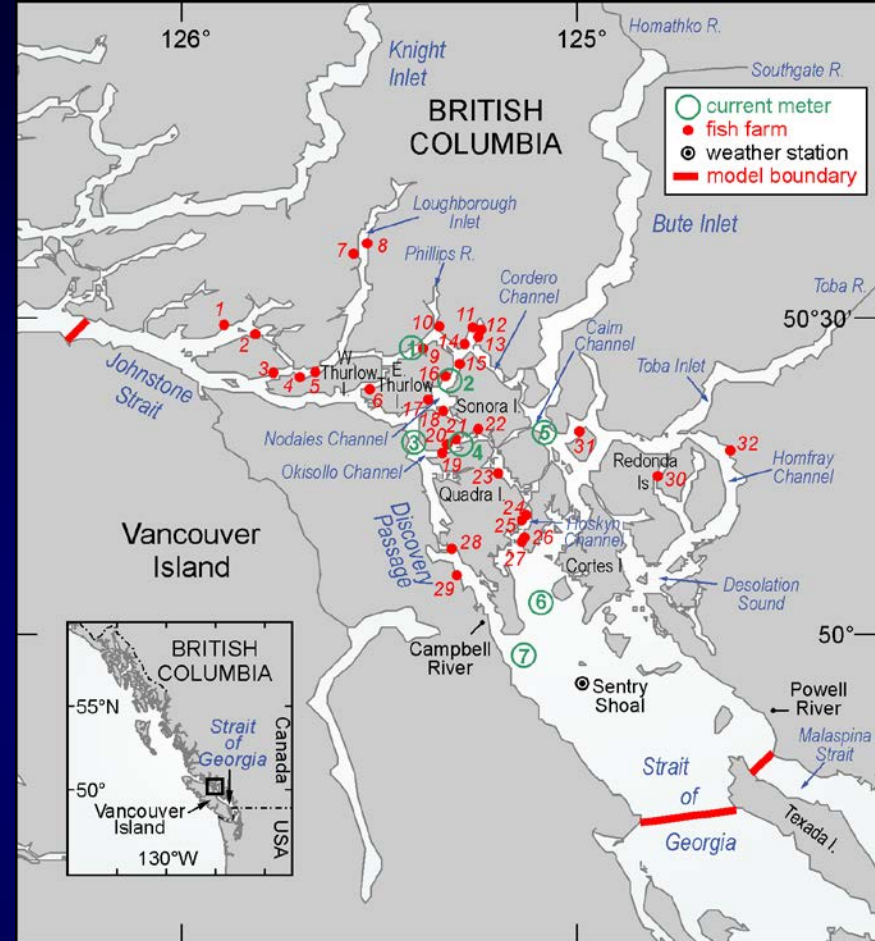
# *Infectious Hematopoietic Necrosis Virus (IHNV)*

- Infects salmon and trout species in western North America*
- In British Columbia, first IHNV detections were in rainbow trout and sockeye salmon 45 years ago*
- Since then, IHNV predominantly occurred in wild sockeye salmon & farmed Atlantic salmon.*



# Project Motivation

- In 2001-02, IHNV disease outbreaks occurred in 14 Discovery Islands salmon farms*
- Water-borne transport may have played a role in transmission between farms*
  - Poor bio-security also important*
- Can high resolution ocean circulation and particle tracking models be used to study and predict this transport & assist in aquaculture management?*



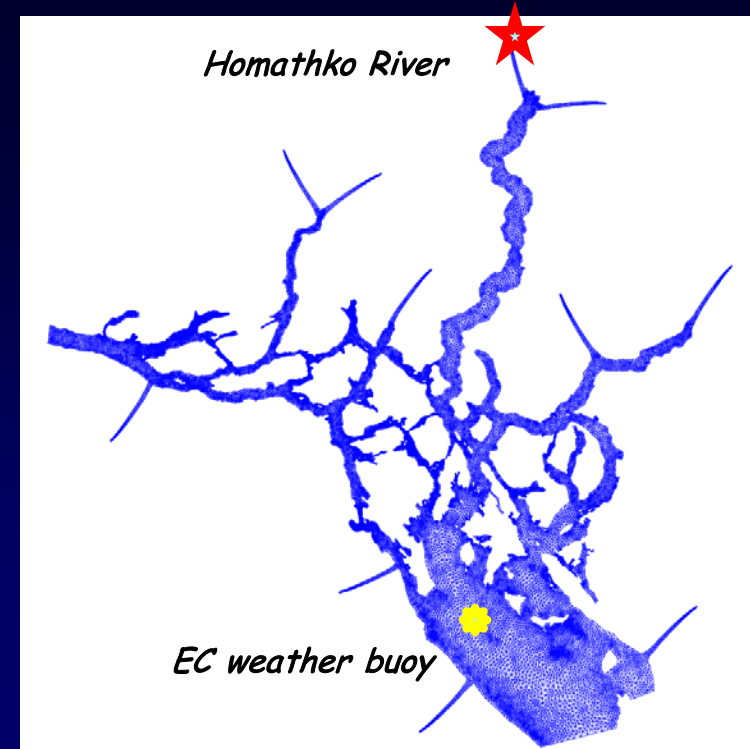
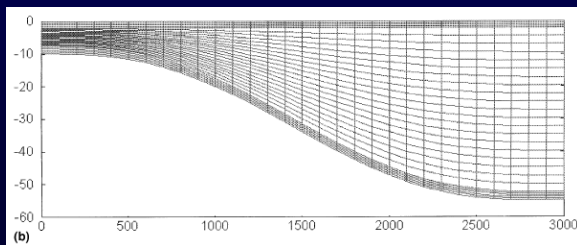
# Biophysical Models

## 1) Circulation model: Finite Volume Coastal Ocean Model (FVCOM)

- 36K nodes, 66K elements, 20 layers
- Resolution from 90m to 1.7km
- Tides, wind, heat flux, 12 rivers
- Partially evaluated in 2012 AO paper

## 2) Offline particle tracking model

- Modified from FVCOM software
- Releases at specific times & locations
- Tracks movement and development/mortality subject to UV & FVCOM input
- Particles can be passive or active
  - IHNV mortality from UV radiation



### Atmosphere-Ocean

Publication details, including instructions for authors and subscription information:  
<http://www.tandfonline.com/loi/tato20>

### A Circulation Model for the Discovery Islands, British Columbia

M.G.G. Foreman<sup>a</sup>, D. J. Stucchi<sup>a</sup>, K. A. Garver<sup>b</sup>, D. Tuelo<sup>a</sup>, J. Isaac<sup>c</sup>, T. Grime<sup>d</sup>, M. Guo<sup>a</sup> & J. Morrison<sup>a</sup>

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<sup>b</sup> Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, British Columbia, Canada

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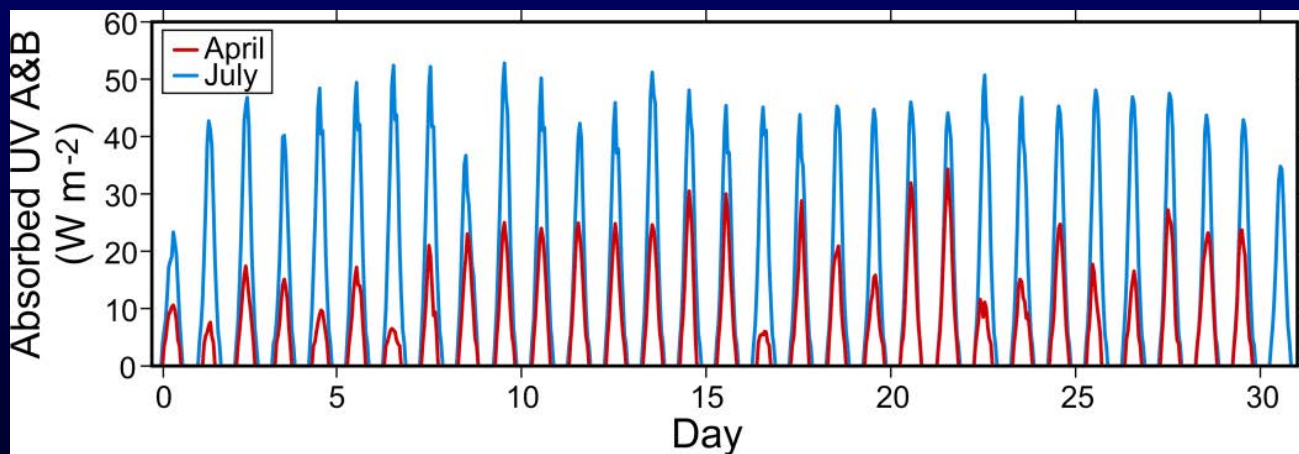
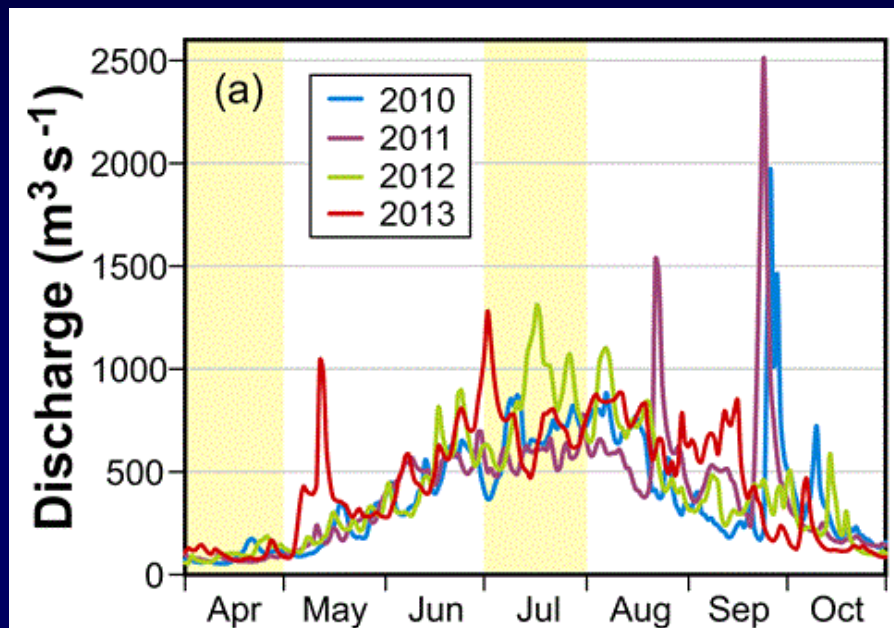
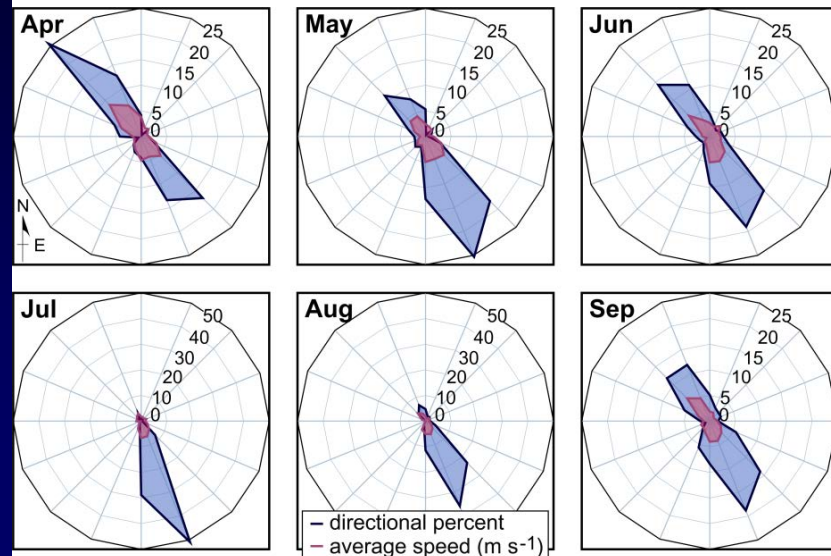
To link to this article: <http://dx.doi.org/10.1080/07055900.2012.686900>



# Important Seasonal & Interannual Differences

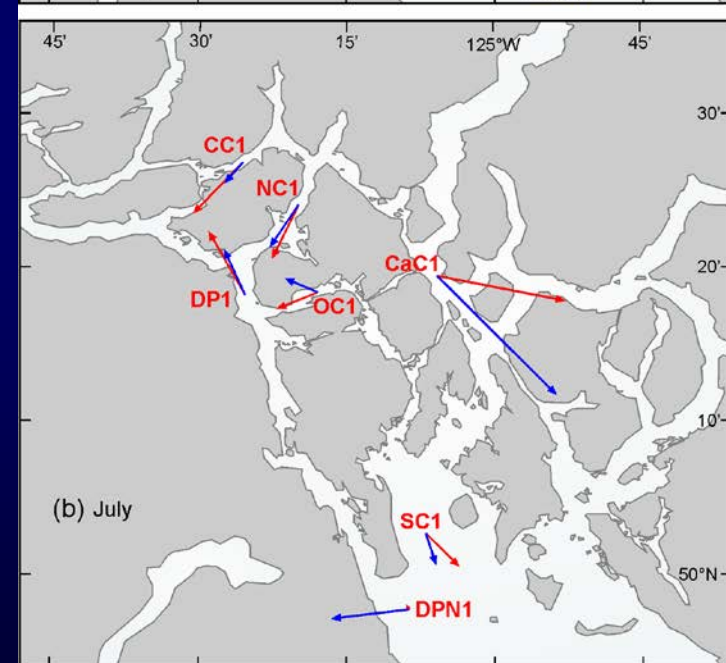
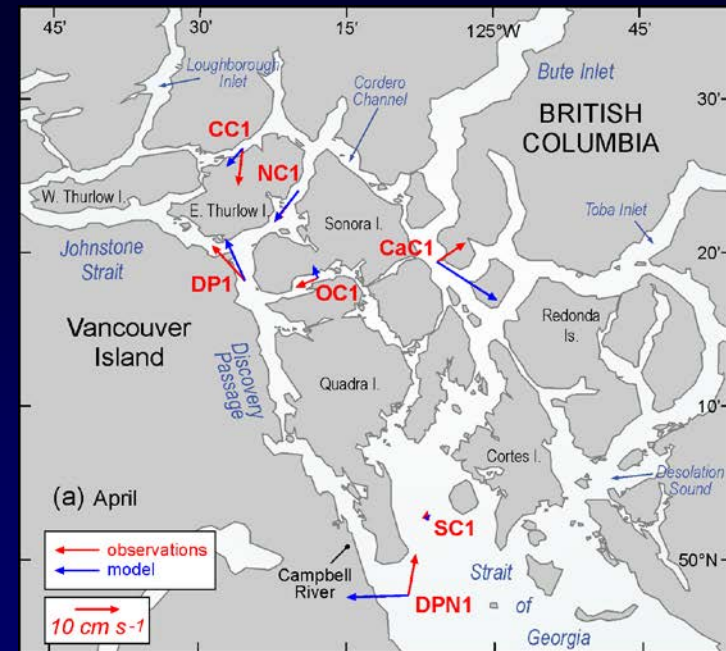
Homathko

Buoy 46131 wind rose, Apr-Sep 2010

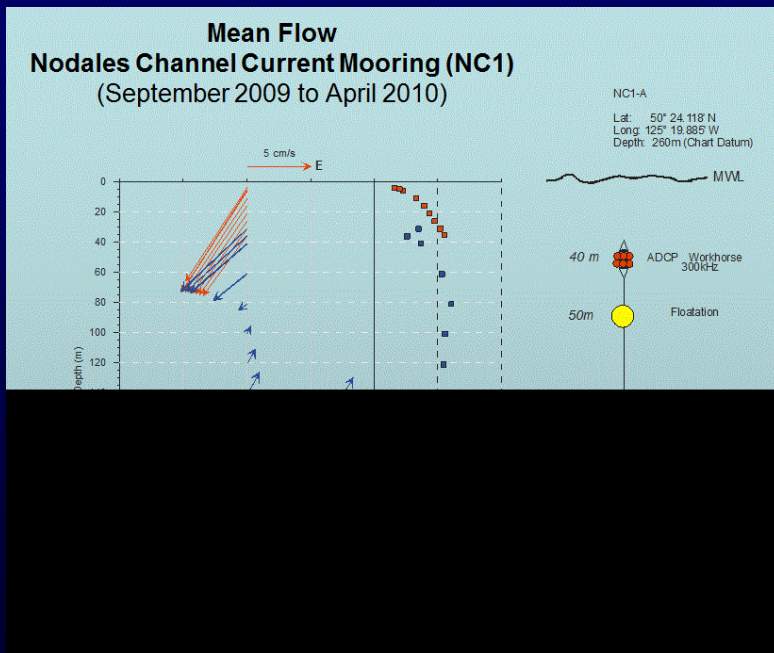


# Further Model Evaluations

- Circulation model runs for April to October 2010
  - Focus on April & July
- ADCP moorings from 2010-14
  - Typically moved every year

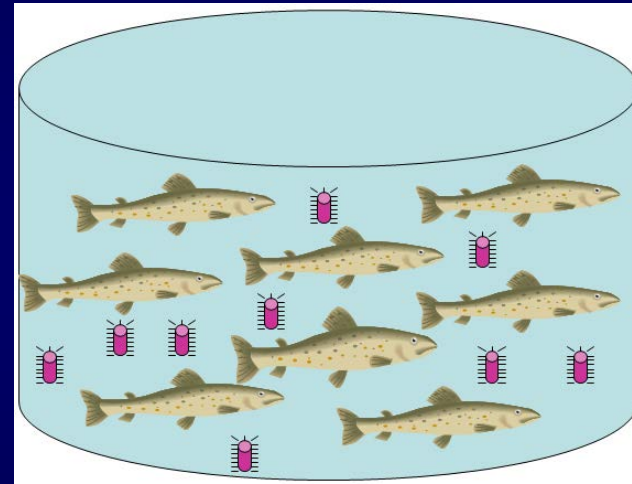


*Average Model vs Observed Currents over top 20m*

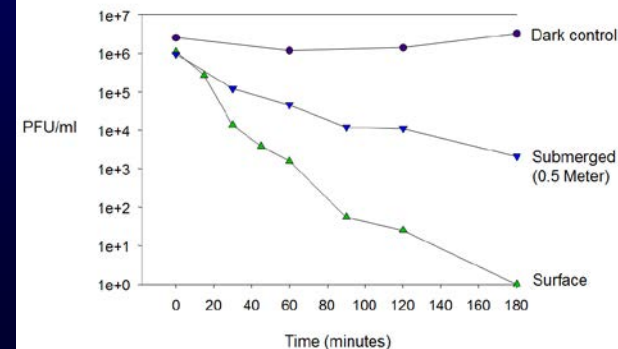


# Particle Tracking Details

- Hourly particle releases from 32 farms for all April & July
  - Random release over 100 X 100 X 20 m
  - Each particle tracked for 8 days
  - Plaque forming unit (pfu) mortality affected by UV radiation & microbial content
  - UV intensity & pfu mortality vary exponentially with depth
  - pfu shedding rates, minimum infective doses, marine mortality based on lab experiments (Garver et al., 2013)

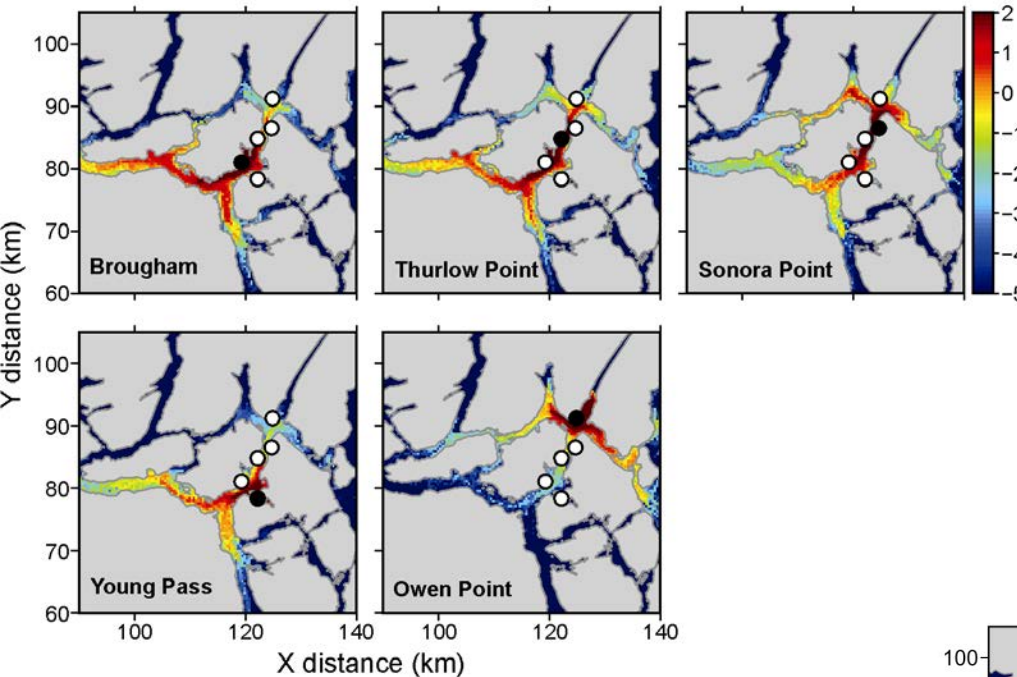


IHNV decay rate due to sunlight exposure



# IHNV concentrations (pfu/m<sup>3</sup>)

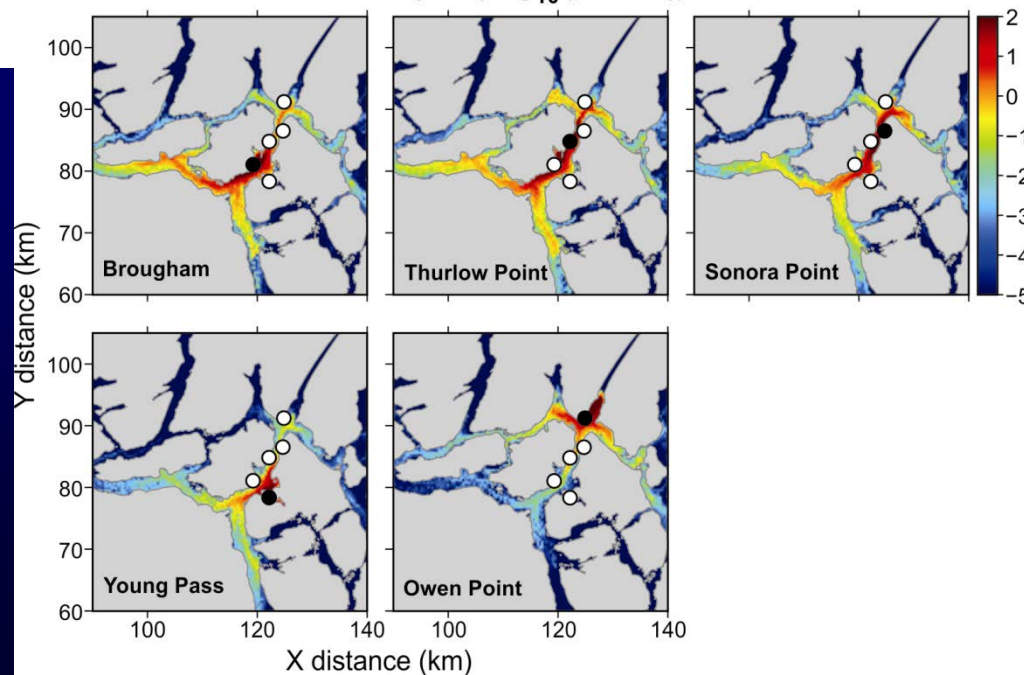
April 15 (Log<sub>10</sub> (pfu m<sup>-3</sup>))



← April 15

July 15

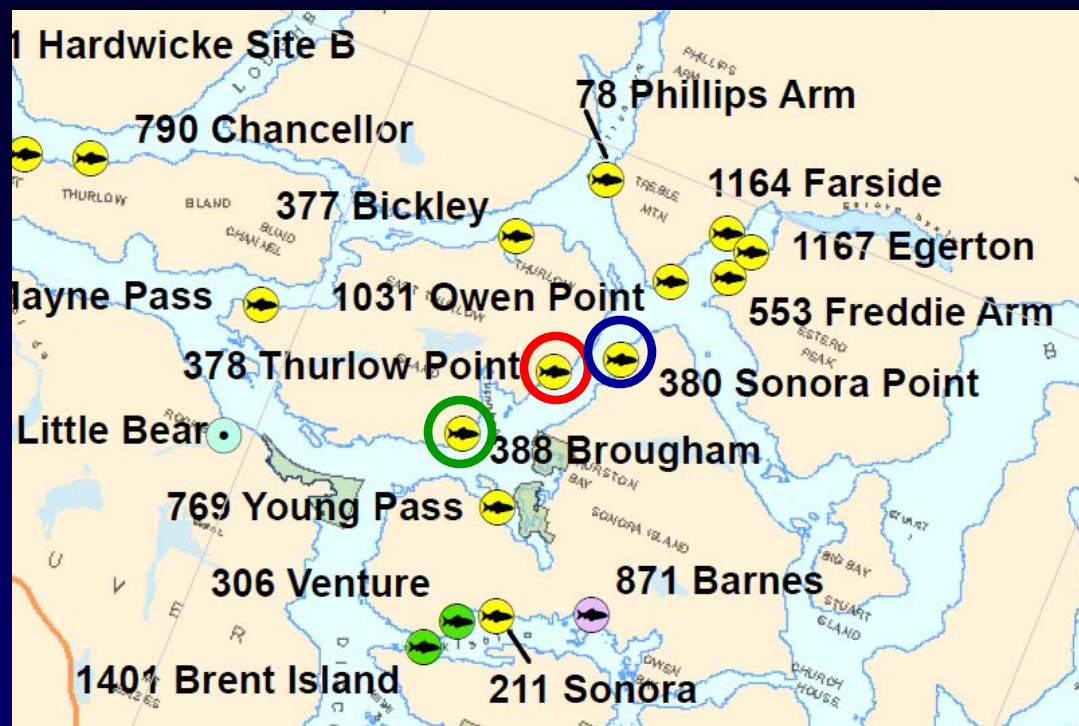
July 15 (Log<sub>10</sub> (pfu m<sup>-3</sup>))



- Sample output from each of 5 "diseased" farms
  - 30 million pfu/hr
- Average concentrations over top 20m on April 15 & July 15
- April concentrations larger
  - July has stronger currents & UV radiation



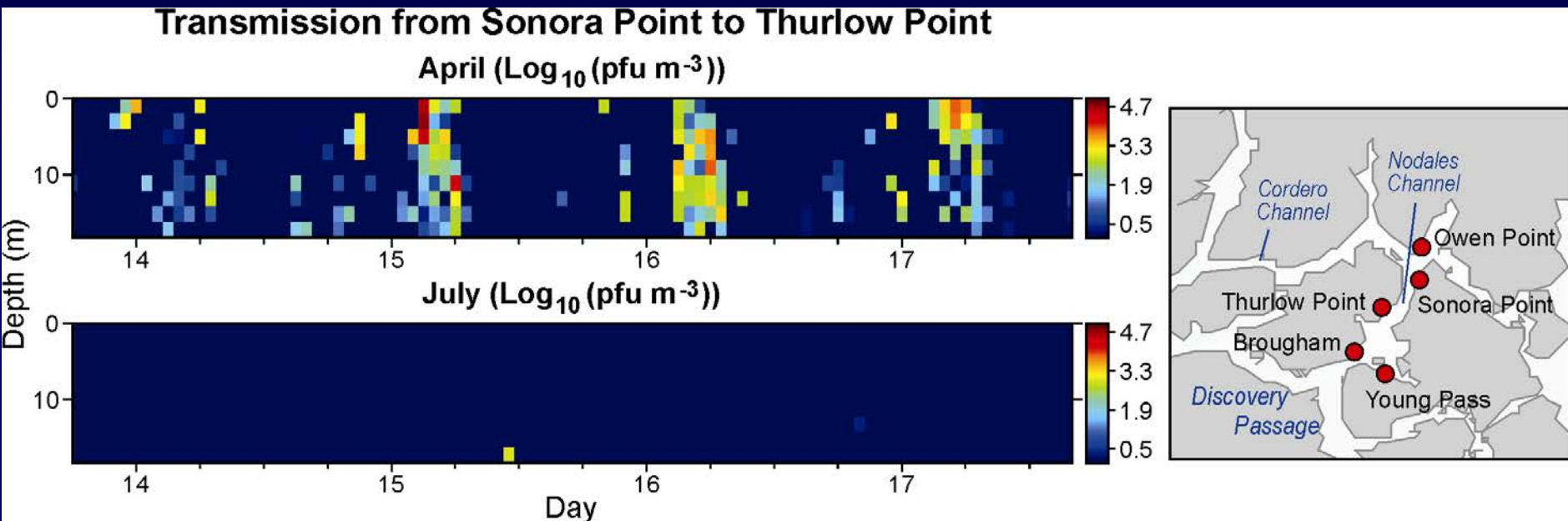
# Could a disease outbreak from one farm infect a neighbour?



- **Worst case scenario:**
  - 0.5 million fish
  - 1% infected
  - $3.2 \times 10^6$  pfu/hr/fish
  - Scale-up previous concentrations by  $5.3 \times 10^3$
- **Some farms are vaccinated**
  - 96% effective
  - $2.1 \times 10^2$  scale-up
- **NB: receiving farm assumed to be un-vaccinated**

- **Concentration fields at "receiving" farm need to exceed minimum infectious dose =  $10^7$  pfu/m<sup>3</sup>**
- **How often and at what depths does this happen?**

# IHNV Outbreak at Sonora Point

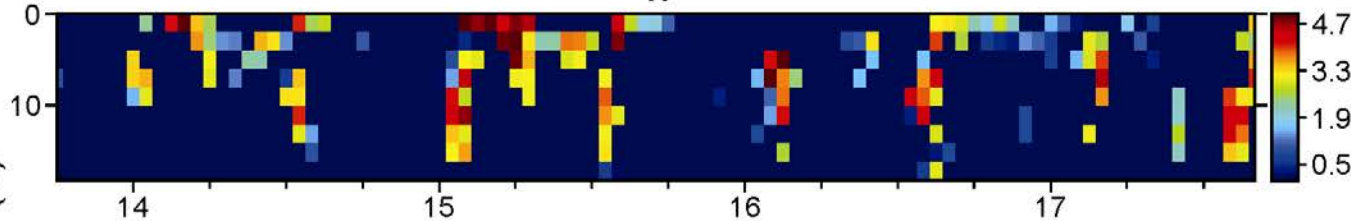


- *With adjusted scaling,  $\log_{10}$  (concentration) threshold for infection from worst case scenario is 3.3 & from vaccinated farm is 4.7*
- *So water-borne transmission is possible but risk varies seasonally*
- *Higher concentrations between approx 6pm and 6am when no UV*

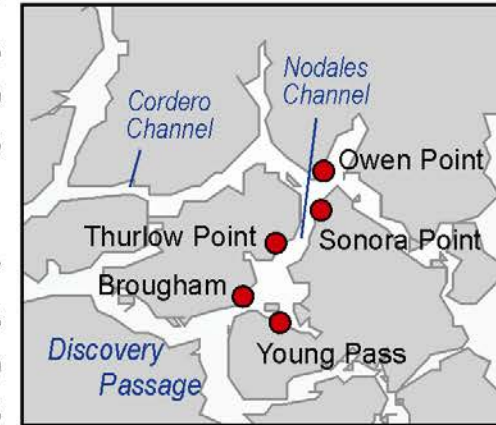
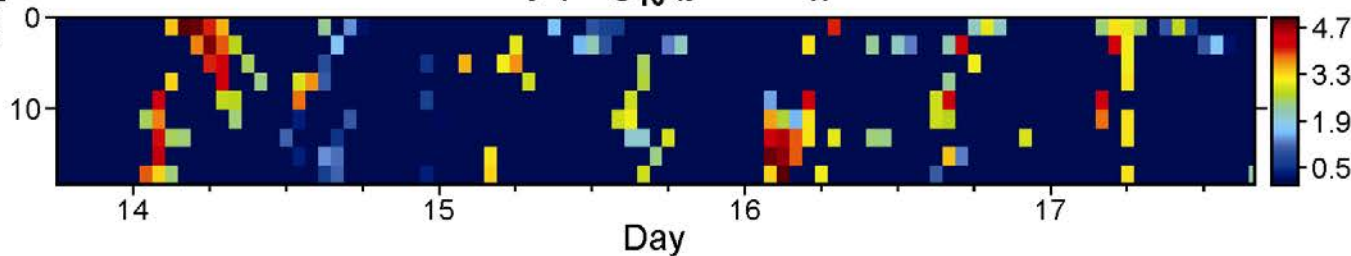
# IHNV Outbreak at Thurlow Point

## Transmission from Thurlow Point to Brougham

April ( $\text{Log}_{10}(\text{pfu m}^{-3})$ )



July ( $\text{Log}_{10}(\text{pfu m}^{-3})$ )

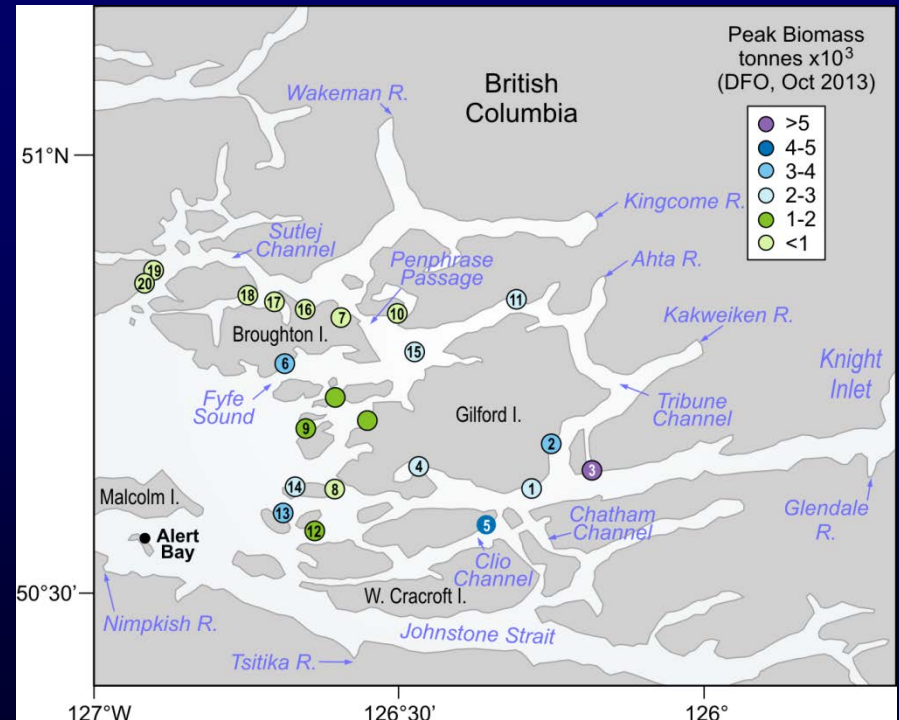


- *Water-borne transmission possible here too, but April vs July differences not as large*
- *Can quantify risk by counting "pixels" that exceed threshold*
- *Will construct connectivity matrices to summarize risks for all farm to farm transmissions*

# Broughton Farm Connectivity Matrix

capture farm	release farm																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1	29867	4078	2372	135	339	25	85	28	3	14	118	1	3	13	25	1	4				
2	282	32400	3032	4	47	82	205	5	9	96	442		3	3	180	11	11	2			
3	236	833	22134	20	80		3	3		1	14	1		1	1						
4	1241	311	363	21113	64		1	20				5	4	4							
5	1030	369	448	620	21784	1	2	281	51		2	121	61	148	7	1					
6	29	14	16	41	14	32400	390	294	339	463	665	158	255	322	1445	41	33	6	10	20	
7						8	32400			517	225				265	801	1078	521	86	31	
8	1887	640	528	3241	954	69	81	32400	3576	103	322	3284	2595	9972	795	4	1		1	1	
9	50	9	19	85	25	111	120	429	32400	137	454	231	323	548	968	10	5				
10		2	2			13	585	2	4	19473	471			1	1	322	86	74	22	5	6
11	4	218	190	2		346	982	40	85	616	16899	13	34	53	877	87	98	28	9	13	
12	291	64	69	416	814	3	1	943	229	1	6	15775	1383	517	38						
13	528	147	181	808	393	5	5	2113	850	12	32	4770	15449	1437	88	1			3	7	
14	1403	464	380	2337	681	39	48	12477	3068	71	227	2755	2365	32400	565	5	1		2	2	
15	4	58	61	14	5	883	1865	156	213	2165	5917	85	127	190	32400	211	221				
16						96	136	4	11	23	16	1	12	10	20	11945	10017	5482	2058	908	
17				1		36	9	4	3	1			6	6	2	2014	12491	4827	658	381	
18						17	4	1					3	7			1164	1641	19349	289	169
19	4	1	3	9	1	805	36	112	164	16	28	90	140	178	69	1850	1016	656	32400	10229	
20	21		4	11	2	1125	31	160	195	19	31	150	197	236	100	1274	689	459	14866	32400	
captured away from release	7010	7208	7668	7744	3419	3664	4589	17072	8800	4255	8970	11665	7512	13646	5767	7561	14889	12056	18018	11801	

- Connectivity among 20 Broughton farms based on 2009 model runs
  - Higher (lower) connectivity is denoted by redder (bluer) colours. White cells denote zero connectivity
  - Not symmetric



# Relevance to 2001-02 Outbreaks

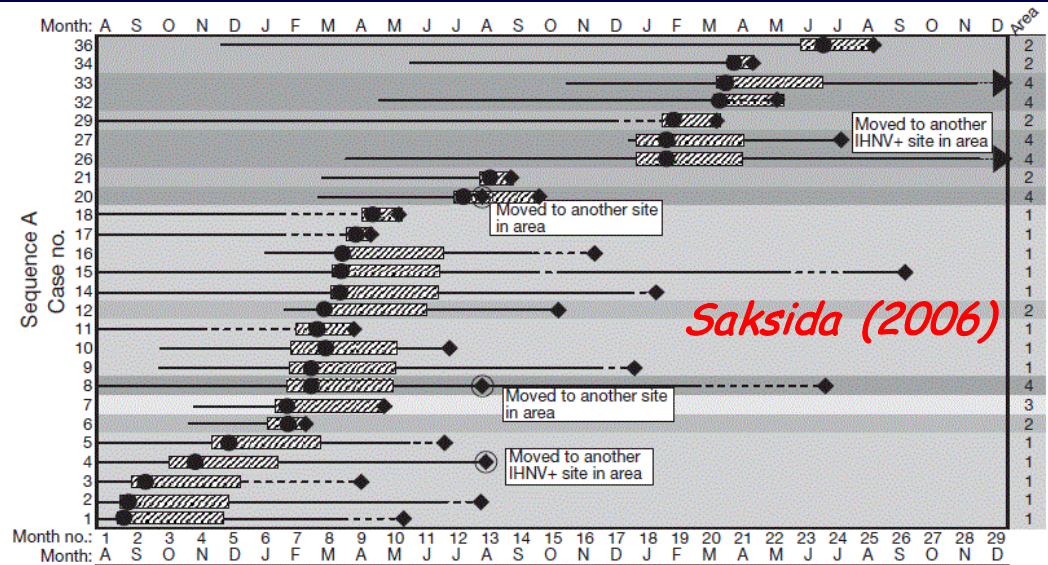
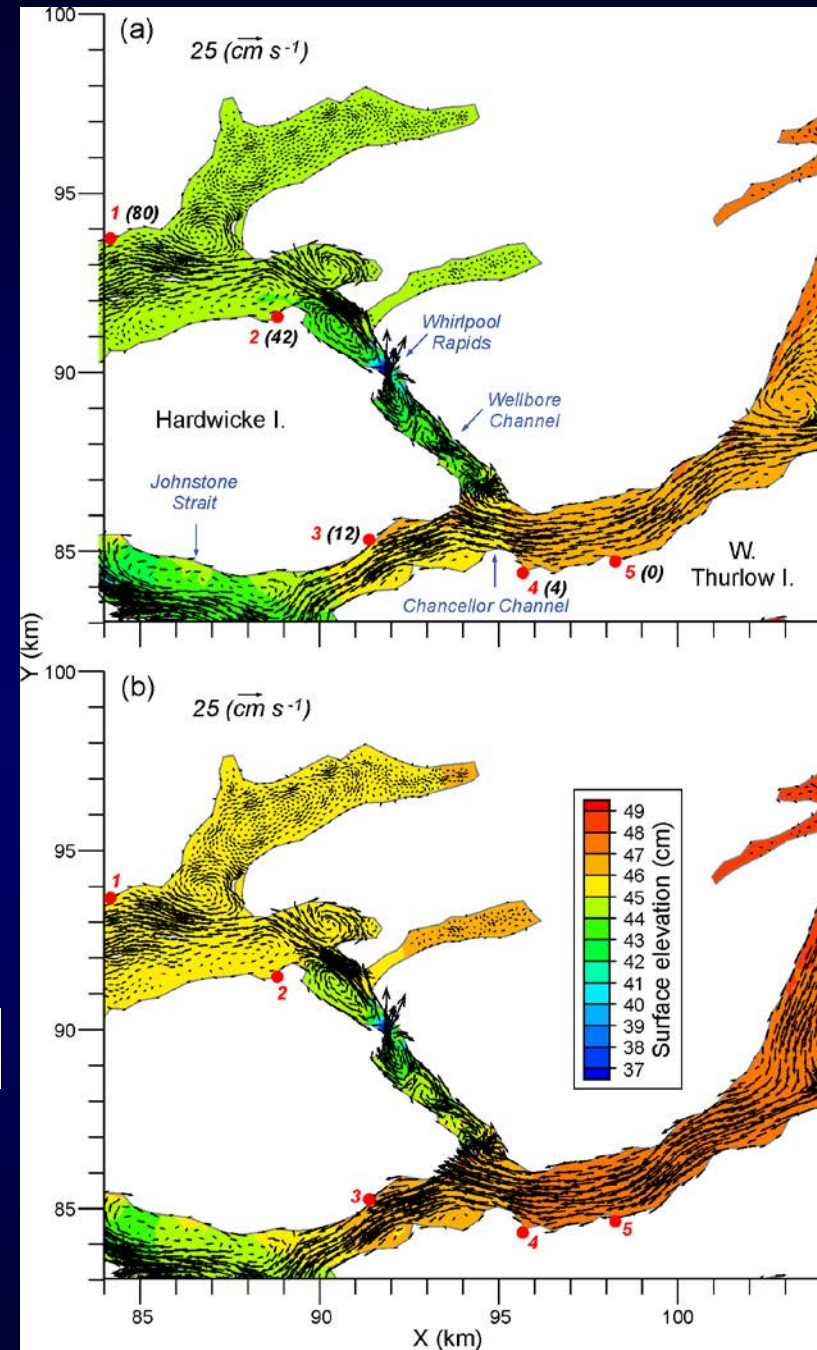


Fig. 2. Progression of IHN epidemic in affected farms in British Columbia. Two sequences were isolated, Sequence A occurring on the east coast of Vancouver Island and west coast of the BC mainland, and Sequence B on the west coast of Vancouver Island



10m mean flows: a) April, b) July

- Initial outbreak, late Aug, at farm 5
- Successively spread to 4, 3, 2, 1
- Consistent with mean flow fields

# Relevance to 2001-02 Outbreaks

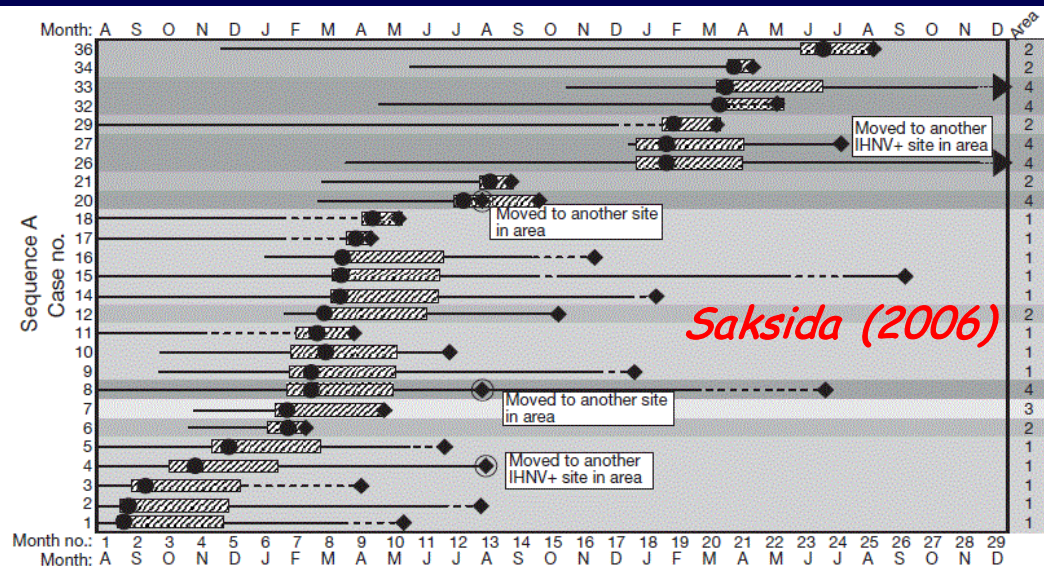
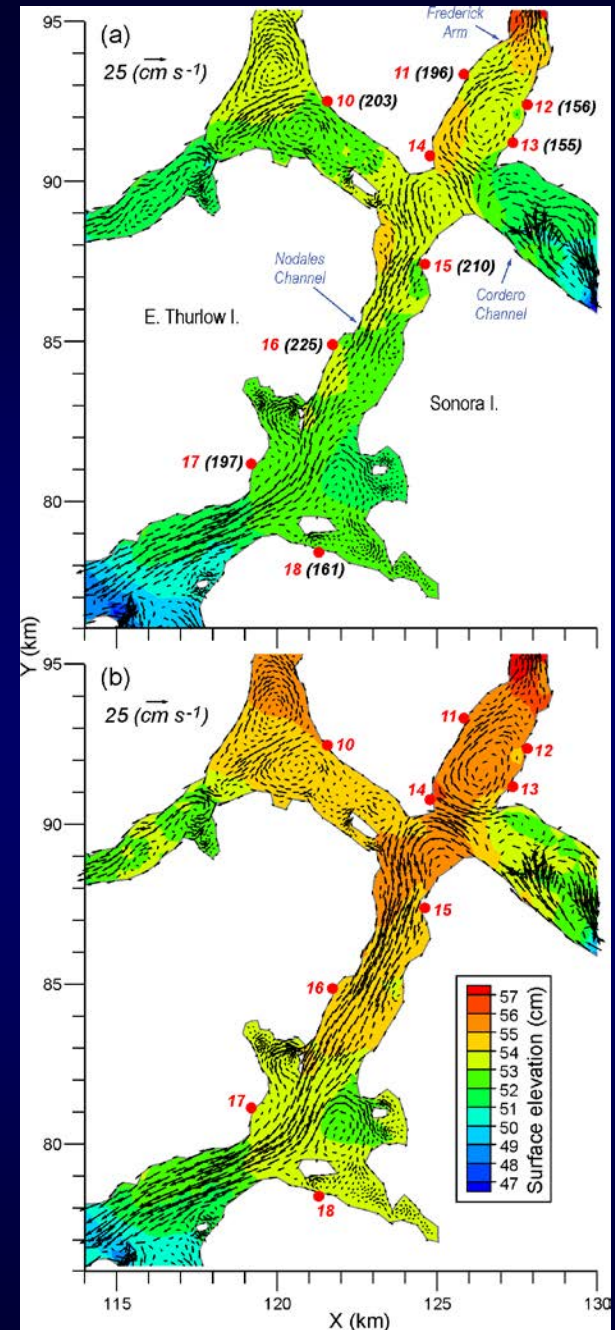


Fig. 2. Progression of IHNV epidemic in affected farms in British Columbia. Two sequences were isolated, Sequence A occurring on the east coast of Vancouver Island and west coast of the BC mainland, and Sequence B on the west coast of Vancouver Island



10m mean flows: a) April, b) July

- Initial outbreak at farm 13
- Successively spread to 12, 18, 11, 17, 10, 15, 16
- Not consistent with flow fields
  - Transmission via poor farm practices ?

# Summary

- *Ocean circulation & particle tracking models have been developed to study water-borne transmission of*
  - a) *IHNV between farms in the Discovery Islands*
  - b) *Sea lice between farms and to wild salmon in the Broughton Archipelago*
- *Preliminary results suggest IHNV disease outbreaks could re-infect nearby farms but there are seasonal (& inter-annual) differences in the risks*
- *IHVN & sea lice connectivity tables should be used to manage fallowing, treatment & siting of new farms*
  - *Seasonal differences here too*



*Broughton weather station*



*Broughton mooring deployment*

# Acknowledgements

- *Aquaculture Collaborative Research and Development Program & Program for Aquaculture Regulatory Research (both FOC)*
- *Marine Harvest Canada, Cermaq Canada, Grieg Seafood*



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