Birds & Shellfish Sanitation session of NSA conference (Monday, March 27 2023, Baltimore Maryland)

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1. **Bird interactions with shellfish aquaculture (Rheault)**

Usage of floating gear is increasing and so issues with birds on floating gear are increasing too (guano)

In 2017 the ISSP (Interstate Shellfish Sanitation Conference) revised the Model Ordinance chapter on aquaculture, and the FDA insisted on new language stipulating if a farm has the potential to attract birds or mammals, the operator must propose an operational plan describing how they will deter such aggregations to prevent the contamination.

In the absence of regulatory guidance, states have had very variable responses – some want to ban floating gear, others want to require 3 weeks depuration of oysters before harvest.

Now, the ISSC created 14 pages of guidance (last week) – the regulatory guidance will be official 6 months from now.

In the meantime, growers have been trying to develop and test various bird deterrents.

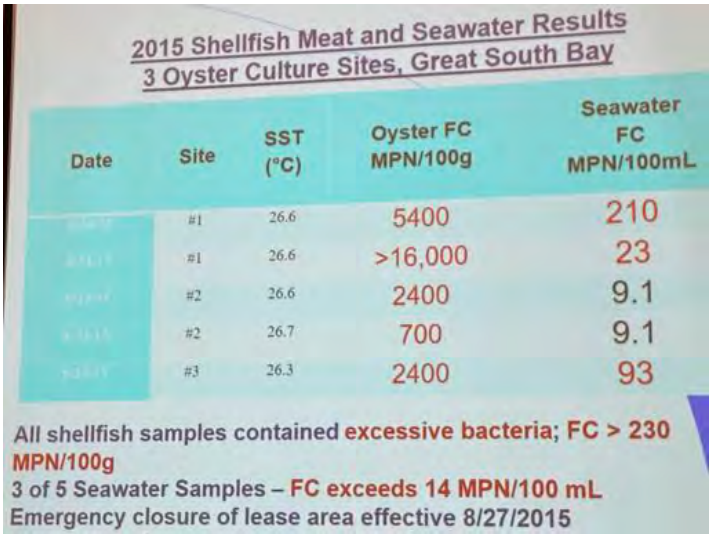
Very little data available describing prevalence of human enteric pathogens in birds waste. Most pathogens are species specific, but we cannot ignore that some human pathogens have been detected in bird waste.

A proper Risk Analyis is needed. There are three scientific articles indicating that purge rates are sufficient to flush pathogens from oysters within 48 hours.

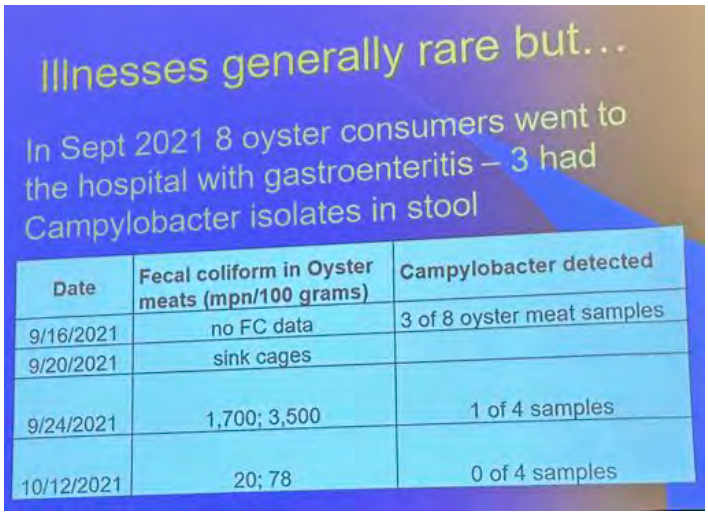
50-80% of bird-associated illness outbreaks come from poultry. Only 2.3% come from wild birds.
The risk is non-zero, but how much?

High fecal coliform MPNs have been detected, yet mysteriously there have been no illnesses. Fecal coliforms are a poor indicator of risk.

Despite absence of a proper risk analysis and rarity of confirmed illnesses, regulators are often mandating expensive control measures.



Oyster meats can contain high fecal coliforms, often not neatly correlated with fecal coliforms in water



Campylobacter present in stools of three oyster consumers (8 were sick with gastroenteritis, but I think *Campylobacter* was only tested in three of them)

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2. **Seasonal patterns of distribution and abundance of waterbirds in relation to oyster aquaculture in coastal Rhode Island (Muller, Paton, McWilliams)**

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3. **Birds and shellfish sanitation – the New York experience (Rivara, Byrnes, Carden, Finora)**

In 2012, cage-based shellfish farming in New York expanded into shallower, nearshore areas of the South Shore Estuary (originally in Peconic Estuary). At the same time, floating gear became very popular and predominant gear used by oyster growers in the area. From 2015-2017, the NY State Department of Envir Conservation (DEC) collected samples from floating farms that revealed elevated bacteria levels in oysters and seawater (>16,000 MPN fecal coliforms) in these shallow areas. They temporarily closed the farms and only reopened them after farmers installed bird deterrents or submerged gear and were able to show from more sampling that bacteria returned to satisfactory levels.

Beginning in 2018, the DEC required growers using floating gear to submit a bird mitigation plan detailing what measures they would use to keep birds off gear and made effective bird mitigation a condition of their permits.

The DEC also developed a guidance document to help growers determine what methods may work best for their situation based on the experience of other growers. Since that time, compliance has generally been good, with only a few temporary closures implemented by the DEC.

Discussed various bird deterrents:

Poke and line (poles anchored in substrate sticking out the water with monofilament stretched across the farm)
Gull sweep (expensive, makes it hard to flip cages)
Zip ties (sticking straight up or bent into loops across float)
Noise makers (not desired)
Kites – works pretty well if there's enough wind but after a while the birds get used to it. Ospreys have gotten tangled on kite string.
Bird coil (only works on one side)
Sinking cages (sometimes growers don't have a deepwater option, adds labor, slows growth, not sure if I heard this right but it took 4 weeks to purge the bacteria? If yes, then it seems to vary a lot between sites. Also raises question of whether there was another source of pathogen other than birds)

If guano is baking in the sun, are any of the bacteria even going to be viable?

FDA insist we measure fecal coliforms even if it isn't the best measure (it seems to be a pretty bad indicator). We need source tracking.

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4. **Observations on the use of bird kites at an oyster farm in southern Mobile Bay, Alabama (Supan, Wilson, Bradley)**

To deal with the waterbirds on floating gear problem (and the guano that comes with it), they deployed a bird kite (BirdAway Hawk System, OysterGro.com) at Navy Cove Oyster Farm to see if it deters the birds.

The site is shallow (<2m depth), 4.3 ha inlet on the southern shore of Mobile Bay, Alabama. The opening (510m wide) to the Bay is bounded by a southerly beach-shoreline of eroding pine forest. Waterbirds including blue herons, pelicans, gulls and terns common.

The kite was deployed in 2019 along the northern edge of the farm above 0.8 ha of sometimes 200 floating cages, particularly during the fall (spring as well) when Royal Terns are most prevalent. The kite was deployed for several weeks and flew well. The Royal Terns immediately responded and left the area and did not return.

The following fall, the tern infestation was worse, requiring a second kite but that did the job – all birds left. Terns are only a problem for ca. 4 weeks so the kites are put in as needed and take care of the issue.

The authors have seen birds of prey (hawks and ospreys) above the farm coming from trees on the nearby shore, which causes all birds perched on the floating gear to flush. They once saw a raptor attack and take a tern right off the gear. They believe the kite simply enhances the natural predator response.

There is now a board of health requirement – fewer than 2 birds per cage in terms of density.
Note: USFW in Alabama don't care about impact on birds. (care more about endangered beach mouse)
However, in RI, DEM says kites will scare the vulnerable marsh swallows.

Notes about kites: in high winds they get shredded. They take kites in if a storm is coming. There are cheaper kites out there (you can buy them online) but they shred faster.

Putting the kite up at two sites and intermittently helps birds habituate less. Though sometimes they calls that someone saw "some bird of prey caught on a fishing line". The kite just looks like a generic raptor shape, not a specific species.

At this farm they actually had no evidence of fecal coliform issues. They were taking 2 samples per month and it was always within acceptable levels. Note – the residential area has city sewage, not septic system and that helps the water quality.

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5. **Small-scale investigations of bird deterrent methods on and around Massachusetts shellfish farms using floating gear (Reitsma, Archer, Booth)**

To help shellfish growers test bird deterrents, in 2021 MA had small grants available (SEMAC) so growers did mini-studies to try stuff out and innovate. Results varied a bit between sites and species. Some used game cameras to measure effect of deterrents.

<u>The good methods:</u>

1) <u>Immersing and suspending gear</u>
   - Reduces functionality – can't flip it
   - Keeps birds off
2) <u>Scare kites</u>
   - Used in MA
   - Radius limited, need to move it around
   - Works for gulls and terns
   - Cormorants don't care – even if you swing the kite right at them when they're roosting on a cage they don't care.
   - Drawbacks: kites fly away at >25 knot winds, contributes to marine debris
3) <u>Poles with monofilament ("pole and line")</u>
   - Scares birds, don't want to fly in
   - Cormorants don't care, swim right in and sat right under monofilament, even when it had streamers.
   - Drawback: needs some maintenance
4) <u>Perching deterrents:</u>
   - Lines over the top of a float: are good if at the right height, but that varies between birds
   - Spikes: stainless steel is expensive, lots of work to modify all gear, have to remove in winter.
   - Zip ties:
     - Looped across works well,
     - In clusters sticking straight up – not very good, birds sit in between
   - Drawback: Round pontoons → hard to fit stuff on it and get it to stay in place
5) <u>Other options:</u>

- Wire or sweeps
- Coyote decoys on a raft (move it around)
- String and bungee structures?

Systematic study with 1) controls, 2) monofilament over area, 3) bamboo skewer perching deterrent over cage combined with monofilament over area

Used game camera to count birds

		# of birds	# of birds per hour
1)	Control	78	0.62
2)	Monofilament	52	0.42
3)	Monofil + bamboo	5	0.04

Option 3 is the best!

What didn't work:

1) Cheapo kites from the dollar store – flew away, didn't scare birds, marine debris
2) Reflective tape – doesn't stay on gear, didn't work
3) Zip ties – not crazy about them. The ones looped across deter birds but you need a lot and they get fouled. The ticklers don't work – even dozens of birds site between them
4) Reflective pinwheels – bad
5) Plastic spikes – bad, difficult to put on
6) Irrigation high pressure sprinkler, 0.25 acre, randomized, deterred birds but had tech problems the whole season
7) Motion activated flare – good, shows promise, but not ready yet
8) Laser scarecrow – needs adaptation and testing for marine use (right now mainly used for cornfields)

Summary:

-Nothing is 100% effective
-Recommends a combination approach
-Varies by species – cormorants are tough
-lasers or bird distress should be tested (peregrine call, tern distress call, not tested, but might have other negative consequences)

Note: monofilament is at 6ft at high tide over the gear, others are 2 ft, extended as far as across ½ acre so it droops in the middle.

Spikes are hard to flip.

Oystergro floats – the ones with grooves for attaching deterrents are actually bad because leaks always happen at the groove because it cracks . The newer model got rid of the groove.

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6. Comparing available deterrent methods to reduce double-crested cormorant attempts to roost on floating oyster cages (Cunningham, Wang, Burr, Tappa, Redd, Glover, Dorr)

Catfish industry → cormorants are a big problem. Birds have very warm body temperatures that should kill bacteria, but it doesn't. They can carry and distribute living pathogens. Pelicans, wood storks and egrets are also an issue in this area.

The Mississippi Field Station of the Wildlife Services – National Wildlife Research Center is working in conjuction with Mississippi State University and conducted a study to test the effectiveness of several commercially available physical bird deterrents available on the open market to reduce roosting time on floating oyster cages which could reduce coliform counts in water and oysters which could lead to the closure of oyster farms due to excessive bacterial counts.

Fifteen double-crested cormorants were captured in night roost in Mississippi or Alabama – using spotlighting to get them to flush out of trees onto the water where they capture them with big nets helpd by people standing in the boat as the birds flew over them. Only works on moonless nights. Now tracking many birds with transmitters too.

Five DCCO were put into each of three aviary enclosures containing a 0.1 acre pond stocked with catfish. Each pond contained a floating oyster cage to which one of 6 deterrents was applied and was monitored by 3 motion activated cameras that recorded DCCO positions and movements.

Deterrent methods tested:

1) Float mounted triangle
2) Bird B Gone Spinning Bird Deterrent
3) Scarem Kite
4) Zip ties around floats
5) Gullsweep Bird and Seagull deterrent
6) Bird spikes for bird/cat/squirrel/raccoon animals repellent

Data collected by deterrent method included:

1) Number of times an individual DCCO successfully landed on floats,
2) Number of individual DCCO on a float
3) Amount of time individual DCCO spent on float
4) Number of times an individual DCCO unsuccessfully attempted to land on floats.

Preliminary analyses indicate variation in effectiveness depending on the deterrent method tested.

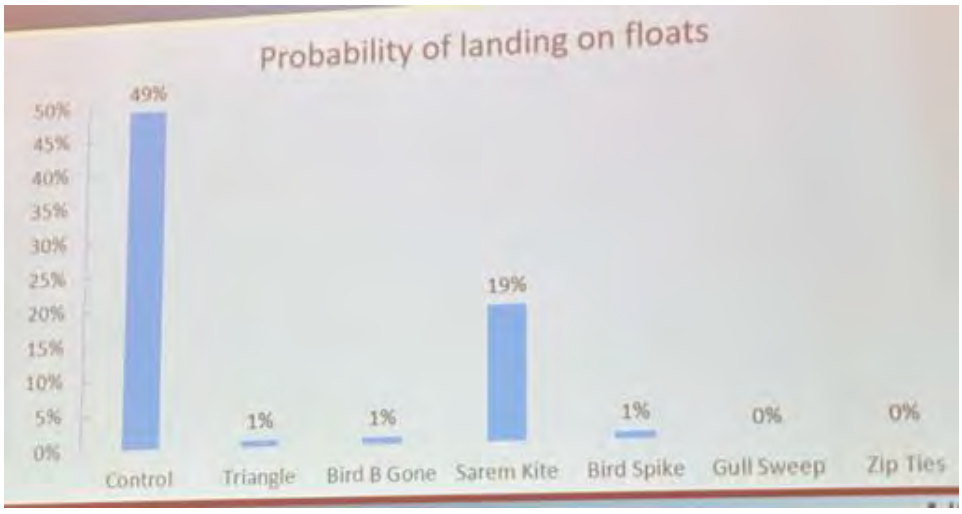
See design and results below:

Study Schedule

WEEK	TEST DAYS	REST DAYS	POND 1 METHOD	POND 2 METHOD	POND 3 METHOD
1	0	7	Control	Control	Control
2	5	2	Control	Triangle	Bird B Gone
3	5	2	Scarem Kite	Control	Zip Ties
4	5	2	Gull Sweep	Bird Spikes	Control
5	5	2	Control	Bird B Gone	Triangle
6	5	2	Zip Ties	Control	Gull Sweep
7	5	2	Bird Spikes	Gull Sweep	Control
8	5	2	Control	Zip Ties	Scarem Kite
9	5	2	Bird B Gone	Control	Bird Spikes
10	5	2	Triangle	Scarem Kite	Control

5 days deterrent, 2 days rest. Rotate in a new deterrent.
Kite- not enough wind for Scarem kite.
Zip ties – 4" gap so LOTS of zip ties needed (43 per float – is 25 enough? Need to test). But they were good.
Bird B gone – cormorants don't care.
Bird spikes only had 1 bird.
Triangle worked well, though 1 cormorant didn't mind it.
Gull sweep – wind driven, expensive, works, might not survive flipping cages.

Cormorants will fly as far as 20km to a foraging area.
Cormorants on floats showed territorial behavior, often didn't let other cormorants join.



Everything worked well for deterring cormorants except Scarem Kite was a little less effective.

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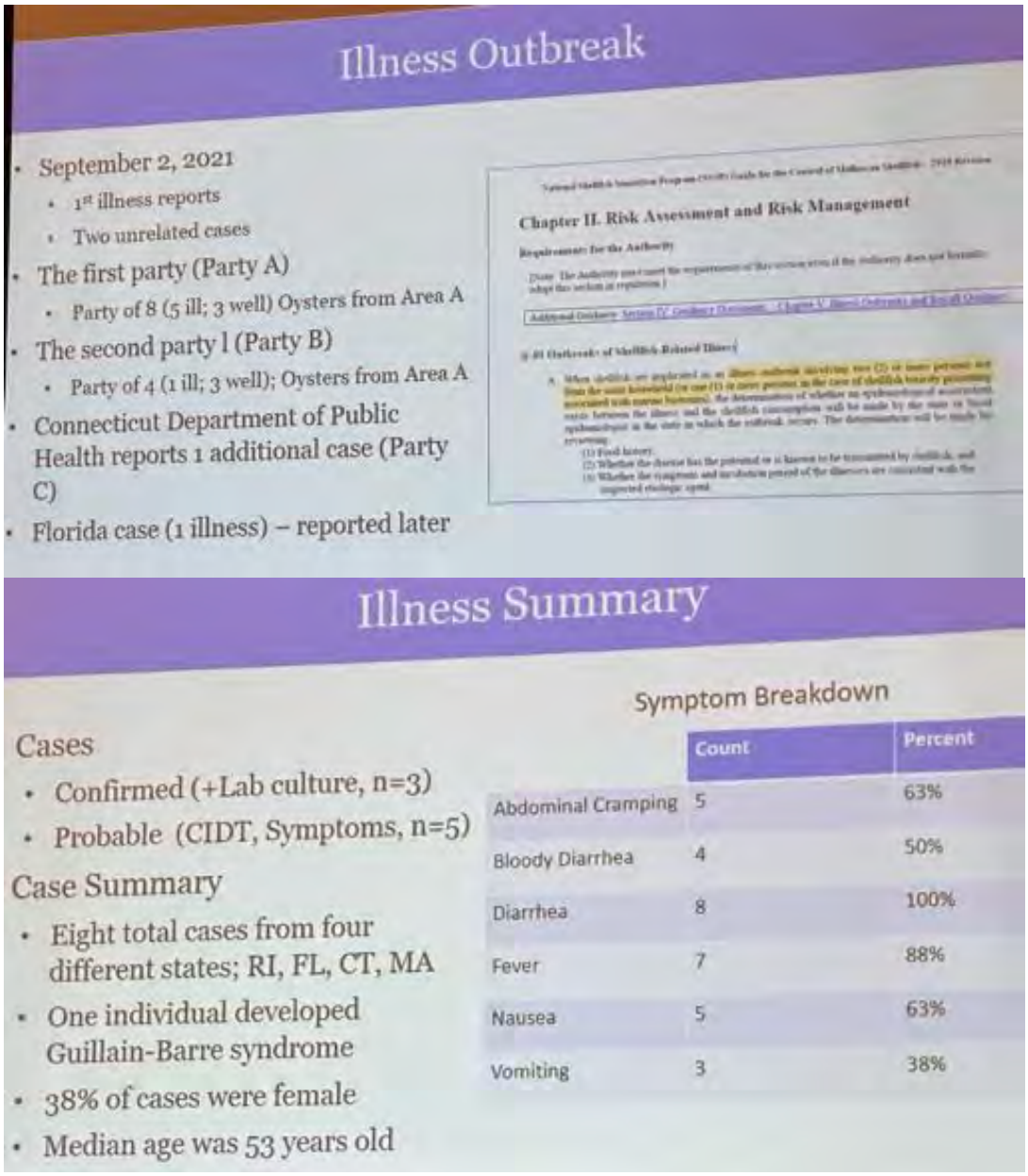
7. **A *Campylobacter* illness outbreak, associated with oysters contaminated by seabirds roosting on floating aquaculture gear (Borkman, Slaten, Miller, Goetsch)**

David Borkman works for DEM in shellfish classification.

A Campylobacter illness outbreak associated with consumption of oysters – presumably due to waterbirds roosting on floating gear.
Eight ill individuals consumed raw oysters grown at a single RI coastal pond location. Campylobacterbacteriosis was confirmed in three cases (as C. jejuni) and was identified as the probably agent in five cases.



Eight people got sick – only cultured bacteria from stool sample for 3 of them (confirmed). So for five of them it was only probable, not confirmed (used a rapid test only).

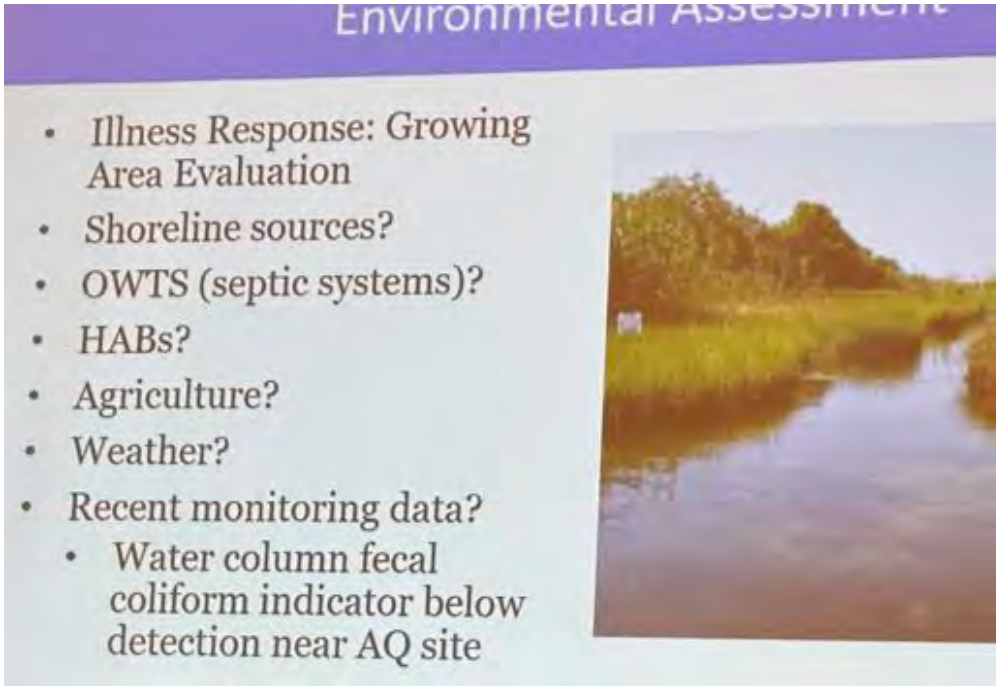
Illness Investigation

Illness Outbreak Response

- NSSP Guidance [Chapter II @01 G (1-3)]
  - Close shellfish area (9/10/2021)
  - Environmental assessment
    - Traceback
    - Evaluate existing data NSSP compliance
    - Investigate potential contamination sources
    - Evaluate WQ subsequent to illness
    - Document findings & actions

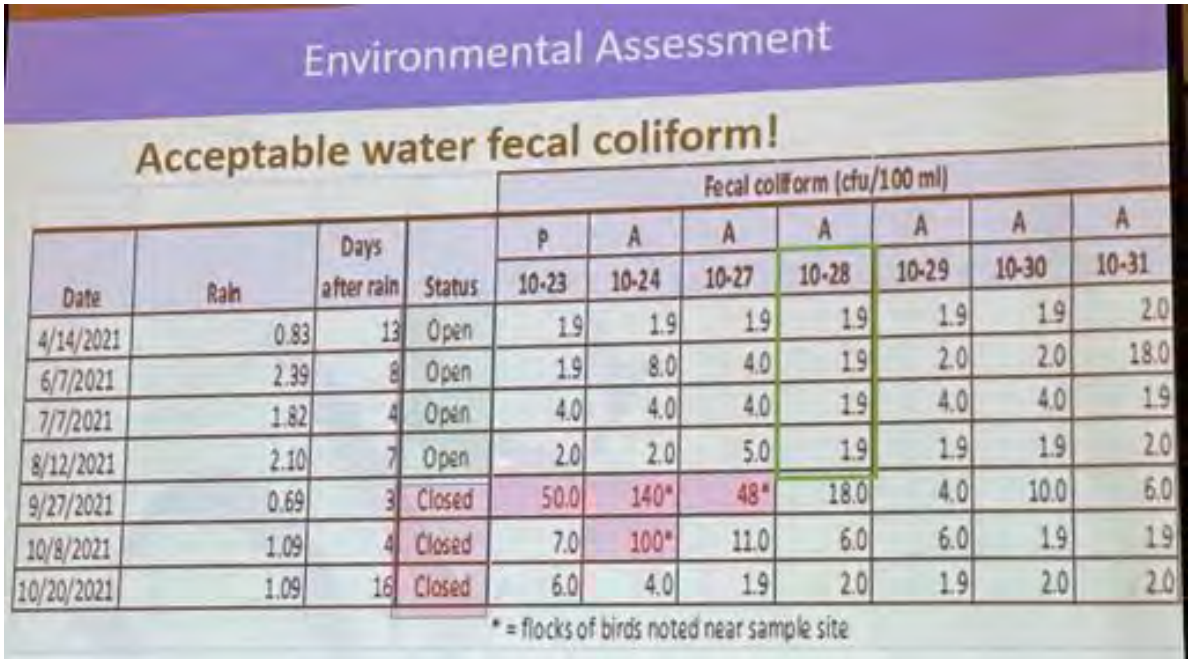
Environmental Health Investigation

- DOH conducted an onsite environmental investigation at Restaurant A
  - No issues at the restaurant
  - Harvest tags were collected
- Traceback
  - Oysters from single AQ lease
- Sample Oysters from Harvest Area A
  - Positive for *Campylobacter lari*
- DOH Contact RIDEM, CRMC, FDA Shellfish Program
- Area Closed to harvest
- Environmental Assessment



No freshwater sources for most coastal lagoons.

Environmental Assessment – showed that growing area fecal coliform concentrates were well below NSSP criteria and there were no probably Campylobacter pollution sources (e.g. failed septic systems, agricultural operations) in the watershed. Fecal coliform and Campylobacter were measured in oysters at approximately weekly intervals.



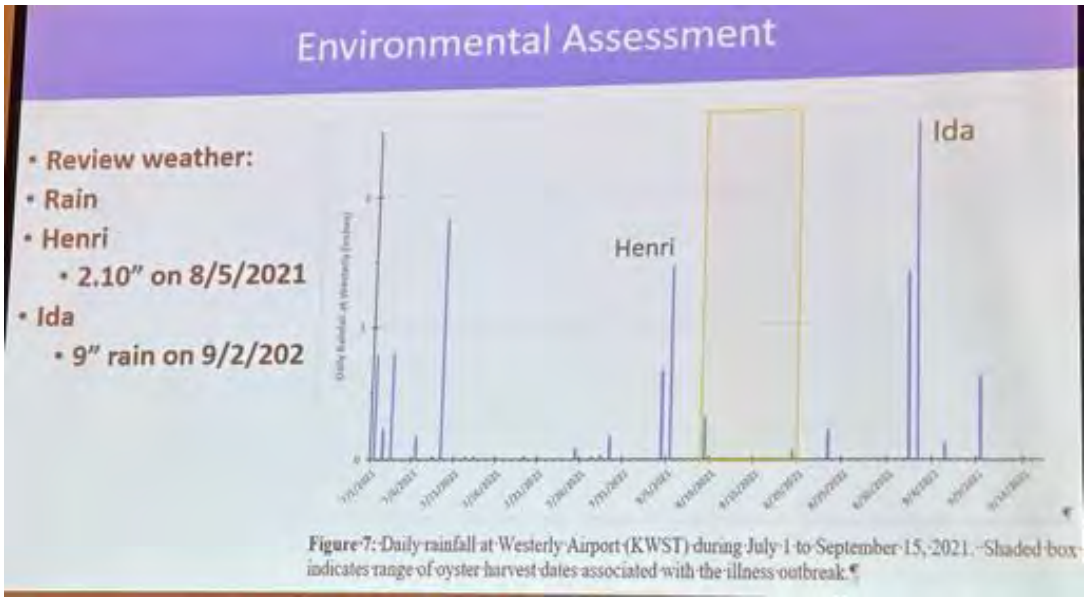
Environmental Assessment

Acceptable water fecal coliform!

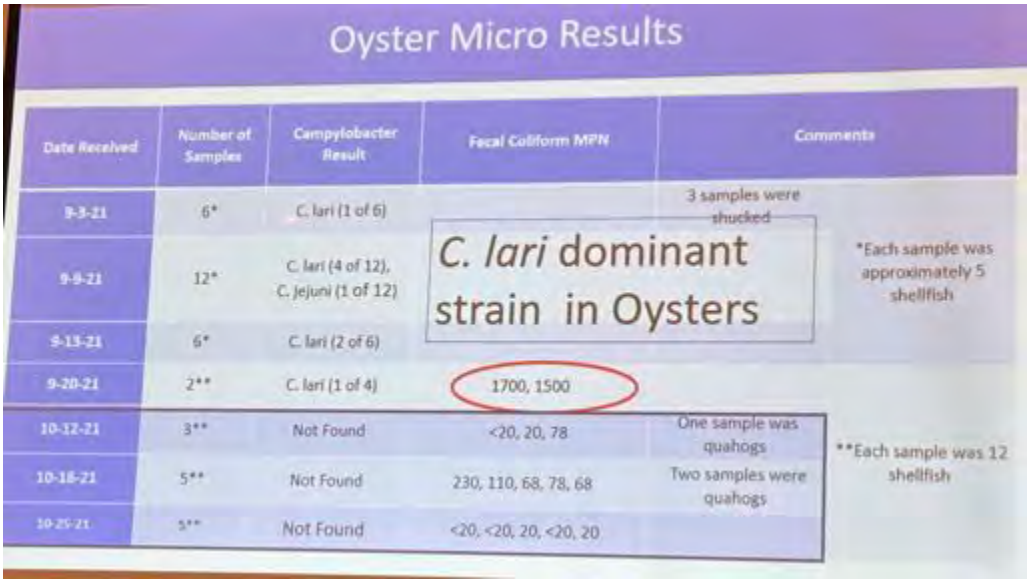
Date	Rain	Days after rain	Status	Fecal coliform (cfu/100 ml)						
				P	A	A	A	A	A	A
				10-23	10-24	10-27	10-28	10-29	10-30	10-31
4/14/2021	0.83	13	Open	1.9	1.9	1.9	1.9	1.9	1.9	2.0
6/7/2021	2.39	8	Open	1.9	8.0	4.0	1.9	2.0	2.0	18.0
7/7/2021	1.82	4	Open	4.0	4.0	4.0	1.9	4.0	4.0	1.9
8/12/2021	2.10	7	Open	2.0	2.0	5.0	1.9	1.9	1.9	2.0
9/27/2021	0.69	3	Closed	50.0	140*	48*	18.0	4.0	10.0	6.0
10/8/2021	1.09	4	Closed	7.0	100*	11.0	6.0	6.0	1.9	1.9
10/20/2021	1.09	16	Closed	6.0	4.0	1.9	2.0	1.9	2.0	2.0

* = flocks of birds noted near sample site

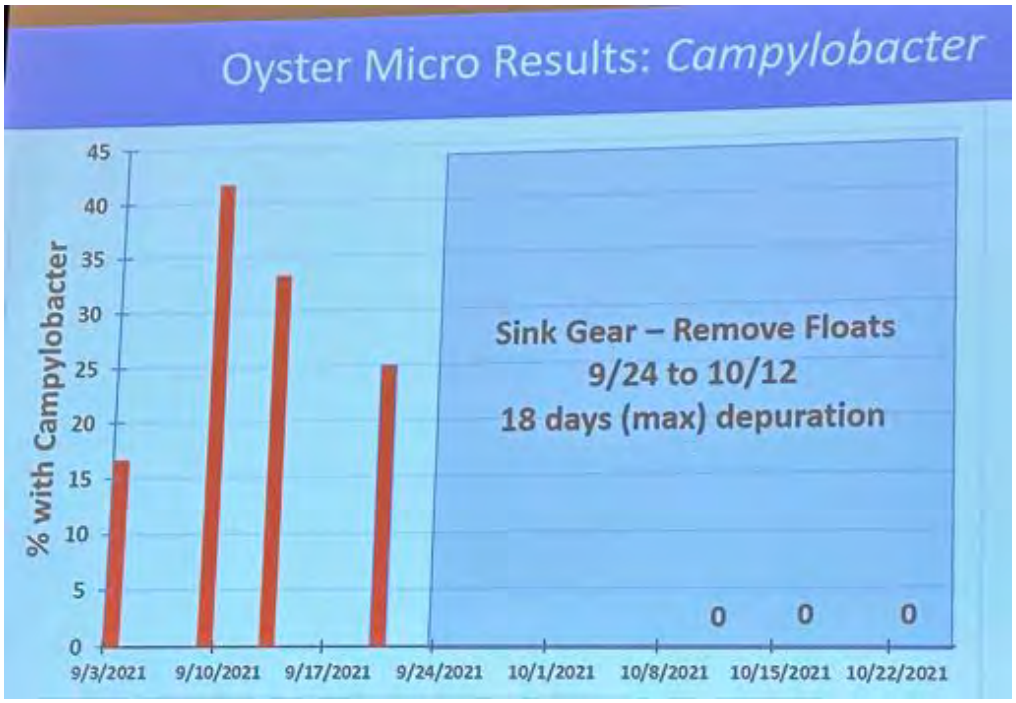
Field observations and detection of Campylobacter lari suggested that waterbirds (gulls, cormorants), which frequently observed roosting on floating gear were a probably but unquantified source of oyster contamination.



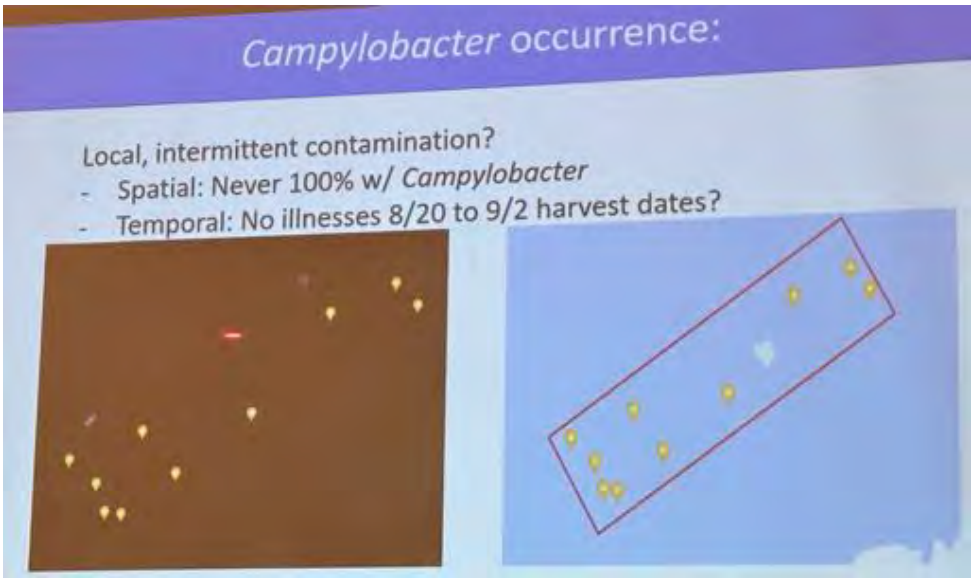
These patterns could reflect the fact that storms affect bird behavior.



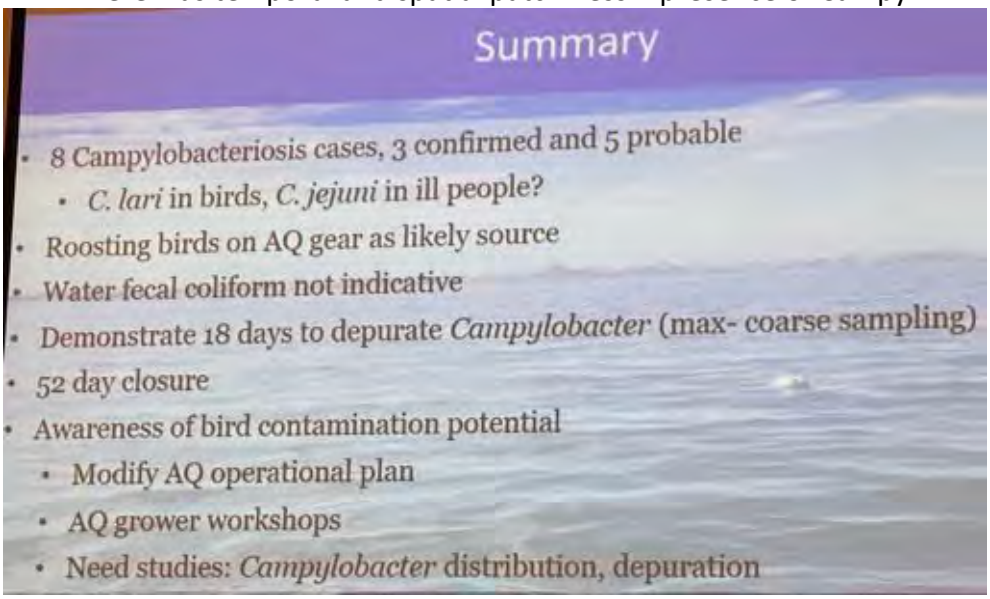
Elevated levels of Campylobacter lari (8 out of 26 samples, 31%), C. jejuni (1 of 26 samples, 4%) and fecal coliform were detected in oysters. While both C. lari and C. jejuni were identified in aquaculture oysters, only C. jejuni was confirmed in ill patients.



Floating gear was removed, and oyster cages were sunk to the bottom to get rid of birds. Campy and FCs went down to acceptable levels in less than 18 days (max time due to to coarse sampling schedule) after birds were gone.



There was temporal and spatial patchiness if presence of Campy.



The illness outbreak and investigation and depuration period resulted in the shellfish area being closed for 52 days.

Note: there is no regulatory NSSP guidance about Campy.
Campy illness cases are very rare.
No samples were taken from birds at this site.
C. lari is the strain found in birds, and C. jejuni in people only.

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8. **The prevalence of birds as sources of fecal contamination in the shellfish waters of the northeast U.S. (Jones, Howell, Foxall, Howell)**

Bacterial indicators, fecal contamination
Information on sources and abundance of different types of fecal-borne water contamination is essential for managing human health and safety risks in shellfish growing waters.

How is Water Quality Monitored?

The State of New Hampshire and all other states have set standard bacterial indicator level criteria for posting advisories at beaches and for recreational uses that are in compliance with the U.S. EPA, and for managing shellfish harvesting in compliance with the FDA.

INDICATOR	THRESHOLD RISK LEVEL
Fecal coliforms for approved shellfish harvesting	14 cfu/100 ml
E. coli for freshwater recreational uses	1 sample > 158 counts/100 ml, or 2 samples > 88 /100 ml
Enterococci for marine water recreational uses	1 sample > 104 counts/100 ml

Bacterial Indicators of Fecal Contamination

- **Fecal coliforms, *E. coli*, enterococci**
  - They are present in all animal feces in high numbers
  - They have been used for decades as standards to manage water quality and uses

There are several important limitations of their use, particularly:

Their presence DOES NOT help to differentiate animal from human sources when routine analyses are performed

Routine monitoring for bacterial indicators of fecal contamination provides little information so strategies termed Microbial Source Tracking (MST) have been developed to provide this information.

Microbial Source Tracking:
Definition

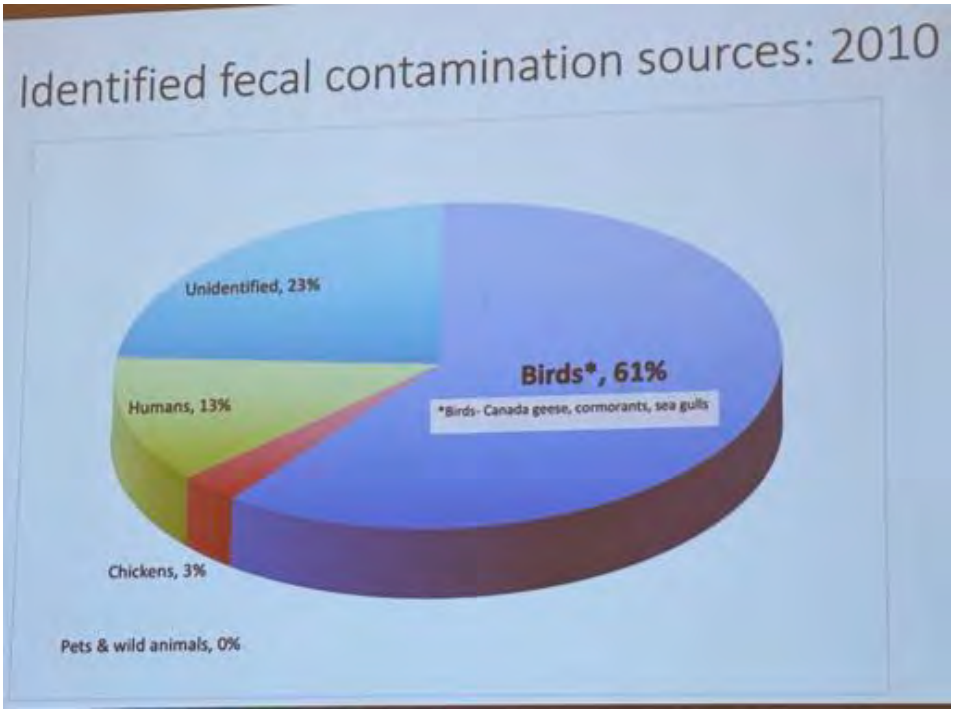
Microbial source tracking (MST) describes **a suite of methods and an investigative strategy for determining fecal pollution sources in environmental waters** that rely on the association of certain fecal microorganisms with a particular host.

MST is used to better classify and allocate the contributions of fecal contamination, particularly from nonpoint sources, within watersheds both in clean and pollution impacted areas.

Fecal coliform and *E. coli* concentrations in local source types

Local Source	Concentration FC /g ww	Concentration Ec/g ww
Goose	230,000	230,000
Goose	11	11
Goose	237,000,000	237,000,000
Cormorant	512	512
Cormorant	<MDL	<MDL
Cormorant	47,778	47,778
Mixed Avian Feces	677,778	666,667
Septage	800,000	800,000
Septage	52,222	2,222

Fecal coliforms and E coli correlated.



Fecal coliform contamination sources in shellfish growing areas.

Microbial Source Tracking: Current UNH (EPA, USGS) Method

PCR of source-specific genetic markers

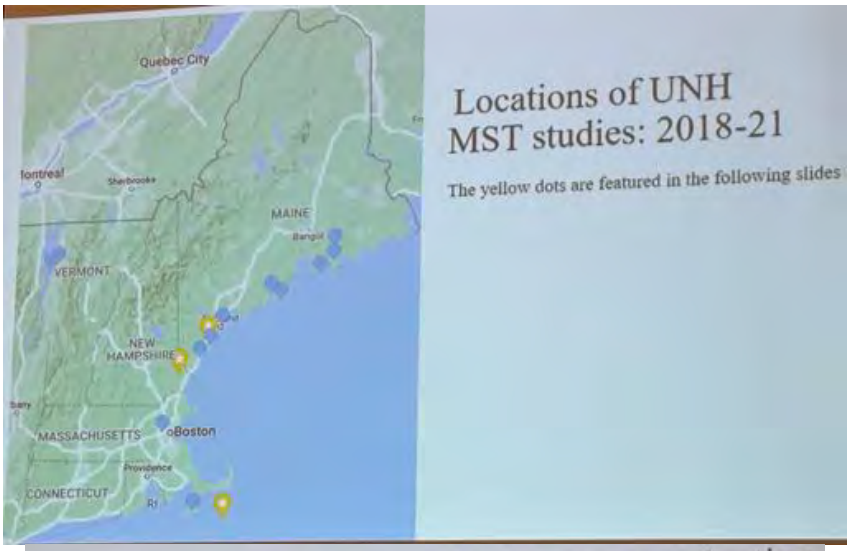
from **Bacteroides spp.* **and other bacterial species

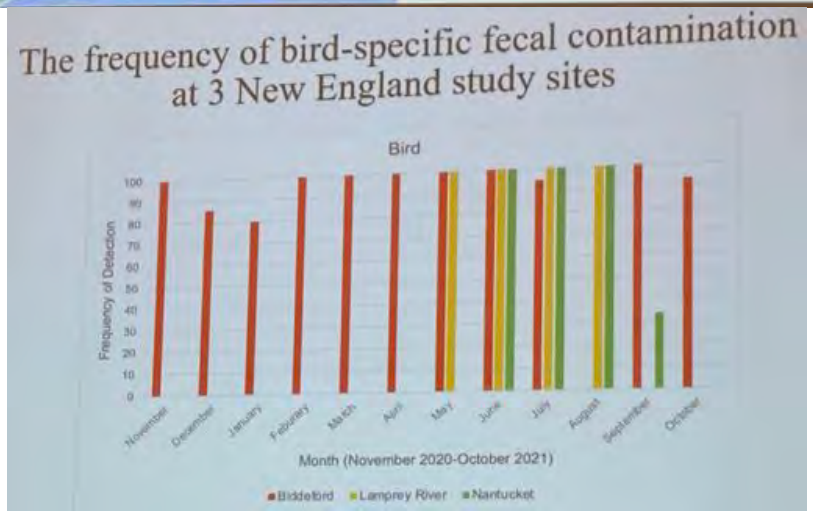
- PCR = Polymerase Chain Reaction
  - Repeated copying of source-specific DNA- increased amount eventually can be visualized
  - Can detect low levels of target DNA in ~3 hours
  - **Target sources**: general fecal (animal) contamination & **human, ruminant, dog, gull, bird, Canada goose, cow, horse**
  - Presence/Absence (PCR) or semi-quantitative (qPCR)

*Bacteroides

- Obligate anaerobes, do not survive long in oxygenated environments
- Found as the predominate genus in the gastrointestinal tract in mammals
- Researchers have been able to differentiate *Bacteroides sp.* on a source level (Human, Dogs, Ruminants, and other wildlife)

MST: source specific genetic markers



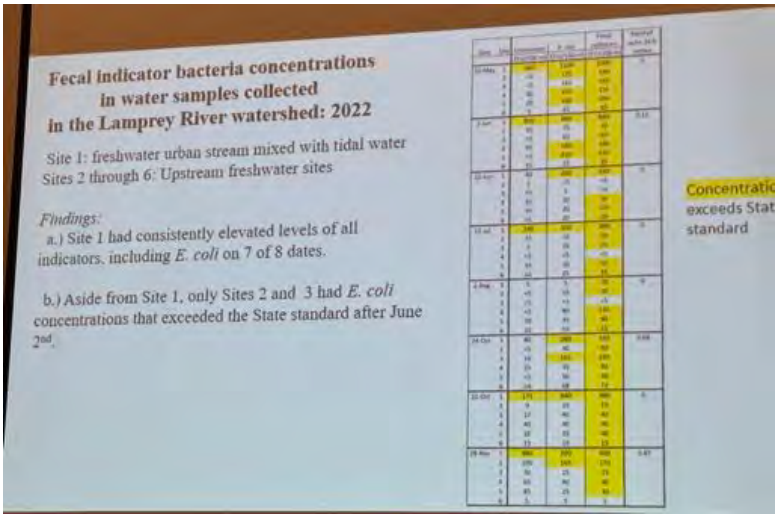


More bird detections in post-breeding period

The frequency of bird-specific fecal contamination at 3 New England study sites

PCR Presence/Absence				
	Biddeford		Lamprey River	
Month	Gull	Canada goose	Gull	Canada goose
November	90.9			
December	28.6			
January	20			
February	87.5			
March	66.7			
April	66.7			
May	65	10.3	0	25
June	38.5	0	25	50
July	61.1	5.6	0	25
August			100	0
September	33.3			
October	29			
Total	53.4	5.3	31.25	25

Gulls and Canada geese FCs

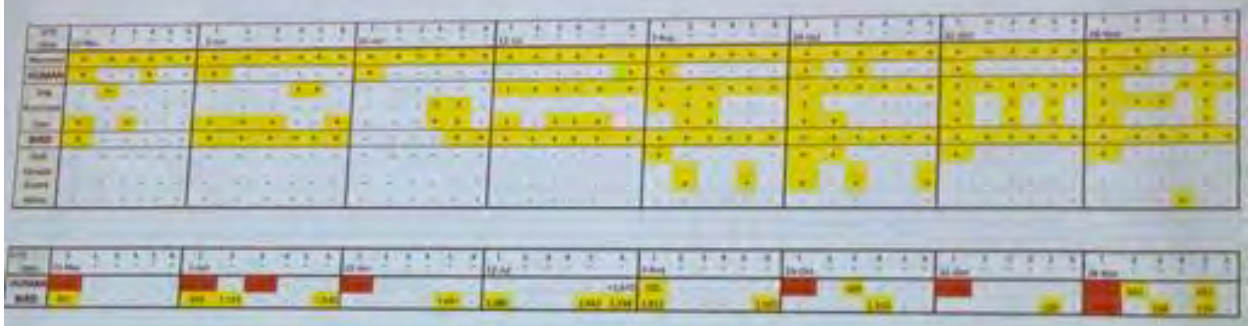


Spatial and temporal patterns of presence and concentrations of different sources of bird fecal contamination – coastal waters of Northeastern US over past several years with chronic and unresolved fecal contamination issues.

Conducted PCR/qPCR-based MST analyses on DNA extracted from water samples, with assays targeting specific contamination sources to complement fecal coliform concentration results. Source-specific assays using both PCR (presence/absence) and semi-quantitative PCR (qPCR, copy number concentrations) assays were used to identify bird, gull, and Canada goose contamination.

The results revealed bird fecal-borne contamination was detected at most sites, varying by season and relative significance as the source of fecal coliforms. The frequency and variable levels of detection for these sources undrly our poor understanding of birds as a health concern. As the understanding of the connection between water quality and public health evolves, shellfish managers and industry will be better able to accurately assign, locate and manage sources of contamination.

Detection of the presence of different pollution sources by MST using PCR (above) and qPCR (below) analyses from May through November 2023.



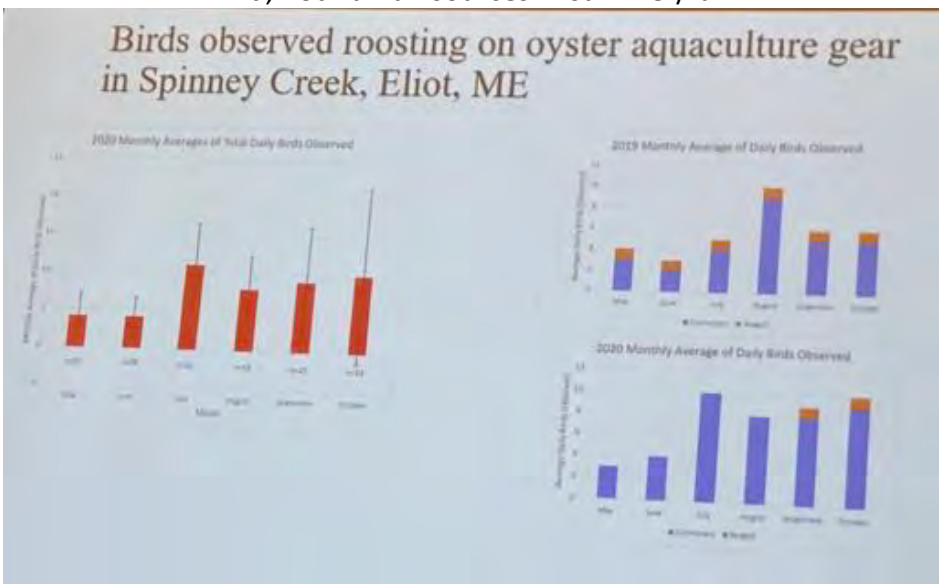
concentration above unacceptable risk threshold of 4200 CN/100 ml

-The human contamination level exceeded the threshold for unacceptable levels of human illness at Site 1 on 6 of 8 sample dates and once at Site 3.

-Various sources contributed to the detected fecal contamination, especially birds, dogs and cows. Site 1 had the most diverse sources, and sources became more diverse after July across all sites.

Bird, not human sources in summer/fall

Birds observed roosting on oyster aquaculture gear in Spinney Creek, Eliot, ME



Counted birds at Spinney Creek – very little impact on FC levels

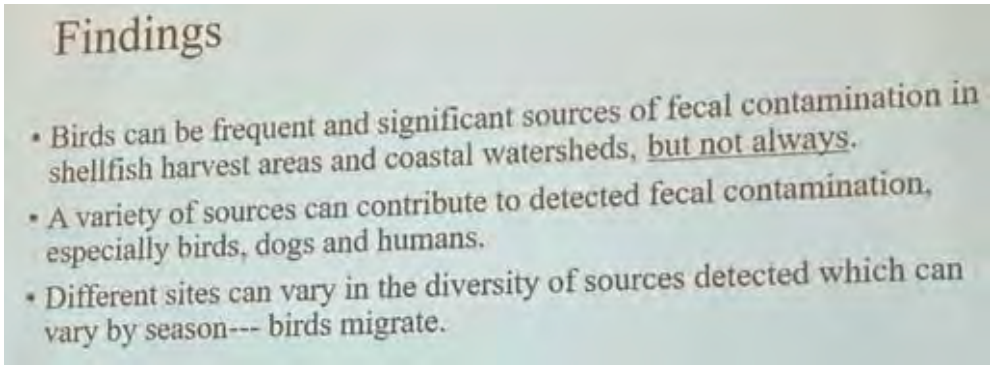
Geometric mean fecal coliform concentrations at study sites and Maine DMR sites

Table 2. Calculated Geomean and Estimated 90th Percentile for three study sites in Spinney Creek, Eliot ME. (NSSP Approved Standard (MF) 31 CFU/100 mL NSSP Restricted Standard (MF) 163 CFU/100 mL)

	Control Site	LPA Site	Headwater Site
Count (n)	24	24	24
Geomean	4.20	6.65	5.22
Estimated 90th Percentile	15.98	31.49	21.93

Table 4. Calculated Geomean and 90th Percentile for two Maine DMR sampling sites in Spinney Creek, Eliot, ME. (NSSP Approved Standard (MF) 31 CFU/100 mL, NSSP Restricted Standard (MF) 163 CFU/100 mL)

	WA015.00	WA016.00
Count (n)	30	30
Geomean	5.25	5.97
Est. 90th Percentile	38.07	43.29



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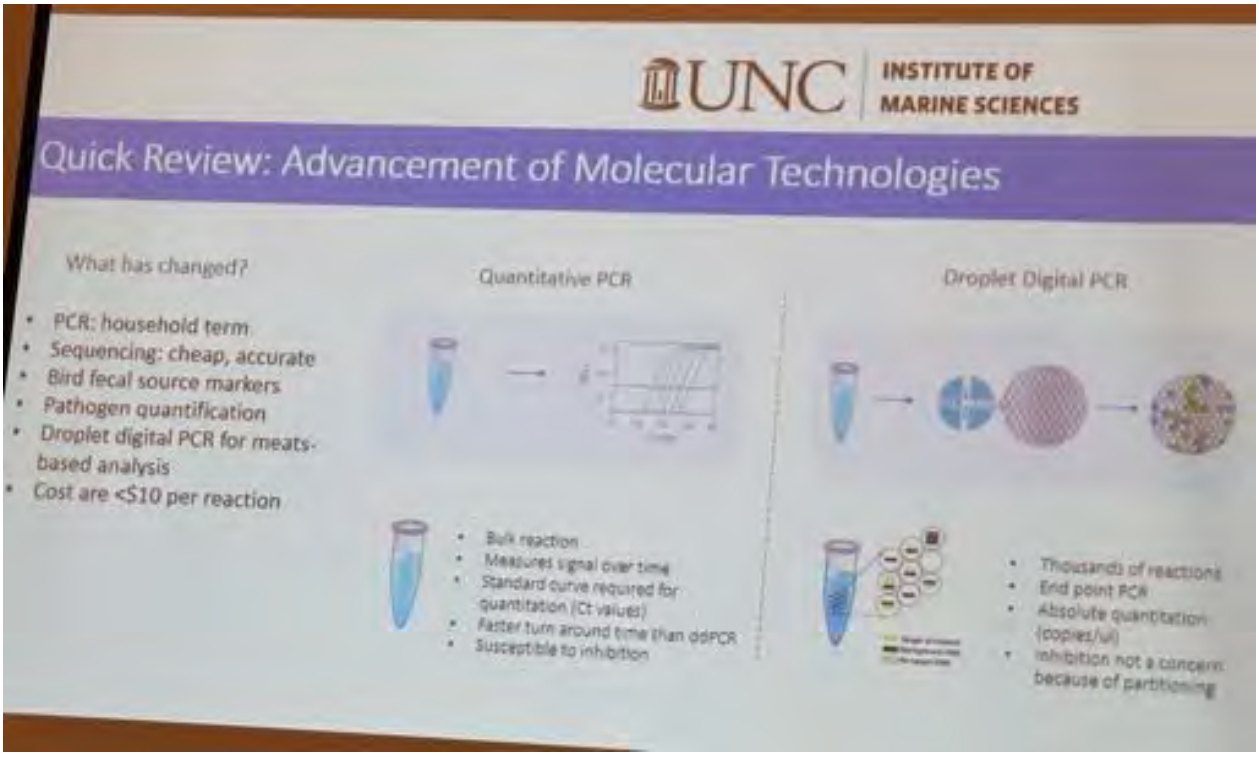
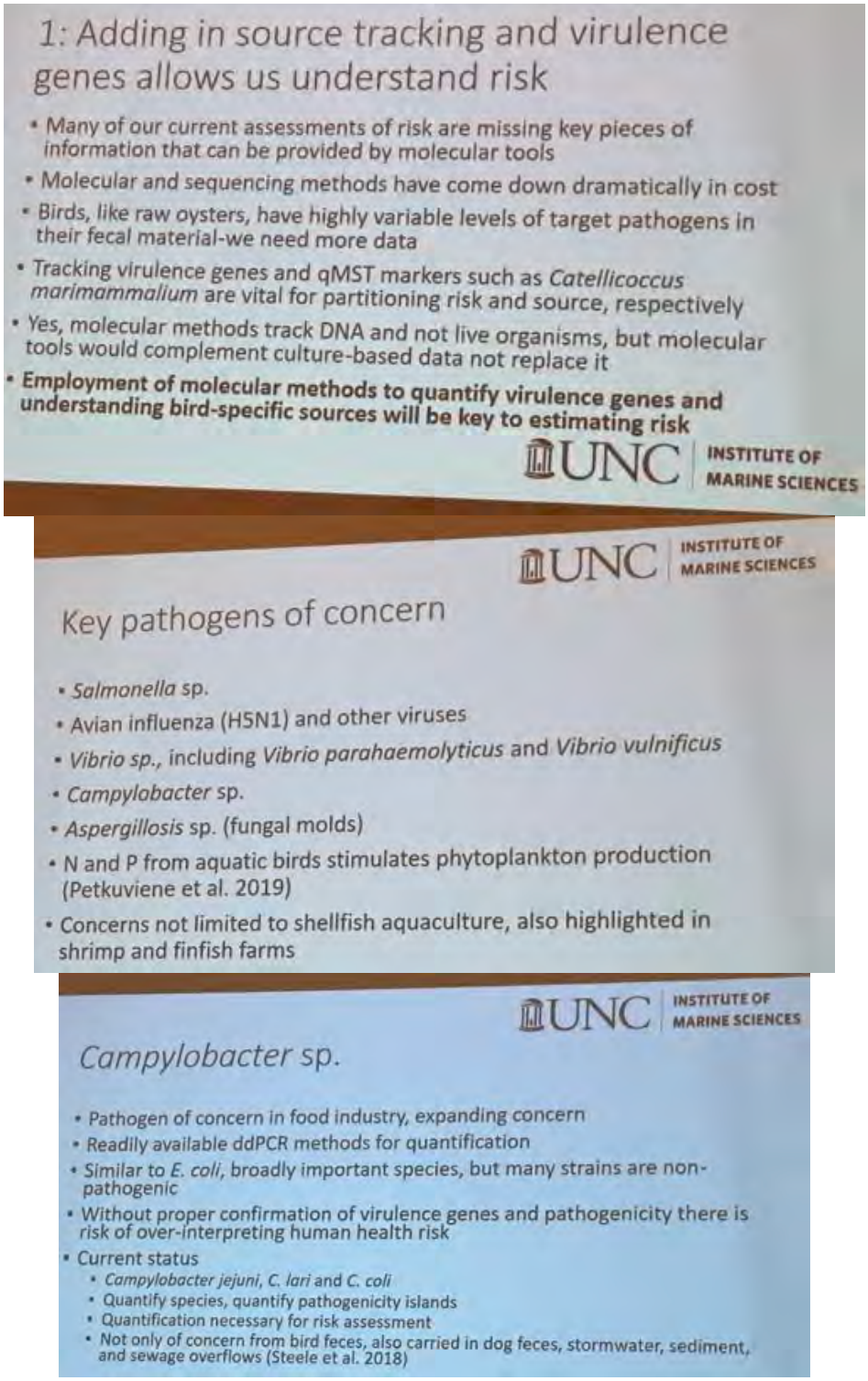
9. **Addressing data gaps in the consideration of bird-based pathogen introduction in shellfish aquaculture (Noble, Ciesielski)**

Pathogens of serious concern from bird feces include Campy, Salmonella, and more recently, avian influenza. Outbreak and causal data are unavailable and problems with illness reporting make it such that any illness associated with bird-feces contaminated shellfish would be difficult to uncover.



QPCR is what's used in covid tests.



Campy very resilient and can live in lots of environments – flexible in temperature and salinity
Species and virulence genes very important

Previous studies have been conducted on both coasts using molecular methods to demonstrate whether there is a relationship between Campylobacter in gull feces and the surrounding water. Many of these studies were hampered by the use of selective media and subsequent PCR-based methods to type isolates which has led to difficulties with bacterial resuscitation.

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Estimates of fecal production by bird type

- Example values for key birds of interest
- 1.7 g per Ibis per event, roughly 10 g per day
- Housed ring-billed gull, roughly 1-2 gram per event, 8.3 g of fecal matter per day
- Coastal gull review, 11.2-24.9 g per day
- Kirschner et al. 2019 describe significant correlation between numbers of wild birds (ducks, geese, gulls), fecal pellet analysis and ENT, FC, and EC concentrations (water)
- Fecal production is highly variable, related to foraging
- Be warned-1 dog event = 6000 gull fecal events (Wright et al. 2004)

NOTE – LOTS of Campy in dog poop. 1 dog poop = 6000 gull poops.

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TABLE 2.

Median and range (in parentheses) of bird abundance, feces input, and investigated FIB at the 7 sampling sites[a]

Site	No. of birds/surveillance area	FTX (feces 100 m^{-2})	FC (CFU 100 ml^{-1})	*E. coli* (CFU 100 ml^{-1})	ENT (CFU 100 ml^{-1})
OS	65 (0-250)	87 (0.0-297)	42 (0-2,300)	52 (0-1,900)	870 (20-17,000)
US	142 (44-490)	47 (0-600)	88 (0-18,000)	70 (0-13,000)	640 (0-60,000)
ZL	85 (34-1,290)	60 (2-167)	0 (0-1,040)	4 (0-620)	780 (28-10,000)
LL1	240 (50-1,000)	70 (12-378)	410 (0-2,400)	210 (10-1,760)	1,380 (290-6,100)
LL2	1,650 (120-5,000)	300 (90-600)	1,800 (100-12,000)	1,200 (50-3,900)	1,700 (250-20,000)
WL	350 (18-500)	123 (9-1,700)	1,150 (0-8,400)	1,000 (0-10,400)	2,650 (0-38,000)
NS	6 (0-70)	11 (0-300)	110 (0-720)	54 (4-900)	96 (4-340)

Open in a separate window

[a]Abbreviations: OS, Oberer Stinker; US, Unterer Stinker; ZL, Zicklacke; LL1 and LL2, two sampling stations at Lange Lacke; WL, Wörthenlacke; NS, Lake Neusiedler See.

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1)

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Carriage rates highly variable across literature

Author	Year	Location	No. Samples	*Salmonella* Carriage Rate
Berg et al.	1972	US (Oregon)	521	2.1%
Fenlon	1981	UK	1241	12.9%
Rosef et al.	1981	Norway	54	1.7%
Kapperud et al.	1983	Norway	179	2.2%
Butterfield et al.	1983	UK	2766	3.4%
Fenlon	1983	UK	20	55.0%
Fricker	1984	UK	1080	17.3%
Girdwood et al.	1985	UK	5858	7.8%
Monaghan et al.	1985	UK	2985	9.5%
Quessy et al.	1992	Canada	264	8.7%
Sixl et al.	1997	Czech Republic	41	51.0%
Wahlstrom et al.	2003	Sweden	111	4.0%
Palmgren et al.	2005	Sweden	1047	2.7%

Table 2.1: Reported *Salmonella* carriage rates in seagull fec

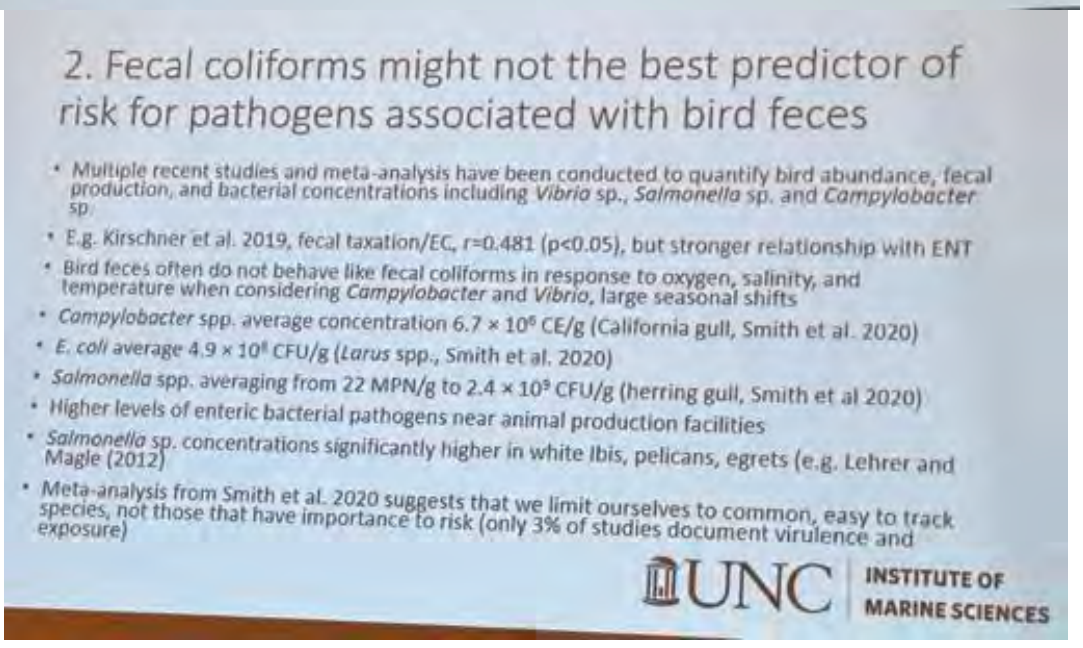
Author	Year	Location	No. Samples	*Campylobacter* Carriage Rate
Rosef	1981	Norway	54	50.0%
Glunder et al.	1989	Germany	65	24.6%
Quessy et al.	1992	Canada	264	15.9%
Kapperud et al.	1993	Norway	179	23.5%
Palmgren et al.	1997	Sweden	50	0.0%
Sixl et al.	1997	Czech Republic	41	63.0%
Broman et al.	2002	Sweden	786	31.8%
Moore et al.	2002	UK	205	13.7%
Wahlstrom et al.	2003	Sweden	104	22.0%

Table 2.2: Reported *Campylobacter* carriage rates in seagull feces

Adapted from dissertation work of Jennifer Murphy, https://core.ac.uk/download/pdf/210597315.pdf

What % of gulls carry Salmonella or Campylobacter?

More recent studies have utilized more advanced sequencing and typing techniques to quantify Campylobacter spp. and Salmonella spp. bacteria in shellfish and have demonstrated that there are strong relationships between bird fecal source markers (such as Catellicoccus) and Campylobacter and Salmonella presence.



NC shellfish aquaculture bird abundance and aggregate data

- All credit to Tyler O'Keefe, in person observations
- Bird abundance, biomass, density observations on 15+ shellfish aquaculture farms over 43 dates from June 2022 through March 2023 (recent data!)
- Seasonal values show dramatic variation
- Represents an amazing resource, broadly valuable for aquaculture assessment of bird-related risk
- **Captures an important set of data from wide range of times and conditions (i.e. not only when farm workers are on farm)**
- Has broad implications for biogeochemical cycling, phytoplankton dynamics, aesthetic appeal, and assessment of bird fecal risk to consumers
- Could it be possible to automate something like this?

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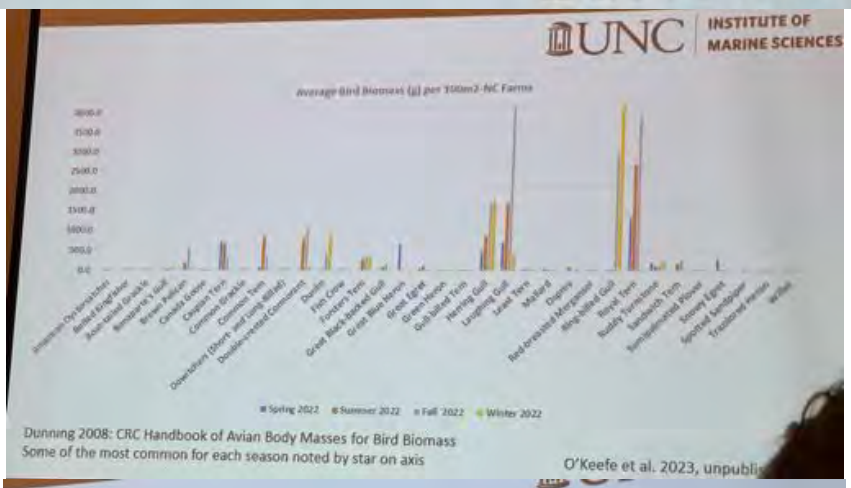
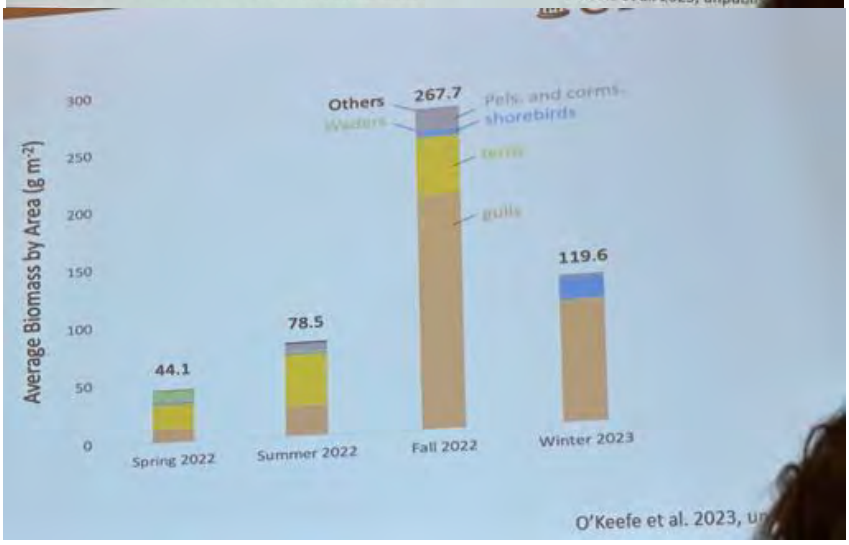
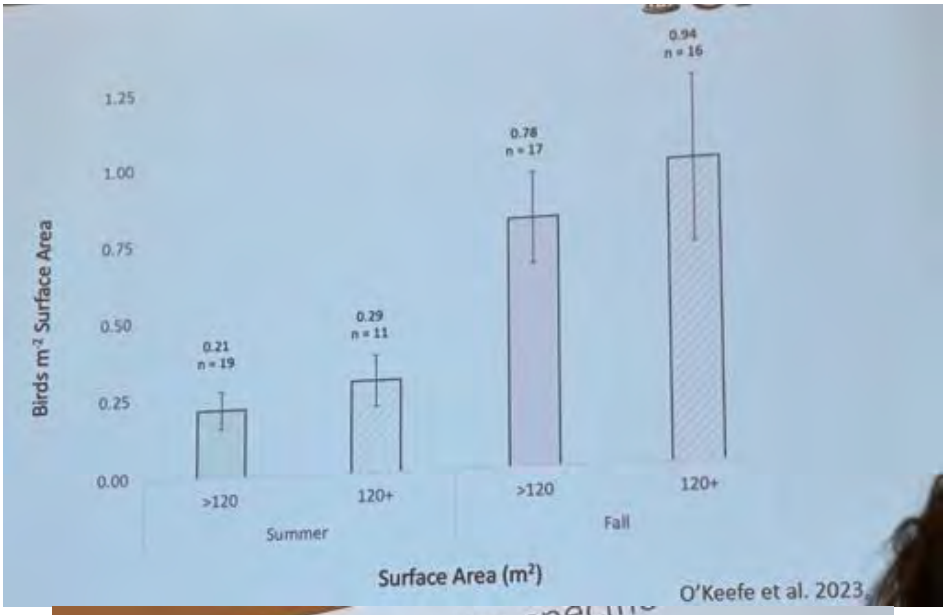


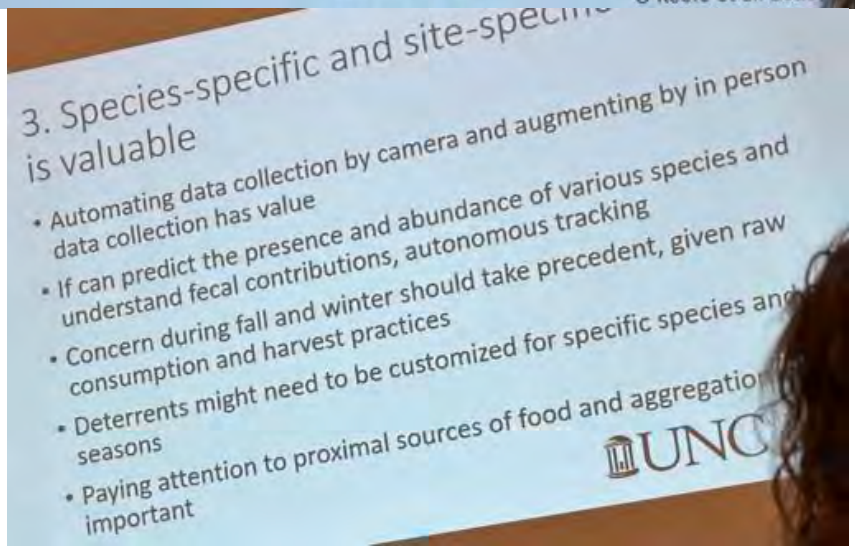
Dunning 2008: CRC Handbook of Avian Body Masses for Bird Biomass
Some of the most common for each season noted by star on axis

O'Keefe et al. 2023, unpubli



O'Keefe et al. 2023, u





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10. Developing strategies for managers and industry to address public health concerns related to bird congregations on floating aquaculture gear (Schillaci, Rheault)

Some places meats trend with water FCs and in some places they don't.

Floating aquaculture gear provides growers with a number of benefits over traditional bottom gear (e.g. avoiding sensitive habitats, ease of handling, improved growth rates, survival, etc) however, floating gear often provides roosting platform for birds.

Waste associated with bird congregations on gear can results in degraded water quality and the introduction of enteric pathogens into growing areas; however, the risk to shellfish consumers associated with bird waste is not fully understood, and we currently do not have an estimate of the correlation of coliforms in wildlife waste and consumer risk; although, the risk is considered to be less than that from human-derived sources.

Interstate Shellfish Sanitation Conference (ISSC)

- 27 member states, FDA, EPA, NOAA, academia, and industry
- The NSSP Model Ordinance (MO) is developed by state regulators and industry members representing each ISSC region
- Individual state agencies are responsible for implementing the Model Ordinance
- FDA evaluates each member state for compliance

FDA U.S. FOOD & DRUG ADMINISTRATION

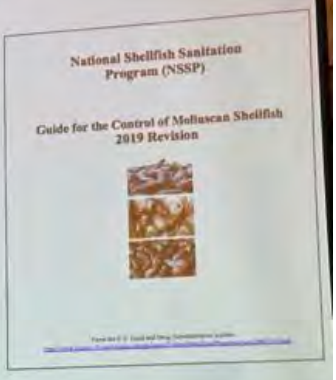
INTERSTATE SHELLFISH SANITATION CONFERENCE ISSC

NOAA FISHERIES

National Shellfish Sanitation Program Model Ordinance

The NSSP MO sets standards for:

- **Classification of Shellfish Growing Waters**
- Patrol and Inspection
- Culture, Harvest, Transport, Processing and Shipping of Live Molluscan Shellfish
- Biotoxin Management
- **Illness Outbreak Response**
- **Aquaculture**
- Recalls of Live Molluscan Shellfish Products



- Employs a preventative approach to protecting public health
- States often set more conservative standards based on resources and state specific industry practices
- Includes guidance chapters to support implementation

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2019 NSSP MO Aquaculture Chapter Update

Under Chapter VI.@04, the Authority is required to evaluate aquaculture sites to determine if the aquaculture operation and the associated culture gear may attract sufficient numbers of birds and/or mammals to the extent that their waste presents a human health risk

If the Authority determines a human health risk may exist or develop, the Authority must require the operator to submit a written operational plan, including mitigation or deterrent measures to minimize the potential pollution impact of birds and/or mammals, to the Authority for approval prior to its implementation.

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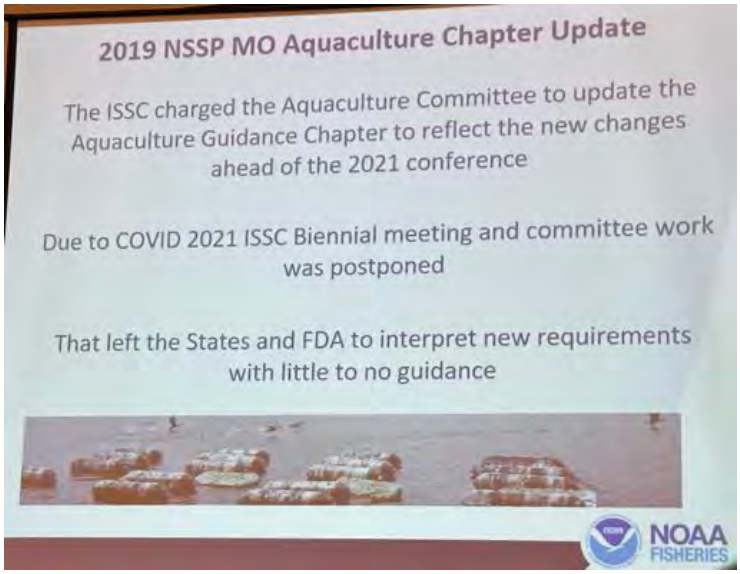
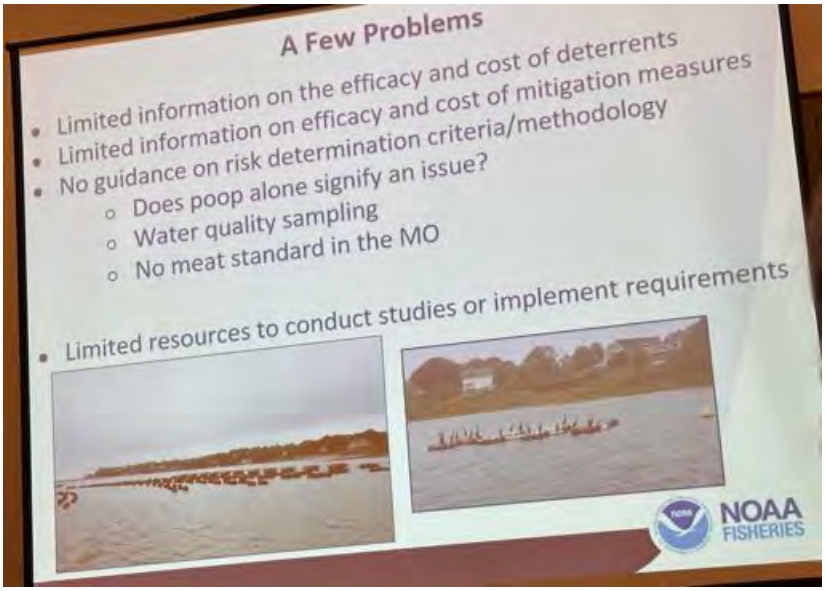


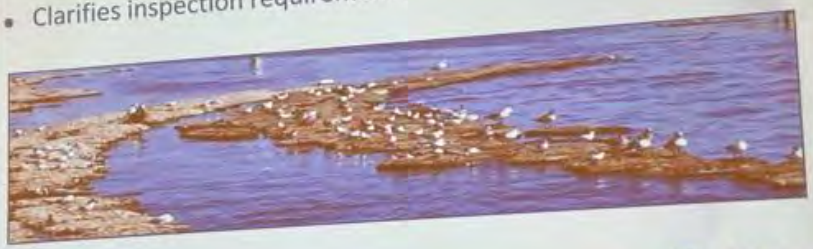


With little guidance on methods to determine risks associated with floating gear and birds, and little information on the efficacy of deterrent measures, industry and state authorities have been challenged to meet new ISSC requirements associated with implementing strategies to manage risk from birds on aquaculture gear.

An ISSC subcommittee has been developing guidance for state authorities that would allow for monitoring and sampling approach to determine risk; however, many state authorities have been forced to adopt a precautionary approach or blanket policy for all floating gear due to lack of resources, expertise and guidance to conduct nuanced risk evaluations.

NSSP Bird & Mammal Congregation Aquaculture Chapter Guidance

- Identifies factors for consideration in risk evaluation
- Outlines two strategies for the Authority to meet new requirements
- Clarifies operational plan requirements
- Clarifies inspection requirements



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NSSP Bird & Mammal Congregation Aquaculture Chapter Guidance

Factors for consideration in risk evaluation

- Seasonal or year round abundance, type, and behavior of birds (e.g. feeding, nesting, migration, etc.)
- Site specific hydrodynamic information (e.g. stratification, tidal magnitude, current velocity, and wave action
- Proximity to other facilities that may attract birds and mammals (e.g. processing facilities, etc.)
- Operation design- The type, extent, and density of exposed gear on the site. Is the gear for nursery and intermediate stages of culture or direct harvest?
- Proactive deterrent measures may provide the Authority with confidence that issues can be avoided before they reach a level of human health concern.

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NSSP Bird & Mammal Congregation Aquaculture Chapter Guidance

Strategies to evaluate risk from new and existing sites

- Monitoring approach- **Authority determines that sufficient evidence does not exist** to preemptively require new or existing aquaculture operators to adopt mitigation or deterrent measures
  - Continue to monitor the growing area in compliance with growing area classification requirements in Chapter IV
  - May require adjusting water quality sampling stations and sampling frequency around aquaculture operations, shellfish sampling, additional inspections
  - May need procedures to rapidly institute operational plans including deterrent and/or mitigation measures should a concern be identified
  - Document any bird and/or mammal congregations on aquaculture sites during aquaculture site inspections, routine water quality monitoring, and consider adjusting sampling/monitoring frequency around any observed trends in wildlife activity

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NSSP Bird & Mammal Congregation Aquaculture Chapter Guidance

Strategies to evaluate risk from new and existing sites

- Preemptive approach- If the Authority determines that **sufficient evidence exists** of a public health concern, or **has insufficient resources** to increase monitoring around new aquaculture operations
  - Blanket mitigation measures (e.g. sink before harvest, seasonal or year round floating gear restrictions, etc.) and/or
  - Blanket deterrent measures (e.g. require all or specific types of operations to employ deterrents)
  - Continue to document any bird and/or mammal congregations on aquaculture sites during aquaculture site inspections, routine water quality monitoring, and monitor water quality within proximity to aquaculture facilities to evaluate efficacy

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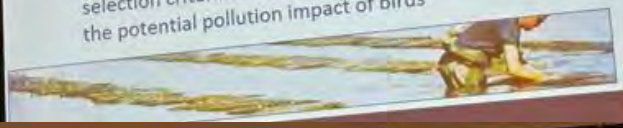
NSSP Bird & Mammal Congregation Aquaculture Chapter Guidance

Strategies to evaluate risk from new and existing sites

- The approach the Authority employs will generally be based on the availability of resources to conduct additional water quality sampling at existing aquaculture sites
- Additional factors include the availability of resources and existing information and past observations at the site
- The information can come from growing area classification documentation, external sources, and/or information provided by the aquaculture operator
- Growers are encourage to describe in application materials any site selection criteria or operational design specifics intended to minimize the potential pollution impact of birds



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Proposed Bird Congregation Aquaculture Chapter Guidance

Operational Plan

- Describe any operational, maintenance, handling and/or sanitary practices to prevent contamination of the growing area from waste attributed to congregations of birds and/or mammals on aquaculture structures.
- This may include a written description, sketches and/or photos of deterrents or mitigation measures to be used.
- Plans should address evaluation of the efficacy of deterrent and/or mitigation measures, and potential triggers that would require changing or adapting deterrent or mitigation measures
- Amendments should be made to the plan, as needed

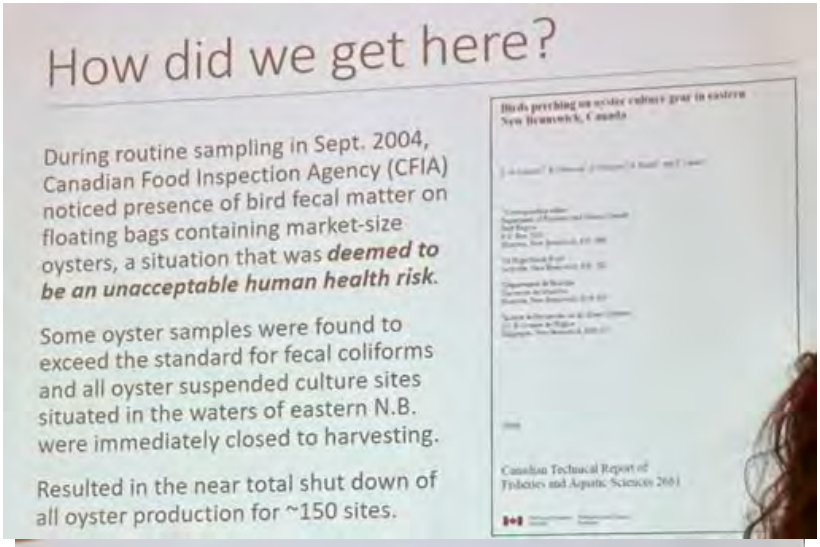
Need to consider developing mgt strategies that take into account a range of considerations such as bird behavior, deterrent efficacy, pathogen prevalence and purge rates, as well as discuss research needs to further refine mgt strategies …

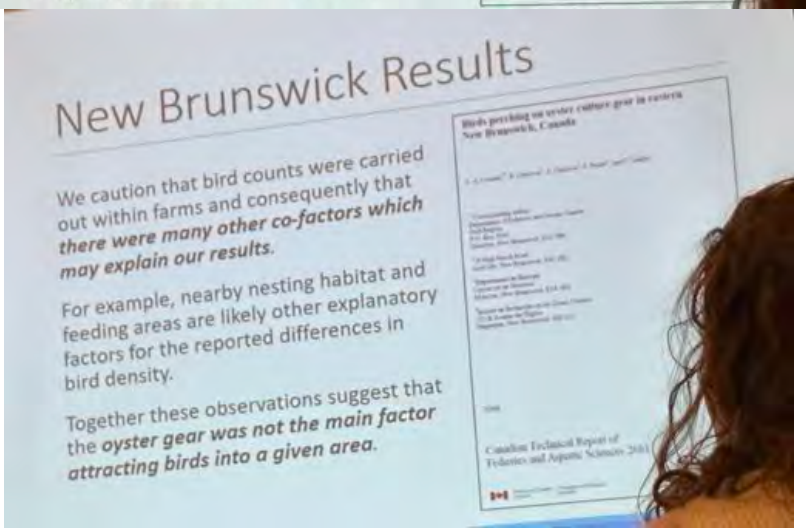
---

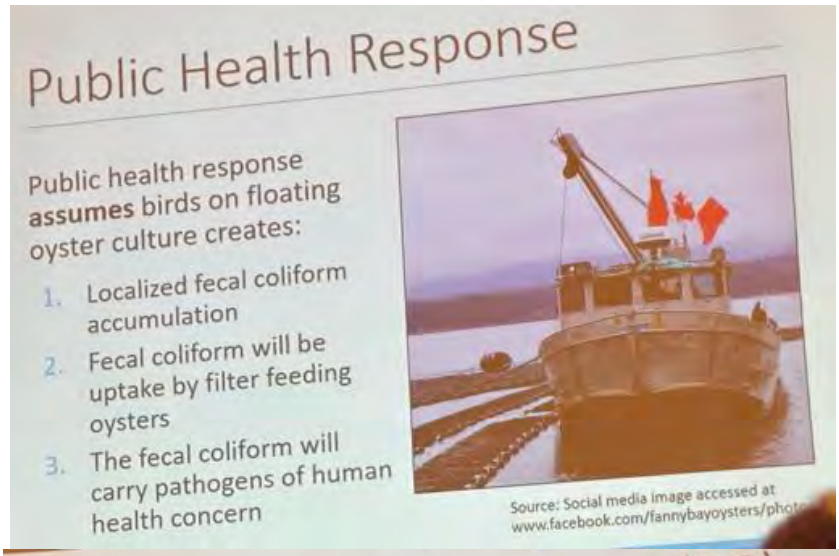
11. Birds on floating culture, oh my! (Hudson)

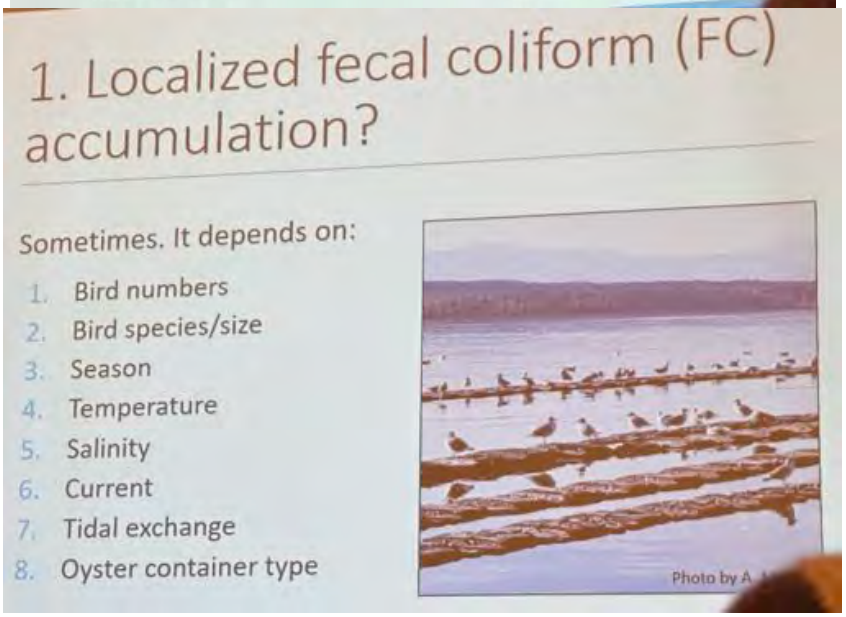
NSSP Model Ordinance – says growers need a bird mgt plan "if presents human health risk"
But this is basically never adequately assessed.

Floating culture systems are used by shellfish farms on the east and west coast of the US, Canada, and the US Gulf Coast.

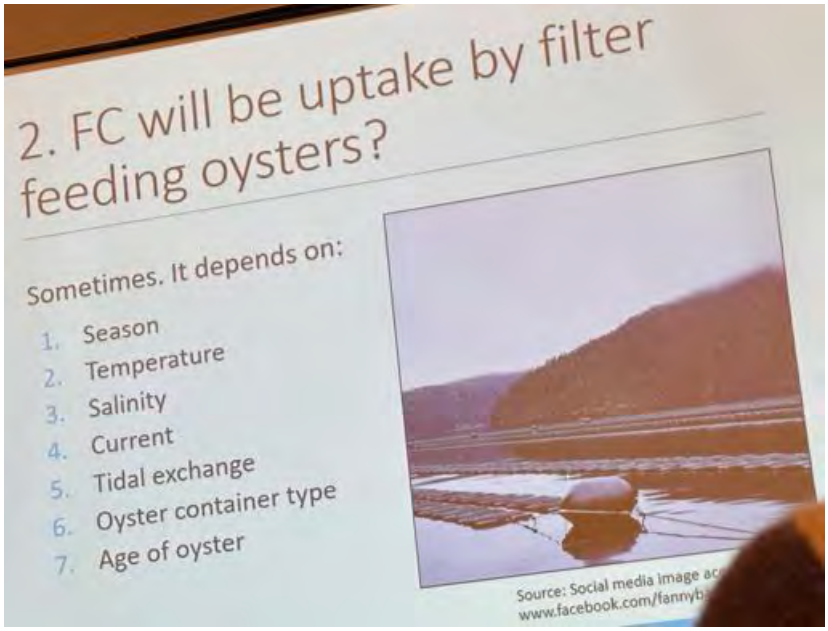




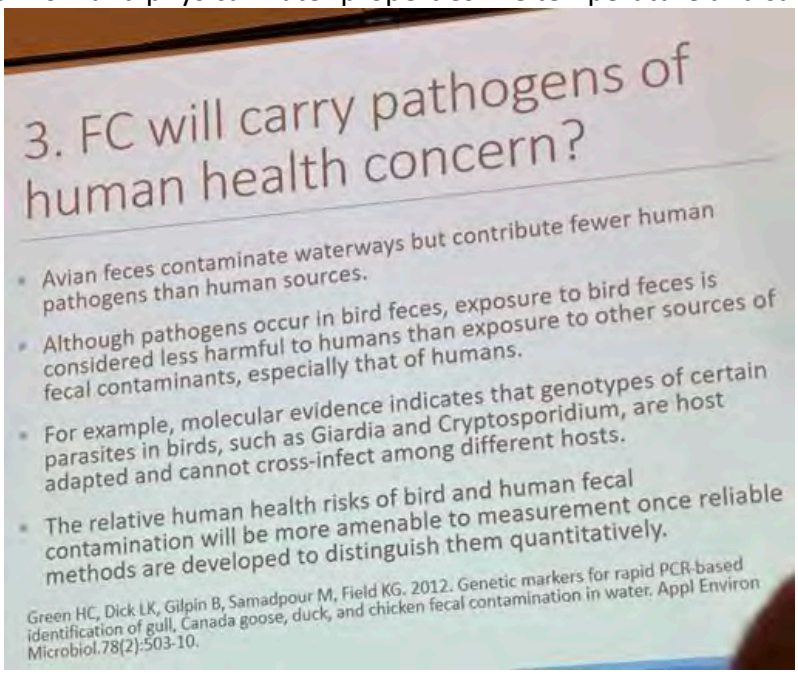




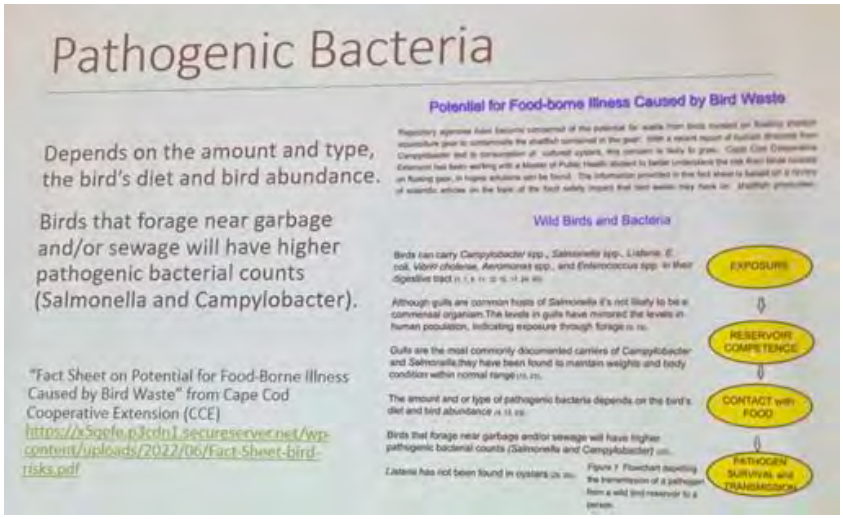
In recent years the fact that these systems provide structures for birds to perch has drawn increasing attention. Bird numbers, species, residence time, and water body dynamics and flushing rate are highly variable

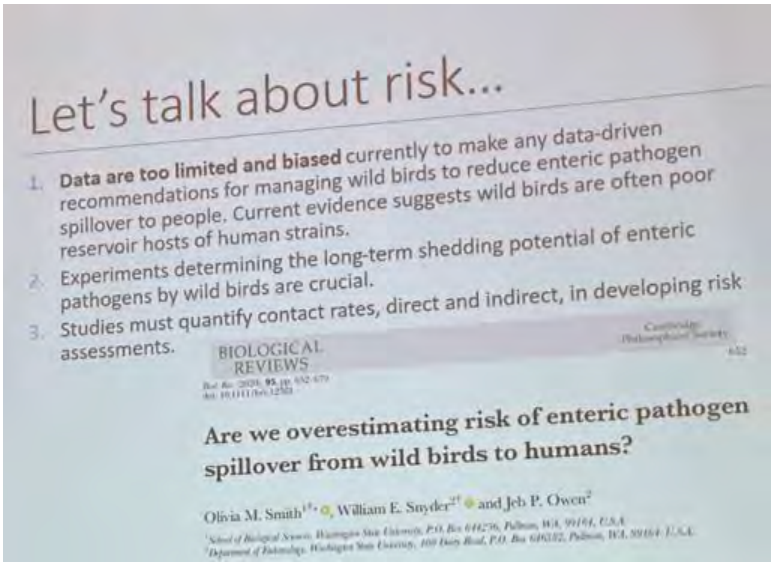


The relationship of birds to fecal coliforms in water and shellfish meats are undoubtedly also highly variable, compounded by seawater flow and physical water properties like temperature and salinity.



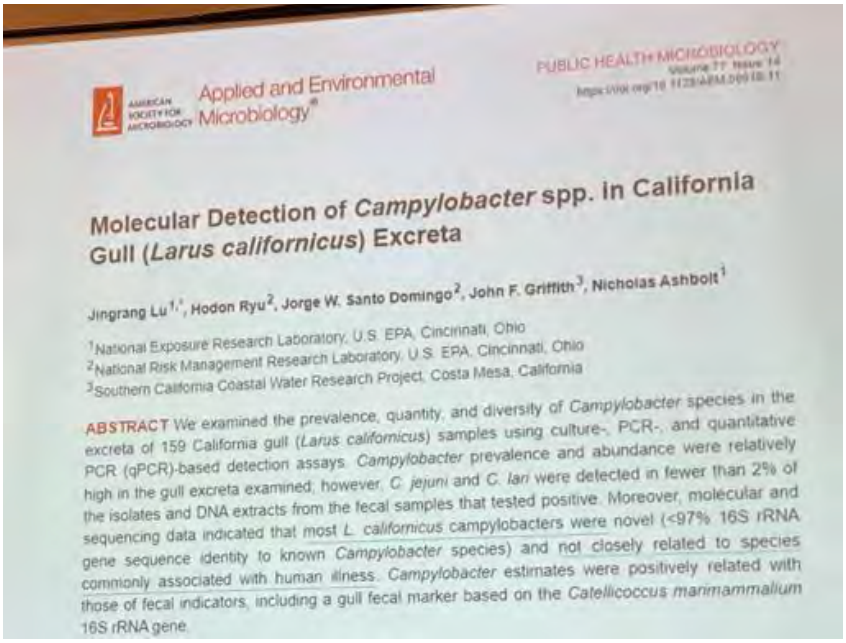
Pathogens often host-adapted – strains in birds don't make humans sick





The NSSP water quality monitoring program is based on measurement of indicator coliform bacteria present in all warm-blooded animal feces. The Fecal coliform standard in NSSP assumes a correlation between pathogens and fecal coliforms in wastewater, not birds.

Birds are actually often poor reservoir hosts of pathogens which cause illness in humans and a recent meta-analysis indicates “data are too limited and biased to make data-driven recommendations for managing wild birds to reduce enteric pathogen spillover to people”



Applied and Environmental Microbiology

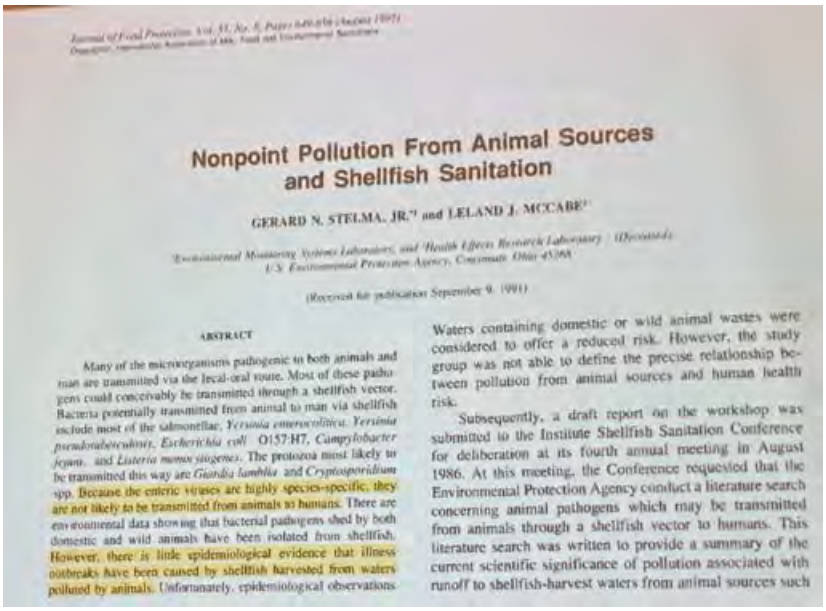
PUBLIC HEALTH MICROBIOLOGY

Molecular Detection of *Campylobacter* spp. in California Gull (*Larus californicus*) Excreta

Jingrang Lu[1,*], Hodon Ryu[2], Jorge W. Santo Domingo[2], John F. Griffith[3], Nicholas Ashbolt[1]

[1]National Exposure Research Laboratory, U.S. EPA, Cincinnati, Ohio
[2]National Risk Management Research Laboratory, U.S. EPA, Cincinnati, Ohio
[3]Southern California Coastal Water Research Project, Costa Mesa, California

ABSTRACT We examined the prevalence, quantity, and diversity of *Campylobacter* species in the excreta of 159 California gull (*Larus californicus*) samples using culture-, PCR-, and quantitative PCR (qPCR)-based detection assays. *Campylobacter* prevalence and abundance were relatively high in the gull excreta examined; however, *C. jejuni* and *C. lari* were detected in fewer than 2% of the isolates and DNA extracts from the fecal samples that tested positive. Moreover, molecular and sequencing data indicated that most *L. californicus* campylobacters were novel (<97% 16S rRNA gene sequence identity to known *Campylobacter* species) and not closely related to species commonly associated with human illness. *Campylobacter* estimates were positively related with those of fecal indicators, including a gull fecal marker based on the *Catellicoccus marimammalium* 16S rRNA gene.



Journal of Food Protection, Vol. 55, No. 8, Pages 649-656 (August 1992)

Nonpoint Pollution From Animal Sources and Shellfish Sanitation

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[1]Environmental Monitoring Systems Laboratory and [2]Health Effects Research Laboratory (Deceased)
U.S. Environmental Protection Agency, Cincinnati, Ohio 45268

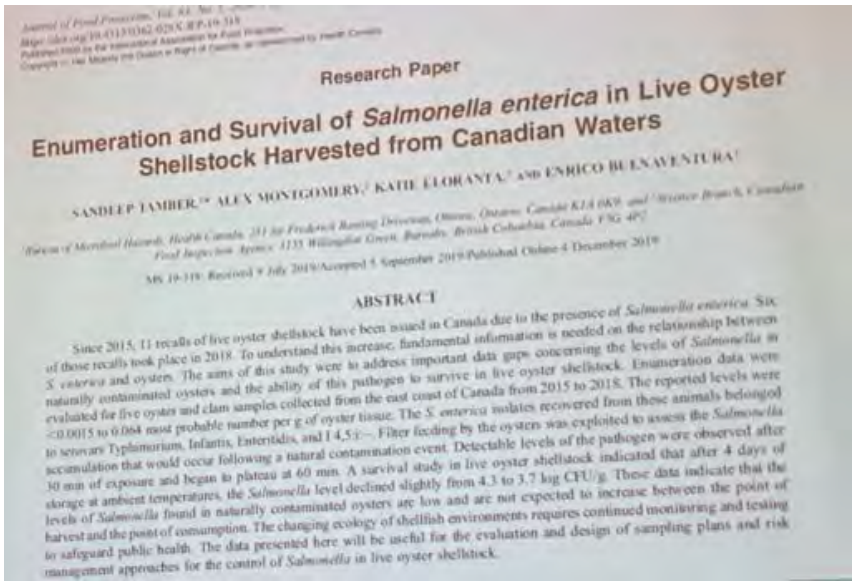
(Received for publication September 9, 1991)

ABSTRACT

Many of the microorganisms pathogenic to both animals and man are transmitted via the fecal-oral route. Most of these pathogens could conceivably be transmitted through a shellfish vector. Bacteria potentially transmitted from animal to man via shellfish include most of the salmonellae, *Yersinia enterocolitica*, *Yersinia pseudotuberculosis*, *Escherichia coli* O157:H7, *Campylobacter jejuni*, and *Listeria monocytogenes*. The protozoa most likely to be transmitted this way are *Giardia lamblia* and *Cryptosporidium* spp. Because the enteric viruses are highly species-specific, they are not likely to be transmitted from animals to humans. There are environmental data showing that bacterial pathogens shed by both domestic and wild animals have been isolated from shellfish. However, there is little epidemiological evidence that illness outbreaks have been caused by shellfish harvested from waters polluted by animals. Unfortunately, epidemiological observations

Waters containing domestic or wild animal wastes were considered to offer a reduced risk. However, the study group was not able to define the precise relationship between pollution from animal sources and human health risk.

Subsequently, a draft report on the workshop was submitted to the Institute Shellfish Sanitation Conference for deliberation at its fourth annual meeting in August 1986. At this meeting, the Conference requested that the Environmental Protection Agency conduct a literature search concerning animal pathogens which may be transmitted from animals through a shellfish vector to humans. This literature search was written to provide a summary of the current scientific significance of pollution associated with runoff to shellfish-harvest waters from animal sources such



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Research Paper

Enumeration and Survival of *Salmonella enterica* in Live Oyster Shellstock Harvested from Canadian Waters

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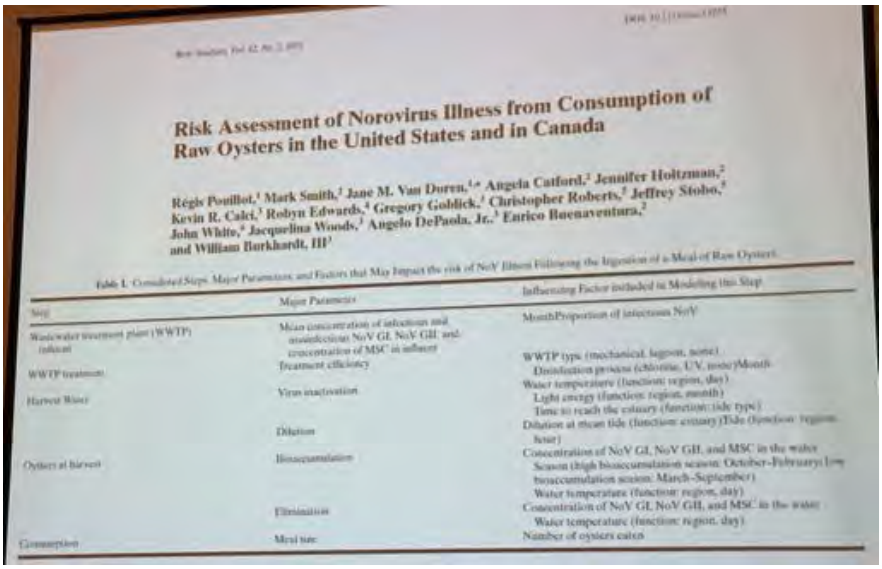
ABSTRACT

Since 2015, 11 recalls of live oyster shellstock have been issued in Canada due to the presence of *Salmonella enterica*. Six of those recalls took place in 2018. To understand this increase, fundamental information is needed on the relationship between *S. enterica* and oysters. The aims of this study were to address important data gaps concerning the levels of *Salmonella* in naturally contaminated oysters and the ability of this pathogen to survive in live oyster shellstock. Enumeration data were evaluated for live oysters and clam samples collected from the east coast of Canada from 2015 to 2018. The reported levels were <0.0015 to 0.064 most probable number per g of oyster tissue. The *S. enterica* isolates recovered from these animals belonged to serovars Typhimurium, Infantis, Enteritidis, and I 4,5:i:−. Filter feeding by the oysters was exploited to assess the *Salmonella* accumulation that would occur following a natural contamination event. Detectable levels of the pathogen were observed after 30 min of exposure and began to plateau at 60 min. A survival study in live oyster shellstock indicated that after 4 days of storage at ambient temperatures, the *Salmonella* level declined slightly from 4.3 to 3.7 log CFU/g. These data indicate that the levels of *Salmonella* found in naturally contaminated oysters are low and are not expected to increase between the point of harvest and the point of consumption. The changing ecology of shellfish environments requires continued monitoring and testing to safeguard public health. The data presented here will be useful for the evaluation and design of sampling plans and risk management approaches for the control of *Salmonella* in live oyster shellstock.



Risk Assessment of Norovirus Illness from Consumption of Raw Oysters in the United States and in Canada

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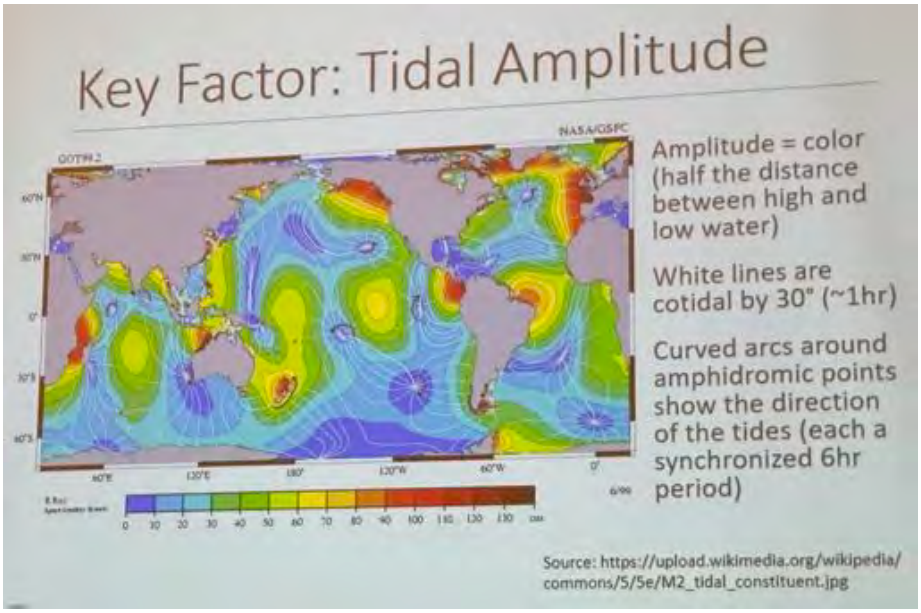
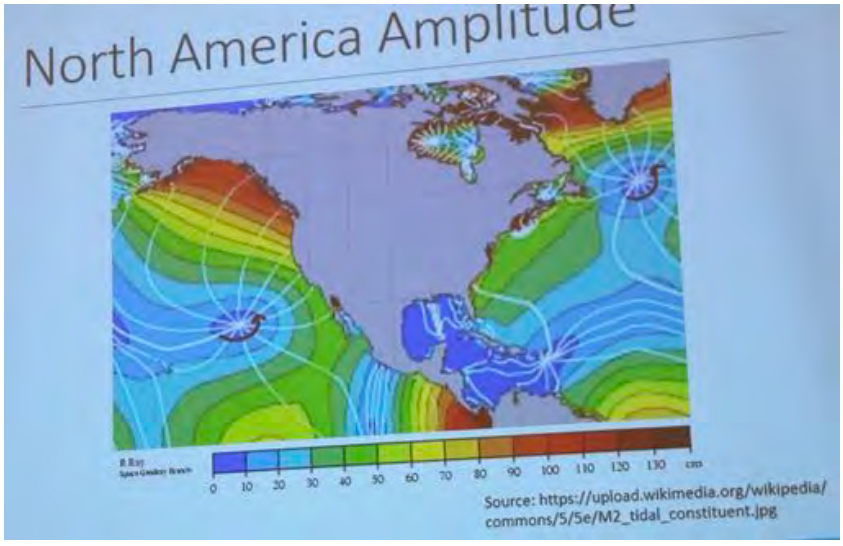
Table 1. Considered Steps, Major Parameters, and Factors that May Impact the risk of NoV Illness Following the Ingestion of a Meal of Raw Oysters.

Step	Major Parameters	Influencing Factor included in Modeling this Step
Wastewater treatment plant (WWTP) influent	Mean concentration of infectious and noninfectious NoV GI, NoV GII, and concentration of MSC in influent	Month/Proportion of infectious NoV
WWTP treatment	Treatment efficiency	WWTP type (mechanical, lagoon, none) Disinfection process (chlorine, UV, none)/Month
Harvest Water	Virus inactivation	Water temperature (function: region, day) Light energy (function: region, month) Time to reach the estuary (function: tide type)
	Dilution	Dilution at mean tide (function: estuary)/Tide (function: region, hour)
Oysters at harvest	Bioaccumulation	Concentration of NoV GI, NoV GII, and MSC in the water Season (high bioaccumulation season: October–February; low bioaccumulation season: March–September) Water temperature (function: region, day)
	Elimination	Concentration of NoV GI, NoV GII, and MSC in the water Water temperature (function: region, day)
Consumption	Meal size	Number of oysters eaten





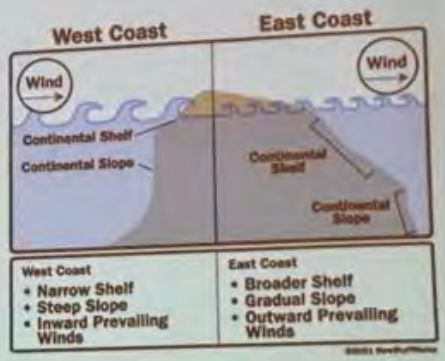
Tidal Height (MLLW)

North America East & West

West Coast: prevailing winds are behind the waves, which increases the waves' energy.

East Coast: prevailing winds blow against the incoming waves, decreasing the waves' energy.

East Coast: the continental shelf is broader, e.g. there's more sand as the shelf drops gradually, like a long ramp.

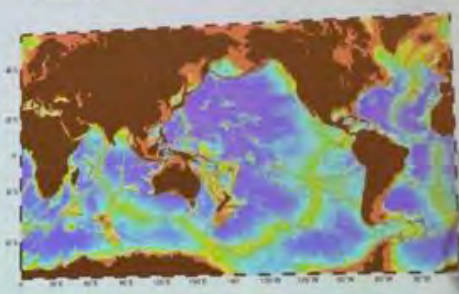


Source: https://science.howstuffworks.com/environmental/earth/oceanography/question628.htm

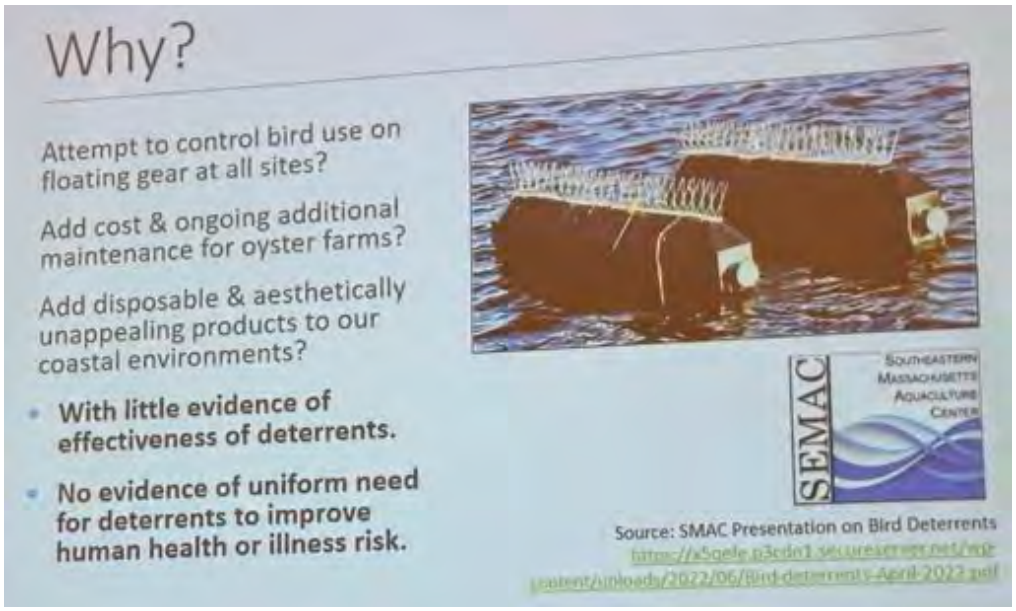
Components of the Sanitary Survey (NSSP)

1. An evaluation of the pollution sources that may affect the growing areas.
2. An evaluation of meteorological factors.
3. An evaluation of hydrographic factors that may affect distribution of pollutants throughout the area.
4. An assessment of water quality.

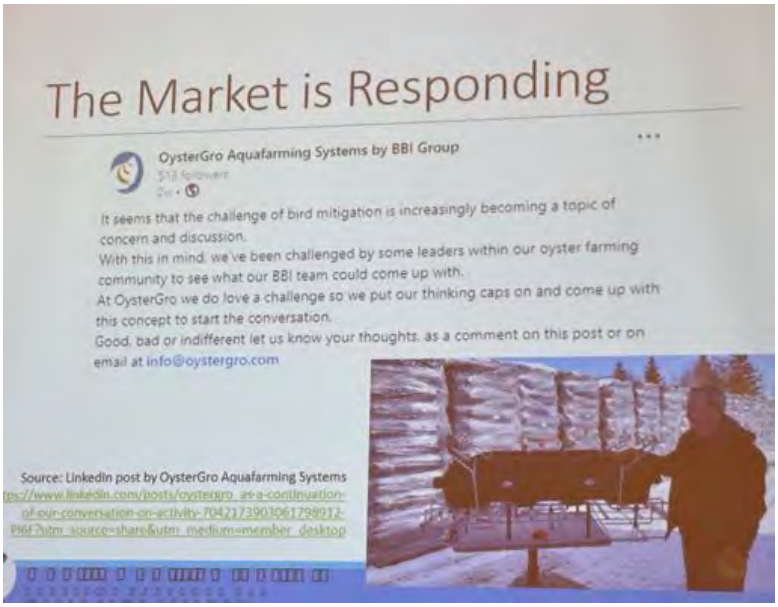
Therefore, shouldn't regulatory requirements for managing birds also consider local conditions?



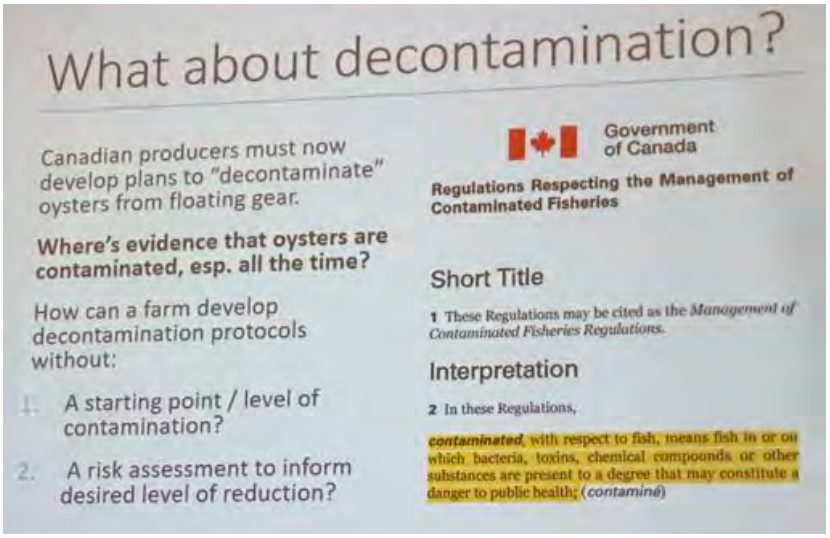
Source: NOAA, http://www.ngdc.noaa.gov/mgg/image/global_topo_large.gif

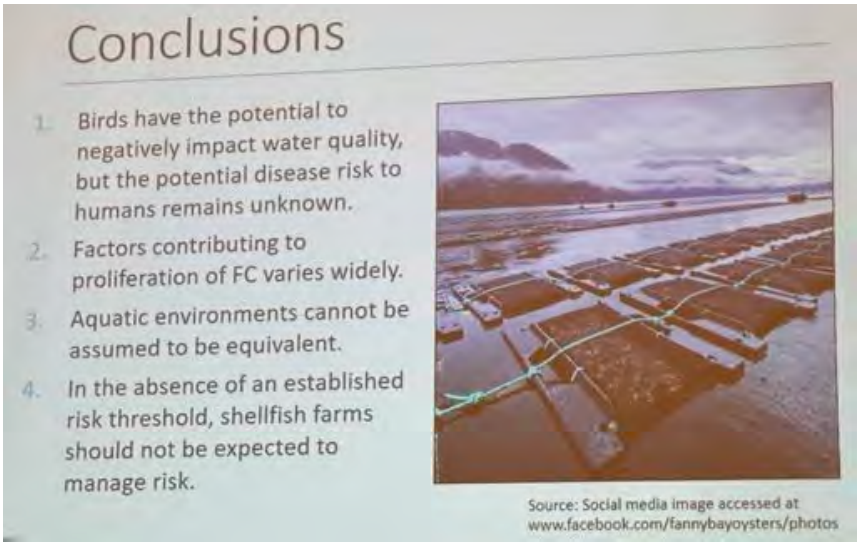


Birds have the potential to negatively impact water quality, but the potential disease risk to humans remains unknown. In the absence of an established risk threshold, shellfish farms should not be expected to attempt to manage risk. Furthermore, factors contributing to the proliferation of fecal coliforms varies widely and therefore risk of birds on floating gear in one aquatic environment cannot be assumed to be equivalent in all environments.



Maybe all this deterrent innovation is putting the cart before the horse – we haven't sufficiently shown that bird-borne pathogens cause human health risk





Discussion after: meat counts in NY were huge but nobody got sick
Looks bad – "putrid filth" is the criteria used by FDA, nothing to do with risk. Just don't want filth on our food. But if they don't fail water quality classification standards, they won't shut down farms and that's the main concern for the grower.