Two independent hydrodynamic models show poor flushing, nutrient concentration and transport to phototrophic zones throughout the bay

First model:

Dr. Chris Kincaid, a physical oceanographer from the URI-Graduate School of Oceanography Coastal Hydrodynamics Lab has provided a 4D ROMS ocean model simulation for the Frenchman Bay area.

Kincaid is part of a multi-disciplinary, multi-institutional NOAA-funded project to better understand the dramatic warming of the Northeast US Shelf (NEUS) (NOAA Award# NA20OAR4310483).

Model Details:

- Discharges from 30 pens at 30m depths, and 2 barges at 2-3m depths.
- Simulated ‘floats’ are released to drift with currents from all 32 discharge sites every hour.
- This model is built on a relatively coarse grid.
- We are working on a higher resolution model.
- 2 week simulation shows massive concentration build up.
- Model provides 3-D, time varying data (every 15 seconds) on:

> ➢ currents,
> ➢ water temperature and salinity,
> ➢ water elevation
> ➢ winds,
> ➢ freshwater input,
> ➢ air temperature, humidity, pressure.

Model circulation responds to both barotropic (tidal) and baroclinic (density) forcing, thereby providing details of tidally driven flows and longer-term residual, or sub-tidal circulation.

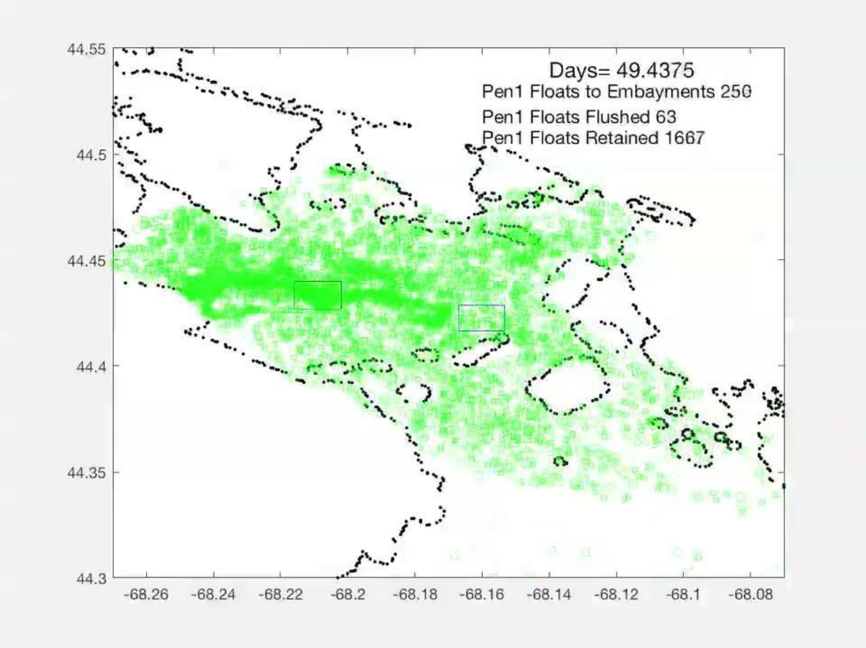
FIGURE 1: BALD ROCK – Video of passive float release from 15 pens (Click left image to see play controls).

Floats are released at:

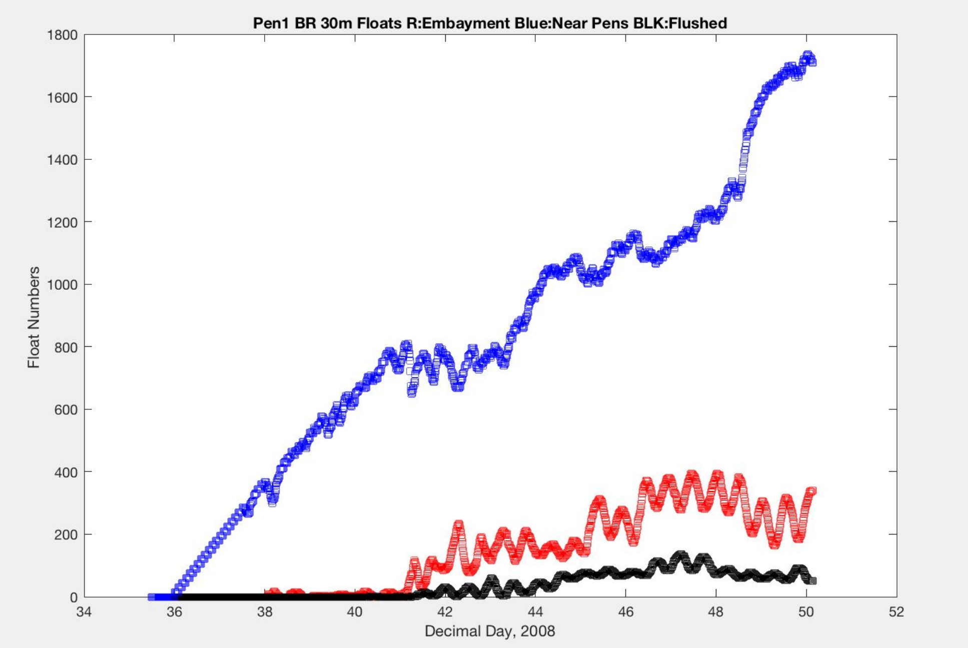
- 1m above the discharge depth (largest symbol)
- the 30m discharge depth (medium symbol
- 1m below discharge depth (smallest symbol)

Float trajectories are updated at each time frame for the 30m floats that have moved:

1. northward into shallower embayments,
2. southward, flushing from the system, or
3. in local, residual gyres that allow floats to be retained near the lease sites.



Movie of passive floats released from Bald Rock
97% of floats (nutrients) are retained in the bay over the two week simulation run time.
Material will concentrate over time.



Temporal evolution for total number of floats in three categories:
into embayments (black), flushed (red), retained (blue)

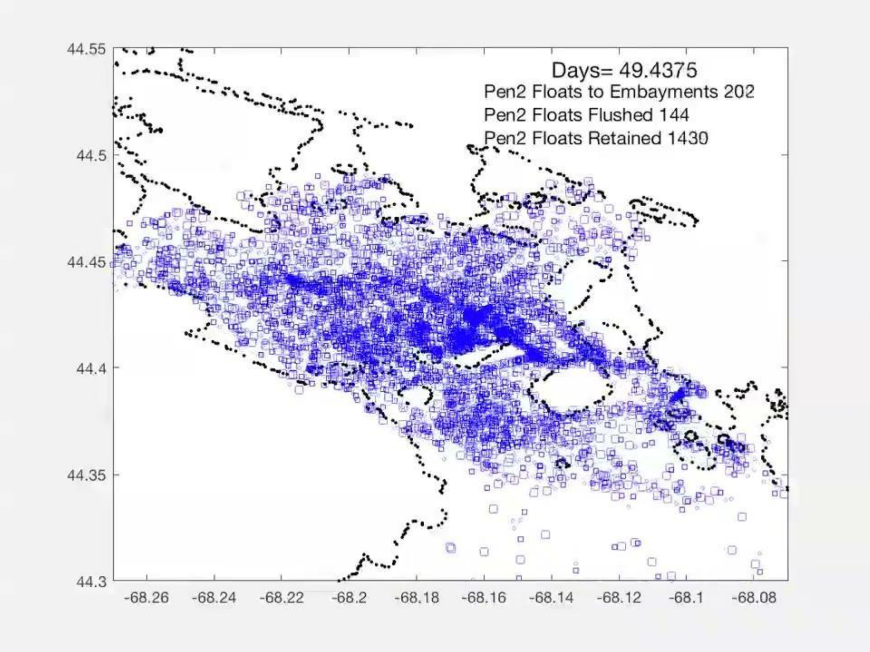
FIGURE 2: Long Porcupine – Video of passive float release from 15 pens (Click left image to see play controls).

Floats are released at:

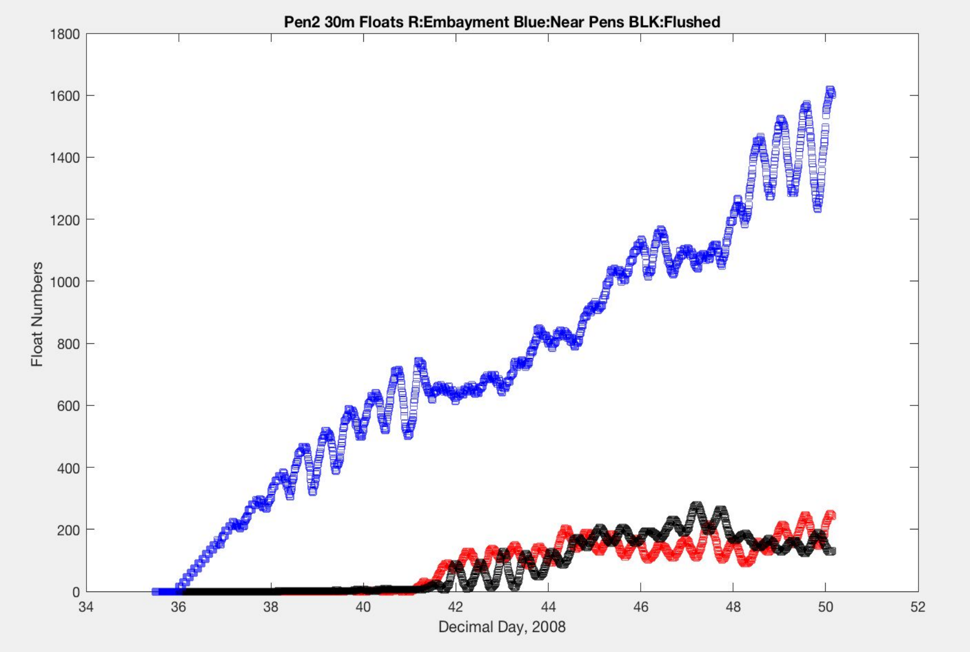
- 1m above the discharge depth (largest symbol)
- the 30m discharge depth (medium symbol
- 1m below discharge depth (smallest symbol)

Float trajectories are updated at each time frame for the 30m floats that have moved:

1. northward into shallower embayments,
2. southward, flushing from the system, or
3. in local, residual gyres that allow floats to be retained near the lease sites.



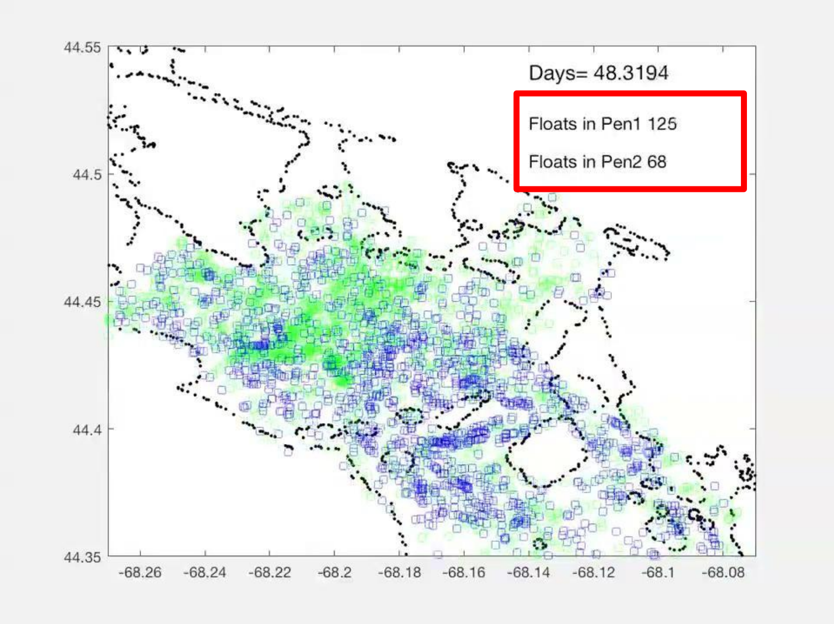
Movie of passive floats released from Long Porcupine.
90% of floats (nutrients) are retained in the bay over the two week simulation run time. Material will concentrate over time.



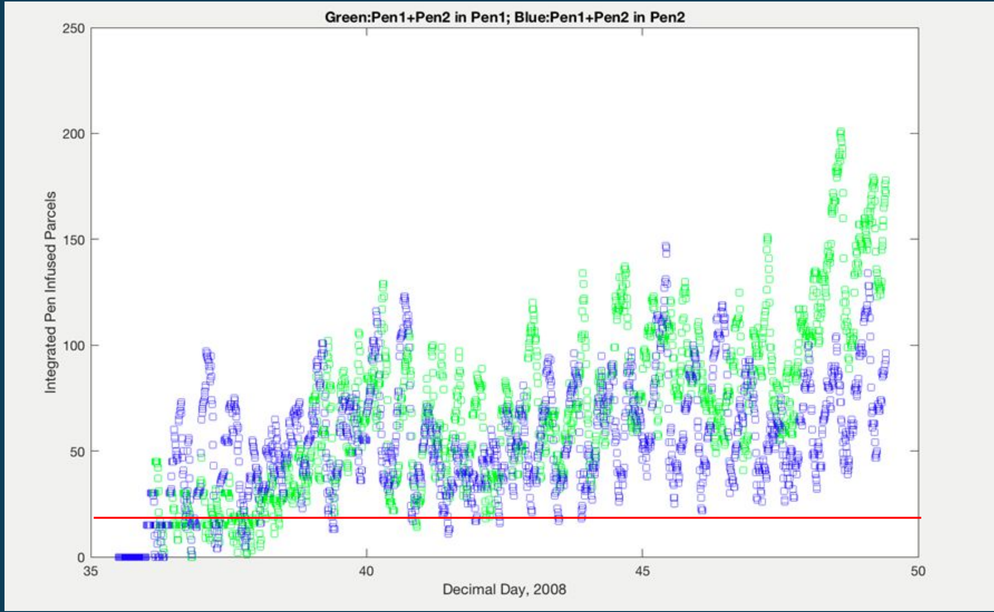
Temporal evolution for total number of floats in three categories:
into embayments (black), flushed (red), retained (blue)

Count of discharged floats re-entering each lease site indicating concentration, not flushing.

In the video on the left, floats track discharges from 15 pens released at 30m depths from both lease sites. The counts in the red box track the number of floats in the lease site at any given time. Anything above the 15 original discharges indicates that previously discharged parcels of water have re-entered the lease site raising nitrogen levels above baseline. Water travelling at this depth shows little evidence of mixing, so nitrogen injected into a parcel of water tends to stay with that parcel.



Counts of floats released from
Long Porcupine (Pen 1) and Bald Rock (Pen 2)
that re-enter either site.



A background float number should be 15, if water is constantly swept away and not re-introduced to the Pen area. The color shows float numbers in each Pen, where floats could have been introduced from either Pen 1 or 2. Below red line @15 means not concentrating.
Green: Num Floats from Pen 1 + Pen 2 in Pen 1 Blue: Num Floats from Pen 1 + Pen 2 in Pen 2

3b. Independent Confirmation by 2nd hydrodynamic model

Similar conclusions of a gyre that moves through the lease sites in a hydrodynamic model by **Dr. Lauren Ross**, Assistant Professor of Civil & Environmental Engineering and Faculty Fellow at the Senator George J. Mitchell Center for Sustainability Solutions, UMaine

Conclusions from modelling:

- While not yet fully validated, assumptions are more valid than Cormix. The URI model agrees with data from the Bar Harbor Tide Gauge, and also with data sampled by the Ransom-deployed ADCPs at both lease sites.
- Floats (and therefore nutrients) do not flush from the bay quickly.
- Discharges from both sites recirculate quickly to the same site, and to the the other site, and therefore concentrate.
- American Aquafarms' discharge concentration calculations which assume clean water at the time of discharge are therefore flawed.
- Nutrients released from both sites, and amplified by repeat visits to sites will be transported to higher (shallower) regions throughout the bay.
- Because effluent is transported throughout the bay, the project has regional impact that demands a Public Hearing with sworn expert testimony and cross-examination.

4. These findings invalidate the applicability of Cormix

- **The DEP requires the use of a software package called Cormix to evaluate discharge plume concentrations. However, here's an excerpt from the Cormix website:**

*CORMIX is a **steady-state** model, whereas tidal environments are inherently **unsteady**. Because most **regulatory mixing zone** analysis requires "worst-case" dilution analysis, analysts sometimes consider conditions at slack tide (often zero ambient velocity) as representative of the "worst-case". However, minimum initial dilution generally will not occur at slack tide, but shortly after slack tide when the plume re-entrains material remaining from the previous **tidal cycle**. In tidal mode, CORMIX considers the reduction in initial dilution due to the re-entrainment of material remaining from the previous cycle. It does not consider **unsteady** build-up of material over several **tidal cycles**, it assumes complete flushing of the historic plume in the **near-field**, will occur within a tidal cycle.*

*If unsteady build-up in the **near-field** or **far-field** over multiple **tidal cycles** is likely at your site, additional methods of analysis may be necessary.*

4. Cormix (continued):

And this quote from American Aquafarms' *"Summary of Q&A from May 6 PIM - Pages from FB01 Long Porcupine General Application for Waste Discharge Permit with Attachments.pdf"*:

> *This model is a steady-state model, which means it does not account for changes in the current direction or current speed over time. That means that in tidal environments the results are only valid if you consider them as a brief snapshot of the mixing, generally less than 15 minutes.*

Cormix is designed for discharges to a river where clean water continually washes away the discharge plume