

Transport and Fate of Radioactive Contaminants in and around Cape Cod Bay

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Presentation Outline

- 1) Introduction to WHOI and Ken
- 2) Radioactivity in ocean
- 3) Introduction to Irina
- 4) Transport in and around Cape Cod Bay
- 5) Fate of radioactive contaminants
- 6) What is on site and what this means for the ocean

About WHOI

- Leading not-for-profit institution in ocean science, engineering and education
- Strict code of conduct stressing scientific independence & integrity
- WHOI's position is that science should lead, to enable decision makers to make informed choices



Ken Buesseler

- Marine radiochemist at WHOI since 1980s
- Director of Center for Marine and Environmental Radioactivity
- Uses natural radioactive elements to study ocean carbon cycle and its role in climate
- Study fate of human-made radioactive elements from nuclear weapons testing, Chernobyl, Fukushima, etc.



***Opinions are my own**

Sources of radioactivity in our world



Naturally occurring

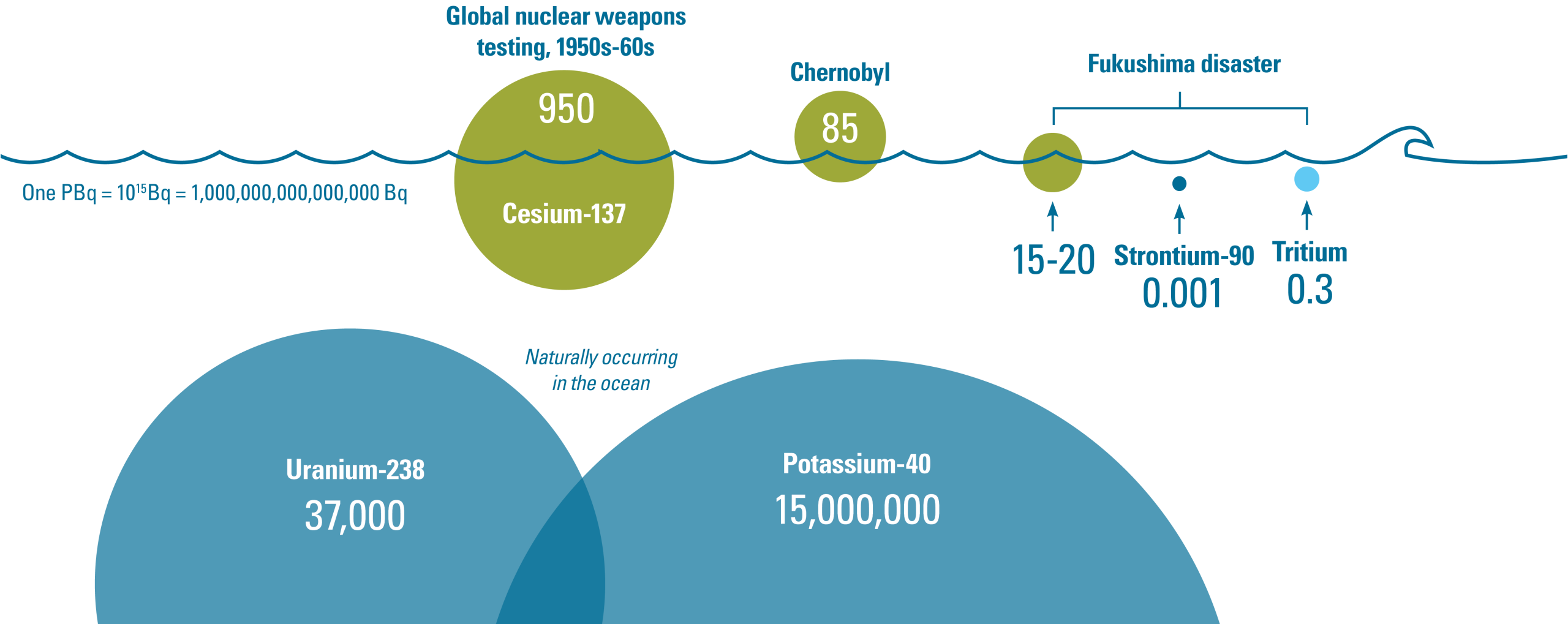


Cosmogenic



Human Activity

Radioactivity in the ocean



What happens to radioactive elements in the ocean?

It all depends

- Transport with ocean currents and dilution
- Accumulation in marine life
- Deposition and accumulation with seafloor sediments
- Radioactive decay

Irina Rypina

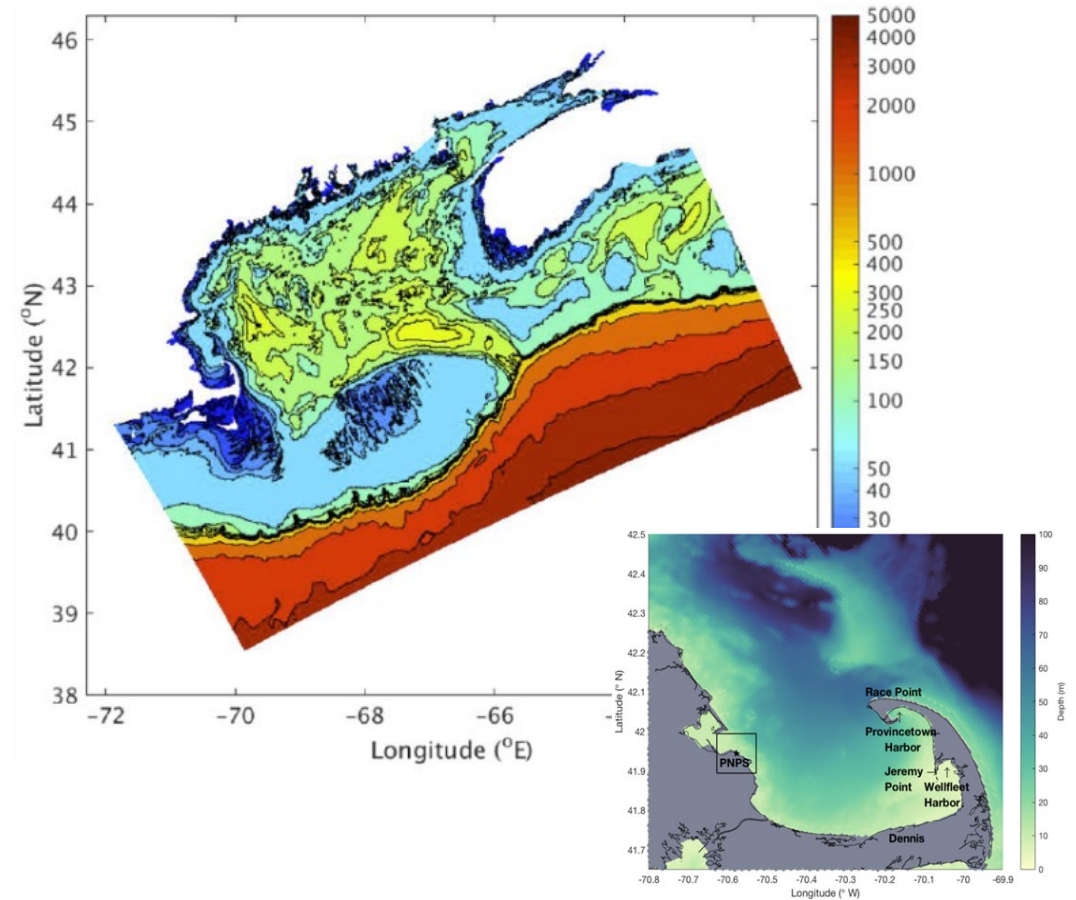
- Physical Oceanographer at WHOI since 2008
- Studies transport of water masses, properties, and tracers in oceanic flows

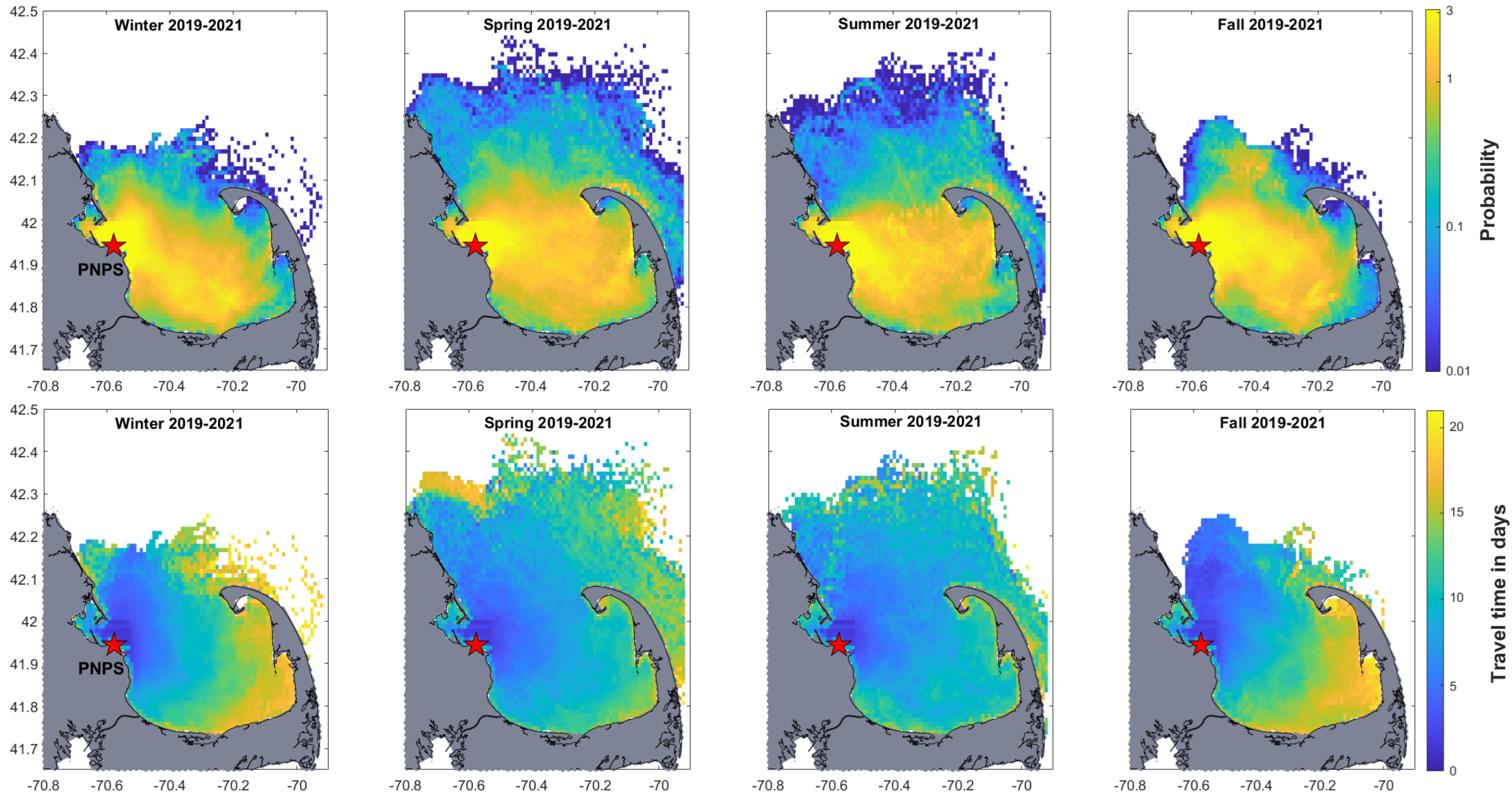


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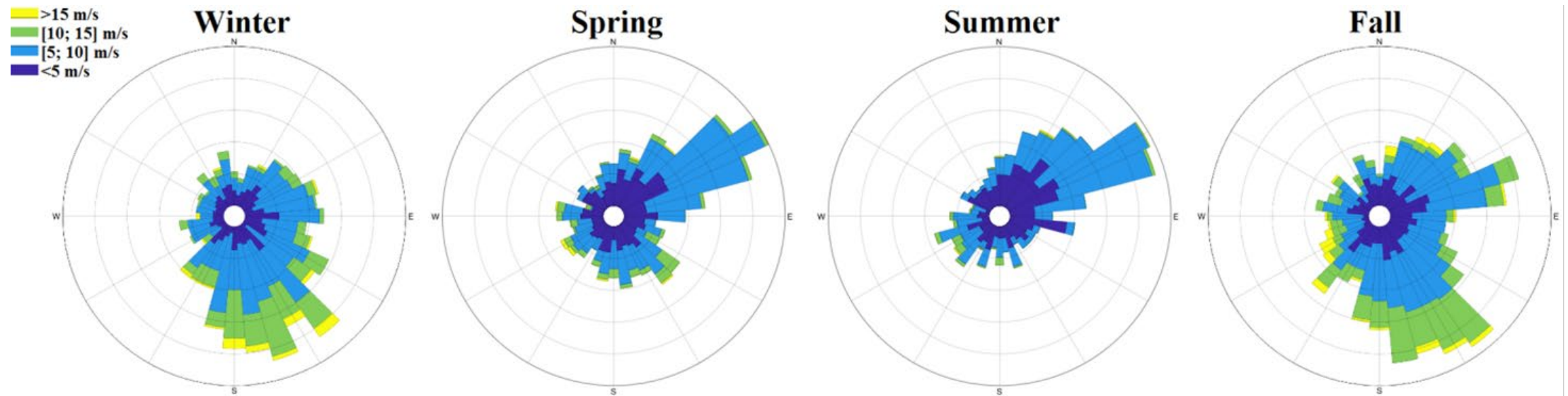
Model-based study of transport in Cape Cod Bay

- The pathways of the proposed wastewater discharge from the Pilgrim Nuclear Power Plant based on a model of the circulation patterns
 - Flow towards inner-bay coastline or flow out without coming close to inner-Bay coastline





Wind conditions

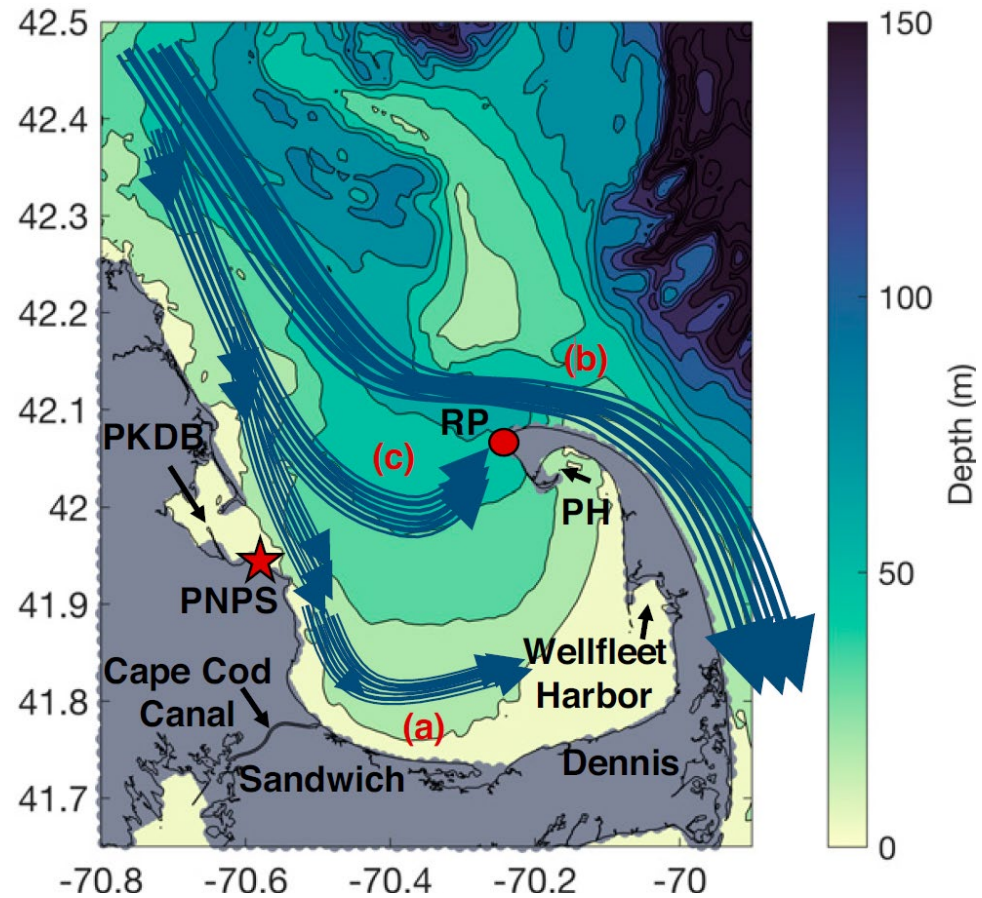


Summary

- The probability of a plume coming close to the inner-Bay shoreline, including coastal waters of Dennis, Wellfleet, and Provincetown, is high.
- The probability of a plume leaving the Bay without coming close to the inner-Bay shoreline is low.
- When some portion of a plume leaves the Bay, it passes north of Provincetown and flows southward along the outer Cape.
- The spreading of a plume depends on the timing of a release.
- In winter and fall the probability of leaving the Bay without coming close to the inner-Bay shoreline is virtually zero and is slightly larger but still low in spring and summer.
- Seasonal differences can be linked to wind conditions.

Future research questions

- Other years
- Transport in 3D
- Model with higher resolution



What happens to radioactive elements in the ocean?

It all depends

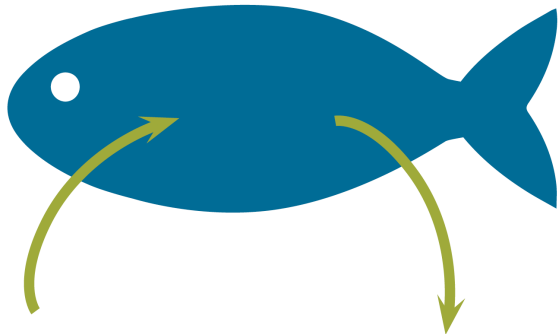
- Transport with ocean currents and dilution
- Accumulation in marine life
- Deposition and accumulation with seafloor sediments
- Radioactive decay

Radioactivity in fish

Time it takes for radioactive contaminants to cycle through fish

Tritium

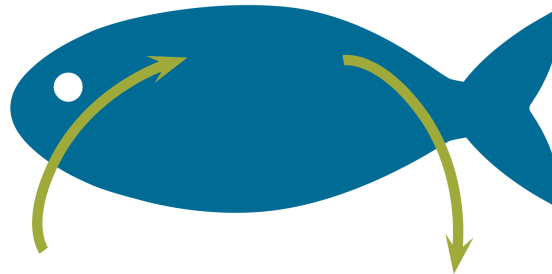
Passes through as H₂O



DAYS

Cesium-137

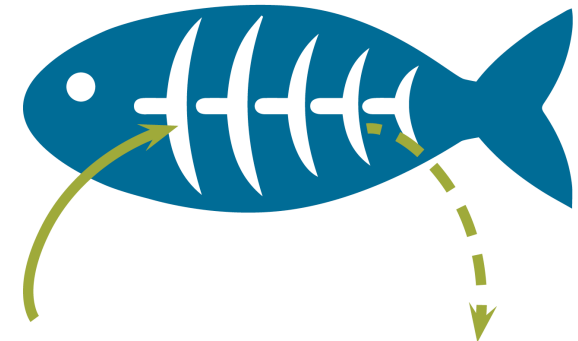
Taken up in muscles/organs



WEEKS

Strontium-90

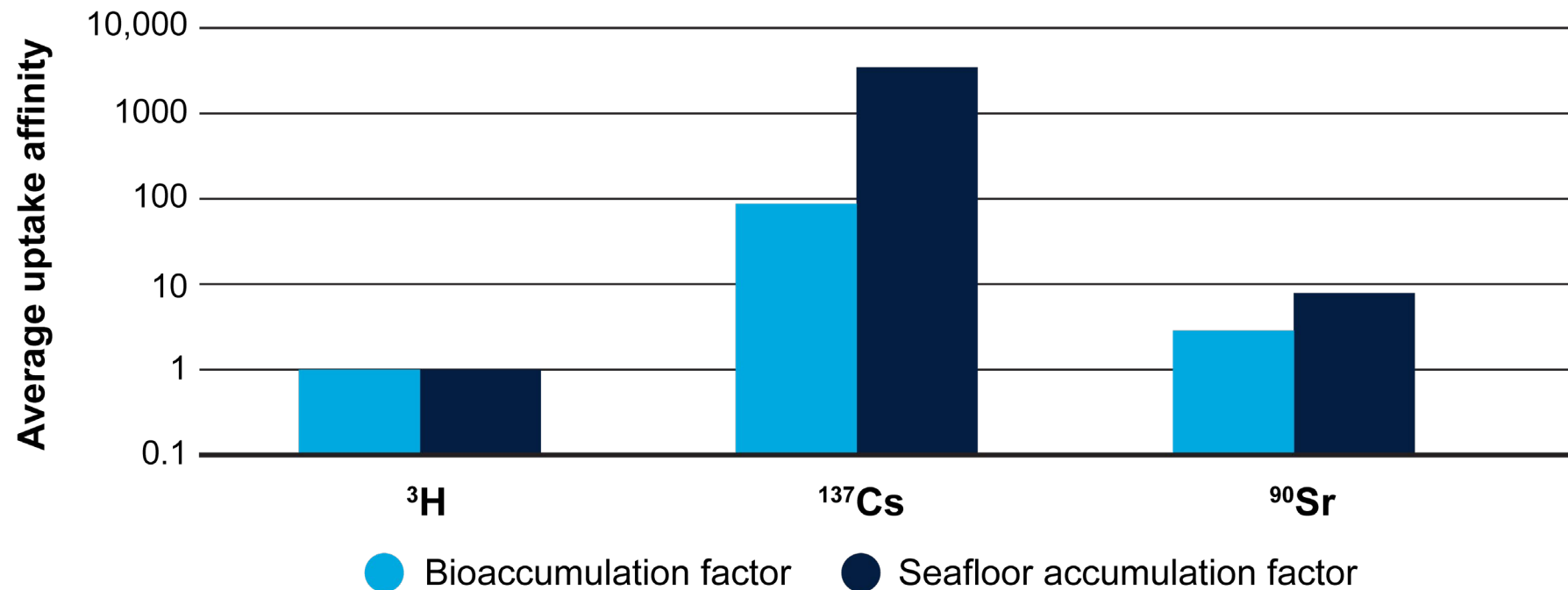
Taken up in bones



YEARS

Behavior of many radionuclides differs from tritium in the ocean

- Higher biological concentration factors – potential fisheries concern
- Higher sediment partitioning – accumulate near outfall pipe



What is currently in source waters at Pilgrim NPP?

**Massachusetts Department of Public Health
Radiation Control Program (RCP)
Untreated Radioactive Wastewater Analysis
Pilgrim Nuclear Power Plant**

Date: May 19, 2023

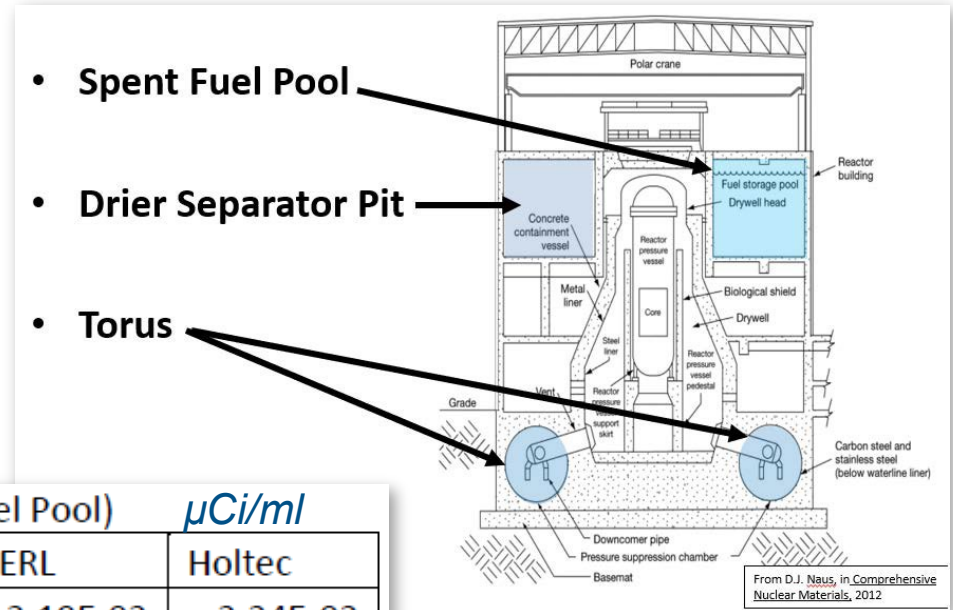
BACKGROUND

In 2022, Holtec, the owner operator of the decommissioning project at Pilgrim Nuclear Plant announced their intention to release 1.1 million gallons of radioactive wastewater into Cape Cod Bay. Subsequently, in March 2023, Holtec, applied for a surface water discharge permit (NPDES) to discharge water from the spent nuclear-fuel pool into Cape Cod Bay. The pending application would modify an existing MassDEP permit.

The Plymouth legislative delegation, including Senator Edward Markey, the MA State Inter-agency Pilgrim Working Group and the Nuclear Decommissioning Citizens Advisory Panel (NDCAP) expressed interest in obtaining baseline information on pollutants including radionuclides in the untreated water. At their request, on April 5, 2023, representatives from DPH and MassDEP collected untreated water samples at the Pilgrim plant. The samples collected were split between Holtec, MassDEP and DPH. MassDEP utilized GEL Labs in South Carolina to analyze their samples for non-radioactive pollutants. DPH utilized our Massachusetts Environmental Radiation Laboratory (MERL) located at the Massachusetts State Public Health Laboratory.

What is currently in source waters at Pilgrim NPP?

- MA results and Holtec agree
- Results are typical of NPPs
- Small subset of radioactive elements were measured
- Levels are much higher than ocean (not unexpected)



Sample #2 (Spent Fuel Pool)		$\mu\text{Ci/ml}$
Analyte	MERL	Holtec
H3 <i>tritium</i>	3.19E-03	3.24E-03
Mn-54	4.27E-05	3.25E-05
Co-60	8.53E-04	6.01E-04
Zn-65	1.69E-04	1.18E-04
Cs-137 <i>cesium</i>	1.01E-02	7.27E-03

How do levels compare to the ocean and other standards

Notes on a Radiation Control Report regarding Pilgrim Nuclear Power Station by Ken Buesseler, May 26, 2023

<https://go.who.edu/notes-on-radiation-control-report>

Spent Fuel Pool	NPP	Drinking water limit		Typical surface ocean	
		Bq/L*	X higher DW	Bq/L*	X higher ocean
Tritium	119,000	740	161	0.100	1,190,000
Cesium-137	321,000	7	45,857	0.002	160,500,000

**Bq/L = Becquerel per liter = one decay event in 1/4 gallons*

Tritium

150 x higher than DW limits
1 million times higher than ocean

Cesium-137

40,000 times higher than DW limits
200 million times higher than ocean

How do levels compare to the ocean and other standards

- No one drinks seawater/wastewater
- Water at NPP remains untreated
- Findings reinforce idea that water should not be released prior to extensive clean up



Does it matter which radioactive elements enter the ocean?

Yes

- Different health concerns
- Different biological accumulation
- Different seafloor accumulation
- Different times for loss by decay

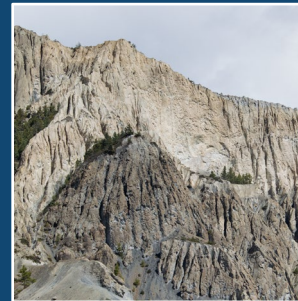
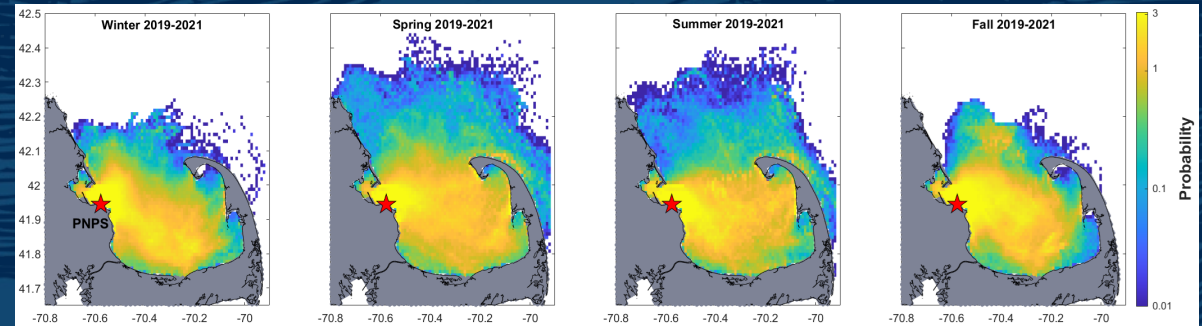
Increasing health concerns



	Measure of safety	Bioconcentration	Measure of sediment accumulation	How long does it remain
Isotope	dose coefficient (nSv/Bq)	K_{bio} for marine fish	K_d for seafloor sediment	half-life (years)
^3H -tritium	0.04	1	1	12.35
^{54}Mn	0.7	500	2,000,000	0.86
^{60}Co	3.4	700	300,000	5.27
^{65}Zn	3.9	2000	70,000	0.66
^{137}Cs	13	100	4,000	30.0

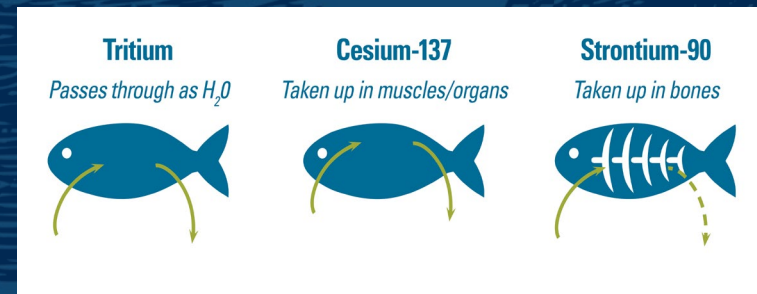
What happens to radioactive elements released from Pilgrim NPP to the ocean? **It all depends...**

- Transport will happen with ocean currents and dilution
 - Waters remain for weeks and potentially more in Cape Cod Bay
- Expect low dose to humans and sea life
 - Depends upon clean-up and release details



What happens to radioactive elements released from Pilgrim NPP to the ocean? **It all depends...**

- Clean up will set accumulation in marine life and on seafloor
 - Not enough info to assess impacts and pre/during/post monitoring needed
- Sets precedent for disposal of radioactive waste in the ocean
 - Consider as waste since NPP no longer providing public benefit of electricity



What happens to radioactive elements released from Pilgrim NPP to the ocean? **It all depends...**

- Consideration of other options
 - Hold for radioactive decay of tritium after clean up

