Radium Tracers of Groundwater Supply and Coastal Water Residence Times

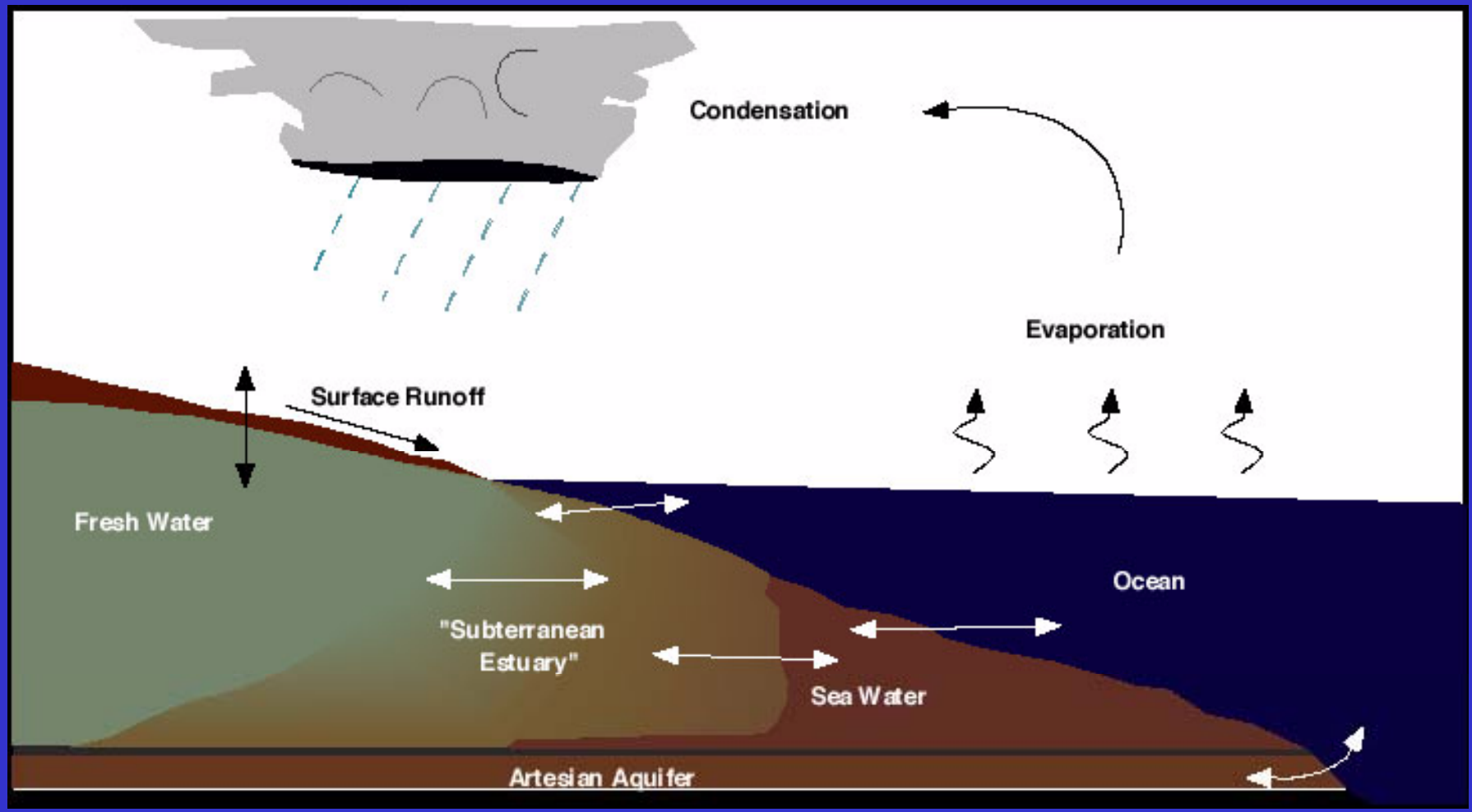
S.B. Moran
Graduate School of Oceanography, University of Rhode Island

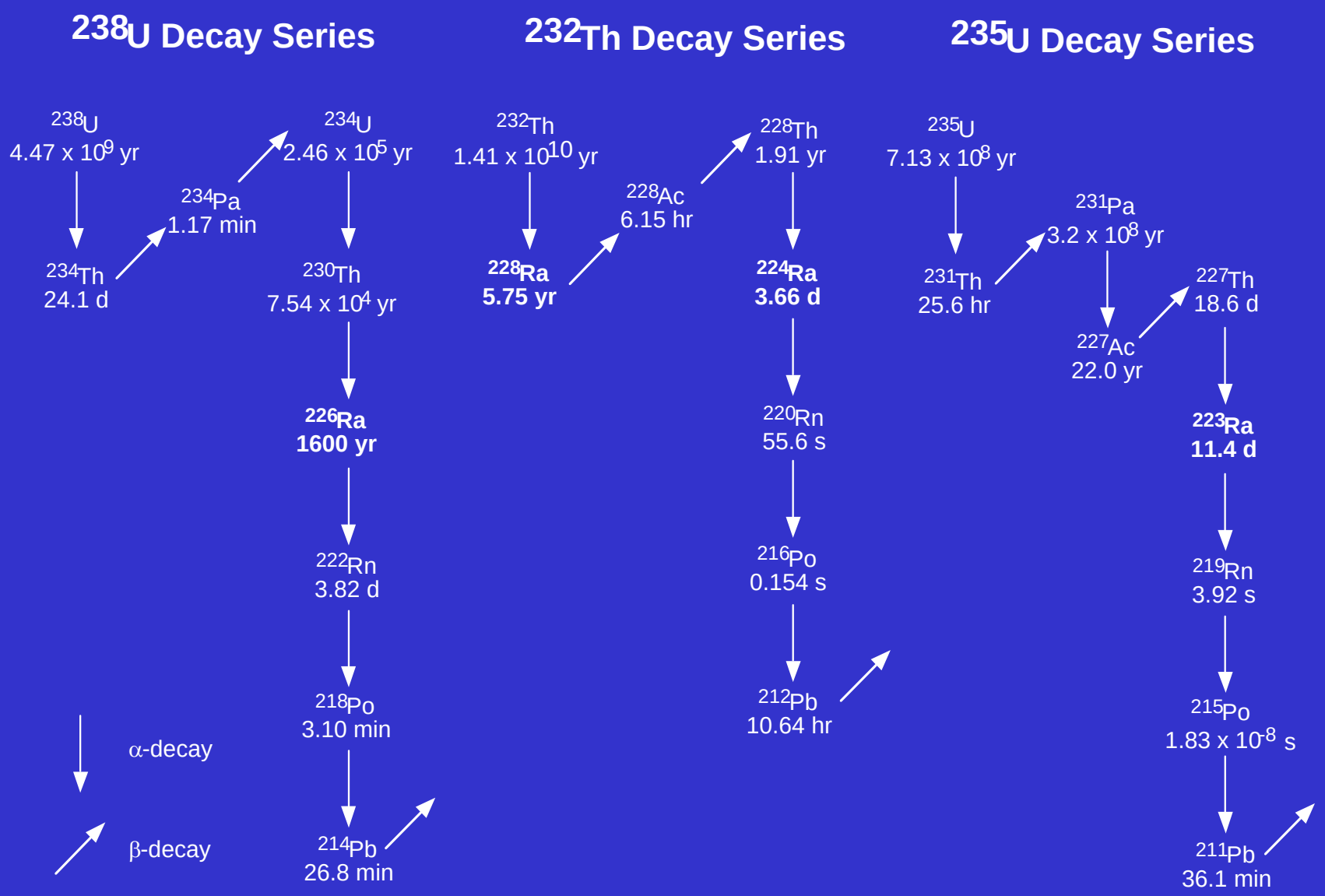
OVERVIEW

- Coastal groundwater systematics
- Application of radium tracers to coastal groundwater input and τ_w
- Study location, sampling and analysis
- Progress: published results and work in progress
- Summary and future directions

Acknowledgements: M.K. Scott, R.P. Kelly, A. Hougham, RI Sea Grant.

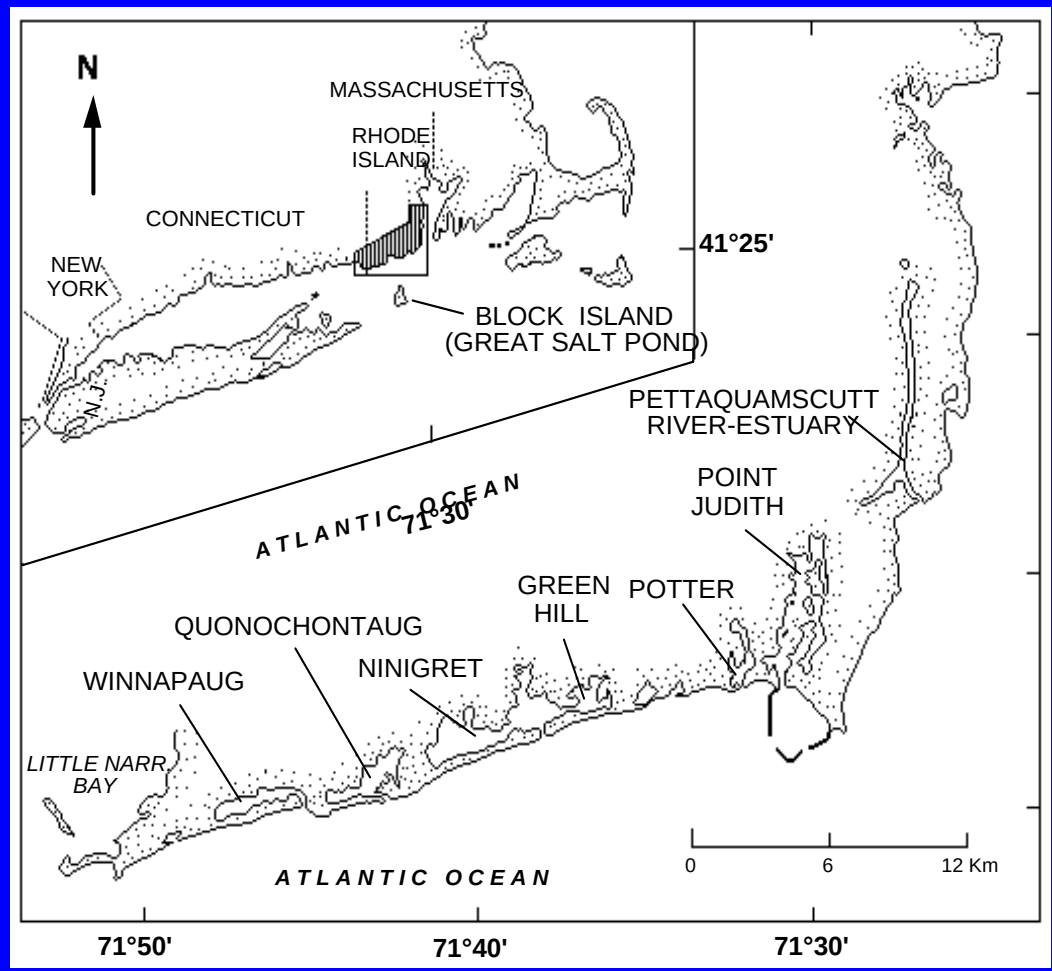
Coastal Groundwater Systematics




238U Decay Series
238U
4.47 x 10^9 yr
234Th
24.1 d
234Pa
1.17 min
234U
2.46 x 10^5 yr
230Th
7.54 x 10^4 yr
226Ra
1600 yr
222Rn
3.82 d
218Po
3.10 min
214Pb
26.8 min
α-decay
β-decay
232Th Decay Series
232Th
1.41 x 10^10 yr
228Ra
5.75 yr
228Ac
6.15 hr
228Th
1.91 yr
224Ra
3.66 d
220Rn
55.6 s
216Po
0.154 s
212Pb
10.64 hr
235U Decay Series
235U
7.13 x 10^8 yr
231Th
25.6 hr
231Pa
3.2 x 10^8 yr
227Ac
22.0 yr
227Th
18.6 d
223Ra
11.4 d
219Rn
3.92 s
215Po
1.83 x 10^-8 s
211Pb
36.1 min

Study Location and Sample Collection

- Monthly sampling of Pett. (99-00); quarterly sampling of ponds (1/02 - ongoing).
- Estuary and salt pond water and groundwater (~1-100 L).
- Analysis of ^{223}Ra, ^{224}Ra, ^{226}Ra, ^{228}Ra tracers, dissolved nutrients, salinity, temp.



Southern Rhode Island Salt Pond Characteristics*

Location	Surface Area (10^5 m^2)	Ave. Depth (m)	Ave. Sal. (ppt)	Watershed Area (10^7 m^2)	Tidal range (cm)
Pettaquamscutt estuary	18.9	2.0	15	3.6	55
Point Judith	78.5	1.8	29	6.6	45
Potter	13.5	0.6	27	1.5	20
Green Hill	15.5	0.8	19	1.4	4.6
Ninigret	64.5	1.3	24	3.1	14
Winnapaug	19	1.5	28	1.1	-
Quonochontaug	30	1.8	29	1.2	-
Little Narragansett Bay	97	2.0	-	3.6	-
Great Salt Pond		-	-	-	-

*Adapted from the RISG South Shore Collaborative.

Estimating Groundwater Input

Groundwater Input:

$$F_{GW} = \frac{J_{Ra}}{Ra_{GW}}$$

where ,

$$Ra_{xs} = Ra_{obs} - Ra_{c}$$

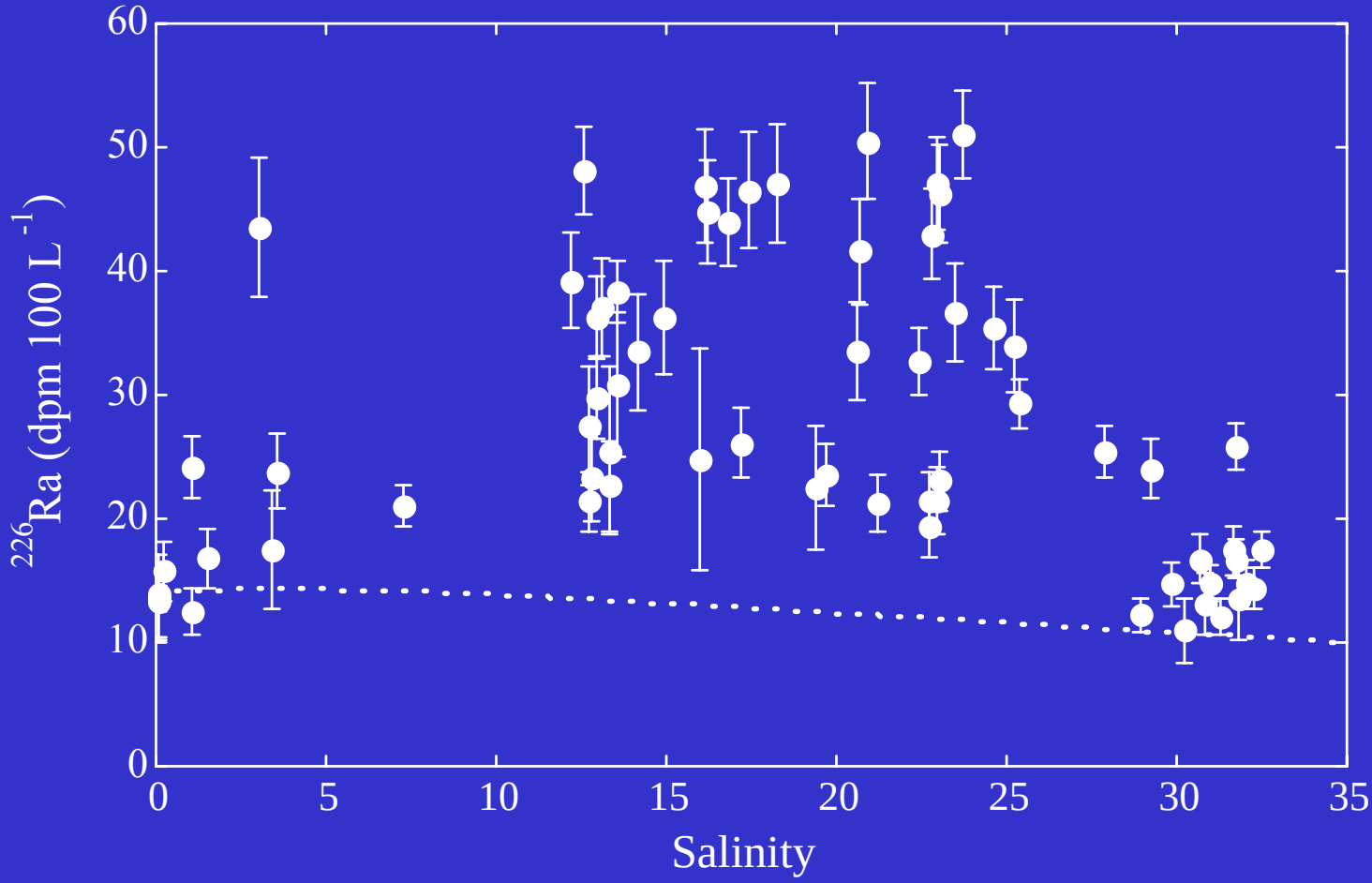
$$J_{Ra} = \frac{Ra_{xs} \times \forall \times \tau}{A_E}$$

$$J_{Ra} = \frac{Ra_{xs} \times V_E}{T_w \times A_E}$$

Recharge Estimate:

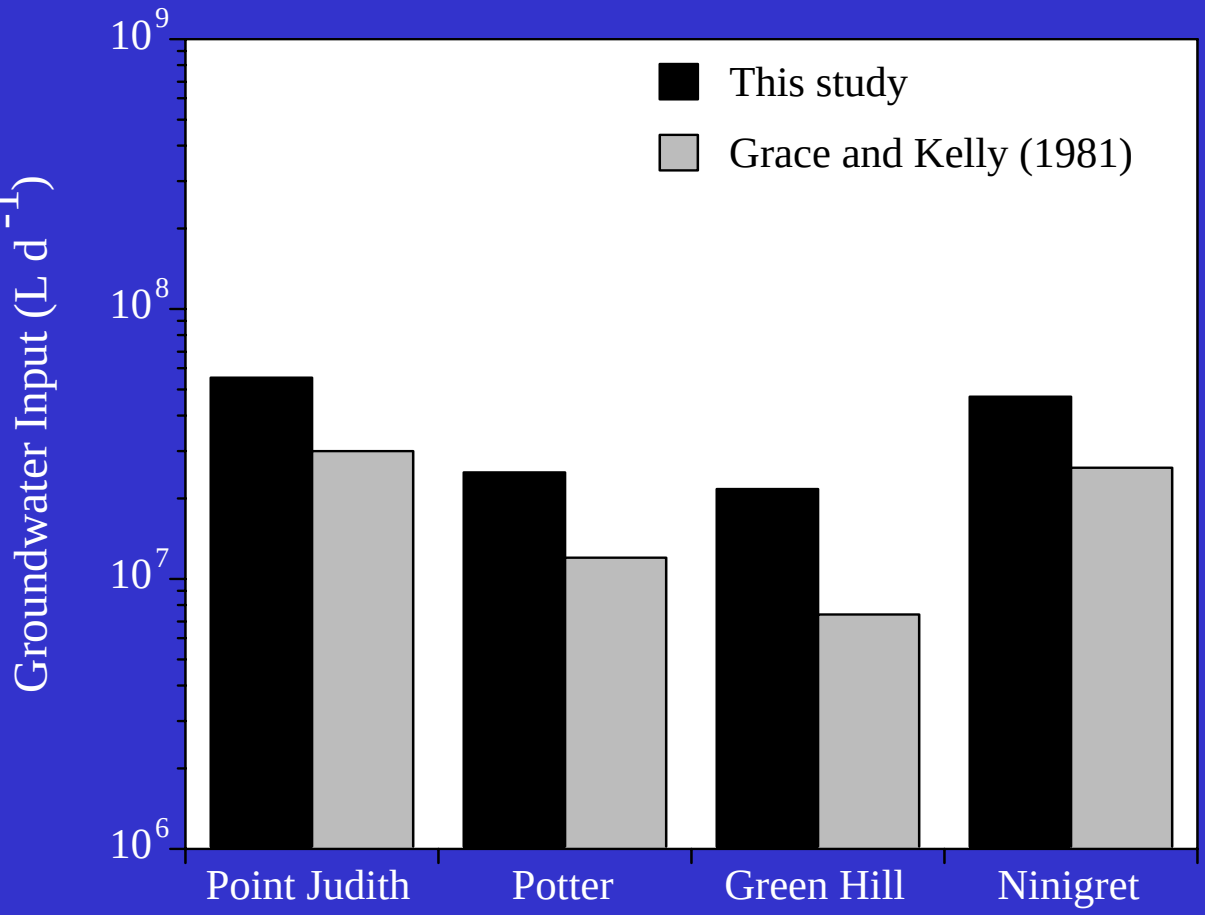
$$P_R = A \times \Sigma P \times \Phi$$

Radium vs. Salinity



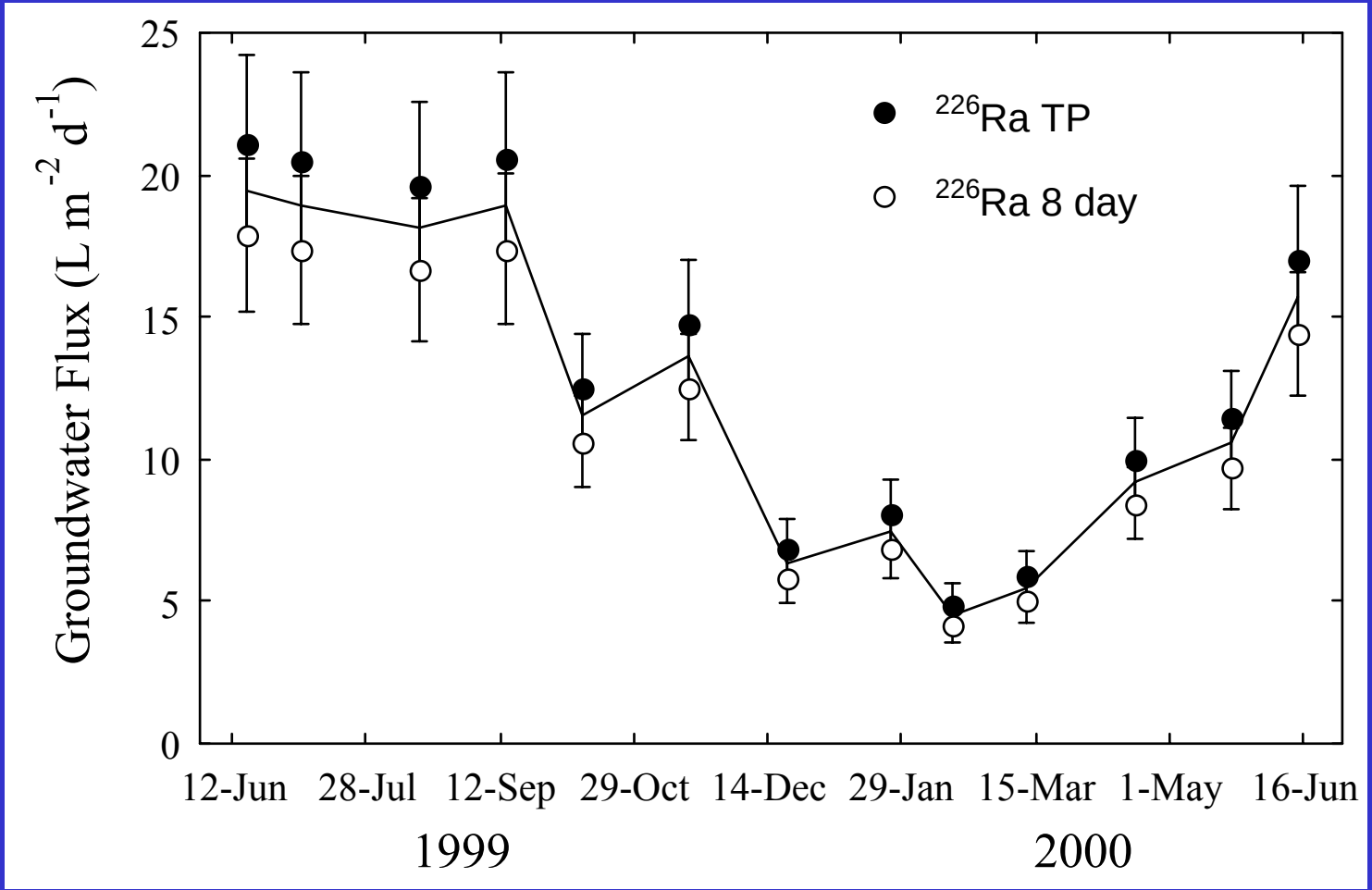
Kelly and Moran (2002)

Preliminary Salt Pond Data Using Ra-226



Scott and Moran (2001)

Seasonal Changes in Groundwater Input: The Pettaquamscutt Estuary



Kelly and Moran (2002)

Estimating Water Mass Residence Times

$$\left(\frac{^{224}Ra}{^{228}Ra_{xs}}\right)_{obs} = \left(\frac{^{224}Ra}{^{228}Ra}\right)_{pw} e^{-\lambda_{224} T_w}$$

and,

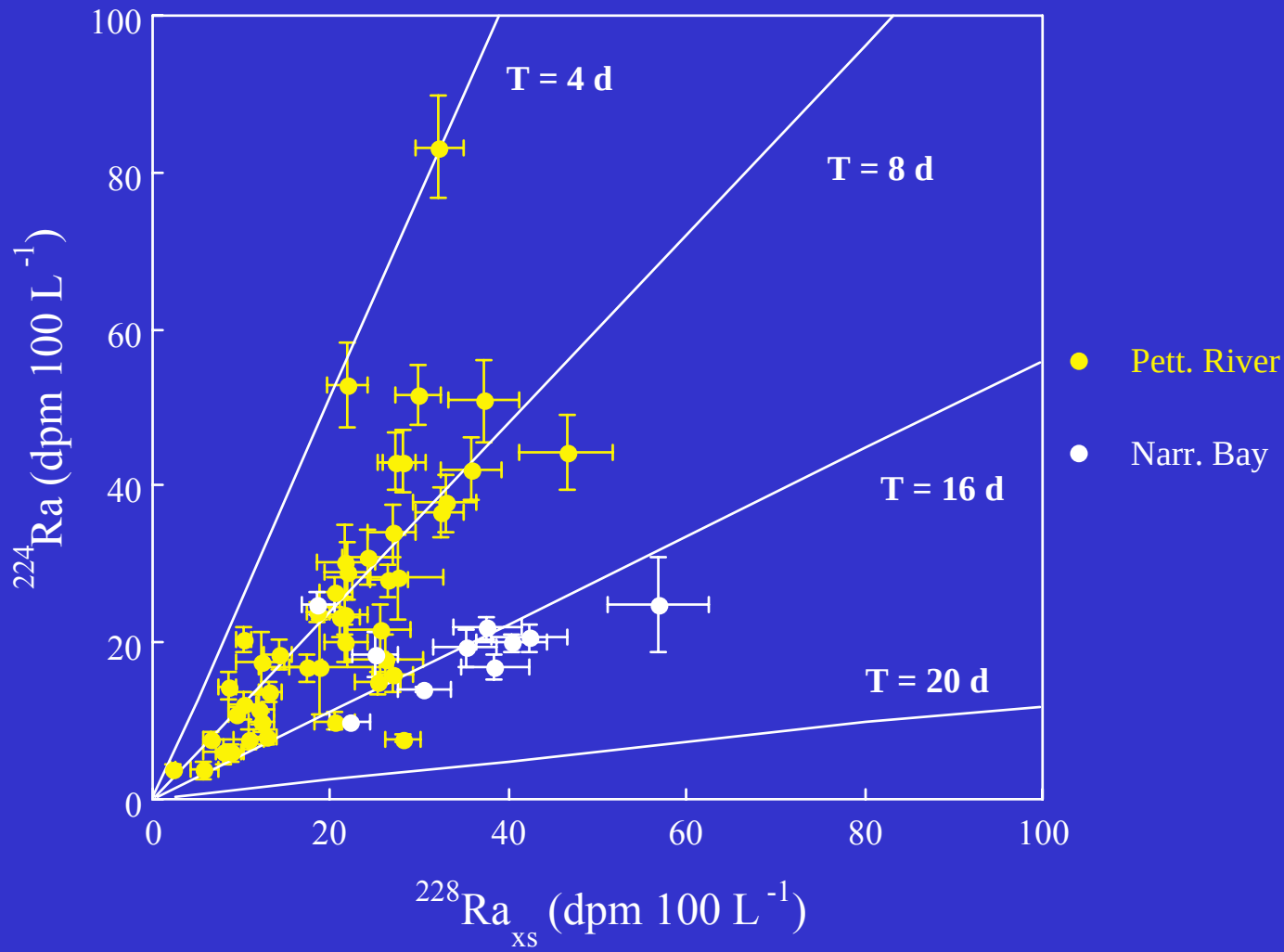
$$T_w = \frac{\ln\left[\left(\frac{^{224}Ra}{^{228}Ra}\right)_{pw} - \left(\frac{^{224}Ra}{^{228}Ra_{xs}}\right)_{obs}\right]}{\lambda_{224}}$$

where,

λ = ^{224}Ra decay constant (d^{-1})

T_w = water mass residence time (d)

Radium Tracer Water Mass Ages



Kelly and Moran (2002)

River/stream, groundwater and groundwater-derived nutrient input to Rhode Island coastal systems

Location	River/Stream (10^9 L yr^{-1})	GW Input (10^9 L yr^{-1})	GW TDIN (mM)	GW DIP (mM)	TDIN Flux (mmol m^{-2} yr^{-1})	DIP Flux (mmol m^{-2} yr^{-1})	T* (d)
Pett. River	18.3	7.9	36.2	2.62	151	11	8
Point Judith	9.5	20	264	0.40	673	1.0	-
Potter	0	9.1	264	0.40	1780	2.7	-
Green Hill	3.3	8.0	264	0.40	1363	2.1	-
Ninigret	2.60	17	264	0.40	696	1.1	-
Winnapaug	-	-	-	-	-	-	-
Quonochontaug	-	-	-	-	-	-	-
Little Narr. Bay	-	-	-	-	-	-	-
Great Salt Pond	-	-	-	-	-	-	-
North Inlet, S.C.	-	390	77	29	883	333	-
Waquoit Bay, MA.	-	14	58	-	208	-	9.4

*T represents water mass residence time (days).

Kelly and Moran (2002)

RI Salt Pond and Groundwater Sampling Sites

Ninigret Pond

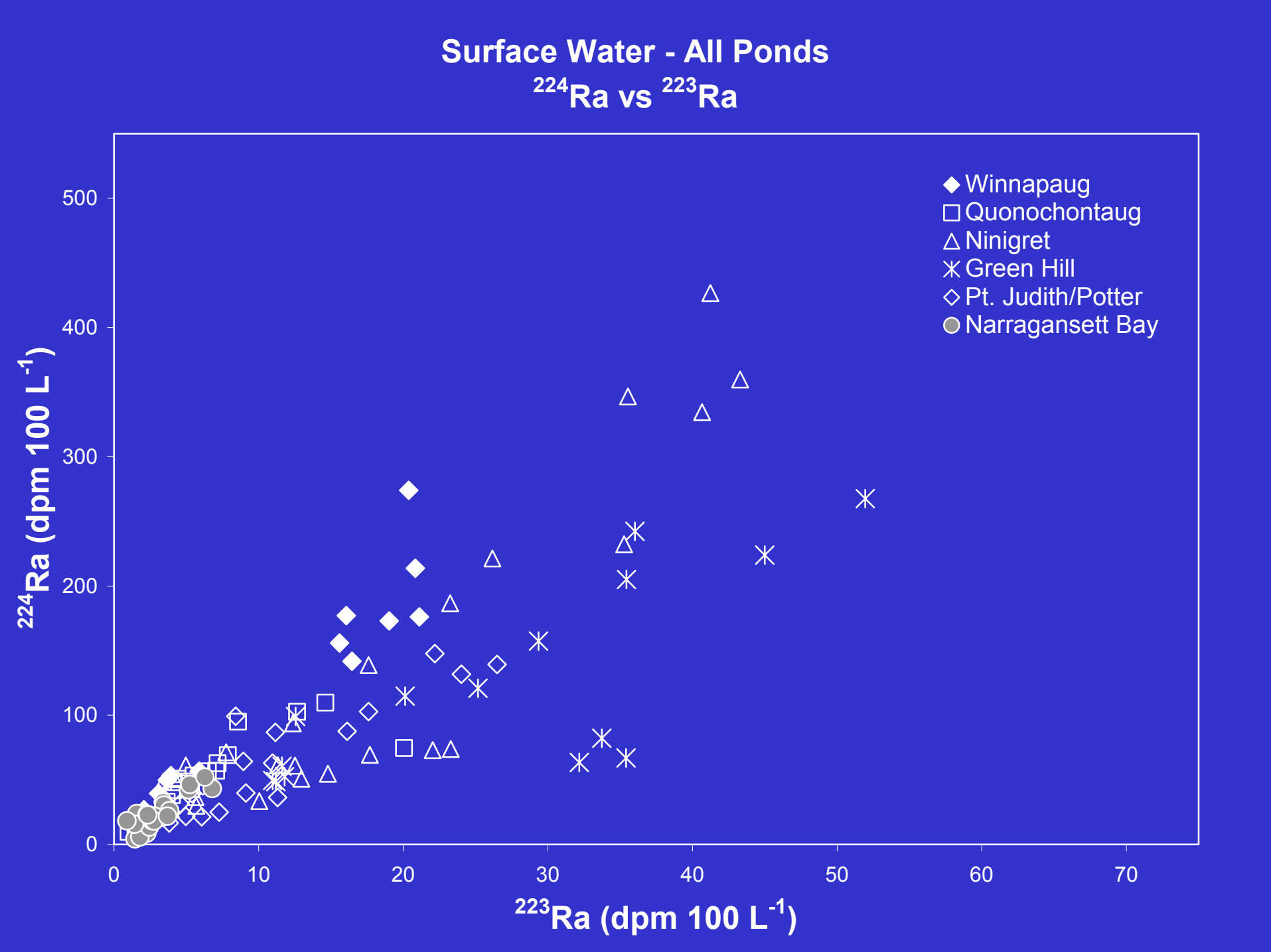
Quonochontaug Pond

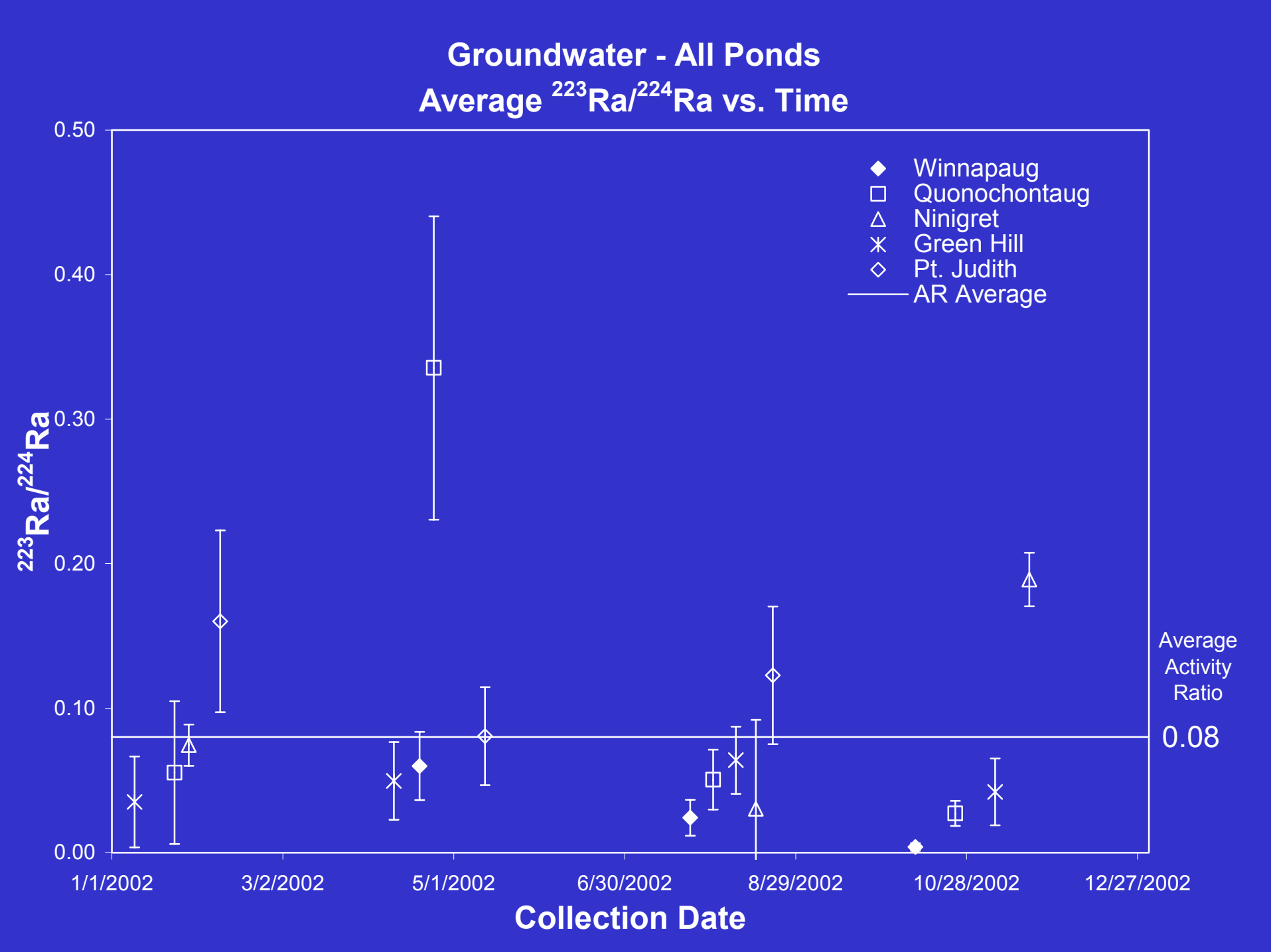
Winnapaug Pond

Green Hill Pond

Potter Pond

Point Judith Pond

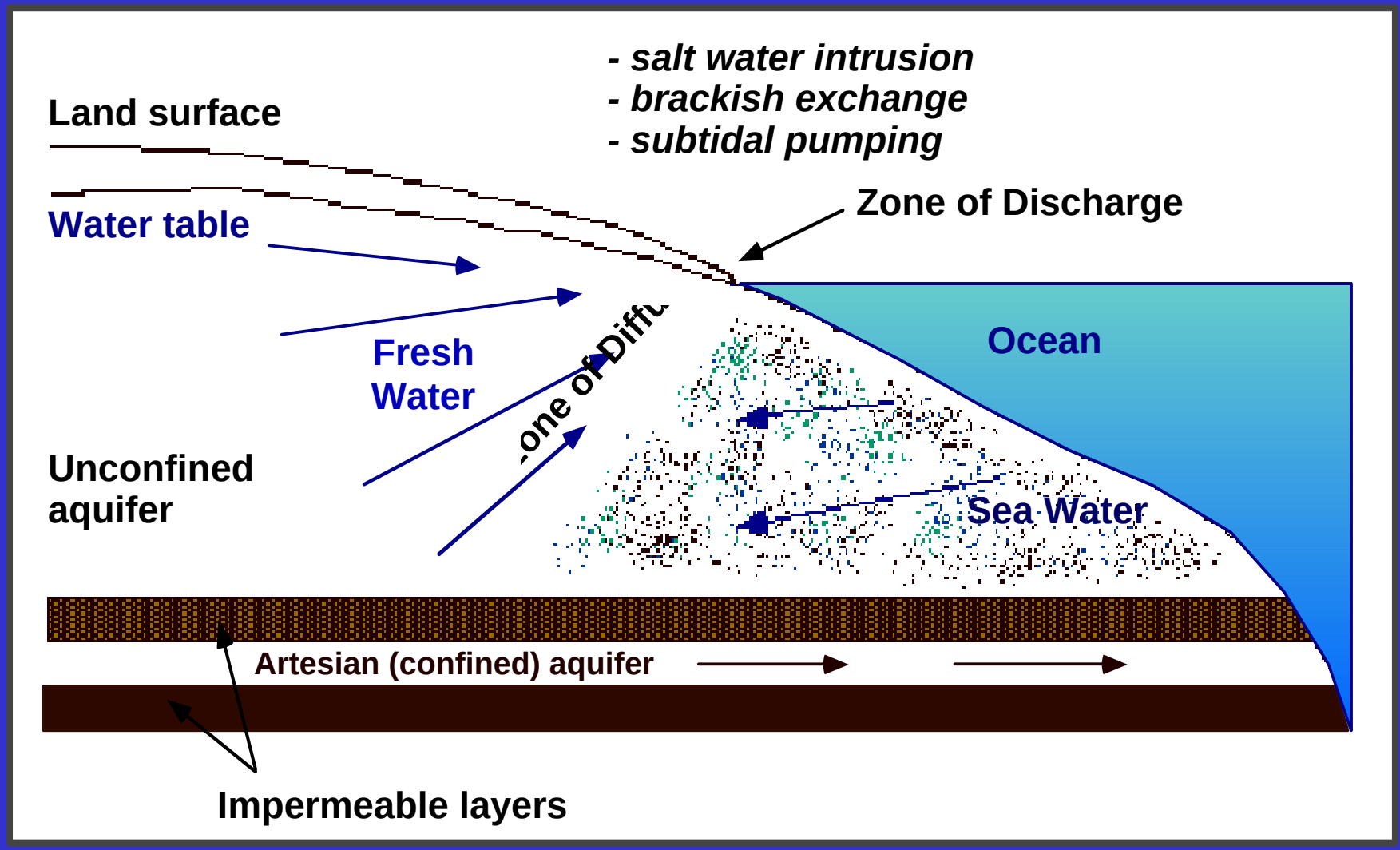

Surface Water - All Ponds
224Ra vs 223Ra
Winnapaug
Quonochontaug
Ninigret
Green Hill
Pt. Judith/Potter
Narragansett Bay
224Ra (dpm 100 L-1)
223Ra (dpm 100 L-1)
0
100
200
300
400
500
0
10
20
30
40
50
60
70


Groundwater - All Ponds
Average 223Ra/224Ra vs. Time
223Ra/224Ra
0.50
0.40
0.30
0.20
0.10
0.00
1/1/2002
3/2/2002
5/1/2002
6/30/2002
8/29/2002
10/28/2002
12/27/2002
Collection Date
Winnapaug
Quonochontaug
Ninigret
Green Hill
Pt. Judith
AR Average
Average Activity Ratio
0.08

Summary and Future Directions

- Radium isotopes are useful tracers of groundwater supply and water mass residence times in coastal environments.
- Groundwater supply varies seasonally.
- Future work directed as seasonal and interannual changes in supply of groundwater and associated nutrients to salt ponds.
- Integrate tracer-based observations of groundwater input with regional groundwater transport models.

Coastal Groundwater Systematics



after Johannes (1980)