Thirty Years Later: Evaluation of Heavy Metals Contamination in Bivalves after Successful Load Reduction in Narragansett Bay

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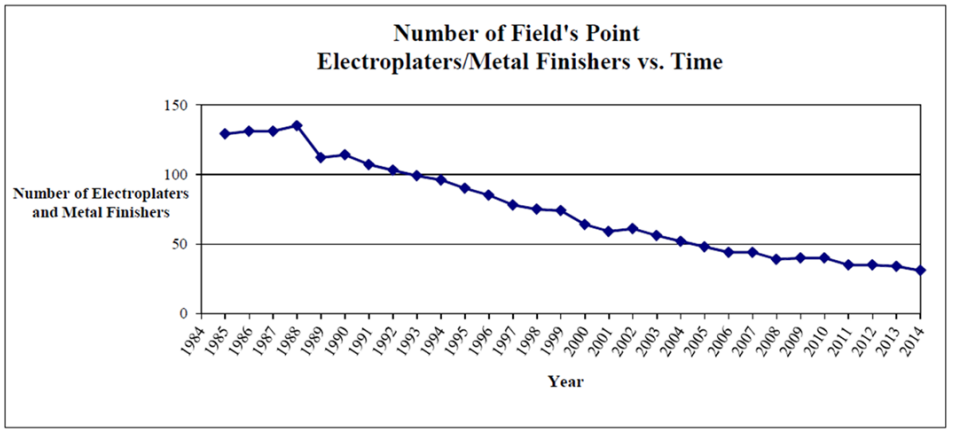
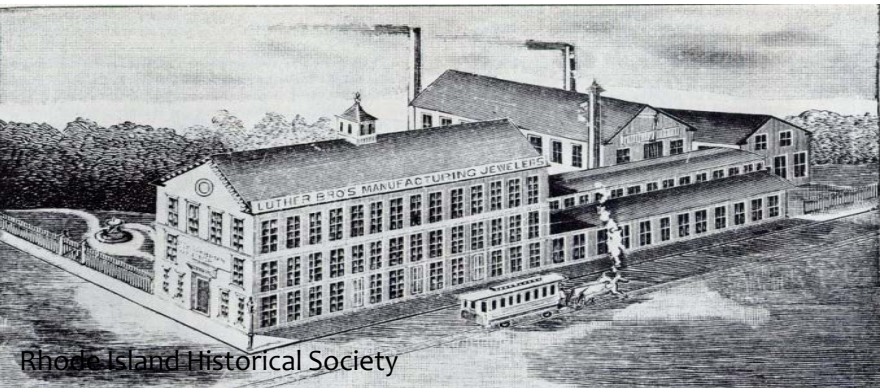
NBC Pretreatment Program



* NBC Pretreatment Program: permits, monitors, regulates industries
  * Protects NBC WWTFs and Narragansett Bay from harmful contaminants
  * ~50 Metal finishers, electroplaters
  * Majority of toxic metal/cyanide loadings to NBC WWTFs
  * Steady decline in this type of industry over last 20 years
* WWTFs –not designed to remove heavy metals, cyanide and other toxic chemicals.
  * Settle out in wastewater, sludge, remainder goes out to receiving waters

History of metal contamination in Narragansett Bay

* Highly industrialized watershed since late 1700's
  * Industrial Revolution, machinery and jewelry manufacturing, plating
* Sediments, surface waters contaminated with variety of anthropogenic metals from many sources.
  * Metals of concern: arsenic, **cadmium, chromium, copper**, iron, **lead**, manganese, mercury, **nickel**, selenium, silver, and **zinc**
* Environmental regulations, local limits, successful pretreatment programs have reduced metal inputs to Narragansett Bay



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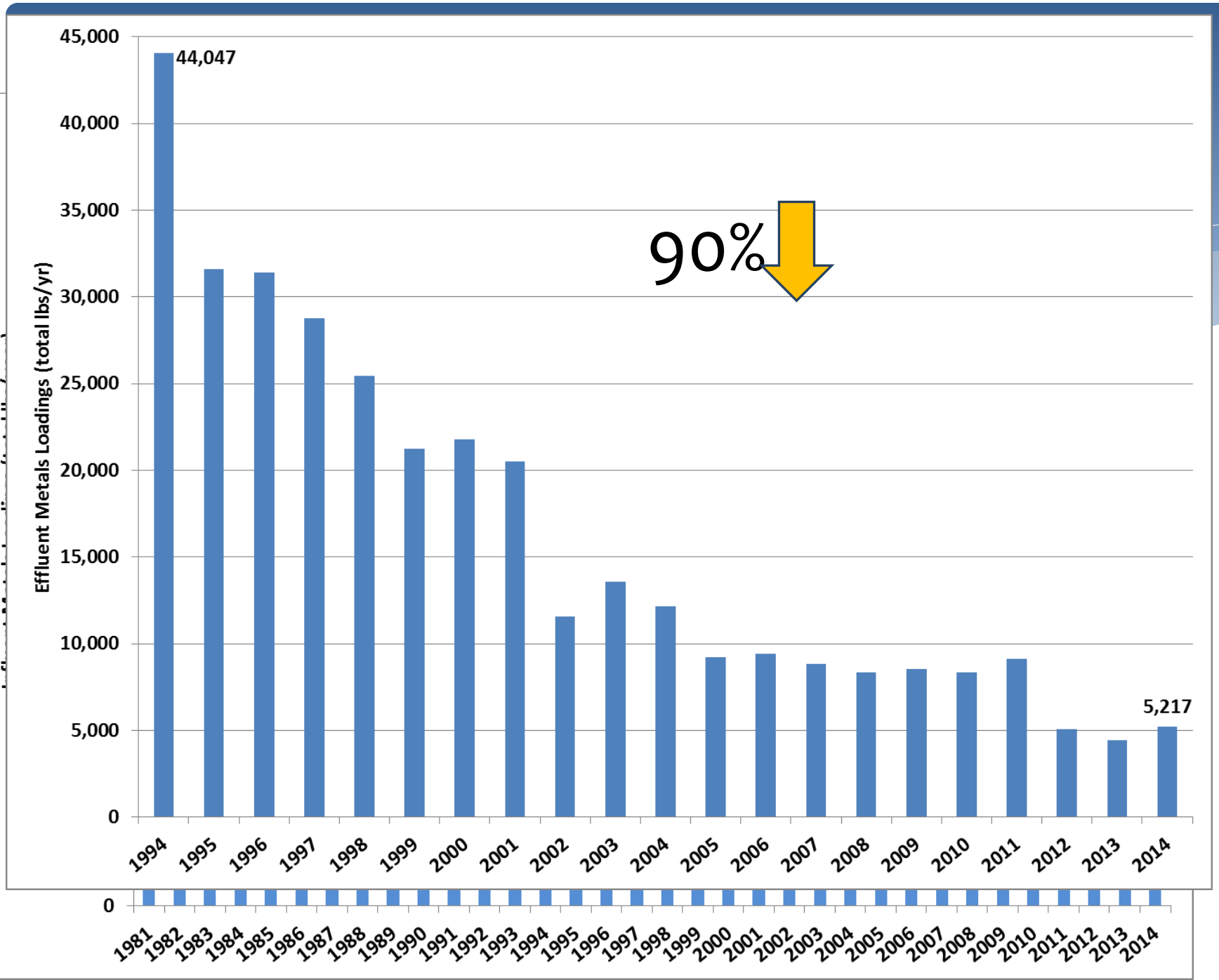
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Effluent Metals Loadings (total lbs/yr)
44,047
5,217
90%
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
0
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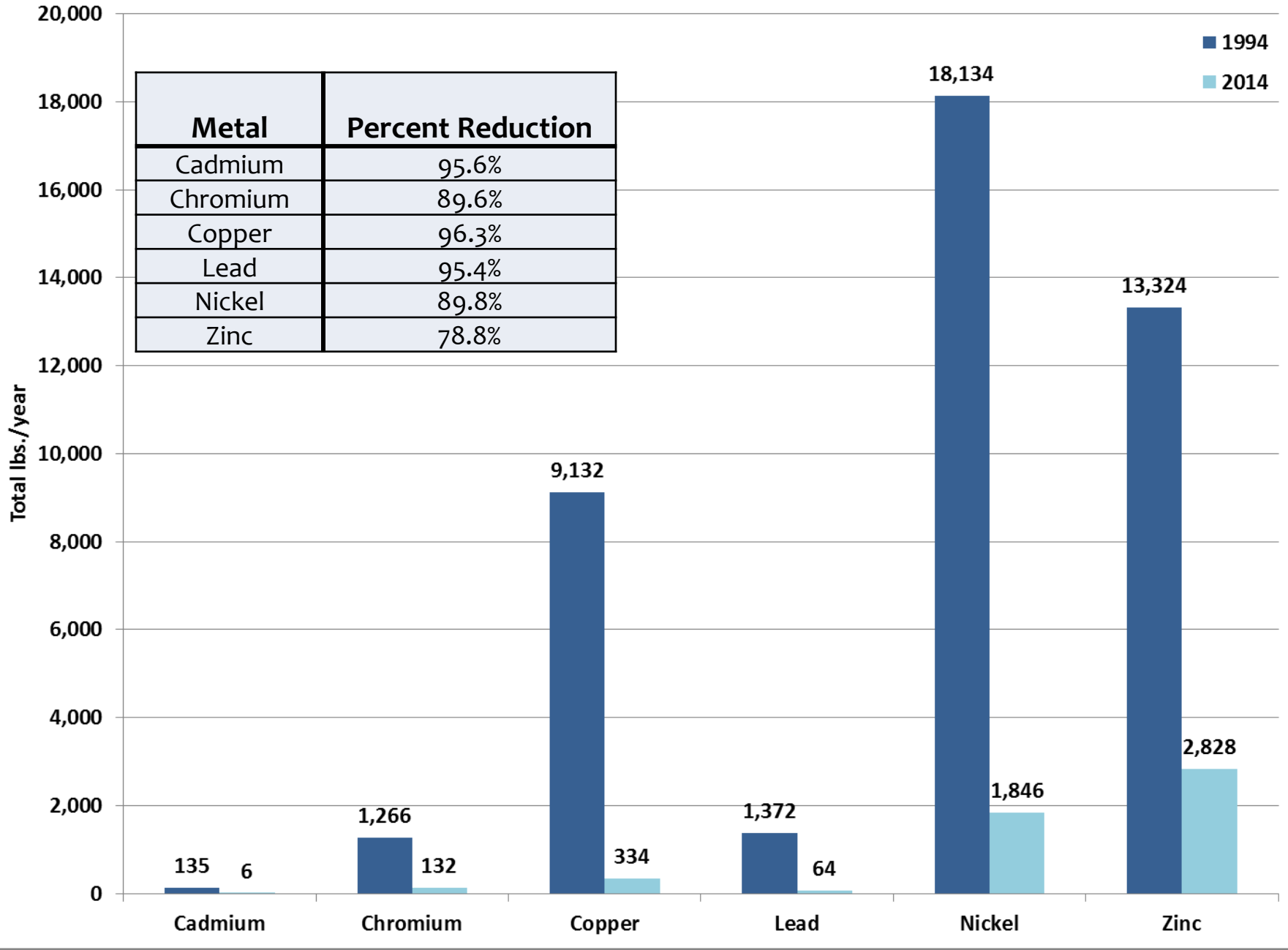
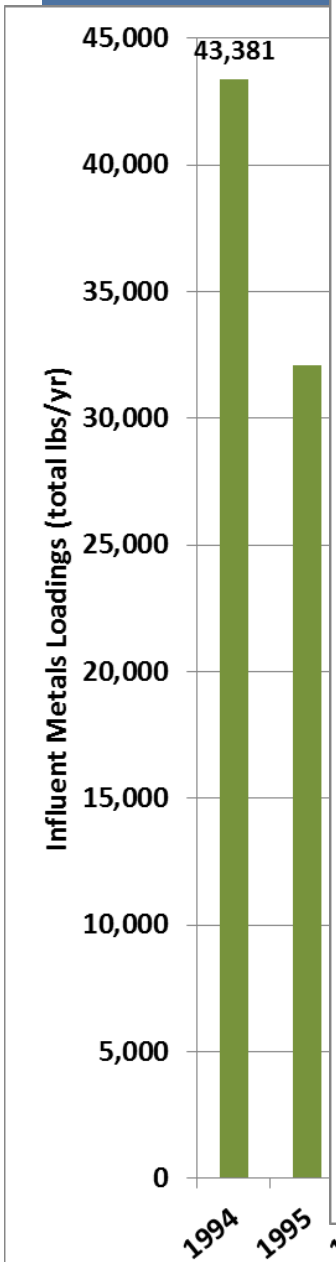
2009
2010
2011
2012
2013
2014

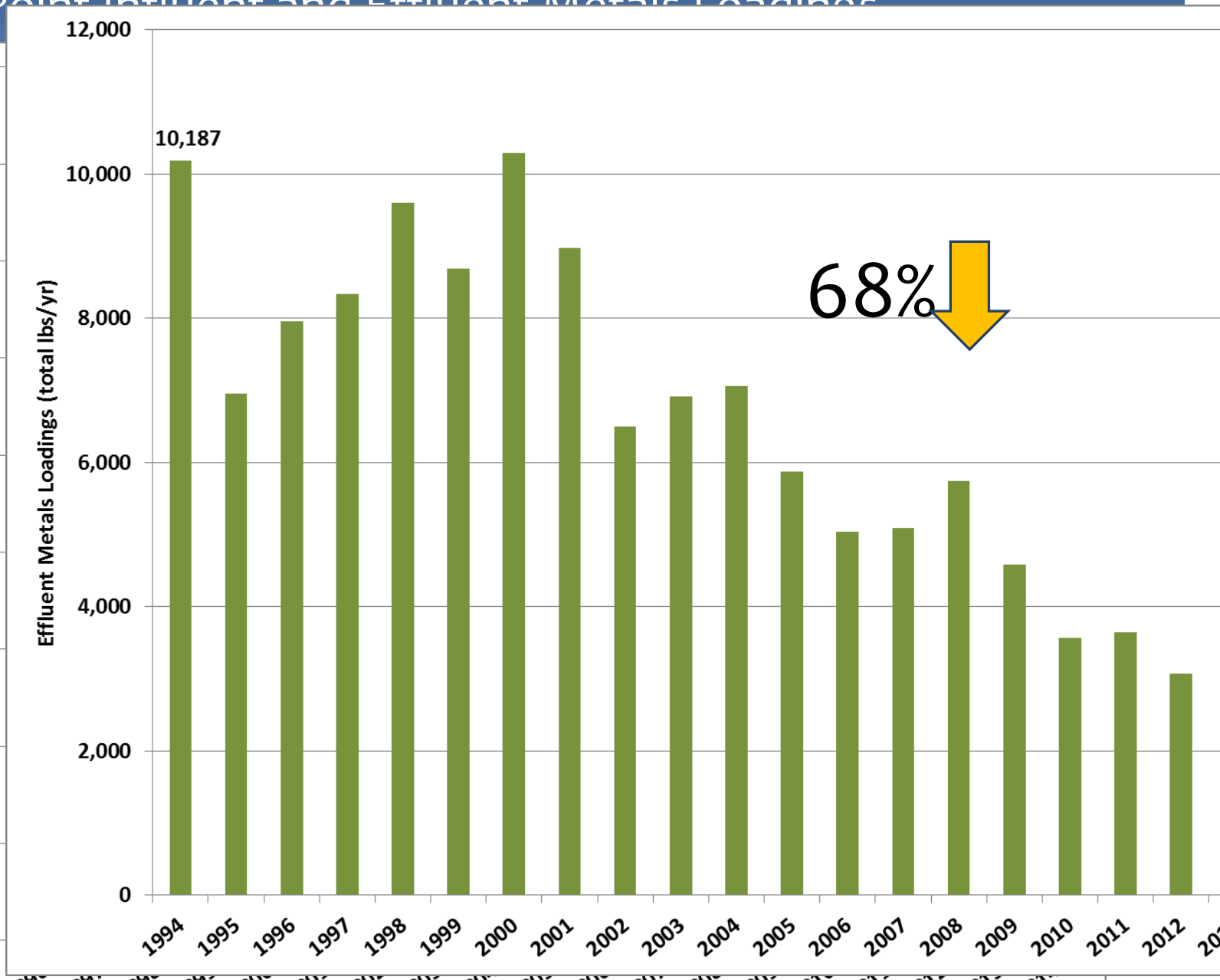
Field's Point Effluent Reductions of particular metals of concern

Metal	Percent Reduction
Cadmium	95.6%
Chromium	89.6%
Copper	96.3%
Lead	95.4%
Nickel	89.8%
Zinc	78.8%



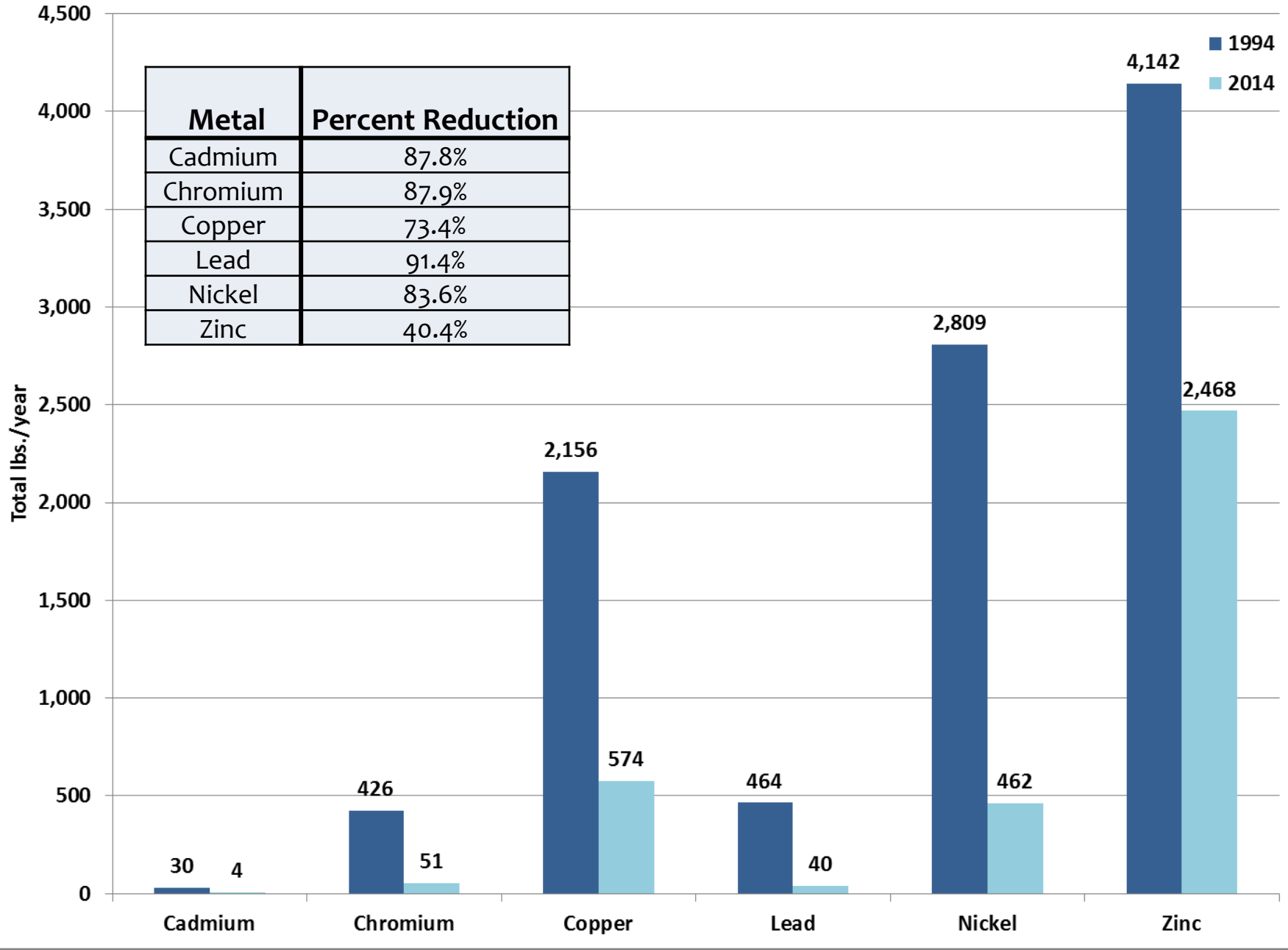
Bucklin Point Influent and Effluent Metals Loadings





Bucklin Point Effluent Reductions of particular metals of concern

Metal	Percent Reduction
Cadmium	87.8%
Chromium	87.9%
Copper	73.4%
Lead	91.4%
Nickel	83.6%
Zinc	40.4%



Purpose of Study

* Major reduction of metals into Narragansett Bay over past 30+ years
* Receiving waters removed from EPA's 303d list for impaired waters for metals in 2004
  * 2000, 2001 data
* Could we biologically see these reductions in a key shellfish species?
  * Replication of EPA study
  * Good baseline
  * Metals data prior to NBC Pretreatment Program

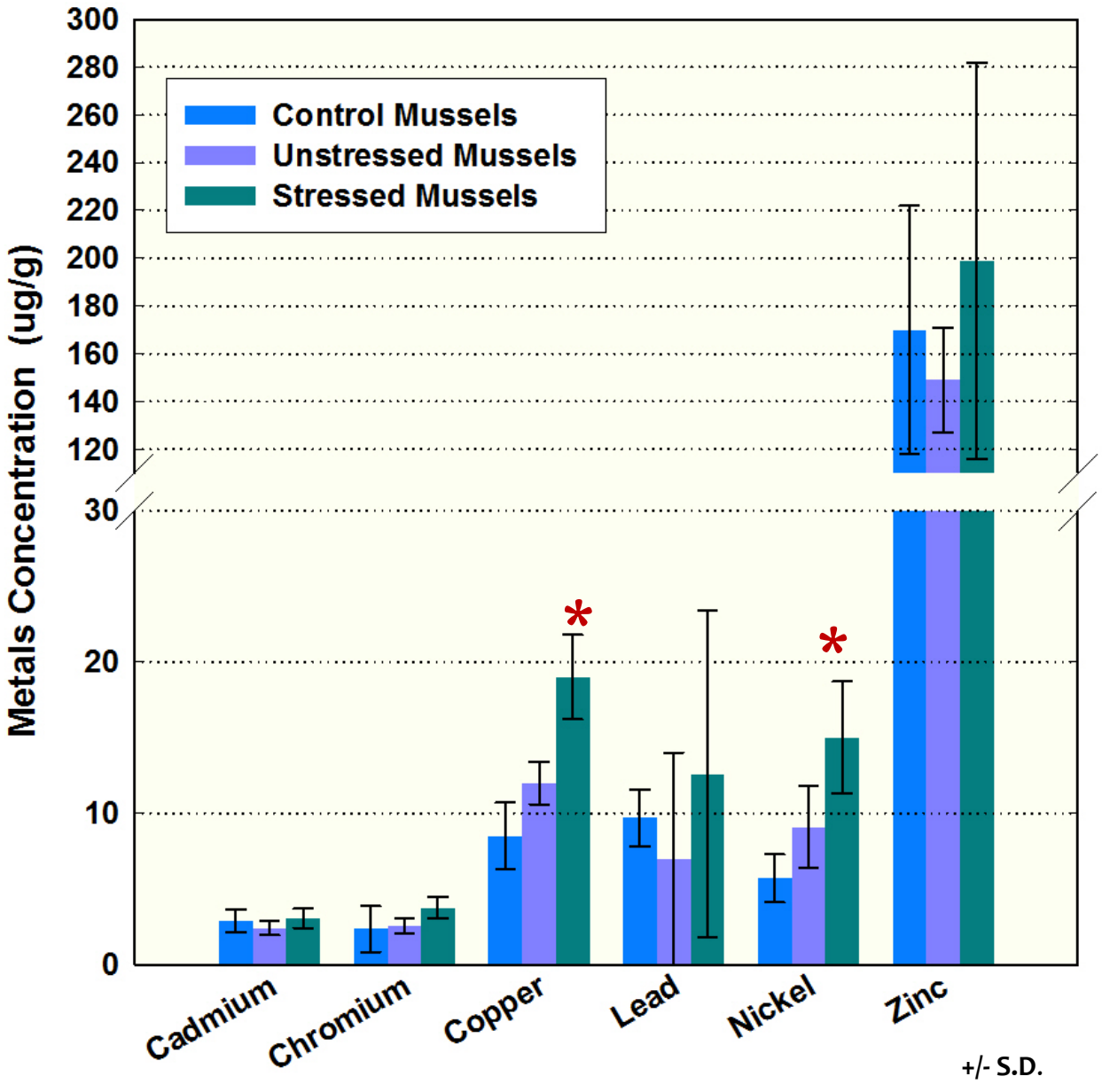
Original study background, Phelps & Galloway, 1979

* 1976 EPA Study, published in 1979
* Blue Mussel, *Mytilus edulis*, effective indicator of metals pollution?
* Collected and relocated mussels from non-polluted to a metals impacted location in Narragansett Bay
* Reference: Phelps, D.K. and Galloway, W.B. 1979. The use of introduced species (*Mytilus edulis*) as a biological indicator of trace metal contamination in an estuary. Advances in Marine Science, Proceedings of a Symposium. Jacoff, F.S., editor. EPA-600/9-79-035

Phelps & Galloway, EPA 1979

* Collected mussels from Popasquash Pt.
* Deployed at 2 locations –
  * Stressed - Conimicut Pt.
  * Unstressed – No. of Jamestown.
  * Lab-held mussels for control
* Compared lab held mussels, unstressed mussels and stressed mussels after 4 wks.
* Summary: *M. edulis* effective indicator of metal pollution along gradient of anthropogenic stress

Results – Phelps & Galloway, 1979



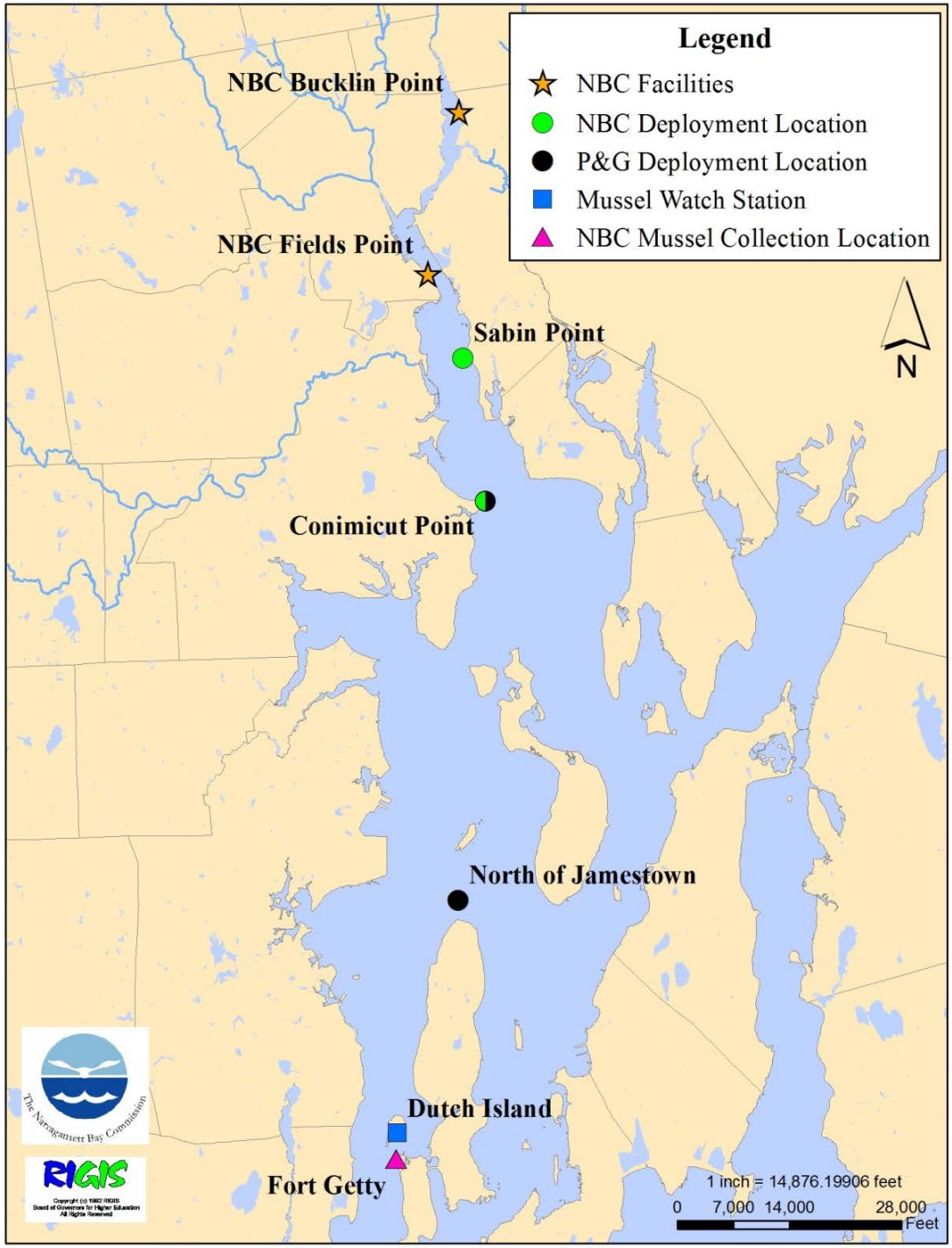
- No significant difference between lab held and unstressed
- Cd: no significant difference
- Cr: no significant difference
- Cu – Stressed mussels significantly higher
- Pb –few mussels above D.L. sample size too small
- Ni – Stressed mussels significantly higher than lab-held
- Zn – Large variability – meaningful comparison not possible

Heavy Metals Contamination in Blue Mussels, *Mytilus edulis*

* Replicated study design from 1976 Phelps and Galloway experiments
* Replicated: Equipment design, deployment location, metals tested
* Differences: original mussel collection location, control design, analysis equipment
* Tested for: cadmium, chromium, copper, lead, nickel, and zinc
  * Compared results to original study results

NBC Study Design

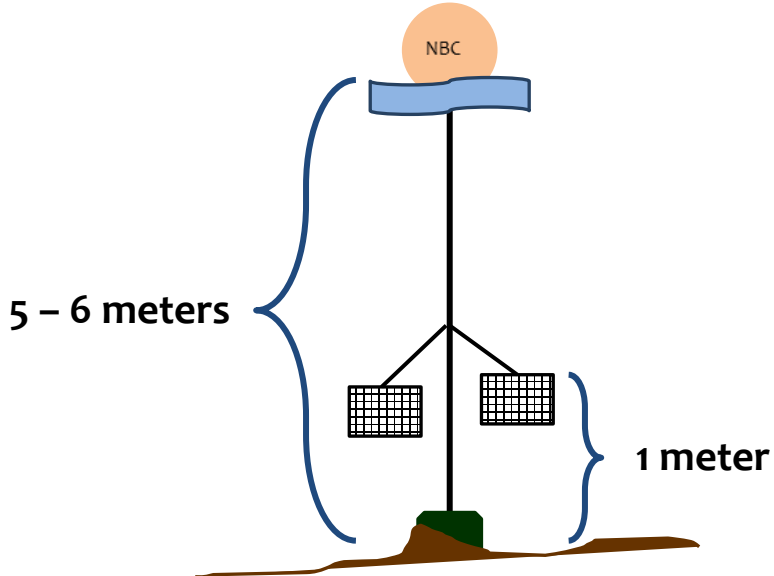
* Mussels collected from Ft. Getty Jamestown, RI during fall season of 2008, 2009, 2012
  * Close proximity to established long-term NOAA Mussel Watch site for comparison
* Some mussels immediately put on ice after collection for analysis as a control
* Mussels deployed at two experimental sites day after collection:
  * Conimicut Point (CP) and Sabin Point (SP)
  * Two separate baskets each containing 15 - 22 mussels
* 2008 - Mussels were deployed at CP and SP for 3 week & 4 week periods
  * 1 basket collected at wk. 3, other basket at wk. 4
* 2009 & 2012 – Mussels deployed for 4 weeks at same locations
  * Both baskets collected at 4 weeks


Legend
NBC Facilities
NBC Deployment Location
P&G Deployment Location
Mussel Watch Station
NBC Mussel Collection Location
NBC Bucklin Point
NBC Fields Point
Sabin Point
Conimicut Point
North of Jamestown
Dutch Island
Fort Getty
N
1 inch = 14,876.19906 feet
0 7,000 14,000 28,000
Feet
The Narragansett Bay Commission
RIGIS


Mytilus edulis – Blue Mussel


Mussel collection site, Fort Getty, Jamestown, RI


Mussel baskets awaiting deployment, 2012


NBC
5 – 6 meters
1 meter

NBC Lab Analysis

* Mussels put on ice immediately after collection and frozen.
* Thawed just before analysis
* De-shelled and mussel tissue was weighed.
* Digested on an Environmental Express hotblock using Nitric and Hydrochloric acids.
* After digestion was complete mussel tissue was brought up to a 50 mL volume with DI water.
* Analyzed on a Perkin Elmer ICP Optical Emission Spectrometer for the desired metals.

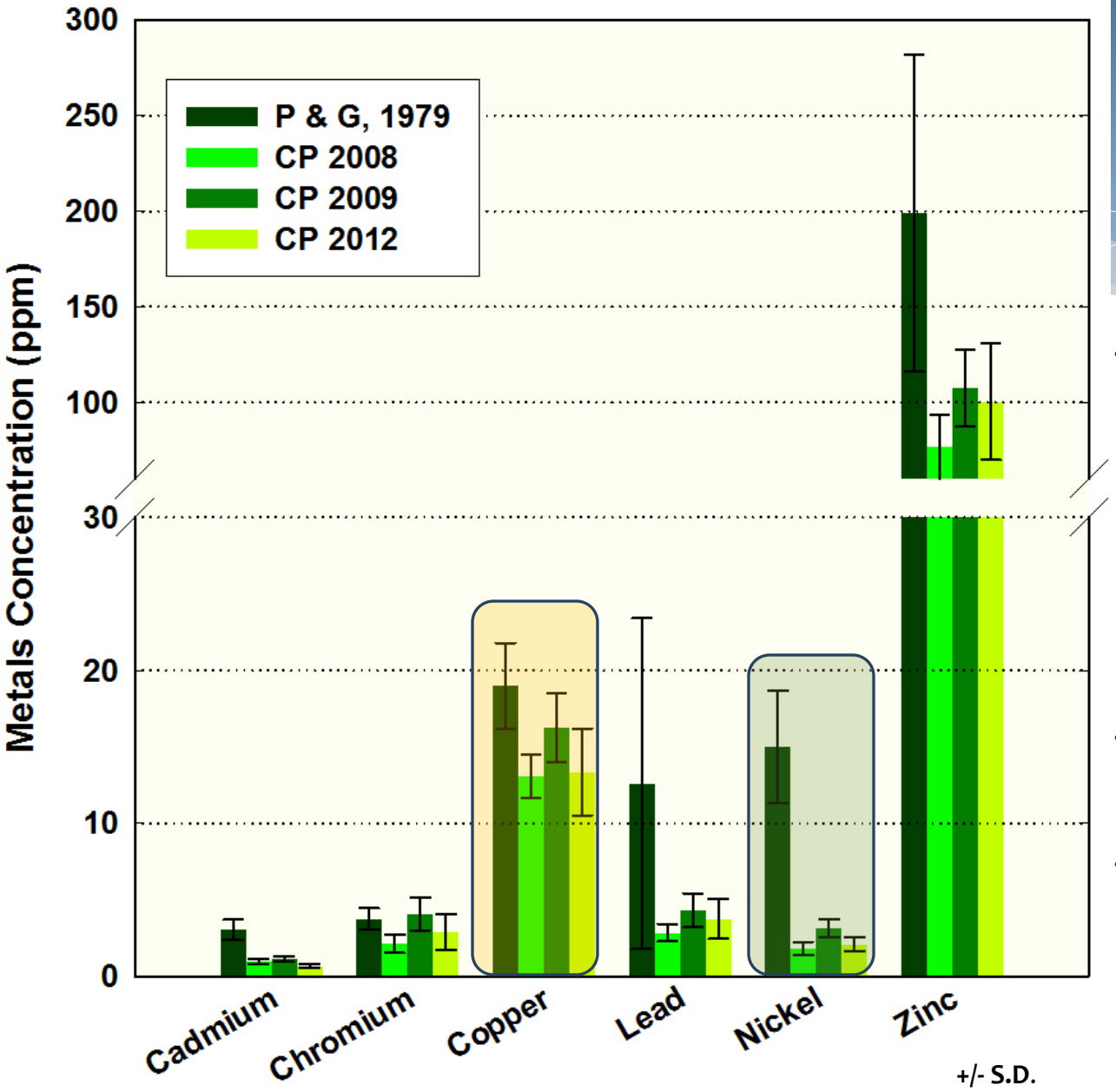
Initial data review and comparison of NBC results to Phelps & Galloway

* Outliers (IQR)
* 2008 – 3 weeks vs. 4 weeks; if no difference, weeks were combined.
  * Difference - used wk 4. (n = 31 or 15)
* 2009 (n = 27), 2012 (n=42)

* Conimicut Point was compared to stressed and unstressed concentration data.
  * ANOVA statistical test

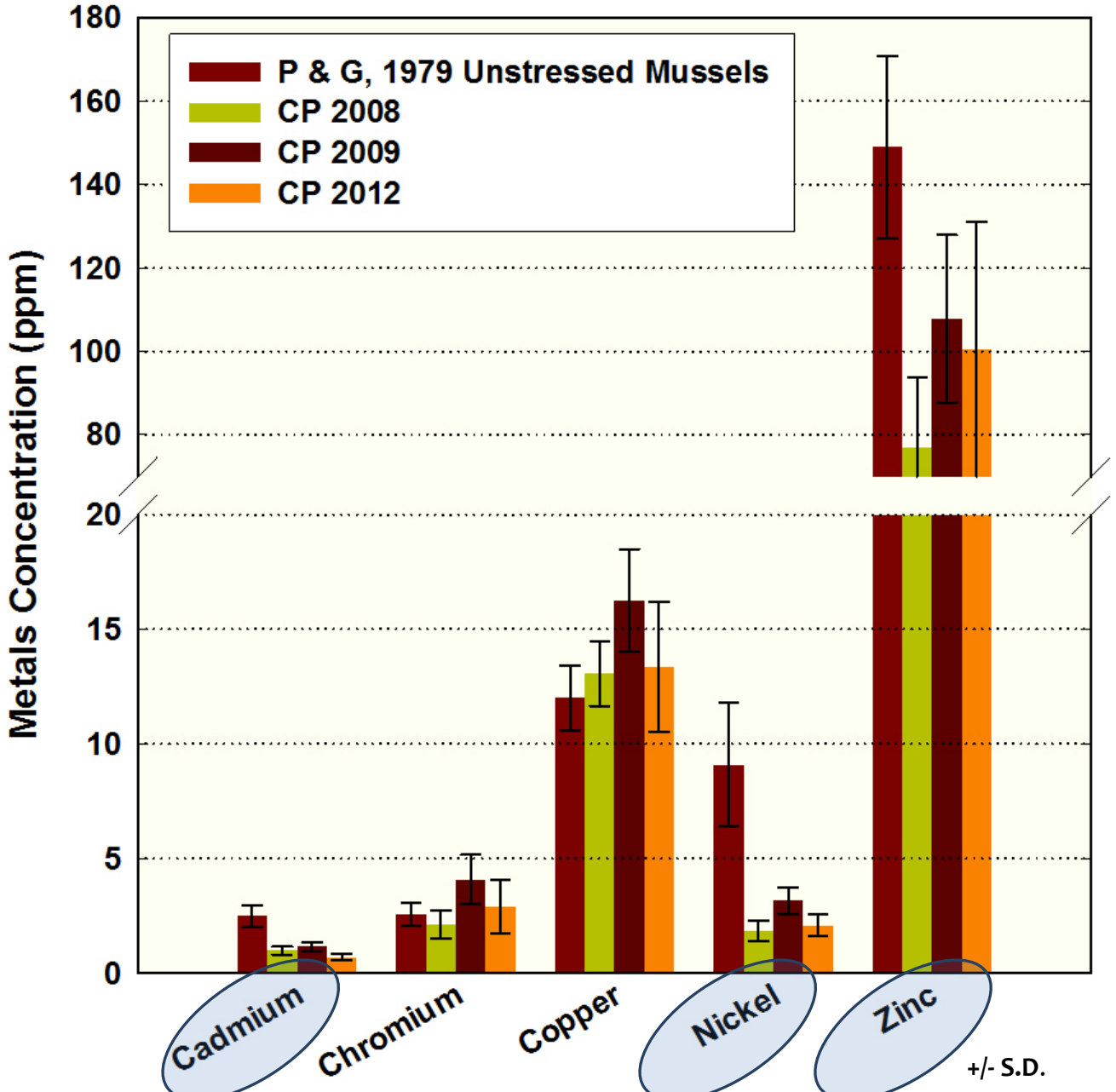
* *Used standard deviation as was reported 1979 paper

Conimicut Point vs. Phelps & Galloway Stressed Mussels



* Concentrations at Conimicut Point all three years were significantly lower
  * except Cr - 2009 no significant difference.
* Largest decrease Ni
  * (avg - 84%)
* Smallest* decrease Cu
  * (avg 25%)

Conimicut Point vs. Phelps & Galloway Unstressed Mussels



* Cd, Ni, Zn:
  * all years significantly lower
* Cr and Cu:
  * no significant difference in 2008, 2012
  * CP was significantly higher in 2009 for both

* Lead not analyzed; n=1 for 1976 data

Results – NBC Experimental Data (Conimicut Pt.) vs. Phelps & Galloway, 1979

* All 3 NBC study years were below concentrations from P&G 1976 data
* **Stressed:** 5 of 6 metals significantly lower than [1976]concentrations: **Cd, Cu, Pb, Ni, Zn**
  * Cr in 2009 - no significant difference
    * (2008 & 2012 significantly lower)
  * Cu - lowest % reduction
  * Ni - highest % reduction
  * Cr - least difference between two study periods
* **Unstressed:** significantly lower for **Cd, Ni, Zn;**
  * Cr and Cu no difference in 2008/2012
  * 2009 was significantly higher.

Take-away Points

* Since inception of NBC Pretreatment Program, huge reduction in metals loadings to and from NBC WWTFs
* Conimicut Point mussel concentration data significantly lower in each NBC study year than in 1976.
* Influent Cu, Ni, Cr decreased by ≥95% since 1981 at FP
  * Cu showed the lowest % reduction (25%)
  * Ni showed the highest % reduction (84%)
  * Cr showed least magnitude of change

* Nickel:
  * Decrease in use of nickel in industry
  * Nickel – mostly dissolved – low % removal in WWTFs

* Copper:
  * Copper still found in more sources (i.e. drinking water)
  * Copper – Particulate – high inf/eff % removal – changes in water column concentrations not as drastic
  * Non-industrial background sources – copper and zinc concentrations high

* Chromium:
  * No significant difference in 2009 from 1976 study
  * Cr- has high inf/eff % removal at WTTFs - particulate
  * Sources of chromium – drinking water, industry
  * Persistent in Sediments

Efficacy of Pretreatment Program

* Able to see this successful reduction of metals in a native aquatic species
* Concentrations for all metals for all 3 NBC study years were significantly lower 1976
* Testament to Pretreatment Programs and local limits development

Acknowledgments:

- NBC - EMDA, PP&R
  - EMDA Monitoring Staff
  - Tom Uva, John Motta, Jim Kelly, Pamela Reitsma, Eliza Moore
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Thank you!

Questions?

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