Ocean Acidification

Assessing Options for Response in Washington State

Preliminary observations on feasibility from research for a report to the Washington Blue Ribbon Panel on Ocean Acidification

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Decision framework

- Low certainty
- High risk
- Irreversible effects

- Vigorous prevention & harm reduction
- Act, learn, act again

SOURCE: Miles, NRC

Three response strategies

- **Mitigation (prevention)**

  — Deep reductions in emissions & nutrient wastes are possible, often profitable.

  — Mitigating acidification in seawater more speculative.

- **Adaptation (defense)**

  — Shellfish industry now relies on monitoring of chemistry & larval performance in hatcheries: controlled environment. Strong ROI demonstrated for now. How long will this work? Can it work in open water?

  —Adaptation methods outside hatcheries largely untested.

- **Remediation (restoration)**

  —Phytoremediation and shell restoration show promise, but need further field testing.

MITIGATION
Assessing sources of problem

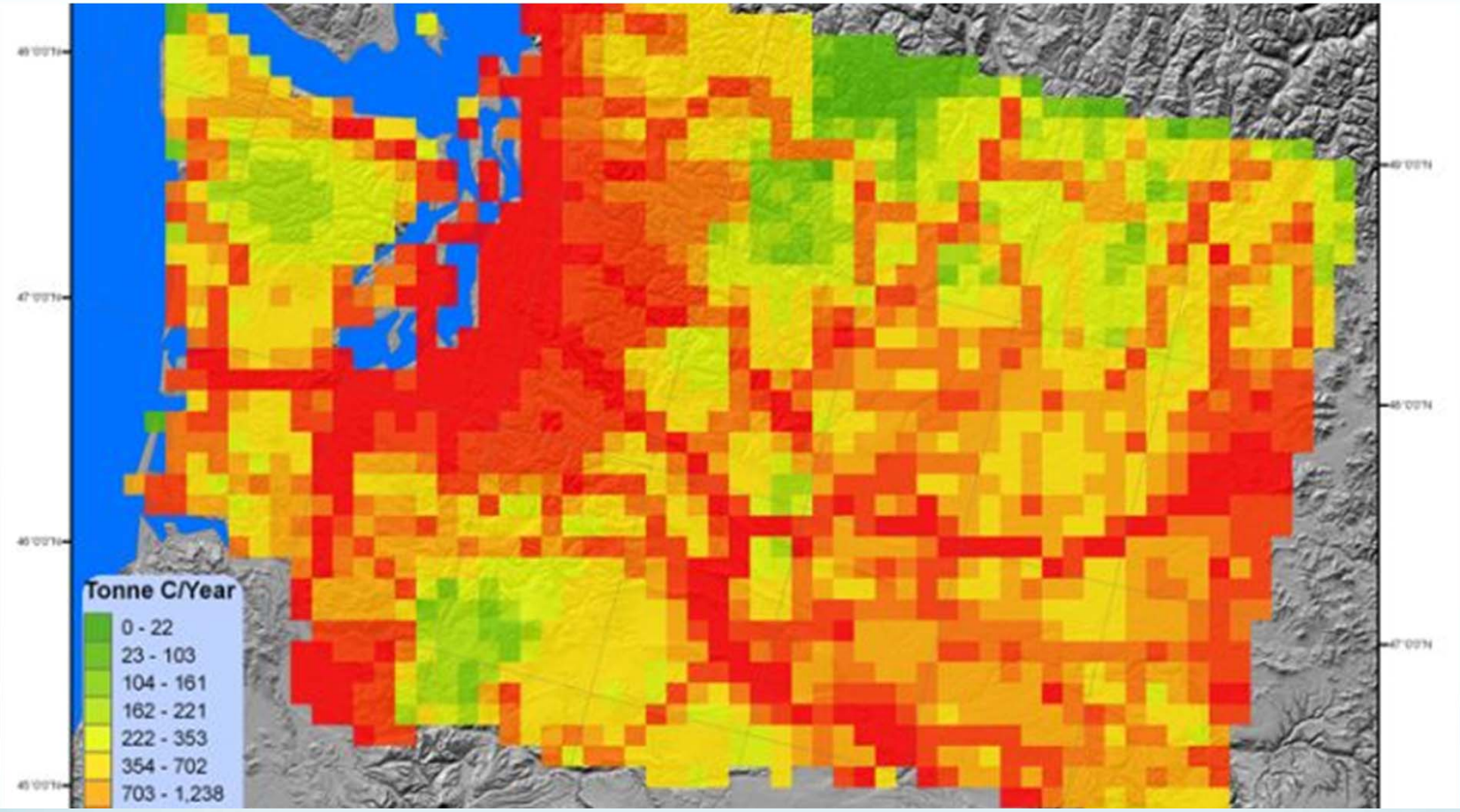
- Which sources contribute most to OA in Washington?
- How much can sources of acidification be reduced?
- Where might reductions achieve most to protect Washington waters from acidifying wastes?

Source analysis can offer guide: Where to focus efforts to influence local acidification

Evaluating mitigation methods

- Proven or speculative?
- Timeline for benefit?
- Scale of potential benefit?
- Feasibility/cost?
- “Shovel-ready” or more study required?
- Research recommendations?

Washington fossil-fuel CO_2 emissions



Total: 16.52 million t/yr. Road transport = 8.19 million t

SOURCE: PMEL/*K. Gurney and Y. Zhou (Purdue University)*
http://www.pmel.noaa.gov/co2/story/WA+State+Emissions

Hypothesis: Some maritime and shore-based air emissions may have outsize effects on seawater chemistry

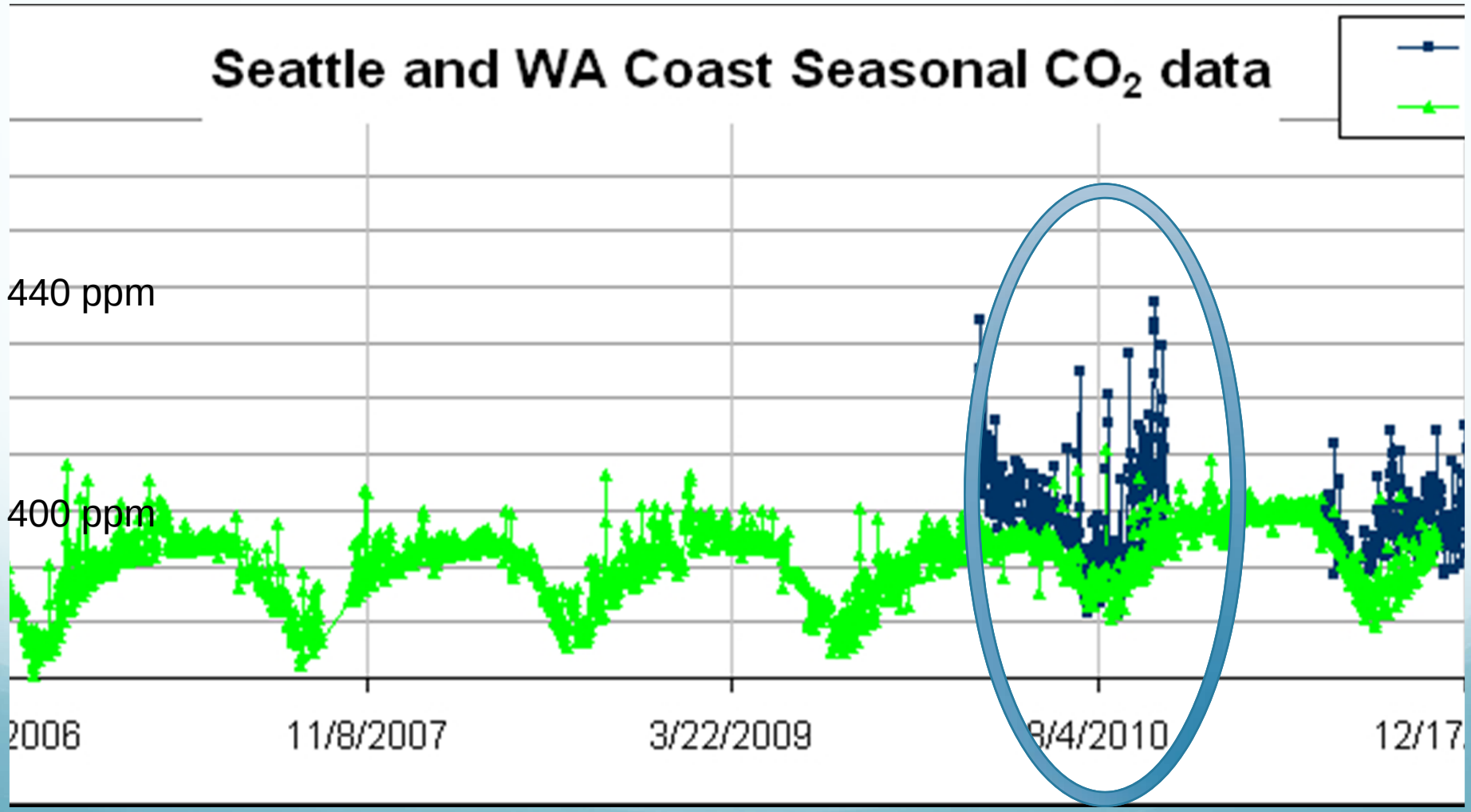
Puget Maritime GHG Emissions: ~1.8% of state total

Table ES.3: Puget Sound 2005 Maritime Air Emissions Inventory Summary, tpy

Source Category	NOx	VOC	CO	SO_2	PM_{10}	$PM_{2.5}$	DPM	Greenhouse Gases, CO_2 eq
Ocean-going vessels:								
Hotelling	2,259	74	191	4,229	262	209	131	274,421
Maneuvering	313	24	33	191	22	17	21	12,481
Transiting	11,390	399	932	7,953	709	566	663	496,844
Harbor vessels	9,555	3,363	16,854	529	495	456	445	689,649
Rail, off-terminal	1,285	57	166	96	35	32	32	59,854
Rail, on-terminal	1,180	67	154	93	35	32	35	48,135
Cargo handling equipment	1,155	103	918	80	74	72	74	111,592
Heavy-duty vehicles, off-terminal	1,120	58	307	35	45	39	39	156,242
Heavy-duty vehicles, on-terminal	203	18	148	4	4	4	4	17,845
Fleet vehicles	10	5	50	0	0	0	0	3,365
Total	28,469	4,167	19,752	13,211	1,682	1,427	1,444	1,870,429

SOURCE: Puget Sound Maritime Emissions Inventory, 2007

Seattle CO_2 concentration: urban, seasonal peaks



Implications of source analysis for mitigation of OA

- **Vehicle emissions: ~50% of Washington total.** Proven fuel efficiency and transportation management options are available. Economic and political resistance?
- **Maritime emissions: Small but localized on water.** Proven fuel efficiency and management options are available, often profitable. Harbor emissions in some ports are subject to potent price signals.
- **Urban emissions:** Can geographic concentration simplify energy management & emissions reduction?

Are deep reductions possible?

Weyerhauser: Reduced GHG emissions 26% during 2000-2010.

Dupont: Reduced GHG emissions 72% 1990-2007, saving $3 billion on energy (Production grew 40%).

Exxon: Has achieved 50% of estimated $1.5 billion in planned energy savings, estimates 80% of remaining gaps can be filled cost effectively.

Bering Sea crab fleet: Reduced emissions by about two thirds by "rationalizing" fishing effort in 2005. (Gleason &Poulsen, Ak Bering Sea Crabbers, pers. comm.)

Icelandic fishing fleet: reduced fuel use 45.5% 1990-2009 (catch value grew 26.9%) (Arnason, pers. Comm. 2010)

SOURCES: Dupont, Weyerhauser & Exxon from company websites & presentations.

Acidifying nutrients

Among U.S. dairies larger than 300 cows in 2000, 75% were spreading manure at rates exceeding crop needs for nitrogen; 96% exceeded crop needs for phosphorus. SOURCE: Ribaudo et al 2003, per WSU Fact Sheet 040E.

Anthropogenic increase in bio-available N exceeds increase in CO_2,
. SOURCE: Howarth et al 2002

Nutrient management tools

- Deep track record, numerous case studies available, including both technical, policy, and voluntary methods.
- Multiple benefits demonstrated: reduced waste disposal costs for producers, contributions to GHG mitigation, F&W freshwater habitat, improved position for climate adaptation.
- Monitoring and control of nutrients may inform site selection for shellfish restoration and habitat restoration.
- Monitoring needed to improve “map” of nutrient contribution to acidification, to guide adaptation & restoration.
- —One key question: How to “piggyback” on existing monitoring (e.g. via Dept of Ecology) to deliver best bang for buck?

RIVERS

All rivers contribute nitrogen to the Salish Sea.

In general, the largest rivers by flow contribute the largest nitrogen loads.

WASTEWATER TREATMENT PLANTS

The largest population centers contribute the largest loads of nitrogen.

COMBINED LOADS

Highest loads enter the Salish Sea on the east side, where the largest rivers and population centers are.

SOURCE: Wash. Dept. of Ecology

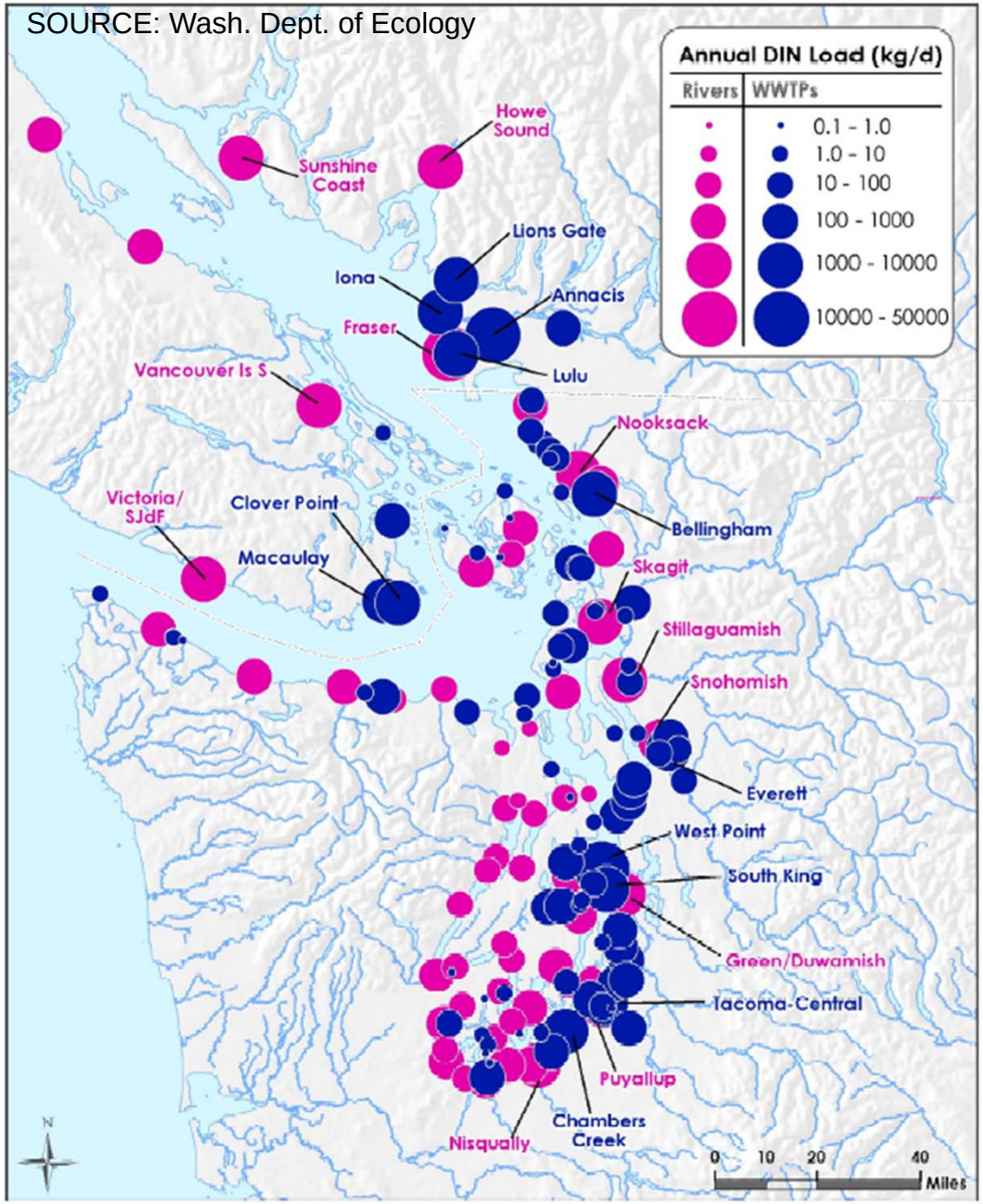


Figure ES-3. Mean annual dissolved inorganic nitrogen (DIN) loads from rivers and WWTPs for 1999 to 2008.

Human activities have more than tripled local DIN loads to the U.S. waters of the Salish Sea from 17,600 kg/d to 63,600 kg/d

Table 12. Comparison of natural and 1998-2008 average annual dissolved inorganic nitrogen (DIN) loads from rivers and WWTPs into the Puget Sound and the Straits.

Subbasin/Region	Average Annual DIN Load (kg/d)			
	Natural Conditions	Human Nonpoint Sources (in rivers)[1]	Human Point Sources (WWTPs)[2]	Total Human
South Sound	1,820	2,300	2,540	4,840
Commencement Bay	1,230	880	2,440	3,320
Elliott Bay	760	880	0	880
Puget Main	850	0[4]	22,700	22,700
Sinclair Dyes Inlet	140	90	1,010	1,100
Whidbey	9,490	3,260	3,470	6,730
Admiralty	20	110	40	150
Hood Canal	570	240	1	240
Strait of Juan de Fuca	350	130	310	440
Strait of Georgia	2,350	3,790	1,760	5,550
Puget Sound Subtotal[3]	**14,900**	**7,700**	**32,200**	**40,000**
Straits (US) Subtotal[3]	**2,700**	**3,900**	**2,100**	**6,000**
Total[3]	**17,600**	**11,600**	**34,300**	**46,000**

[1] Human nonpoint sources = (1999-2008 annual average river loads) – (natural condition loads).

[2] Human point sources = 1999-2008 annual average WWTP loads.

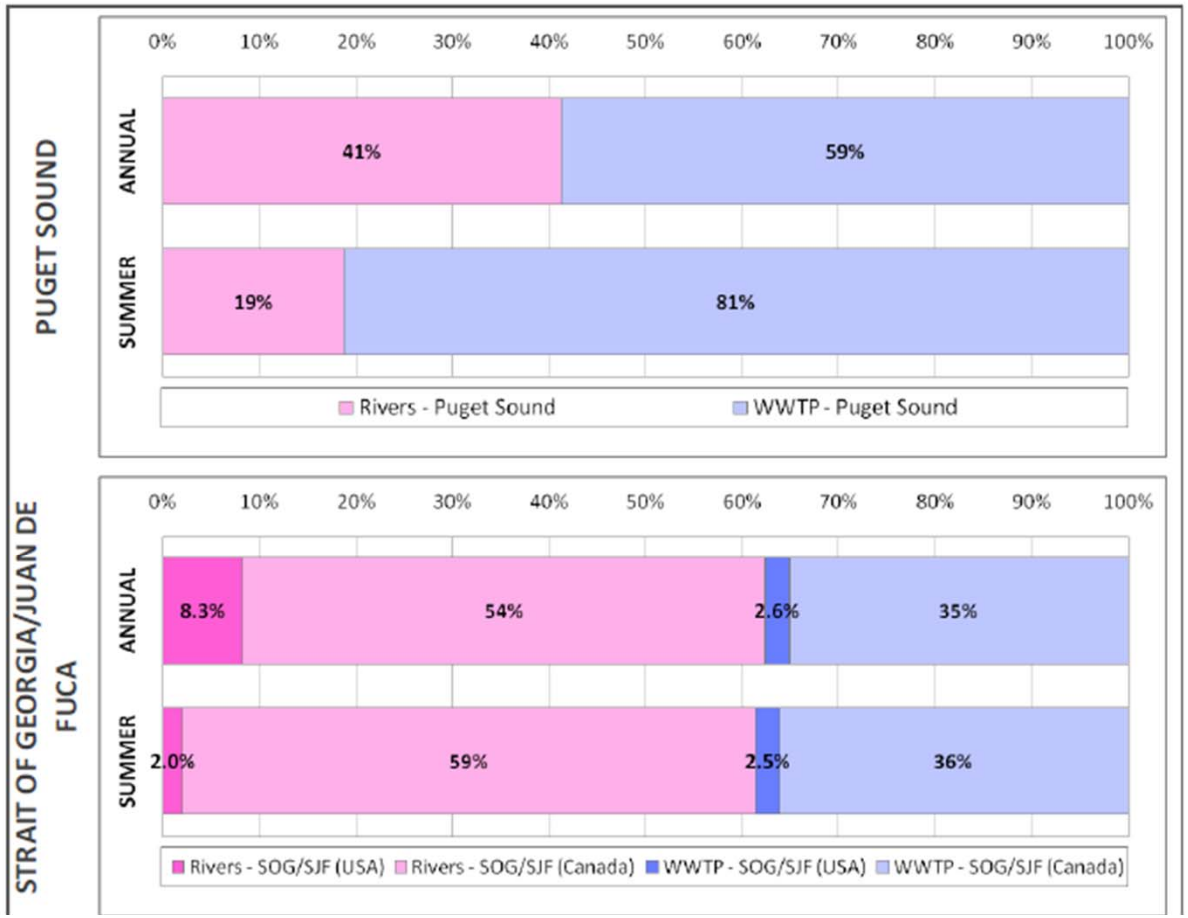
[3] These totals have been rounded to the nearest 100 kg/d.

[4] Estimated natural DIN loads into the main basin of Puget Sound were comparable to current nonpoint sources, so the calculated value for *human* nonpoint sources is zero based on the difference between current and natural loads. Current loads were estimated using more information, while natural loads were estimated from fewer ambient data from the Cedar River.

SOURCE: Wash. Dept. of Ecology

RIVERS discharge 41% of the annual DIN load to Puget Sound, south of Admiralty Inlet. The Skagit River contributes the largest river flow but the Snohomish produces the largest nitrogen load to U.S. waters.

WASTEWATER TREATMENT PLANTS contribute 59% of the annual DIN load to Puget Sound but 81% in the summer months. The increase in proportion reflects the seasonal decreases in river flows.



SOURCE: Wash. Dept of Ecology

Reducing nutrients and emissions

- Nationwide, dairy manure digesters reduce CO_2e emissions by > 860,000 t, generating 52.8 mw of power.

- Six dairy digesters in Washington reduced CO_2e emissions by 44,870 t.

- Tulalip's project has enfranchised farmers in habitat efforts.

ADAPTATION

- So far, monitoring to protect larvae in hatcheries is primary method for shellfish adaptation.
- Water treatment in hatcheries: a supplementary method, still being refined.
- Selective breeding: potential for resistant strains?

REMEDIATION

Use of shell