THE ROLE OF SALMON CARCASSES

AN ALTERNATE INTERPRETATION

Phelps Freeborn
Ecology – Water Quality
CRO, Yakima

An Early Report on Salmon Carcasses

“This river is remarkably Clear and Crouded with Salmon in maney places, I observe in assending great numbers of Salmon *dead* on the shores, floating on the water and in the Bottom which can be seen at the debth of 20 feet. the cause of the emence numbers of dead salmon I can't account for So it is I must have seen 3 or 400 dead and maney living...”

William Clark, journal entry for 18 October 1805

Salmon (genus Oncorhynchus)

Name		Juvenile time in freshwater (yrs)	Breed
common	taxonomic		
Chinook	O. tshawytcha	<1 and >1	once
Chum	O. keta	<1	once
Coho	O. kisutch	>1	once
Pink	O. gorbuscha	<1	once
Sockeye/Kokanee	O. nerka	>1	once
Cutthroat	O. clarki	>1	multiple
Rainbow/Steelhead	O. mykiss	>1	multiple

Cederholm, et al.:

"As the decline of wild salmon continues throughout the Pacific Northwest, it is logical to assume that the productivity of some freshwater and terrestrial ecosystems will also decline. Decreased production could be self-perpetuating, as salmon stocks already in decline are likely to decrease further in a negative feedback loop."

Pacific Salmon and Wildlife, 2000, p 68

Cederholm, et al.:

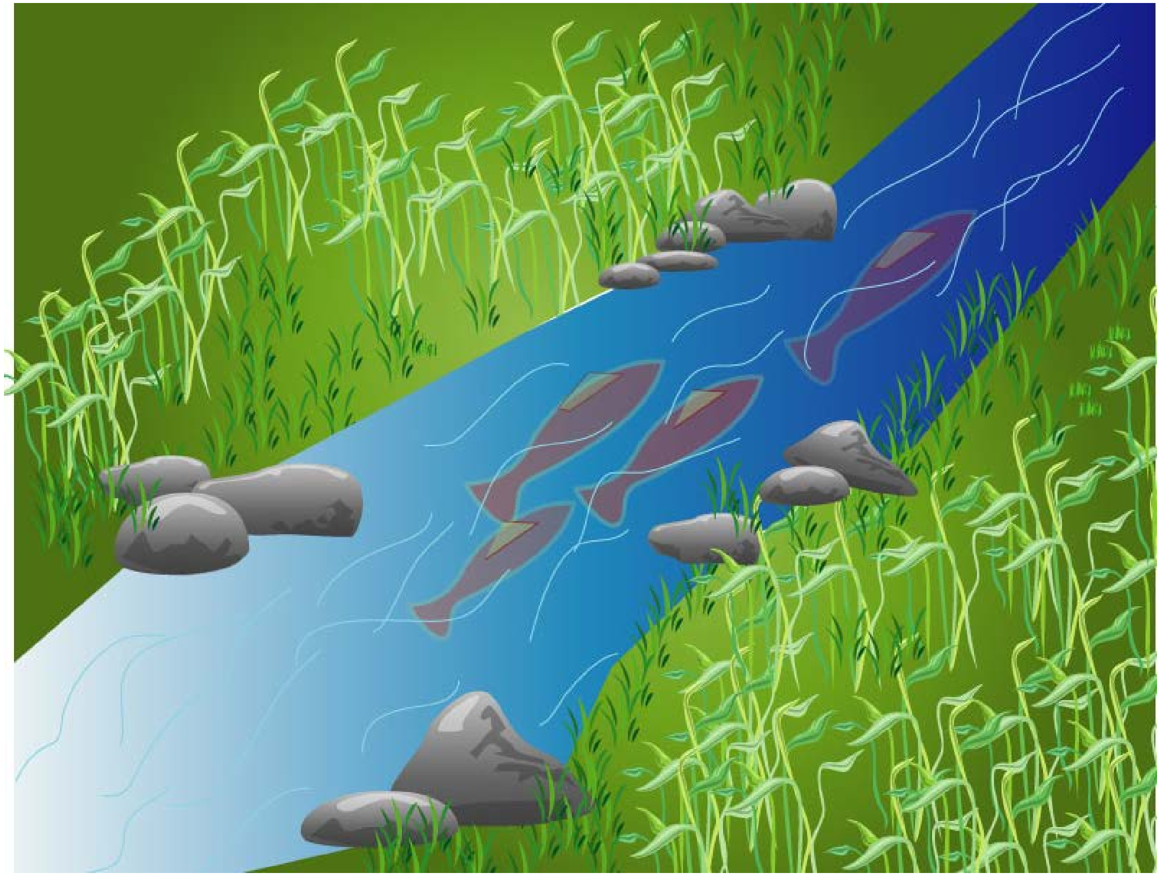
Recent calculations by Gresh et al. indicate that only three percent of the marine-derived biomass once delivered by anadromous salmon to the rivers of Puget Sound, the Washington Coast, Columbia River, and the Oregon Coast is currently reaching those streams.

Pacific Salmon and Wildlife, 2000, p iv

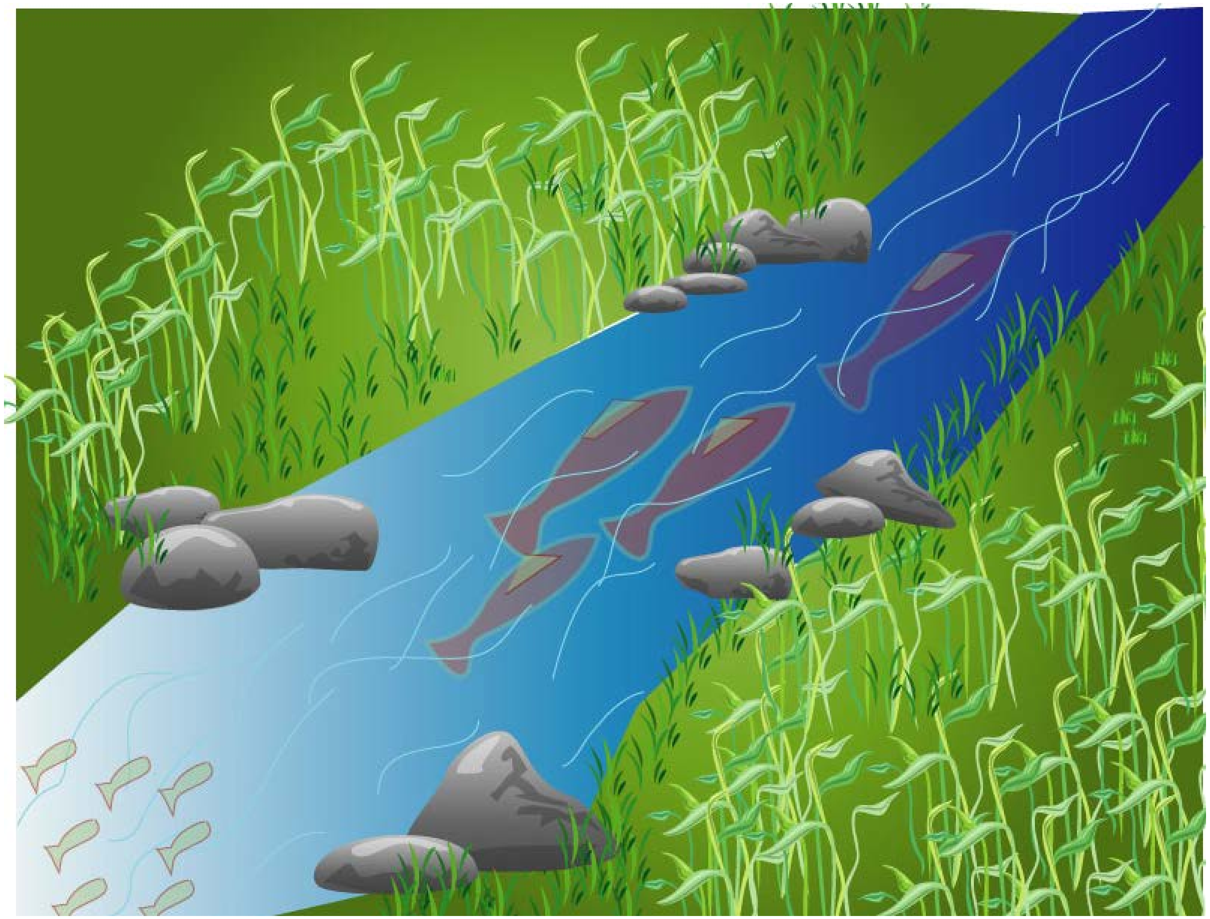
First Concern

The MDN or marine nutrient pump model has focused on the upstream movement of nutrients (N, P and calories, plus?) to the almost complete exclusion of all other nutrient fluxes:

Adult Salmon Migration



Adult & Juvenile Salmon



Hypothetical Example (>1 year in freshwater)

STAGE	NUMBER	SIZE each	TOTAL WEIGHT
Adults	2	5 kg	10 kg
Eggs	5000	0.5 g	2.5 kg
Fry	1000	0.4 g	0.4 kg
Smolts	200	50 g	10 kg

80% loss from egg to fry and 80% loss from fry to smolt for a survival from egg to smolt of 4% but the mass of smolts is the same as the adults

Hypothetical Example (<1 year in freshwater)

STAGE	NUMBER	SIZE each	TOTAL WEIGHT
Adults	2	5 kg	10 kg
Eggs	5000	0.5 g	2.5 kg
Fry	1000	0.4 g	0.4 kg
Smolts	750	5 g	3.75 kg

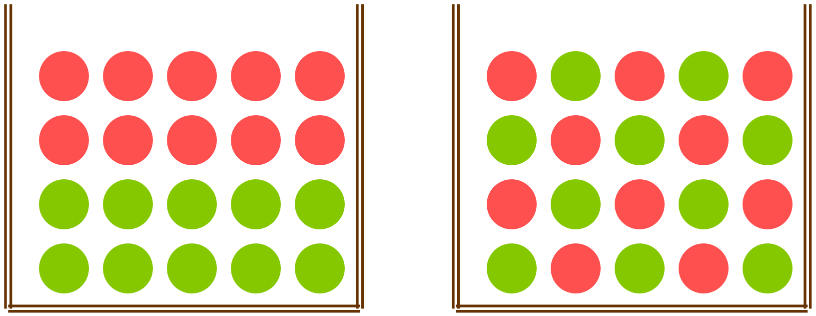
80% loss from egg to fry and 25% loss from fry to smolt for a survival from egg to smolt of 60% but the mass of smolts is a significant fraction of the adult mass

Mixing of Nitrogen Isotopes

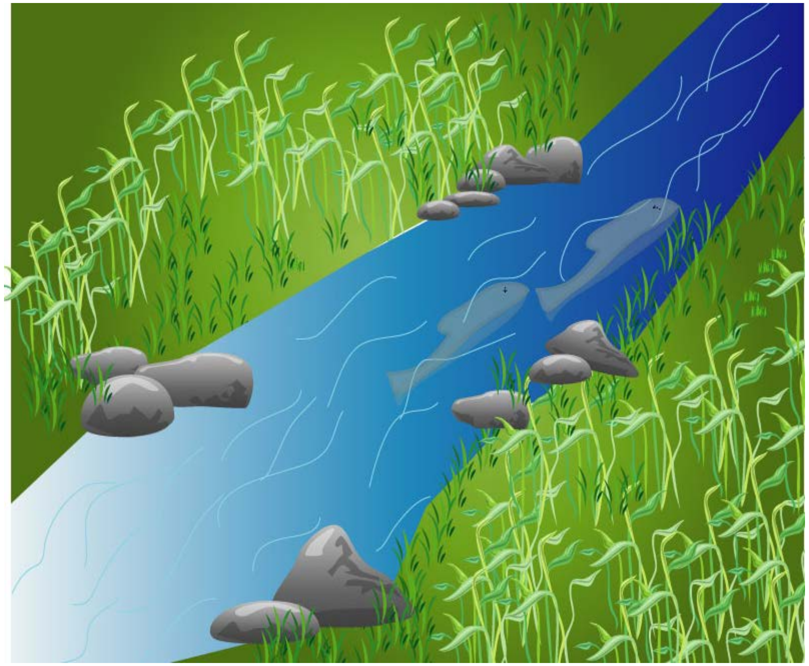
Measurements of Nitrogen isotopic compositions of stream reaches supplemented by salmon carcasses and reaches without supplementation show a pattern consistent with mixing of marine and terrestrial nitrogen.

This is not the same as demonstrating that salmon account for a net addition of nutrients to the freshwater system.

Mixing Is Not Proof of Addition



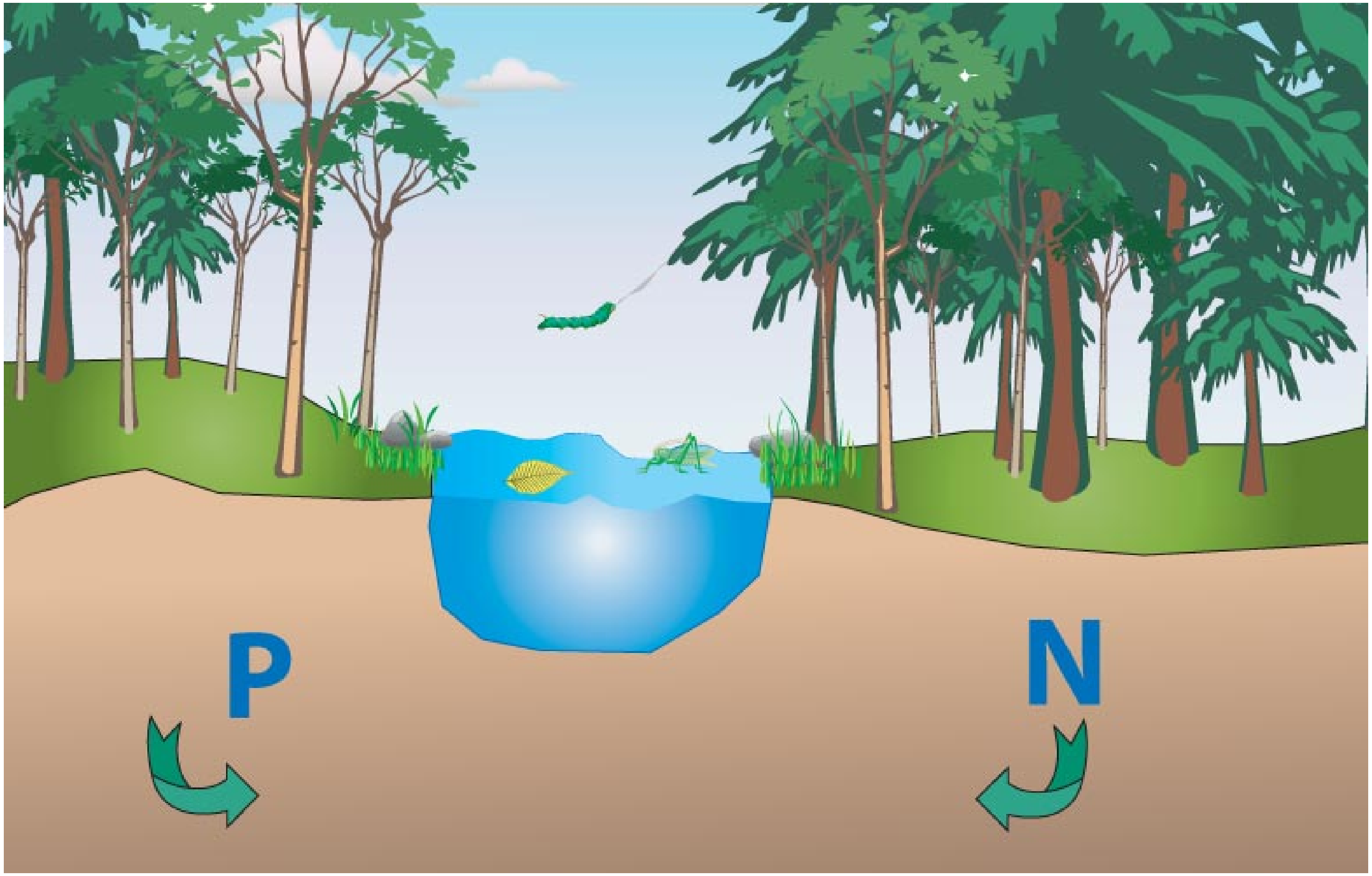
Comparison of Models



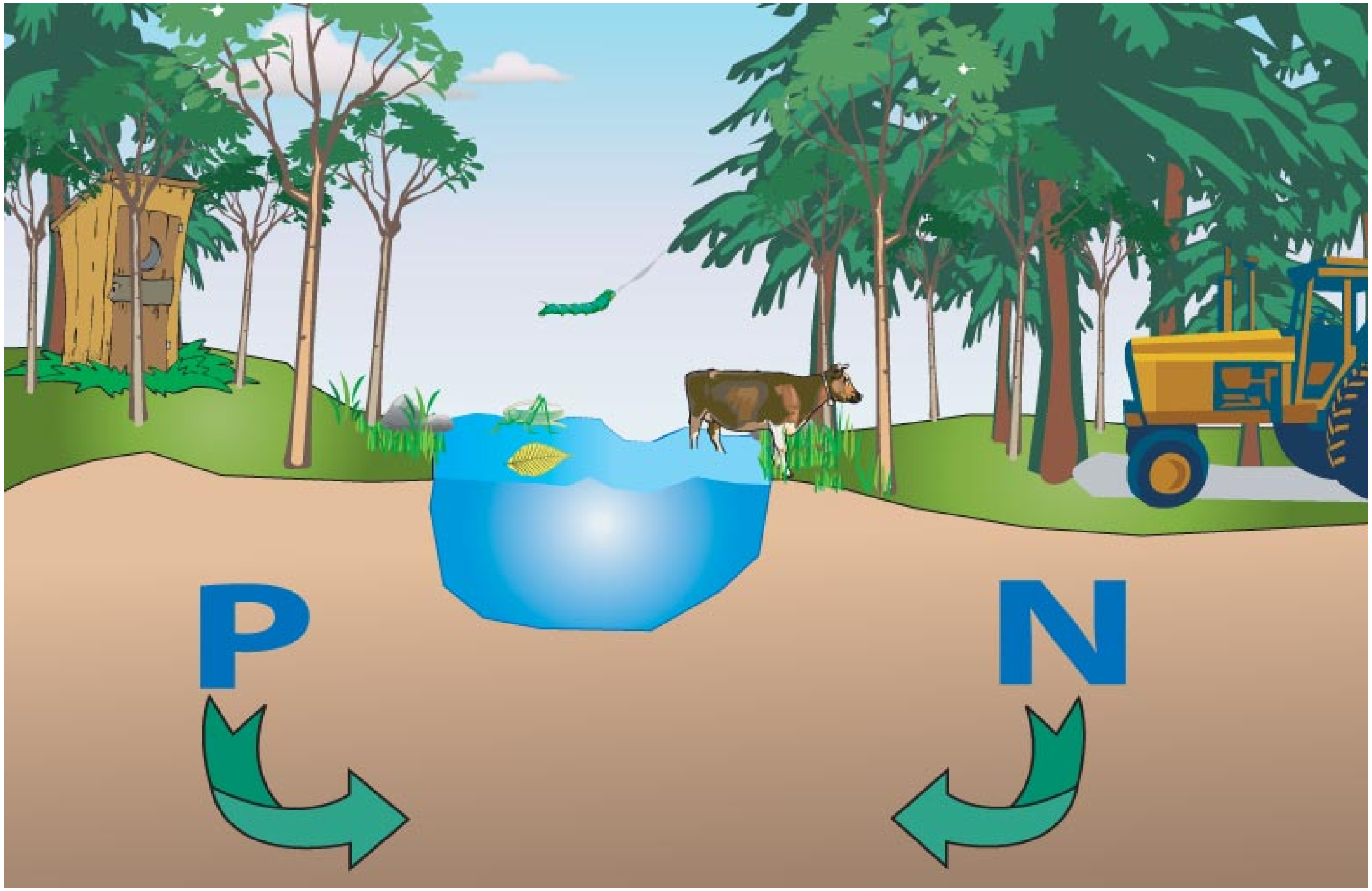
MDN

Net Nutrient Transport

Fluxes To Be Considered Natural



Fluxes
Including Anthropogenic Impacts



Nutrient Fluxes

Origin	Phosphorus Flux (million kg/yr)
Watershed	2.0
Spawning salmon	0.6
Modern	3.4

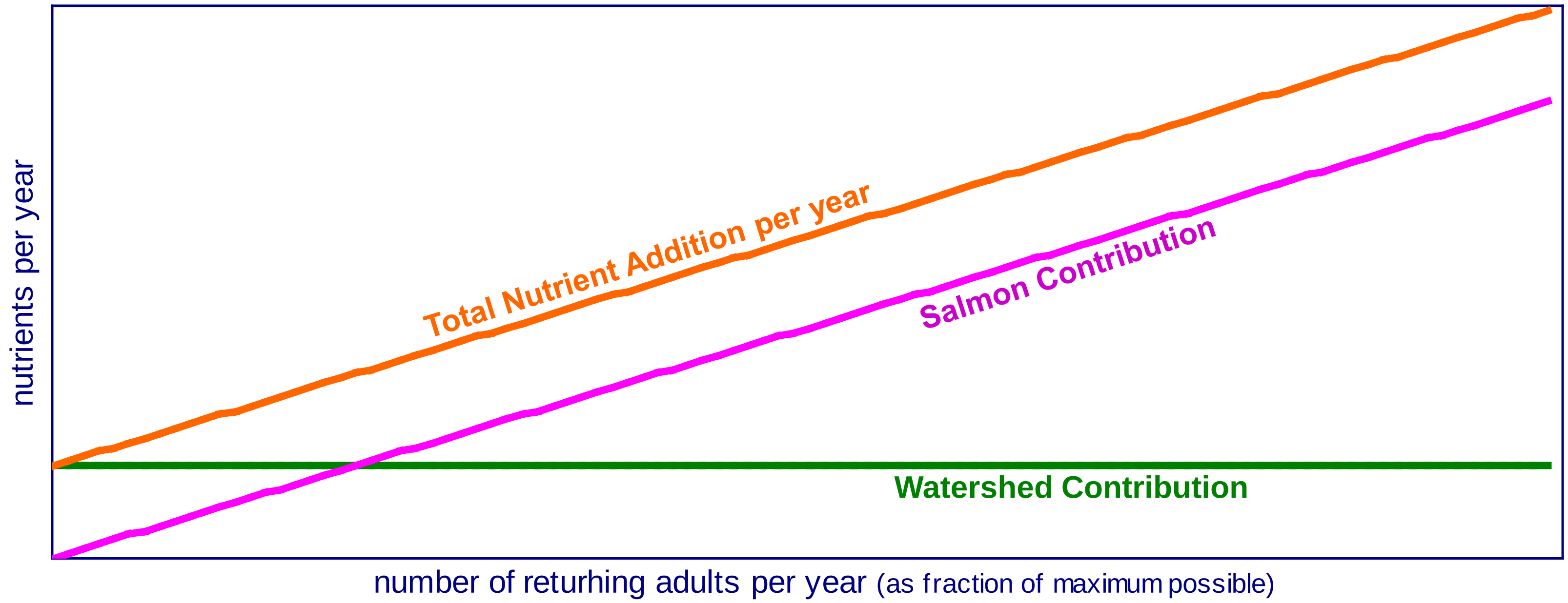
near the mouth of the Columbia River

Nutrient Loadings

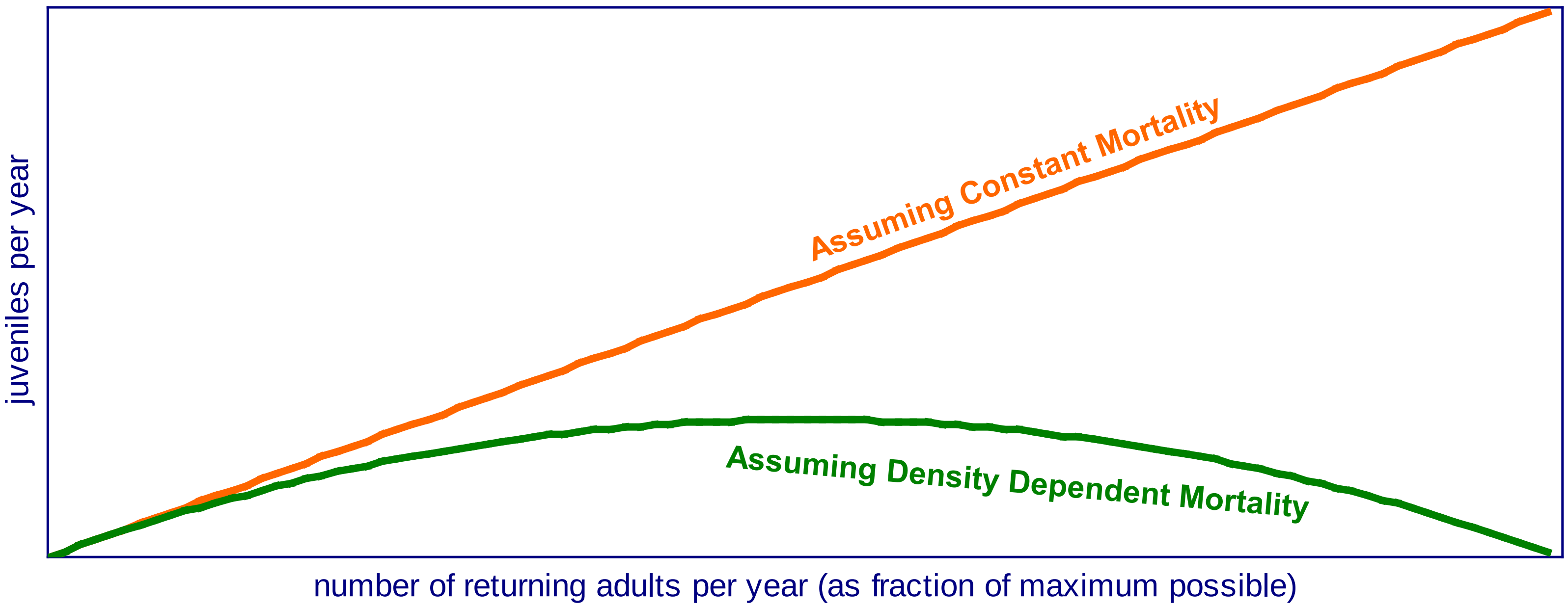
Nutrient loadings can be reported different ways:

- kg N/sq meter of stream bed
- kg N/kilometer of stream
- g N/juvenile

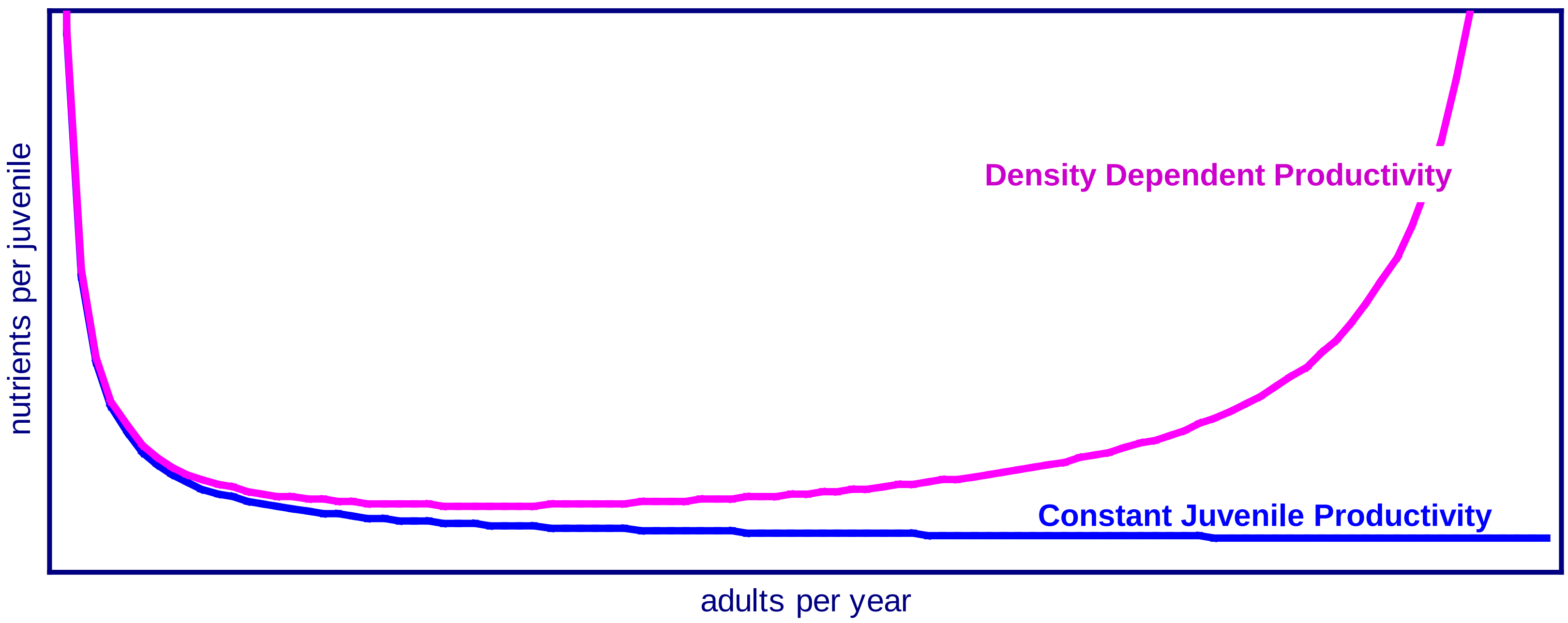
Nutrient Inputs



Juvenile Production



Juvenile Nutrition



Summary

The nutrient flux carried by adults is just one of three natural fluxes of similar magnitude.

The anthropogenic flux of nutrients is significant.

Any MDN model for the input of nutrients by adults has to take into account the export of nutrients by smolts and anthropogenic inputs need to be included in any enrichment scheme.

Interpretation

For relatively small spawning runs – carcass additions should not be necessary the background flux should be sufficient.

Interpretation (continued)

Carcasses are important ONCE there are juveniles present but the returning adults should be sufficient.

The lowest nutrient availability per juvenile occurs at the peak spawning success (maximum number of juveniles survive).

Additional Implications

A small class of spawners is expected to result in good survival and growth, which could result in a net export of nutrients with the smolts

This possibility was noted by Scheuerell, Levin, et al., 2005, who concluded that this meant nutrient supplementation was especially important at low spawner densities

Potential Consequences of Applying the Wrong Model

Increasing the density of salmon carcasses without a corresponding increase in the number of smolts moving downstream will lead to increased nutrient densities in the region where the carcasses are added and an increased spiraling flux of nutrients downstream (that is assuming that there is a longer residence time for nutrients in the stream in the absence of salmon than there is with salmon present and smolt migration).

Potential Consequences of Applying the Wrong Model

1) The additional nutrients will support other species in the stream (e.g. resident trout and small fish or algae).
2) These species will prey on fry or compete with juveniles more.
3) Shift ecosystem from a salmon stream to a stream dominated by resident species.
4) Raise nutrient levels to point that areas with adequate sunlight grow enough phytoplankton to create severe swings in dissolved oxygen (areas without sunlight could also become low dissolved oxygen due to bacterial utilization of carcass material).

Potential Consequences of Applying the Wrong Model

5) The nutrient spiral will add to any nutrient excesses caused by human utilization of the lower basin.

Development of a TMDL for nutrients will require a reduction of inputs, which would require additional reductions from other sources to offset nutrient introductions for salmon restoration.

Distinguishing Between Restoration and Aquaculture

An aquaculture model will result in the run returning to the level prior to intervention upon cessation of supplementation.

A restoration model should lead to the condition that terminating human intervention will not result in a return of the salmon run to the levels before intervention.

Restoration versus Aquaculture

If the activity qualifies as aquaculture, a wastewater discharge permit may be required

If the activity is truly restoration, other oversight mechanisms can be used

Needs

Flesh out the stick figure model I have presented with data on smolt out migration rates and natural nutrient fluxes.

The impact of releasing masses of hatchery reared smolts needs to be included in any attempt to fully quantify the nutrient cycle. Do they die before exiting the stream and add nutrients or do they feed during the journey and mine the stream of nutrients?.

The ecology associated with spawning salmon needs to be understood in greater detail.

The ecology associated with spawning salmon needs to be understood in greater detail.

What characteristics distinguish starved from healthy from over-enriched photosynthetic and invertebrate communities.

Develop criteria for when nutrient (or calorie) additions are required and when corrective actions to reduce nutrient inputs are needed which reflect conditions in the watershed, not just the observation that the spawning runs are depleted.

Suggestions (if salmon carcass placement is to continue):

Concentrate the available carcasses (resources) in a few streams and use the others for controls.

Measure productivity of supplemented and un-supplemented streams for several generations, then switch treatments for half of the control streams. The response should distinguish between whether the carcass placement functions as aquaculture or restoration.

Comment:

The differences in juvenile lifestyles and one shot versus multiple spawning can be used to increase the understanding of the importance of salmon carcasses.

There have been a number of studies of the impact of adding salmon carcasses or carcass analogs to streams which have not produced measurable results. There are two likely causes: the addition was small compared to the natural flux (i.e. the result was inherently not measurable) and nutrients were not the limiting factor, other considerations (e.g., rearing habitat) were more important to their survival and growth.