Effect of salmon-derived nutrients and matters on riparian ecosystems in the Shiretoko World Natural Heritage area

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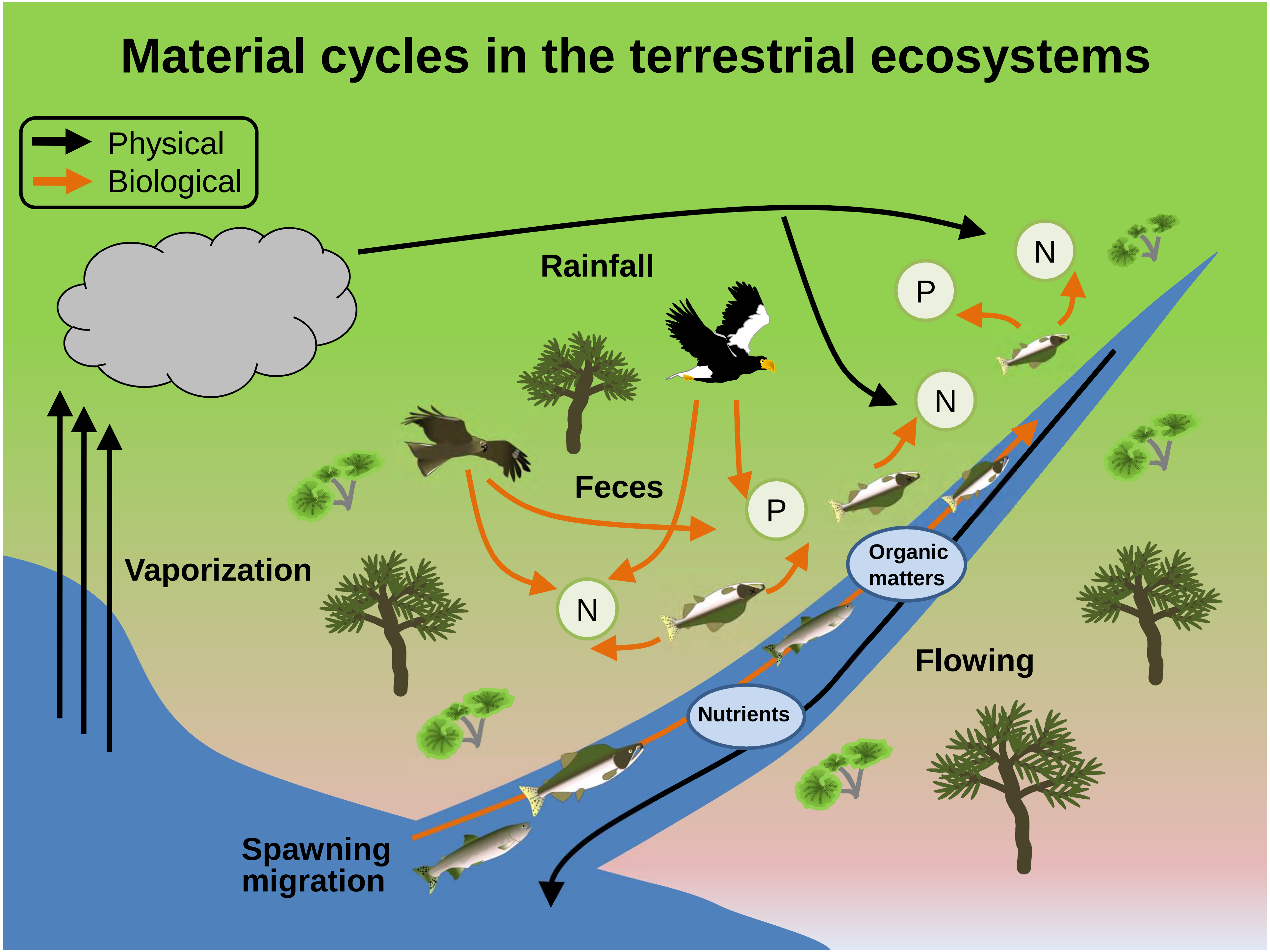

Material cycles in the terrestrial ecosystems
Physical
Biological
Rainfall
Feces
Vaporization
N
P
N
P
N
P
N
Organic matters
Nutrients
Flowing
Spawning migration

Pacific salmon contributed on the productivity and biodiversity as Ecosystem-Transboundary Materials (ETMs)

- Pacific salmon supply a large amount of nutrients to natal spawning ground (e.g. Juday et all. 1932; Donaldson 1967; Johnson & Johnson et al.2003)
- Marine-derived nutrients (**MDN**) facilitate growth rate and body condition of aquatic organisms (Bilby et al. 1998; Wipfli et al.2003)
- Riparian vegetation increase growth rate and biodiversity in salmon spawning area (Helfield & Naiman 2001; Bilby et al. 2003)

Various trophic levels

Disruption of salmon spawning environment

Anthropogenic impacts

- River channel modification
- Artificial river constructions
- Hatchery programs

→

Disturbance

- Freshwater ecosystems
- Reproduction of wild salmon

Anthropogenic impacts negatively affect the wild salmon reproduction (Kaeriyama & Edapalina 2004)

Objects

- Pacific salmon play a significant role in the terrestrial ecosystems as biodiversity and productivity in order to transport marine-derived nutrients (MDN) at the spawning period

- As an example of ETMs, we evaluate the MDN contributions for freshwater and riparian ecosystems in the Shiretoko World Natural Heritage area, Japan, using carbon and nitrogen stable isotope analysis

■ Field sampling

Shiretoko Peninsula (World Natural Heritage Area)

2006-2009 Pre-spawning: July
Spawning : September to October

Spawning (Rusha River)

- Three artificial dams for controlling erosion in lower reach

Non-spawning (Akai River)

- Investigation in non-spawning area between the impassible dams

Stable isotope analysis

Samples

Biofilm

Aquatic invertebrates
- Mayfly
- Caddisfly
- Stonefly
- Amphipod
- Chironomid

Salmonids
- Dolly Varden
- Masu salmon
- Pink salmon

Plants
- Willow
- Butterbur
- Bamboo
- Male fern
- Alder

Mammals
- Brown bear
- Yezo sitka deer

$\delta^{13}C$ or $\delta^{15}N$ (‰)

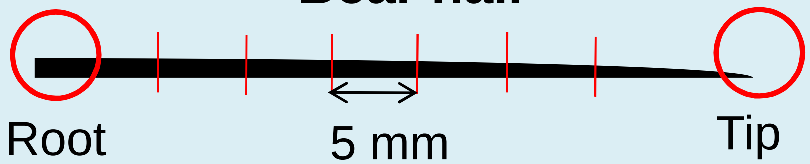
$$=(R_{sample}/R_{standard}-1)\times 1000$$

$R = {}^{13}C/{}^{12}C$ or ${}^{15}N/{}^{14}N$

Feeding history of brown bear

Growth Section Analysis (GSA)

Bear hair



(Mizukami et al. 2005)

MDN enrichment

$$=(\delta X_{se}-\delta X_{c})/(\delta X_{s}+(TL\cdot\delta X_{e})-\delta X_{c})$$

δX_{se} = the isotope ratios of the organism in areas enriched with salmon

δX_{c} = the isotope ratio of the organism in areas without salmon enrichment

TL = the trophic level

δX_{s} = the isotopic ratio of salmon

δX_{e} = the isotopic enrichment factor

(Johnston 1997)

■Stomach contents analysis

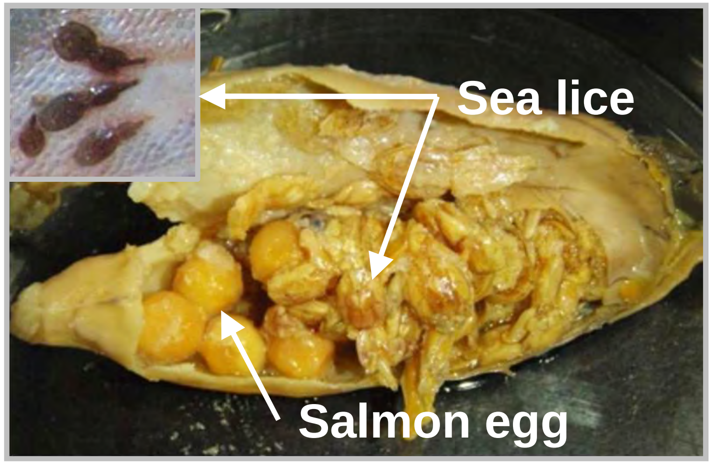
Dolly Varden (*Salvelinus malma*)

IRI = (N + W) × F

N : % by number of prey
W : % by weight of prey
F : frequency
（Pinkas et al. 1971)

Four categories:

1) Terrestrial invertebrates
2) Aquatic invertebrates
3) Salmon eggs
4) Sea lice (*Lepeophtheirus salmonis*)

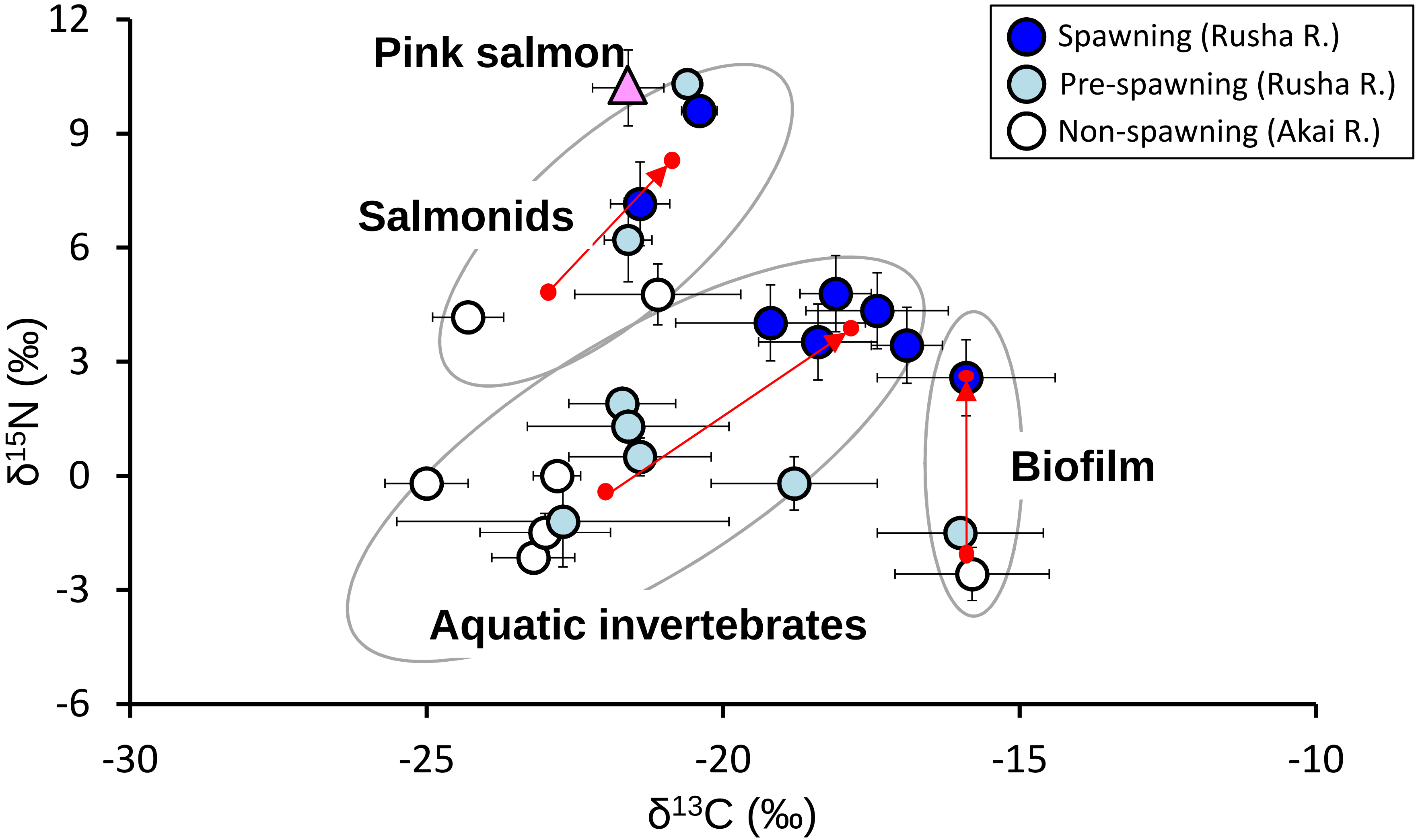


■Discrimination of pink salmon carcasses

Bear-killed carcass

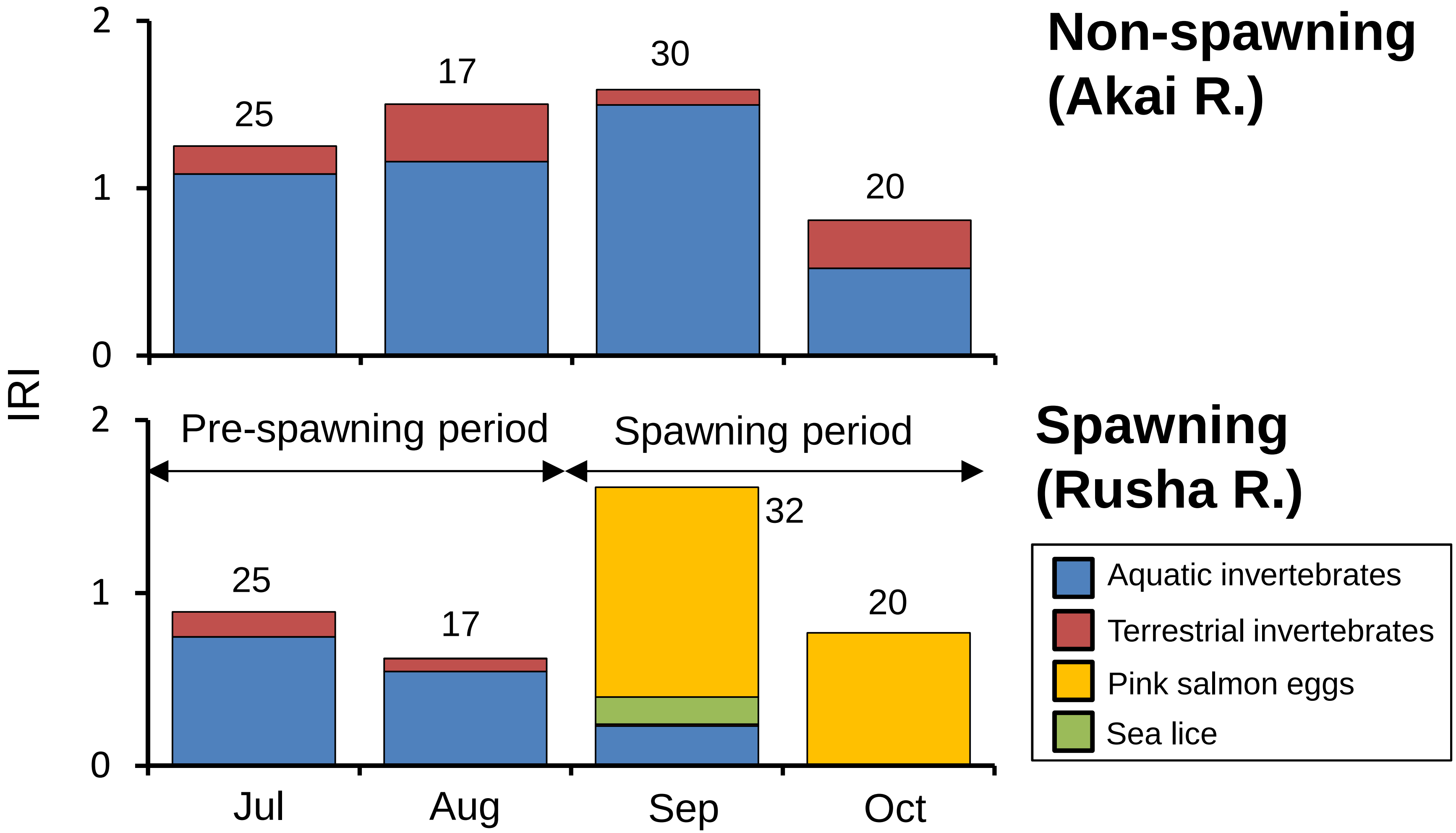
Senescent carcass

The C-N map of freshwater organisms



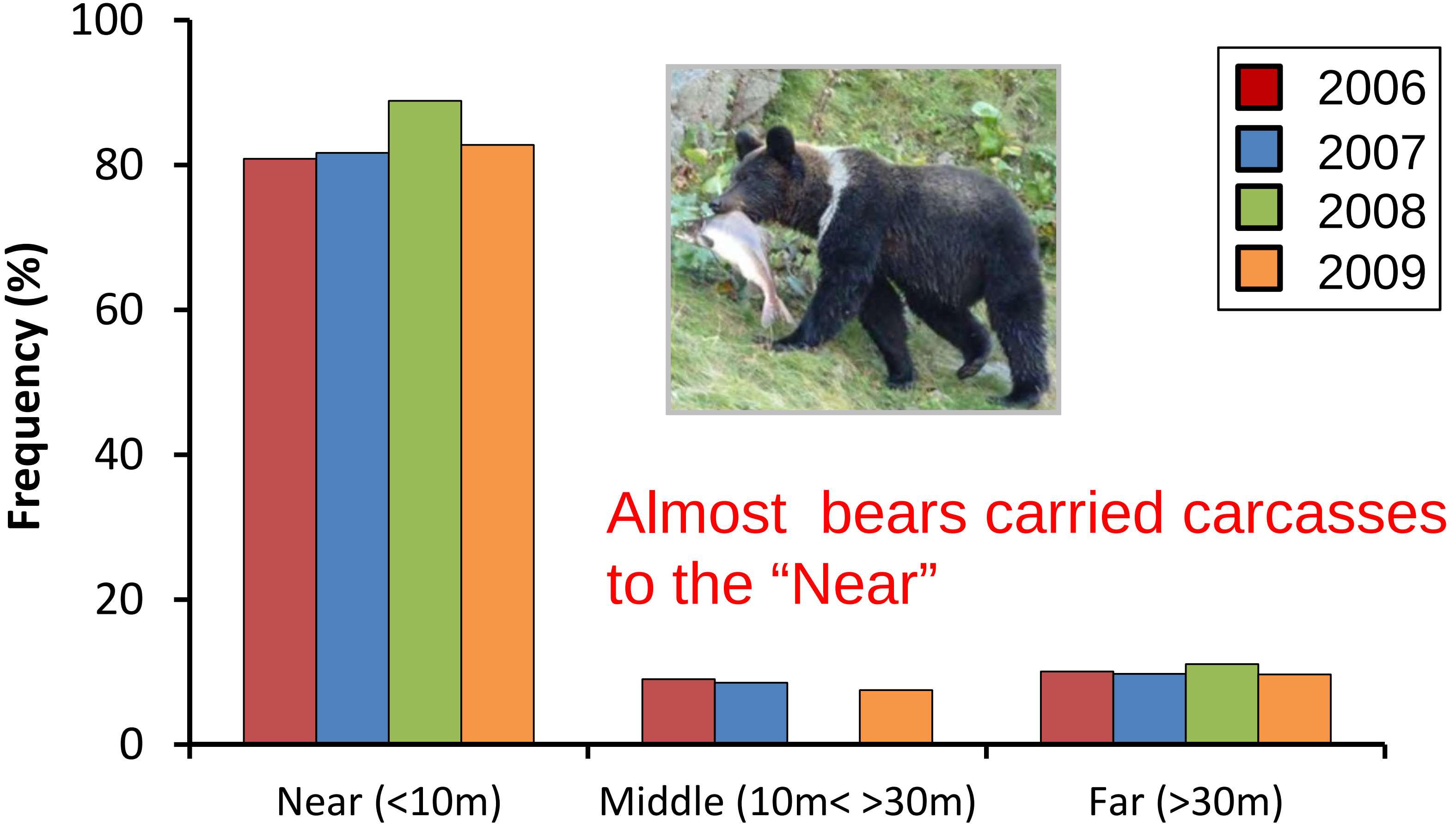
MDN changed trophic position of organisms in the food-web of freshwater ecosystems

Feeding habits of Dolly Varden in the Shiretoko



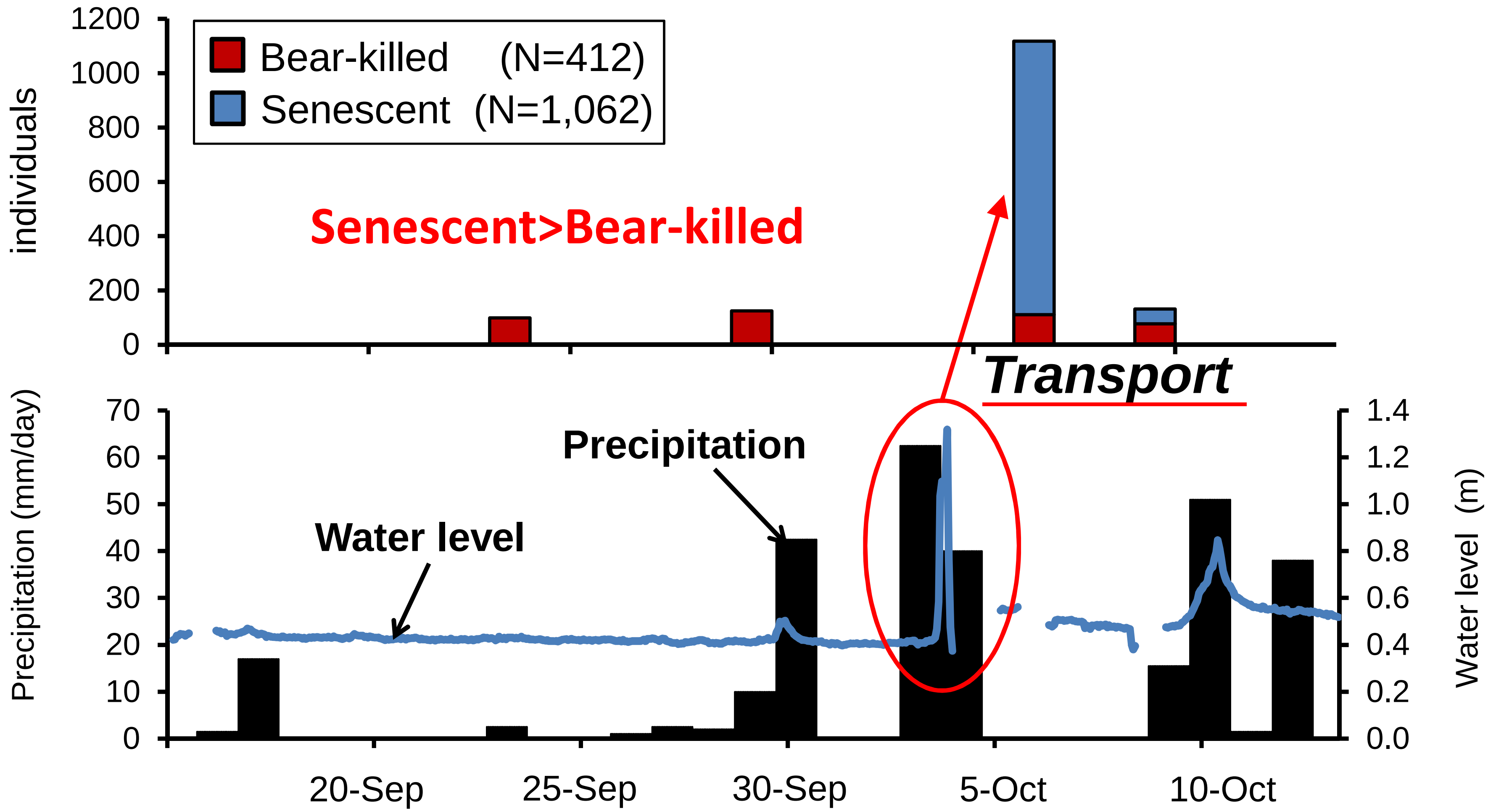
Dolly Varden switched preys from invertebrates to salmon eggs in salmon spawning period

Distance of carcass transported by brown bear from the river



Brown bears serve as a vector of salmon carcass in riparian area

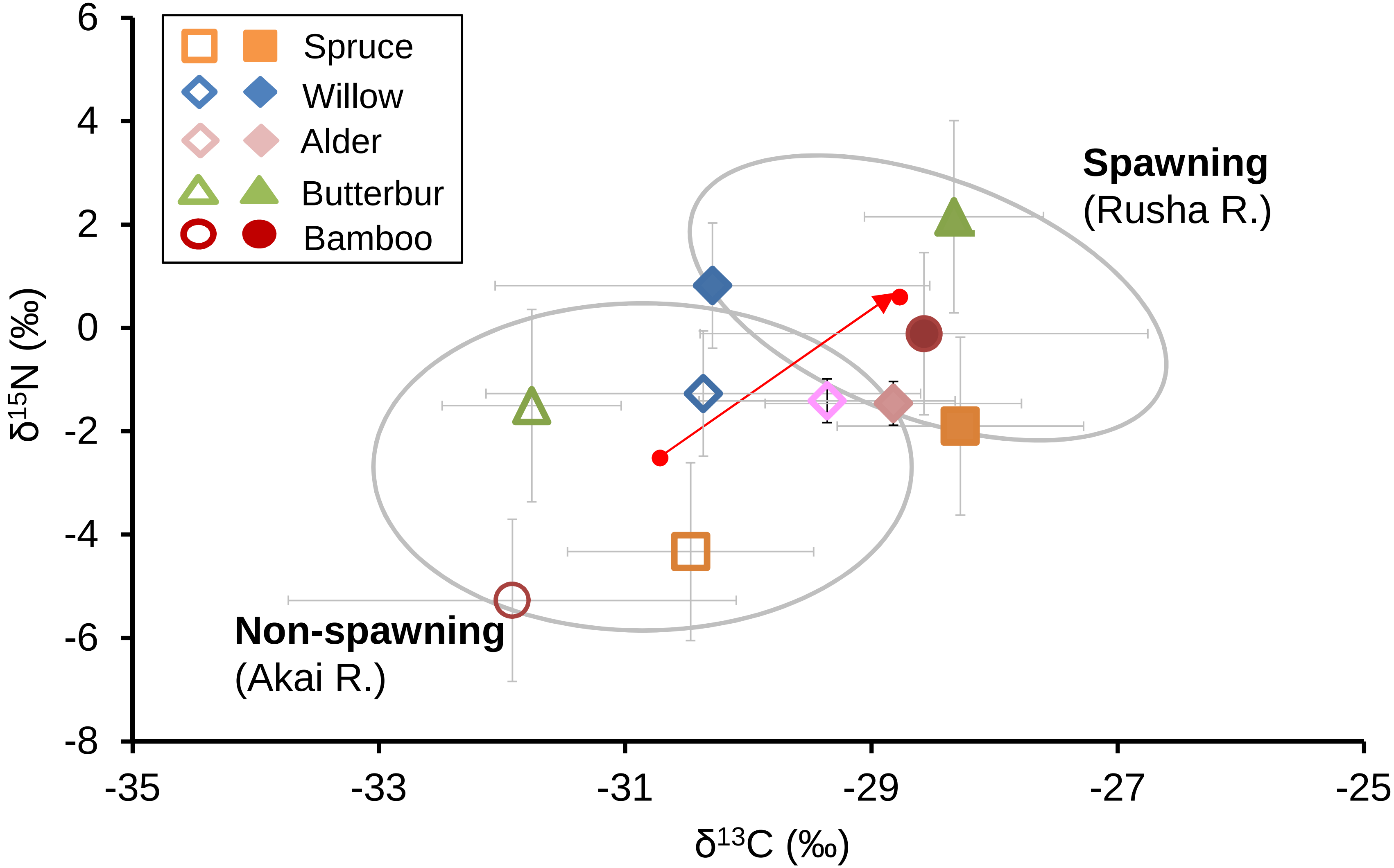
Temporal change in number of pink salmon carcasses on the riparian area in 2009



The flooding is one of the main process for carcass transport as well as brown bear

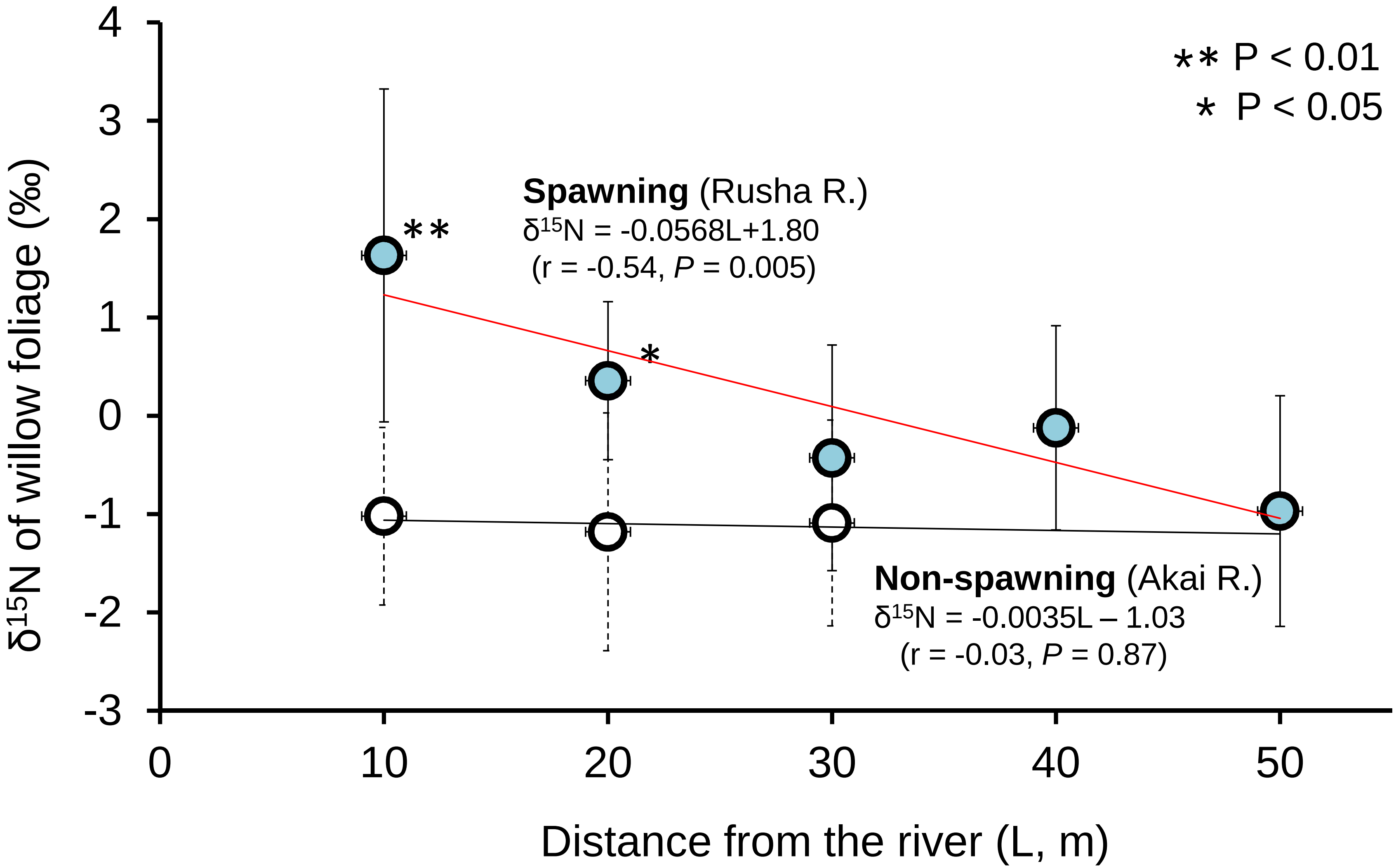
The C-N map of riparian vegetation

(collected within 10m from the river)



Riparian vegetation around the Rusha River had higher stable isotope than those of the Akai River

Relationship between δ15N of willow and the distance from the river



MDN was incorporated within 50 m from the river

Conclusion

■MDN contribution to Rusha River terrestrial ecosystems

Averaged MDN enrichment ･････**24 %**

	Rusha R.		North America	
Biofilm	**30 %**		**73 %**	(Chaloner et al. 2002)
Aquatic invertebrates	**21 %**	$<$	**40 %**	(Chaloner et al. 2002)
Salmonids	**23 %**		**40 %**	(Bilby et al. 1996)
Riparian tree	**22 %**		**24 %**	(Helfield and Naiman 2001)
	Low		**High**	

Antropogenic impact

- Artificial dams disturb the spawning behavior (Boggs et al. 2004, Caudill et al. 2007)
- The spawning-redd density of pink salmon;
  Rusha River : 0.02 - 0.12 /m^2 (Yokoyama et al. 2010)
  North America : 1.1 - 2.0 /m^2 (Heard 1991)

MDN incorporation in the Rusha River region was negatively affected by anthropogenic impacts despite the World Natural Heritage area

MDN pathways in terrestrial ecosystems

MDN flow

Freshwater ecosystem : Direct feeding, Food chain

Riparian ecosystem : Flooding, Vector