Transfer of marine-derived nutrients by pink salmon (*Oncorhynchus gorbuscha*) to terrestrial ecosystems in the Shiretoko World Natural Heritage area, Japan

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Introduction

Pacific salmon (*Oncorhynchus* spp.) transport marine-derived nutrients (MDN) to the terrestrial ecosystem in the North Pacific Rim (e.g., Kline et al. 1990, Wipfli et al 1998). The Shiretoko Peninsula is one of the critical places where pink (*O. gorbuscha*) and chum salmon (*O. keta*) spawn naturally in Japan. Although Shiretoko Peninsula is registered as the World National Heritage area, spawning migration of these salmon has been prevented because of a number of river artificial constructions. In Japan, salmon reproduction has been prevented from those constructions and material cycle through marine to upland were almost ruined (Kaeriyama and Edapalina 2004). Because of a few studies on the MDN transport by salmonids in Japan (Yanai and Kochi 2005, Nagasaka et al. 2006), the mechanism on pathways of MDN intake has not yet to be definitely demonstrated in Japan. The objective of this study is to elucidate the MDN intake and pathway in Shireoko terrestrial ecosystems, using stable isotope analysis.

Materials & Methods

Stable isotope analysis

$\delta^{13}C$ or $\delta^{15}N$ (‰)

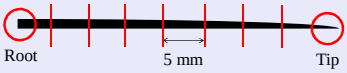
$= (R_{sample} / R_{standard} - 1) \times 1000$

Where R is ratio of heavy isotope to light isotope

Feeding history of brown bear

Growth Section Analysis (GSA)

Bear hair



(Mizukami et al. 2005)

MDN enrichment (%)

$=(\delta X_{se}-\delta X_c)/(\delta X_s+(TL \times \delta X_e)-\delta X_c)$

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

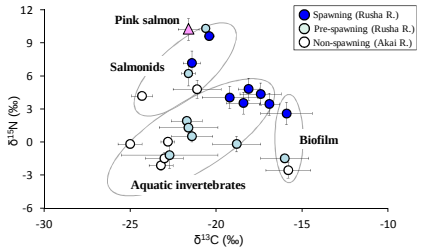
(Pinkas et al. 1971)

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

Discrimination of carcasses

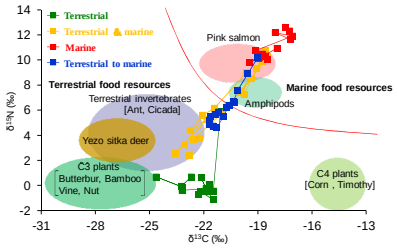
Results & Discussion

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



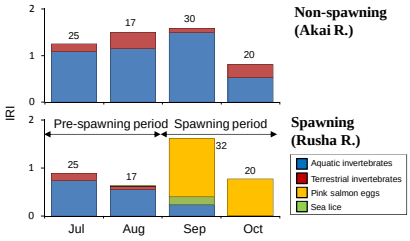
The C-N map of freshwater organisms

Brown bears greatly fed on pink salmon in the autumn



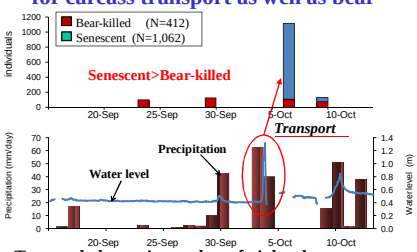
C-N map of brown bear (hair) analyzed with GSA

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



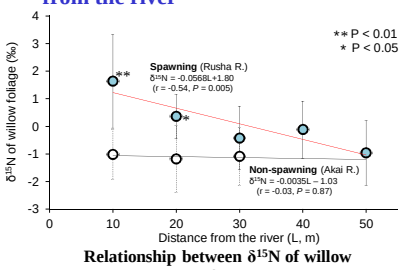
Feeding habits of Dolly Varden in the Shiretoko

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



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

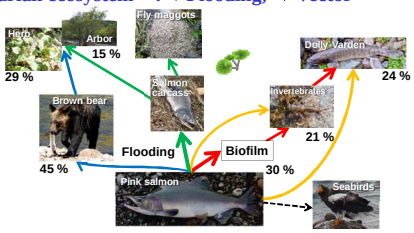
MDN was incorporated within 50 m from the river



Relationship between $\delta^{15}N$ of willow and the distance from the river

MDN flow

Freshwater ecosystem: ⇨Direct feeding, ➡Food chain
Riparian ecosystem : ⇨Flooding, ➡Vector



MDN pathways in the Shiretoko terrestrial ecosystem

Conclusion

- MDN contribution to the terrestrial ecosystem of the Rusha (**24%**) was relatively **lower** than those of North America
  Negatively affected by artificial dams (Redd density : 0.02 – 0.12 N/m^2 in the Rusha River, 1.0-2.2 N/m^2 in North America
- The MDN-pathway is classified to **4 patterns (Direct feeding, Food chain, Flooding and Vector)**
  Contribute to the biodiversity and productivity of ecosystems in Shiretoko World Natural Heritage area