Abstract

Spatio-temporal changes of salmon consumption by brown bears: An example of

human-induced alterations in marine-terrestrial linkage

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Introduction

Human intervention in natural ecosystems has been the most influential ecological factor since the last glacial period. Among the human impacts on ecosystems, alterations of food webs are difficult to study because it sometimes occurs without extinctions of any member of the ecosystems. Some studies have been suggested that a historical segregation of salmon-bear linkage has occurred in Hokkaido islands, Japan. In this thesis, I focused on the salmon predation by brown bears, which should be one of the important pathway to transfer the marine derived nutrients to terrestrial ecosystems, and examined spatio-temporal differences of the salmon-bear linkage in the Hokkaido islands, Japan. Significant human development began in Hokkaido islands in approximately mid-19th century and has proceeded rapidly in the last 200 years. Therefore, Hokkaido is suitable to test the relationship between human impacts and diet components of bears. The goal of this study is to show an evidence of a human-induced change in the marine-terrestrial linkage using the prey-predator interaction between salmon and brown bears as an indicator.

Study site and methods

This study was conducted in the Hokkaido Island, the northernmost island of Japan. Food habits of brown bears were estimated by quantitative stable isotope analysis using carbon, nitrogen and sulfur stable isotope ratios. I collected thighbones of brown bears and diet

items including C_3 herbs, C_3 fruits, corn, ants, deer and salmon. I extracted collagen from thighbones of brown bears, and then measured carbon, nitrogen and sulfur stable isotope ratios of bear bone collagen and their prey items. In Chapter 3, I estimated the food habits of modern brown bears in Shiretoko peninsula using stable isotope analysis and Bayesian mixing model, and compared them with grizzly bears in North America. In Chapter 4, I reconstructed historical brown bears in western and eastern region in Hokkaido and examined the temporal dietary shifts in each regions. In Chapter 5, I tested the relationship between diet compositions of brown bears and their body size using carbon and nitrogen stable isotope values of brown bears and the length of their thighbones. In Chapter 6, I analyzed the spatial differences of salmon consumptions of brown bears relating to land developments in Shiretoko region using joint method of stable isotope analysis and least-cost modeling based on graph theory.

Results

In Chapter 3, I estimated salmon consumptions of brown bears in Shiretoko peninsula and compared them with the grizzly bear populations in North America. While Shiretoko region is regarded as the best region in Hokkaido for bears to eat salmon, the contributions of salmon for bear's diet at the region were extremely low compared to the bears in North America. In Chapter 4, historical dietary shifts of brown bears in western and eastern regions of Hokkaido were revealed. In eastern region, contributions of salmon to bear's diet were significantly decreased from the time period before the onset of development (18.7%) to the period after the onset of developments (8.2%). In Chapter 5, I examined the relationship between body size and food quality of brown bears. The amount of high quality food was strongly correlated with mean thighbone length of male bear

subpopulations. In Chapter 6, relationship between salmon consumption of individual bear and their habitat quality was tested. Individual variation of proportions of salmon was strongly explained by spatial configuration of anthropogenic land-use, in-stream structures and home range of brown bears.

Discussion

In this thesis, I showed a human-induced depletion of marine-terrestrial linkage. Given the fact that the mobile links (biological interaction beyond the ecosystem boundaries) have greater impacts on their sinks, further research should give more focus to such cross boundary biological interactions and human impacts on the linkages. In addition, my result suggests that brown bears are suitable species for an indicator of underlying terrestrial webs, because they are opportunistic omnivores with larger body size and home range, and bears change their food habits flexibly depending on the resource availability. The observed dietary shifts of Hokkaido brown bears well agreed with the environmental change related to human development both in temporally and spatially, and the results strongly suggested the high indexical potential of bears for the change of underlying food web structure. My triple-isotope approach also pointed out the limit of dietary estimations by dual-isotope method depending on the isotope distributions of prey items. To achieve the proper implementation of stable isotope analysis, especially for the application of mixing model analysis, to select the appropriate stable isotope elements should be one of the important points. In Shiretoko region, some management approach to recover the salmon-bear interactions have been proceeding. Results of this thesis can provide helpful information to achieve the restoration of salmon-bear interactions such as a target figure for the ideal salmon-bear linkage and the prediction of the effects of each management

action.