주요발표 내용

세미나 제목 (국문)	기후변화와 토지이용변화에 따른 종분포의 시·공간적 변화 - 시스템 생태학적 접근
세미나 제목 (영문)	**Spatiotemporal variation in the species distributions under climate and land-use change - Systems ecological approach**
주요발표 내용 (구체적으로 기재)	**1. 기후변화에 따른 Red Spruce(*Pciea rubens* Sarg.)의 성장 및 분포의 시·공간적 변화 예측: 시스템 생태학적 접근** 본 연구는 red spruce(가문비나무속에 속하는 수종)의 성장쇠퇴와 고사가 심각하게 발생하고 있는 미국 남동부에 위치한 Great Smoky Mountains National Park에서 수행되었다. 성장쇠퇴 및 고사의 원인과 이에 따른 종분포 변화를 예측하기 위하여, 시스템 모형과 경관생태 모형을 융합한 세 개의 모형들을 개발하였다. 먼저, Envirogram 기법을 이용하여 red spruce의 성장에 영향을 미치는 모든 환경 요인들에 대한 연구 결과들을 융합하는 개념모형(ARIM.CON)을 개발하였다. 개념모형(ARIM.CON)을 바탕으로 red spruce 성장을 예측하는 시스템 모형(ARIM.SIM)을 개발하여, red spruce의 현재 성장 쇠퇴의 원인을 밝히고, 기후변화에 따른 미래의 성장을 예측하였다. 시스템 모형(ARIM.SIM)을 경관생태 모형과 융합하여 서식지 모형(ARIM.HAB)을 개발하고, 이를 바탕으로, red spruce의 현재 분포와 기후변화에 따른 미래의 분포를 예측하였다. **2. 기후변화와 유역의 도시화에 따른 연갑조개(*Mya arenaria*) 성장의 시·공간적 변동성** Plum Island Sound estuary는 미국 동북부에 위치한 장기생태연구지역으로 강유역의 도시화에 따른 강하구 상부에 부영양화가 발생하고 있다. 본 연구는 도시화에 따라 부영양화의 원인인 질소가 강유역의 분수계 시스템을 통하여 강하구에 유입되는 것을 종합적으로 분석하는 연구의 일부로 진행되었다. 본 연구의 구체적인 목적은 연갑조개 성장의 시공간적 변동성을 결정하는 요인이 무엇이며, 부영양화의 약화에 연갑조개가 유용한지를 밝히는 것이다. 이를 위해 야외조사 및 실험, 실내 실험들이 적용되었으며, 이 실험과 조사결과들을 분석하기 위하여 다양한 모형들이 사용되었다. 마지막으로 분석결과들을 종합적으로 고려하는 시스템 생태학적 접근을 통하여 연갑조개의 성장의 공간적 변동성을 결정하는 환경인자들을 밝히고, 기후변화에 따른 성장의 시공간적 변동성을 예측하였다. 또한, 이 결과들을 바탕으로 부영양화의 약화를 위한 연갑조개의 유용성 여부를 제시하였다. **3. 기후변화에 따른 한반도 한대성 상록활엽수의 시·공간적 분포변화 예측** 한대성 상록활엽수는 기후변화에 취약한 고산과 아고산에 서식하는 수종들로 기후온난화에 따라 서식지가 감소될 것으로 예측되고 있다. 본 연구의 목적은 한대성 상록활엽수의 분포를 결정하는 기후요소들을 밝히고, 기후변화에 따른 서식지 분포변화를 예측하는 것이다. 이를 위해, Multimodel Inference 통계 모형을 바탕으로 종분포 모형이 개발되었다. 이 통계 모형의 특징은 여러 모형들의 평균치를 사용함으로 모형 예측의 신뢰도를 높인다는 것이다. 또한, 모형 예측의 불확도를 지도화하여 제시함으로 예측결과의 신뢰도를 공간적으로 보여준다는 것이다. 본 연구는 한대성 상록활엽수의 분포는 기온에 매우 민감하며, 기후온난화에 따라 서식지가 급격하게 축소될 것을 보여 주었다. 이 결과는 기후변화에 따른 한반도 고산 및 아고산 생태계의 변화를 예측하고 취약성을 평가하기 위한 기초자료가 될 것이다.

주요발표 내용 (구체적으로 기재)	**1. Coupling Systems Modeling with GIS Landscape Modeling to Predict Climate Change Impacts on Red Spruce (*Picea rubens* Sarg.) in the Southern Appalachian Mountains, USA** Red spruce is an ecologically and commercially important boreal and subboreal coniferous species in Eastern USA. Like other alpine and subalpine trees, it has low genetic diversity and is adapted to low optimum temperatures. It is considered vulnerable to climate warming. Good prediction of responses to climate change is considered critical for effective long-term management. Most predictions of climate change impacts on tree distribution are based on correlative niche models. Such predictions have been questioned because the models contain too little information about the complexities of ecological and physiological processes involved in actually producing range changes. These mechanisms include direct and indirect factors, and the latter especially are almost never taken fully into account. In this research we employed a three-phase complex-systems modeling approach to predict growth and distribution impacts of climate change on red spruce in the Great Smoky Mountains National Park (GSMNP). Each phase focused on Annual Radial Increment of growth and so our composite Model we call ARIM. In Phase 1, ARIM.CON, information and data assembly were achieved in the form of a qualitative network envirogram. This is in effect a conceptual model identifying all known direct and indirect factors influencing radial growth. In Phase 2, ARIM.SIM, the conceptual envirogram information was used to formulate a zero-dimensional simulation model employing the software Stella. This model quantified the envirogram information and simulations identified the dominant mechanisms determining habitat suitability and growth. In Phase 3, ARIM.HAB, the Stella simulation results were scaled up to two-dimensional, spatially distributed, landscape models of habitat suitability with ArcGIS software. Results showed low habitat suitability at higher elevations (1850-2028 m), medium suitability at lower elevations (1400-1650 m), and high suitability at intermediate elevations (1650-1850 m). Suitability was sensitive to elevation, slope, aspect, and distance to nearest stream at the lower levels, but only to elevation at higher levels, where air pollution factors such as increased acid precipitation and cloud immersion were dominant. We conclude that climate change in interaction with air pollution will cause red spruce habitats to shrink at both lower and higher elevations in GSMNP. Our complex-systems modeling approach is general, and extendable to other species and regions.

주요발표 내용 (구체적으로 기재)	**2. Spatiotemporal Dynamics of the Soft Shell Clam, *Mya arenaria*, as Influenced by Climate Change and Watershed Urbanization** Plum Island estuary (PIE) in Massachusetts is a productive ecosystem beginning to show signs of eutrophication in the upper estuary. Clams may help limit eutrophication by filtering phytoplankton from the water column. This research aims to identify spatiotemporal dynamics of clam biomass under climate change and estimated the effectiveness of soft-shell clam in reducing eutrophication in Plum Island Sound, MA. This goal was accomplished by examining the relationship among phytoplankton density, available food resources of clams and clam growth. Water samples for particular organic matters (POMs), plants (*Spartina Patens, Spartina Alterniflora,* and T*ypha Arigustifolia*) and approximately 40 clams (2" and 4") were collected monthly from May to November in 2010 and April 2011 at eight sites in PIE. The eight sites were selected from three regions of the estuary: the lower, the middle and the upper, according to salinity gradients from high to low. The archived phytoplankton, water temperature and salinity data were obtained from the PIE Long Term Ecological Research (LTER) database. Clam biomass along the estuary was estimated using the growth functions developed from the internal annual growth ring analyses. Chlorophyll-a concentration in the water samples were estimated through fluorometry. The stable isotope analyses of δ13C, δ15N, δ34S and δD were performed on adductor muscles of clams, plants and POMs filtered from water samples. The spatial patterns of clam biomass and environmental factors were fitted to mathematical functions, and the correlations among factors were analyzed. The spatial variation of clam diet was explored using a Bayesian isotope mixing model with δ13C, δ15N, and δ34S. The results showed clam biomass, winter water temperature and salinity increased from the upper to the lower estuary, while Chl-a concentration and summer water temperature decreased from the upper to the lower estuary. The results of mixing model reflected that clams in the middle and lower regions primarily depend on marine food resources. The correlation analysis and isotopic mixing modeling showed spring salinity was only significant factor determining the clam biomass distribution. The effects of climate change, increased spring precipitation, on the distribution of *M. arenaria* biomass were negligible at the marginal habitats. These results indicate that clams cannot effectively reduce eutrophication in the upper estuary under both current and future climate conditions.

주요발표 내용 (구체적으로 기재)	**3. Potential Effects of Climate Change on the Distribution of Cold-tolerant Evergreen Broadleaved Woody Plants in the Korean Peninsula** Climate change has caused shifts in species' ranges and extinctions of high-latitude and altitude species. Most cold-tolerant evergreen broadleaved woody plants (shortened to cold-evergreens below) are rare species occurring in a few sites in the alpine and subalpine zones in the Korean Peninsula. The aim of this research is to 1) identify climate factors controlling the range of cold-evergreens in the Korean Peninsula; and 2) predict the climate change effects on the range of cold-evergreens. We used multimodel inference based on combinations of climate variables to develop distribution models of cold-evergreens at a physiognomic-level. Presence/absence data of 12 species at 204 sites and 6 climatic factors, selected from among 23 candidate variables, were used for modeling. Model uncertainty was estimated by mapping a total variance calculated by adding the weighted average of within-model variation to the between-model variation. The range of cold-evergreens and model performance were validated by true skill statistics, the receiver operating characteristic curve and the kappa statistic. Climate change effects on the cold-evergreens were predicted according to the RCP 4.5 and RCP 8.5 scenarios. Multimodel inference approach excellently projected the spatial distribution of cold-evergreens (AUC=0.95, kappa=0.62 and TSS=0.77). Temperature was a dominant factor in model-average estimates, while precipitation was minor. The climatic suitability increased from the southwest, lowland areas, to the northeast, high mountains. The range of cold evergreens declined under climate change. Mountain-tops in the south and most of the area in the north remained suitable in 2050 and 2070 under the RCP 4.5 projection and 2050 under the RCP 8.5 projection. Only high-elevations in the northeastern Peninsula remained suitable under the RCP 8.5 projection. A northward and upper elevational range shift indicates change in species composition at the alpine and subalpine ecosystems in the Korean Peninsula.