京都大学生態学研究センター 公募ワークショップ

From biodiversity to sustainability: Key challenges of theoretical ecology

理論生態学の展望：生物多様性から生態系の持続的な管理まで

・日時：10 月 31 日(火)　9：30ー17：30
・場所：京都大学理学研究科セミナーハウス（京都大学北部構内）
〒606-8224 京都府京都市左京区北白川追分町
・事前申し込み不要・参加無料
・連絡先：谷内茂雄（京都大学生態学研究センター）yachi@ecology.kyoto-u.ac.jp

・懇親会：ワークショップ終了後、京大北部生協会館２階多目的ホールにて 18：15 開催（参加費：4000 円）。参加ご希望の方は、予約の都合上、10 月 23 日（月）までに上記連絡先までご連絡ください。

開催主旨

本ワークショップでは、生物多様性・群集・生態系の関係から生態系の持続的な管理に至る研究領域の主要なテーマを対象に、国内外の研究者による話題提供と議論を通じて、今後推進・挑戦すべき理論的研究課題について意見交換をおこないます。ワークショップでは、フランス「生物多様性理論・モデリング研究センター（CBTM）」からMichel Loreau教授とClaire de Mazancourt博士を招へいしました（「JSPS外国人研究者招へい事業」および「京都大学教育研究振興財団助成金」）。Loreau教授は、理論生態学の世界的リーダーの一人であるとともに、DIVERSITAS（現在は、Future Earthに統合）の第二期議長を務めるなど、生物多様性・生態系保全の国際枠組みの構築・推進に関しても大きな貢献をされてきました。また、de Mazancourt博士は、Loreau教授とともにCBTMにおいて精力的に理論的研究を推進されています。

ワークショップでは、まずLoreau教授にご自身の研究とこの研究領域の進展についてお話しいただきます（基調講演）。次いで、A）生物多様性・群集・生態系、B）社会ー生態システムのダイナミクスと持続可能な管理、の各セッションでは、演者の皆さんにいくつかの重要なトピックスについて話題提供していただきます。セッションCでは、まず３人のコメンテータの方にコメントをいただいて、今後重要となる研究課題や研究方法について、話題提供者・コメンテータ・参加者を交えた自由な意見の交換をおこないます。最後に議論の内容を集約してワークショップの成果を会場の皆さんと共有したいと思います。

From biodiversity to sustainability: Key challenges of theoretical ecology

A theoretical ecology workshop

Date：31st (Tues.), October　9：30 - 17：30

Venue：Kyoto University, Seminar House

9:00 – 9:30　Registration

9:30 – 9:40　Opening remarks (S. YACHI)

Keynote Lecture

9:40 – 10:30

Michel LOREAU (Center for Biodiversity Theory and Modeling)

Linking biodiversity, ecosystems, and people across scales: challenges for ecology and sustainability

10:30 – 10:40　Break

Session A: Biodiversity, communities and ecosystems

10:40 – 11:15

Toshiyuki NAMBA (Osaka Prefecture University)

Indirect interactions in ecological networks and structure and stability of ecosystems

10:15 – 11:50

Michio KONDOH (Ryukoku University)

Complexity-stability relationships of ecological network: some theoretical predictions and their implications for ecosystem conservation

11:50 – 13:00　Lunch

Session A (Cont.): Biodiversity, communities and ecosystems

13:00 – 13:35

Claire DE MAZANCOURT (Center for Biodiversity Theory and Modeling)

Invariability: measuring and understanding the effect of biodiversity on ecosystem stability

13:35 – 14:10

Takeshi MIKI (Institute of Oceanography, National Taiwan University)

Application of bio- and chemo-informatics to better quantify microbial functional diversity and its link to taxonomic and genomic diversities

14:10 – 14:30 Break

Session B: Social-ecological dynamics and sustainable management

14:30 – 15:00

Akiko SATAKE (Kyushu University)

Coupled dynamics of social-ecological systems on forested landscape

15:00 – 15:30

Reiichiro ISHII (Research Institute for Humanity and Nature)

Modeling the ecosystem-human society interaction as Ecosystem Network

15:30 – 16:00

Shigeo YACHI (Center for Ecological Research, Kyoto University)

How community-based ecosystem restoration can guarantee watershed-scale sustainability: origins and overcoming of scale mismatches in social-ecological dynamics

16:00 – 16:10 Break

Session C: Challenging issues on theoretical ecology

16:10 – 16:30
Comments

Atsushi YAMAUCHI (Center for Ecological Research, Kyoto University)

Keiichiro TOKITA (Nagoya University)

Tadashi MIYASHITA (University of Tokyo)

16:30 – 17:30
Discussion: challenging issues on theoretical ecology

17:30　Closing address (N. YAMAMURA)

18:15-　Welcome Party (京大生協北部生協会館2 階多目的ホール)

Organizers

Shigeo YACHI (CER, Kyoto University)
Reiichiro ISHII (Research Institute for Humanity and Nature)
Akiko SATAKE (Kyushu University)
Norio YAMAMURA (Kyoto University Professor Emeritus)

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Linking biodiversity, ecosystems, and people across scales: challenges for ecology and sustainability

生物多様性・生態系と人々をスケールを超えてリンクする：
生態学と持続可能性の課題

People are now driving the sixth mass extinction in Earth's history, and yet biodiversity enhances many of nature's benefits to people. The influence and dependence of people on biodiversity have mainly been studied separately and at contrasting scales of space and time, but new ecological theory is beginning to link these relationships across scales. This theory shows that biodiversity loss substantially diminishes many ecosystem services by altering ecosystem functioning and stability, especially at the large temporal and spatial scales that are most relevant for policy and conservation. The influence and dependence of people on biodiversity also generate an important if poorly understood feedback loop between humans and nature. New models of social-ecological systems emphasize the role of feedbacks and scales in human-nature interactions and the importance of foresight for the sustainability of human societies. They call for the development of integrative management approaches that account for the coupled dynamics of human populations, biodiversity and ecosystems across multiple spatial and temporal scales.

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Indirect interactions in ecological networks and structure and stability of ecosystems

生態ネットワークにおける間接相互作用と生態系の構造と安定性

It has been one of the central problems in ecology to understand relations between structure and functions of ecological communities and systems. Ecological communities are networks composed of many species linked by direct interactions between component species. In such communities, many kinds of indirect effects appear between species which are not directly linked. Complex dynamics appearing in small communities composed of three or more species have been extensively studied since 1970's and recent concerns are the roles of such community modules to determine diversity and stability of the whole community.

In 1955, Robert MacArthur studied relations between diversity and stability of food webs. He considered that a food web which can absorb or resist disturbances in abundance of some species is stable and that the amount of choice which the energy has in following the paths up through the food web is a measure of the stability of the community. In other words, he used the Shannon's information index calculated from the fraction of energy flowing up through each link as diversity index. In contrast, Charles Elton in 1958 considered that simple communities are unstable because they are prone to violent fluctuations in population densities and susceptible to invasion of exotic species. In 1960's, there had already appeared many views of relations between diversity, succession, stability, and productivity (Loucks 1970).

Since Robert May's seminal paper in 1972, the long-standing debate on the relationships between complexity (diversity) and stability is still in progress (McCann 2000, Namba 2015). Although many brilliant ideas have been proposed and some of these will be presented in this workshop, there seems to remain some points which are not fully appreciated in these studies. In this presentation, I focus on a few questions in researches on the relationship between diversity and stability.

The first is that diversity is not necessarily determined in advance before stability in natural communities. Although these studies tend to reveal how diversity determines stability, diversity and stability are usually determined through interactions between species and between species and environments at the same time. The second point is susceptibility to invasion. If complex communities are assembled through invasion success of exotic species to simple native communities, susceptibility to invasion is not an undesirable feature of simple communities. The third point is explicit consideration of indirect effects. In diversity-stability studies, ecological interactions such as predation, competition, and mutualism tend to be considered independently, and indirect effects caused by the interplay between different kinds of interactions are likely to be ignored. I will explain these questions using a simple model community composed of an herbivore and many plant species.

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Complexity-stability relationships of ecological network: some theoretical predictions and their implications for ecosystem conservation

生物群集を種間相互作用ネットワークとして理解する
ー理論的予測とその生態系保全における意味—

An ecological community can be viewed as a network of interacting species, where countless interspecific effects are transmitted between species and propagate over other parts of community to generate the community-level dynamics. Community complexity, often measured with species richness and density of interspecific interactions, is a characterizing feature of real ecological communities. Yet, according to theory derived with a simple mathematical model, a complex community is inherently unstable and has less chance to persist. This being so, what maintains species diversity in the natural, complex communities?

In this talk I focus on the three mechanisms that, according to recent theoretical predictions, potentially reverse the classically negative complexity-stability effect into a positive one, (1) interaction flexibility[1,2], (2) interaction-type diversity[3,4] and (3) meta-community complexity[5]. Interaction flexibility arises from organism's adaptive behaviors, such as adaptive diet choice[1] and adaptive anti-predator defense[2], and facilitates dynamical food-web reconstruction that buffers environmental fluctuations. Interaction-type diversity, which is realized by coexistence of different interaction types, such as competition, antagonism and mutualism, can stabilize a complex community and gives rise to a positive complexity-stability relationship[3,4]. Meta-community complexity is another factor that explains the maintenance of complex food webs. When isolated, a more complex food web may be less stable in agreement with the classic theory. However, a simple model shows that, when a number of local food webs are connected via inter-habitat movements to form a complex, meta-food web network, increasing food-web complexity can stabilize demographic stability[5].

The three hypotheses, indicating that whether community complexity is stabilizing or destabilizing is condition-dependent, implies not only stability, but also potential fragility of natural ecosystems. According to the three hypotheses, the complex community is self-maintaining, only in the presence of (1) interspecific adaptation, which would be shaped through evolutionary history, (2) the diverse types of interspecific interactions or (3) the meta-community complexity. In other words, any anthropogenic processes that destroy those conditions can reverse the positive complexity-stability relationship into a negative one, make the otherwise most stable, complex communities into the least stable ones and trigger irreversible destruction of ecological communities.

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Invariability: measuring and understanding the effect of biodiversity on ecosystem stability

不変性：生物多様性が生態系の安定性に与える影響を評価し理解する指標

Stability can be defined in many different ways; different branches of ecology use radically different notions, thus preventing a constructive dialog between them. Theoretical ecology mainly studies asymptotic resilience, while policy applications mainly consider Holling’s resilience; however, empirical measures of both resilience notions are problematic and therefore not readily operational. Empirical ecology mainly studies temporal variability, but we lack theoretical grounding for these types of stability measures.

In this talk I will present some new theoretical developments of invariability, the inverse of temporal variability. I will show how invariability relates to other stability measures. I will introduce the Invariability – Area Relationship, that spells out how invariability changes with spatial scale. Finally, I will estimate invariability using experimental data to show the mechanisms through which biodiversity stabilize communities.

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Application of bio- and chemo-informatics to better quantify microbial functional diversity and its link to taxonomic and genomic diversity

微生物群集における、生物情報学・化学情報学を用いた機能的多様性の定量化と種多様性との関係の解明

EcoPlate is a 96 microplate with three technical replicates of 31 response wells with different sole carbon substrates + 3 control wells. The color development pattern of these wells obtained by incubation of environmental samples represents a metabolic fingerprinting, which is further statistically processed for quantifying community-level functional diversity and functional composition. With combining this simple and classical method and emerging tools in bioinformatics and chemoinformatics, we have developed two approaches to better link microbial taxonomic diversity, genomic diversity, and functional diversity. The first approach integrates the comparative genomic analysis and microcosm experiment simulating initial loss of taxonomic richness in bacterial communities. On one hand, the microcosm experiment demonstrated that 5% loss of taxonomic richness (from 20 to 19 strains) resulted in statistically detectable reduction of functional diversity, which was quantified by EcoPlate analysis. On the other hand, the degree of the reduction of functional diversity can be predicted by the reduction of community-level functional gene richness[1]. The second approach aims to improve the statistical power to detect the differences in functional composition among samples quantified by EcoPlate analysis. With the chemoinformatics tools, we developed a novel dissimilarity metrics of microbial functional composition by incorporating information of pairwise chemical dissimilarity among 31 carbon substrates into the computation[2]. Finally, I will briefly address the importance of integrating multiple approaches (phenotyping by EcoPlate, omics approaches, dynamical modeling, and experimental manipulation) to better understand the responses of microbial functions under environmental changes.

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Coupled dynamics of social-ecological systems on forested landscape

森林景観に関わる社会−生態システムの結合ダイナミクス

Landscape change is the outcome of both natural and anthropogenic disturbances. Natural disturbances (e.g., forest fires, land slides, and floods) are episodic and stochastic events that occur across a wide range of spatial and temporal scales. Anthropogenic disturbances (e.g., forest clearance for agriculture, timber harvest, or pasture) also occur at various temporal and spatial scales, but often at a faster rate and a more extensive scale than natural disturbances. Deforestation is especially an important environmental problem because of its impact on biodiversity, carbon cycling associated with global climate, biogeochemical cycling, and other ecosystem functions. A key factor inducing landscape change is the human behavior that underlies these changes. The simplest way to consider this is to develop a model which traces the responses of landowners to the change of socioeconomic and ecological conditions. We introduce a Markov chain model for land-use dynamics in a forested landscape [1-4]. The model emphasizes the importance of coupling socioeconomic and ecological processes underlying landscape change.

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Modeling the ecosystem-human society interaction as Ecosystem Network

生態系と人間社会の相互作用を生態系ネットワークとしてモデル化する

Relationship among the three fundamental elements of ecological material flows, “ecological resource”, “local inhabitant (direct consumer)” and “enterprise (indirect consumer or inter-regional trader)”, were schematically modelled as Ecosystem Network to understand the keys for conservation of ecosystems under pressure of growing human activities. By comparing the case studies from two typical terrestrial ecosystems, grassland and tropical rain forest, we found that the relationship between local people and enterprises differs depending on ecosystems, that is, they always form serial relation in grassland while they can easily become parallel in tropical forest. The model analysis clarified the conditions for coexistences of these elements in ecosystems of different types, which in turns suggests how the ecosystems should be restored from current ecosystem degradation problems. The concept of Ecosystem Network can be applied to other problems associated with managing ecological resources.

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How community-based ecosystem restoration can guarantee watershed-scale sustainability: origins and overcoming of scale mismatches in social-ecological dynamics

コミュニティベースの生態系再生が流域規模の持続可能性につながる条件：社会−生態ダイナミクスにおけるスケールミスマッチの克服

Among the difficulties of large-scale ecosystem management, here, I focus on 1) temporal mismatch: differences in characteristic time-scales between typical cycles of human social systems and natural systems (M. Higashi 2000, unpublished manuscript), and 2) spatial discrepancy: differences in priorities of issues between heterogeneous stakeholders (e.g., K. Wakita 2002). First, in accordance with Higashi's discussion, I will introduce his idea to overcome the first temporal mismatch and then explain a basic idea for discussing the second spatial discrepancy using a dynamic model.

Higashi argued that the essential factor of global environmental problems lies in the mismatch of temporal scales between human social cycles and natural cycles. He reasoned that human and natural systems maintain each characteristic temporal cycle as a result of non-linear oscillations generated by characteristic negative feedbacks incorporated in themselves. As human activities become more active, more intense human disturbance interfere with natural systems. The disturbance is transformed into a natural system disturbance of the similar time scale, which then affects human systems up to the far future generations. Higashi states there is no choice but to incorporate into our social system the long-term social cycle beyond generations that can cope with the disturbances amplified back from the natural systems. In other words, it can be said to develop "culture" as a long-term (social) memory device.

Mismatch in spatial scale can also be a major obstacle in sustainable ecosystem management. In the context of ecosystem restoration, management at watershed scale is regarded as effective; however, as the management scale becomes larger, the diversity of stakeholders increases and so the discrepancies of the issue of high priority. One of the urgent issues typically observed in regional towns and/or countryside in Japan expresses as decline of community functions due to depopulation and aging that accompanies ecosystem degradation due to underuse. Under such circumstances, ecosystem restoration itself cannot be highly prioritized in the concerned communities. It is suggested that community-based ecosystem management which focuses on the role of ecosystem services evaluated in each community's context could resolve this situation. The essential mechanism lies in the emergence of multiple functions or multiple services of the ecosystem (biodiversity) which can work as effective services in the context of community restoration as the ecosystem restoration proceeds. By using a community-based ecosystem restoration model, I discuss the conditions under which community-based ecosystem restoration overcomes the difficulties arising from spatial mismatch.

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