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研究課題名（和文）個体群動態に与える個体履歴の影響

研究課題名（英文）Impacts of individual history on population dynamics

研究代表者

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交付決定額（研究期間全体）：（直接経費） 13,400,000円

研究成果の概要（和文）：我々は、個体の歴史が個体群動態に強く影響し、現在使われているモデルではこの影響が失われていると仮定した。その結果、個体史は実際にそのような強い影響力を持つことがわかり、現在使われている個体群動態予測・サイズ予測手法の有用性に疑問を投げかける結果となった。私たちは、個体群動態を考慮した場合と考慮しない場合の両方について、個体群動態を予測できるソフトウェアを開発し、研究者や学生が自身の研究のためにこれらの手法を習得できるよう、大量の技術資料を作成しました。また、これらの手法に関するワークショップも開催している。

研究成果の学術的意義や社会的意義

今回の研究は、現在利用されている個体群予測のモデルや手法が、個体履歴の影響を正確に考慮していないことを明確に示している。この結果は、個体群生態学者に、標準的なマトリックスモデル手法から、個体履歴を考慮することで生じる長期的なトレードオフや関連現象を組み込んだ大規模マトリックス手法への移行を促すものである。このことがもたらす潜在的な影響の1つは、人間の人口規模を予測するために用いられる手法の見直しである。現在の人口予測はばらつきが大きすぎて使い物にならないが、我々のアプローチは、予測を意味のあるものに絞り込むのに役立つかもしれない。

研究成果の概要（英文）：We hypothesized that the histories of individuals would influence population dynamics strongly, and that this influence is lost in currently used models. We found that individual history does, indeed, have such strong influences, and our results cast doubt on the utility of currently used methods to project population dynamics and predict population size. We developed a software package that allows researchers to project populations forward in time with or without individual history incorporated, and have also developed a large amount of technical material allowing researchers and students to learn these methods for their own research. We have also run workshops on these methods.

研究分野：進化生態学

キーワード：個体群動態 生態学

1 . 研究開始当初の背景

Demographers summarize the vital rates, including mortality and fertility rates, of entire populations. These vital rates are most strongly influenced by the age, size, or life history stages of organisms. However, such population ecological studies make a critical assumption: that vital rates in some year depend only on the age, size, or stage of the organism in the previous year, and so *do not depend on the history of the individual*. The history-independent rates assumption is typically operationalized in research by treating vital rates as statistically independent of previous size, state, or life history events. Thus, the survival of individuals from year t to year $t+1$ is assumed to depend only on an individual's condition in year t , and the fecundity of individuals in year $t+1$ depends only on condition in year t . However, the influence of condition in prior years has occasionally been tested in specific case studies, and many of these studies have shown that **individual history can strongly influences vital rates**.

The implications of individual history impacting population dynamics are broad and profound. For example, in two plant populations, analysis of natural selection in wild populations yielded vastly different inferences when individual history was considered than when it is not (Shefferson et al., 2014). Such differences appear to be polarized when population dynamics are functions of previous density (as was assumed in the game theoretical evolutionary analyses conducted in Shefferson et al., 2014), but may still be large when density plays a minimal role in determining population dynamics. These differences appear to be driven by the contrasting impacts of trade-offs operating across different lengths of time. Also, plants do not perfectly grow to match environmental conditions, and can sometimes pay a cost of growth to future survival. In these situations, plants grow too large in good years and do not accumulate resource reserves, leading to high mortality if the next years are stressful. Because demographically, growth can only be observed across years, a cost of growth to survival can only be analyzed with a minimum of 3 years of data, thus requiring the incorporation of individual history.

2 . 研究の目的

This project aimed to clarify whether the **history-independent rates assumption** is generally sound. If it is not sound, then it will clarify why this assumption is incorrect, and it will provide tools to analyze vital rates properly. This assumption is at the heart of analytical methods in population ecology, particularly matrix projection analysis. **My project aimed to answer firmly the research question: Does individual history matter to population dynamics?** We also aimed to create statistical tools to help ecologists develop their own projection matrices, particularly historically formatted matrices.

3 . 研究の方法

I developed a series of empirical case studies testing the specific mechanisms through which individual history may influence population dynamics, which is being used in a large-scale meta-analysis assessing the extent to which this phenomenon may be general and fundamental to

herbaceous plant populations. I also developed an *R* package with functions to test the impacts of individual history on vital rates, and to analyze population dynamics under the assumption of individual history, entitled *lefko3*. I also made some key datasets available publicly, along with study materials including tutorials, a technical manual / textbook, and workshop literature for this.

4 . 研究成果

Our grant research has produced strong theoretical evidence that individual history alters asymptotic population dynamics. Particularly, if the previous state that an individual was in in time $t-1$ strongly affects the transition from state in time t to state in time $t+1$, and the population is not at stage equilibrium (which is probably the typical condition), then individual history alters the asymptotic population growth rate. It may also impact the left and right eigenvectors, although it appears that once standardized, the right eigenvector should be similar to that when individual history is not considered.

Our research has also shown that predicted population dynamics under individual history-based matrix models differ from standard matrix projection models. We have currently explored this in four major datasets, and find that the differences in projection can be quite extreme. In the most extreme case, in that of a 27-year dataset of *Cypripedium parviflorum*, we found that standard models predict rapid population growth while individual history-based matrix models predict rapid extinction. Clearly, individual history has a profound effect on population dynamics.

Our research included the production of a software package focused on the production and analysis of individual history-based matrix projection models. Since releasing this package, which is free and available online for the *R* programming language, we have added more and more functionality to it to make it a package that can create every kind of matrix projection model (including age-based, stage-based, age-by-stage, function-based, raw empirical, ahistorical, and historical. It is also capable of producing deterministic, stochastic, and cyclical projections, as well as density-dependent versions of each of these. We have conducted five online workshops on the use of the package, and we have also written and published a free technical manual / textbook to teach ecologists how to use the package. So, our research has been very productive.

5. 主な発表論文等

〔雑誌論文〕 計4件（うち査読付論文 4件/うち国際共著 4件/うちオープンアクセス 2件）

1. 著者名 Shefferson Richard P., Kurokawa Shun, Ehrlen Johan	4. 巻 12
2. 論文標題 lefk03: Analysing individual history through size-classified matrix population models	5. 発行年 2020年
3. 雑誌名 Methods in Ecology and Evolution	6. 最初と最後の頁 378 ~ 382
掲載論文のDOI (デジタルオブジェクト識別子) 10.1111/2041-210X.13526	査読の有無 有
オープンアクセス オープンアクセスとしている (また、その予定である)	国際共著 該当する

1. 著者名 Coughlin Erin M., Shefferson Richard P., Clark Stacy L., Wurzburger Nina	4. 巻 29
2. 論文標題 Plant-soil feedbacks and the introduction of Castanea (chestnut) hybrids to eastern North American forests	5. 発行年 2021年
3. 雑誌名 Restoration Ecology	6. 最初と最後の頁 e13326
掲載論文のDOI (デジタルオブジェクト識別子) 10.1111/rec.13326	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

1. 著者名 Bashirzadeh Maral, Shefferson Richard P., Farzam Mohammad	4. 巻 12
2. 論文標題 Plant-plant interactions determine natural restoration of plant biodiversity over time, in a degraded mined land	5. 発行年 2022年
3. 雑誌名 Ecology and Evolution	6. 最初と最後の頁 1-14
掲載論文のDOI (デジタルオブジェクト識別子) 10.1002/ece3.8878	査読の有無 有
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1. 著者名 Shefferson Richard P, Jacquemyn Hans, Kull Tiiu, Hutchings Michael J	4. 巻 192
2. 論文標題 The demography of terrestrial orchids: life history, population dynamics and conservation	5. 発行年 2019年
3. 雑誌名 Botanical Journal of the Linnean Society	6. 最初と最後の頁 315 ~ 332
掲載論文のDOI (デジタルオブジェクト識別子) 10.1093/botlinnean/boz084	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

〔学会発表〕 計7件（うち招待講演 1件 / うち国際学会 6件）

1. 発表者名 Richard P. Shefferson
2. 発表標題 Addressing the importance of individual history on population dynamics with R package lefko3
3. 学会等名 3rd Annual Power Demography Meeting (招待講演)
4. 発表年 2020年

1. 発表者名 Richard P. Shefferson
2. 発表標題 Analyzing the influence of individual history on population dynamics and life history with R package lefko3
3. 学会等名 Annual Meeting of the Australasian Evolution Society (国際学会)
4. 発表年 2020年

1. 発表者名 Richard P. Shefferson
2. 発表標題 Addressing the importance of individual history on population dynamics with R package lefko3
3. 学会等名 Annual Meeting of the British Ecological Society (国際学会)
4. 発表年 2020年

1. 発表者名 Richard P. Shefferson
2. 発表標題 Individual history in population matrix projection models: a general framework for analysis
3. 学会等名 Annual Meeting of the Evolutionary Demography Society (国際学会)
4. 発表年 2020年

1. 発表者名 Richard P. Shefferson
2. 発表標題 Individual history in population models: a general approach in R.
3. 学会等名 Annual Meeting of the Ecological Society of America (国際学会)
4. 発表年 2020年

1. 発表者名 Richard P. Shefferson
2. 発表標題 Building and analyzing matrix models in R
3. 学会等名 Annual Meeting of the Ecological Society of America (国際学会)
4. 発表年 2022年

1. 発表者名 Richard P. Shefferson
2. 発表標題 Building and analyzing matrix models in R
3. 学会等名 Annual Meeting of the Ecological Society of Japan (国際学会)
4. 発表年 2022年

〔図書〕 計0件

〔産業財産権〕

〔その他〕

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6. 研究組織

氏名 (ローマ字氏名) (研究者番号)	所属研究機関・部局・職 (機関番号)	備考
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7. 科研費を使用して開催した国際研究集会

〔国際研究集会〕 計0件

8 . 本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関
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