『ぼくらが因果鉄道の旅に出る理由』

あるいは、自分たちの研究が統計的因果推論と
どのような関係にある／ありうる
のかという話

林岳彦

国立環境研究所環境リスク研究センター

「統計学的因果推論ってよく分からない…」

原因1：いわゆる統計学 ＋矢印の話

原因2：自分の研究とどう関係しうる
のかが分からない

原因1：いわゆる統計学 ＋矢印の話

$A \leftarrow B$　　$P(A|B)$

Bが「givenの原因」で、Aは「その結果」　？

$$P(A|B)=P(B|A)P(A)/P(B)$$
$$P(B|A)=P(A)/P(B)P(A|B)$$

等式では因果の矢印(A←B)は表現することすらできない！

↓

因果関係(A←B)は”代入式”的な論理であり
そこが「よく分からなさ」に繋がっている

”代入式”的な論理をどう統計的確率論にimposeするか→星野先生、清水先生のご講演

原因2：自分の研究とどう関係しうるのかが分からない

別に、いままで統計的因果推論

なんて知らなくてもやってこれたし…

『ぼくらが因果鉄道の旅に出る理由』
というものもあるのです！

私はなぜ統計的因果推論と関わるハメになったのか

もともとは私は進化生態学者でした

@東北大学理学部理学研究科博士取得

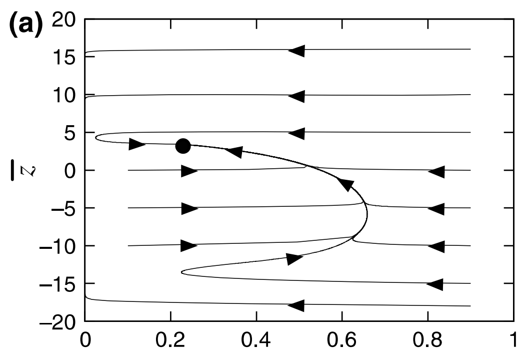
@テネシー大学(ポスドク)

『性淘汰と種分化理論の研究』

$$W_{\mathrm{I,nat}}(x) = [1 - s_x(x-\theta_x)^2](1-s_\mathrm{c}),$$

$$W_{\mathrm{U,nat}}(x) = 1 - s_x(x-\theta_x)^2 \text{ and}$$

$$W_{\mathrm{m,nat}}(y) = 1 - s_y(y-\theta_y)^2.$$



Hayashi et al. (2007) in J. Evol. Biol., 20 2154-2164

昨日2006/3/15発売！！

第二章『性淘汰理論を整理する』林岳彦

この世の(真)理が
知りたい！

私はなぜ統計的因果推論と関わるハメになったのか

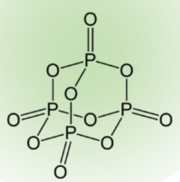
化学物質の生態リスクの分野へ

@産総研化学物質リスク管理研究センター

@国立環境研究所環境リスク研究センター

『化学物質の生態毒性予測の研究』

化学構造式



化学物質
の物性

急性毒性
の値

メダカの
慢性毒性の
予測

予測がしたい！

Hayashi et al. (2011) in ESPR 18:365–375

Environ Sci Pollut Res (2011) 18:365–375
DOI 10.1007/s11356-010-0380-5

RESEARCH ARTICLE

A Bayesian approach to probabilistic ecological risk assessment: risk comparison of nine toxic substances in Tokyo surface waters

Takehiko I. Hayashi · Nobuhisa Kashiwagi

Received: 24 July 2009 / Accepted: 22 July 2010 / Published online: 5 August 2010
© Springer-Verlag 2010

Abstract
Background, aim, and scope Quantitative risk comparison of toxic substances is necessary to decide which substances should be prioritized to achieve effective risk management. This study compared the ecological risk among nine major toxic substances (ammonia, bisphenol-A, chloroform, copper, hexavalent chromium, lead, manganese, nickel, and zinc) in Tokyo surface waters by adopting an integrated risk analysis procedure using Bayesian statistics.
Methods Species sensitivity distributions of these substances were derived by using four Bayesian models. Environmental concentration distributions were derived by a hierarchical Bayesian model that explicitly considered the differences between within-site and between-site variations in environmental concentrations. Medians and confidence intervals of the expected potentially affected fraction (EPAF) of species were then computed by the Monte Carlo method.
Results The estimated EPAF values suggested that risk from nickel was highest and risk from zinc and ammonia were also high relative to other substances. The risk from copper was highest if bioavailability was not considered, although toxicity correction by a biotic ligand model greatly reduced the estimated risk. The risk from manganese was highest if a conservative risk index estimate (90% upper EPAF confidence limit) was selected.
Conclusion It is suggested that zinc is not a predominant risk factor in Tokyo surface waters and strategic efforts are required to reduce the total ecological risk from multiple substances. The presented risk analysis procedure using EPAF and Bayesian statistics is expected to advance methodologies and practices in quantitative ecological risk comparison.

Keywords Ecological risk assessment · Probabilistic risk analysis · Quantitative risk comparison · Bayesian statistics · Uncertainty analysis · Species sensitivity distribution

1 Background, aim, and scope

The purpose of ecological risk assessment is to assist decision-making about risk management of chemicals (Suter 2006). Typical ecological risk assessments are conducted to consider whether risk reduction measures are required for a single substance (e.g., European Commission 2003; OECD 1995). However, there are generally multiple toxic substances in the environment. It is therefore often necessary to decide which substances should be prioritized to achieve effective risk management given limited financial and human resources. For prioritization, it is necessary to assess quantitatively the ecological risk from different chemicals. For such quantitative risk assessment, a risk analysis technique that can handle uncertainty and variability by probabilistic methodologies is considered suitable (EUFRAM 2006; Vose 2007). Species sensitivity distribution (SSD) methodologies are widely used in probabilistic

Responsible editor: Philippe Garrigues

Electronic supplementary material The online version of this article (doi:10.1007/s11356-010-0380-5) contains supplementary material, which is available to authorized users.

T. I. Hayashi (✉)
Research Center for Environmental Risk,
National Institute for Environmental Studies,
16-2 Onogawa,
Tsukuba, Ibaraki 305-8506, Japan
e-mail: hayashi.takehiko@nies.go.jp

N. Kashiwagi
The Institute of Statistical Mathematics,
10-3 Midori-cho,
Tachikawa, Tokyo 190-8562, Japan

Springer

私はなぜ統計的因果推論と関わるハメになったのか

環境基準値等の公共政策の案件へ

@国立環境研究所環境リスク研究センター

『化学物質や農薬の規制に関する研究』

・水生生物保全に係る水環境基準の策定
（亜鉛、ノニルフェノール、ニッケル等々）

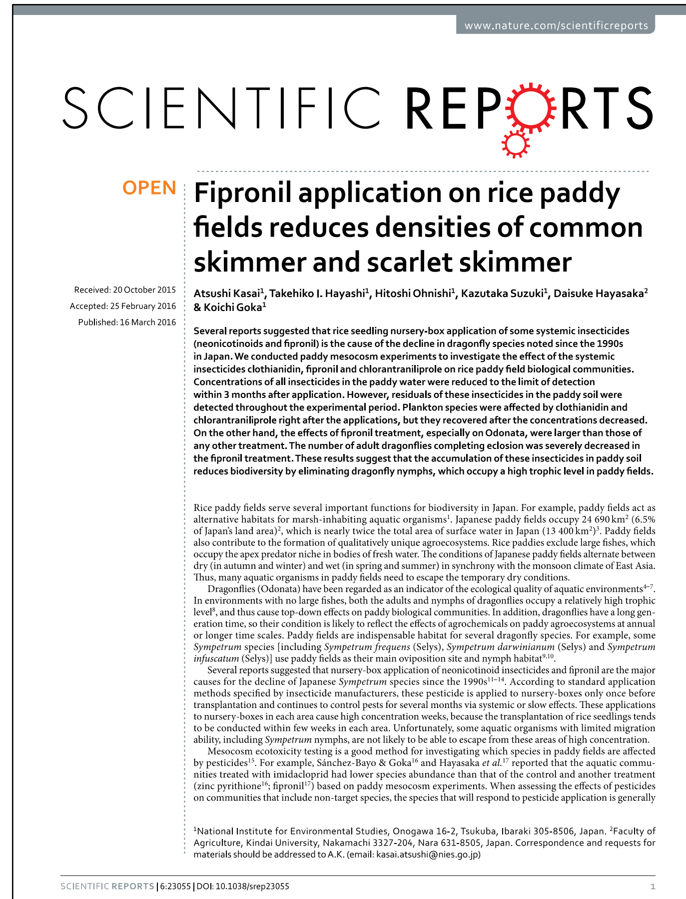
⇨ ニッケルの排出を規制したら生物は回復する？

・ネオニコチノイド系農薬等の生態系への
影響評価と保全施策の検討

⇨ 農薬の使用を規制したら水田生物は回復する？

規制等による介入の効果を推測したい！

3/16本日19時プレスリリース発表！


www.nature.com/scientificreports

SCIENTIFIC REPORTS

OPEN

Fipronil application on rice paddy fields reduces densities of common skimmer and scarlet skimmer

Received: 20 October 2015
Accepted: 25 February 2016
Published: 16 March 2016

Atsushi Kasai[1], Takehiko I. Hayashi[1], Hitoshi Ohnishi[1], Kazutaka Suzuki[1], Daisuke Hayasaka[2] & Koichi Goka[1]

Several reports suggested that rice seedling nursery-box application of some systemic insecticides (neonicotinoids and fipronil) is the cause of the decline in dragonfly species noted since the 1990s in Japan. We conducted paddy mesocosm experiments to investigate the effect of the systemic insecticides clothianidin, fipronil and chlorantraniliprole on rice paddy field biological communities. Concentrations of all insecticides in the paddy water were reduced to the limit of detection within 3 months after application. However, residuals of these insecticides in the paddy soil were detected throughout the experimental period. Plankton species were affected by clothianidin and chlorantraniliprole right after the applications, but they recovered after the concentrations decreased. On the other hand, the effects of fipronil treatment, especially on Odonata, were larger than those of any other treatment. The number of adult dragonflies completing eclosion was severely decreased in the fipronil treatment. These results suggest that the accumulation of these insecticides in paddy soil reduces biodiversity by eliminating dragonfly nymphs, which occupy a high trophic level in paddy fields.

Rice paddy fields serve several important functions for biodiversity in Japan. For example, paddy fields act as alternative habitats for marsh-inhabiting aquatic organisms[1]. Japanese paddy fields occupy 24 690 km^2 (6.5% of Japan's land area)[2], which is nearly twice the total area of surface water in Japan (13 400 km^2)[3]. Paddy fields also contribute to the formation of qualitatively unique agroecosystems. Rice paddies exclude large fishes, which occupy the apex predator niche in bodies of fresh water. The conditions of Japanese paddy fields alternate between dry (in autumn and winter) and wet (in spring and summer) in synchrony with the monsoon climate of East Asia. Thus, many aquatic organisms in paddy fields need to escape the temporary dry conditions.

Dragonflies (Odonata) have been regarded as an indicator of the ecological quality of aquatic environments[4–7]. In environments with no large fishes, both the adults and nymphs of dragonflies occupy a relatively high trophic level[8], and thus cause top-down effects on paddy biological communities. In addition, dragonflies have a long generation time, so their condition is likely to reflect the effects of agrochemicals on paddy agroecosystems at annual or longer time scales. Paddy fields are indispensable habitat for several dragonfly species. For example, some *Sympetrum* species [including *Sympetrum frequens* (Selys), *Sympetrum darwinianum* (Selys) and *Sympetrum infuscatum* (Selys)] use paddy fields as their main oviposition site and nymph habitat[9,10].

Several reports suggested that nursery-box application of neonicotinoid insecticides and fipronil are the major causes for the decline of Japanese *Sympetrum* species since the 1990s[11–14]. According to standard application methods specified by insecticide manufacturers, these pesticide is applied to nursery-boxes only once before transplantation and continues to control pests for several months via systemic or slow effects. These applications to nursery-boxes in each area cause high concentration weeks, because the transplantation of rice seedlings tends to be conducted within few weeks in each area. Unfortunately, some aquatic organisms with limited migration ability, including *Sympetrum* nymphs, are not likely to be able to escape from these areas of high concentration.

Mesocosm ecotoxicity testing is a good method for investigating which species in paddy fields are affected by pesticides[15]. For example, Sánchez-Bayo & Goka[16] and Hayasaka *et al.*[17] reported that the aquatic communities treated with imidacloprid had lower species abundance than that of the control and another treatment (zinc pyrithione[16]; fipronil[17]) based on paddy mesocosm experiments. When assessing the effects of pesticides on communities that include non-target species, the species that will respond to pesticide application is generally

[1]National Institute for Environmental Studies, Onogawa 16-2, Tsukuba, Ibaraki 305-8506, Japan. [2]Faculty of Agriculture, Kindai University, Nakamachi 3327-204, Nara 631-8505, Japan. Correspondence and requests for materials should be addressed to A.K. (email: kasai.atsushi@nies.go.jp)

SCIENTIFIC REPORTS | 6:23055 | DOI: 10.1038/srep23055 1

Kasai et al. (2015) in Scientific Reports 6:23055

振り返ってみると:理の探求→予測→介入

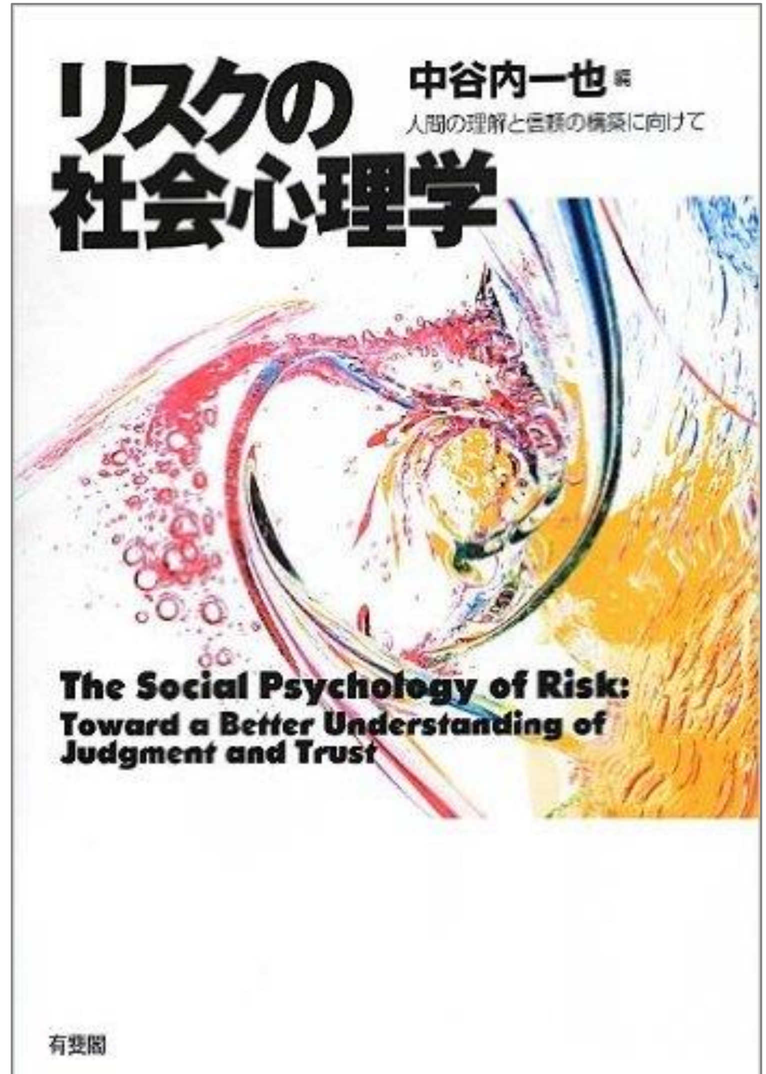
研究の目的とそれぞれの判断における統計学的規範

研究内容	研究の目的	依るべき規範
性淘汰の理論	理が知りたい	周辺尤度系 周辺尤度、尤度比 ベイズファクター等
化学物質の 毒性の予測	予測したい	予測誤差系 （広義の）クロスバリデーション AIC等
規制措置の 効果推定	介入したい	因果推論系 交絡の調整、強い無視可能性 バックドア基準等

今、あなたが研究で「やりたいこと」「やっていること」「やるべきこと」はどこに位置しますか？

社会心理学の研究が統計的因果推論と
どのような関係にある／ありうる
のかという話

リスク関連の社会心理学の本を読んでみた



たいへん現象の理解に役にたちました（あるある！）

Q. 社会心理学の統計は「介入」の議論に使えるのか？

市民参加型ごみ処理基本計画が市民に受け入れられ，
行政への信頼を醸成するために何が必要か

広瀬・大友（2014）社会安全学研究(4), 43-50より引用

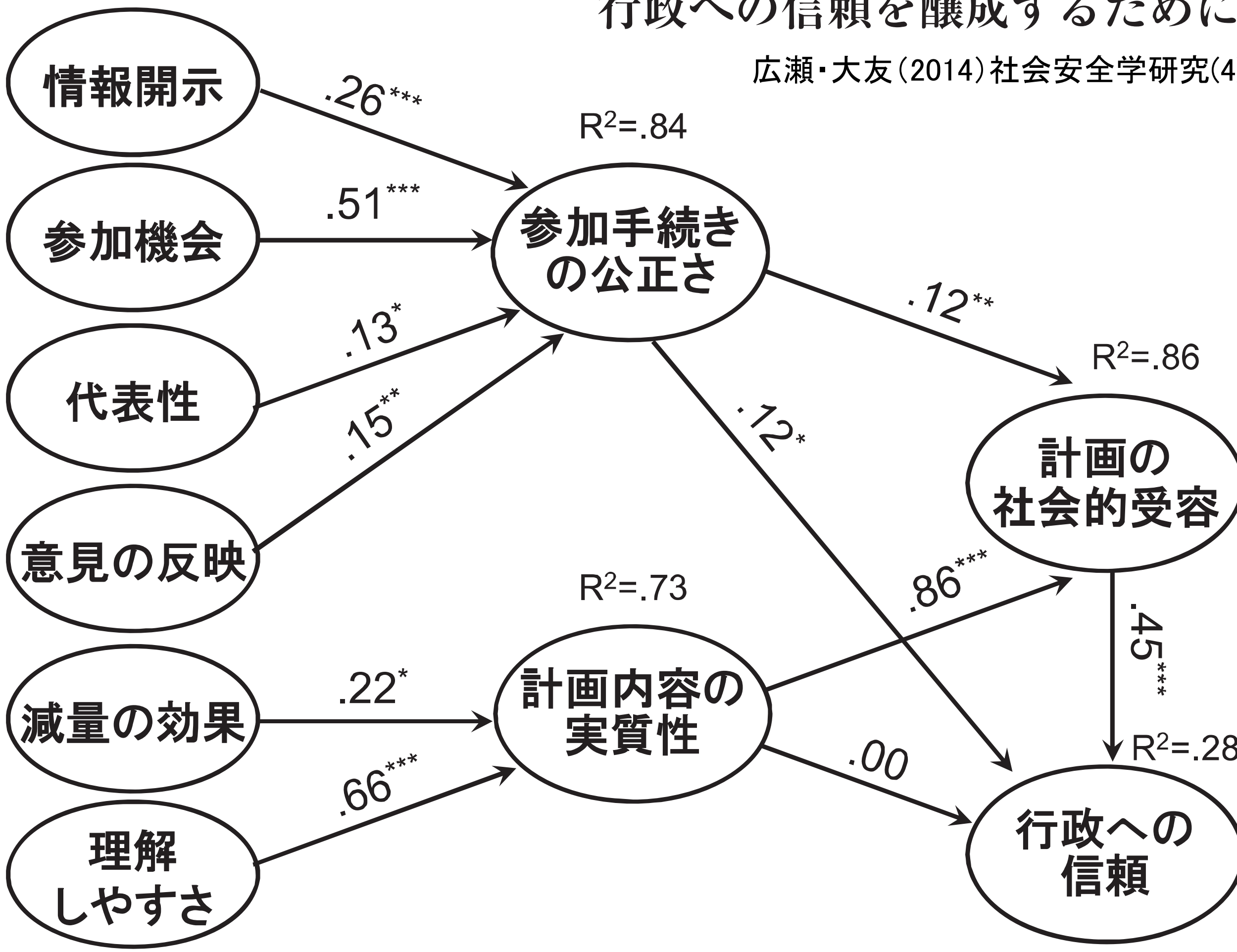


図２　仮説にもとづく共分散構造分析の結果

$^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

Q. 社会心理学の統計は「介入」の議論に使えるのか？

敢えて「介入効果の推定」の観点から見たときに気になる点

市民参加型ごみ処理基本計画が市民に受け入れられ，
行政への信頼を醸成するために何が必要か

広瀬・大友（2014）社会安全学研究(4), 43-50より引用

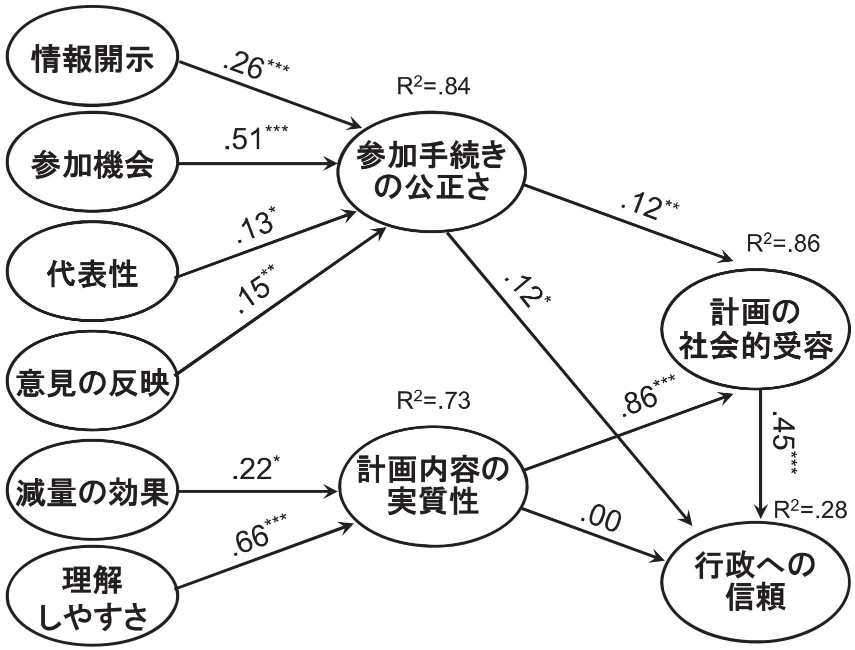


図 2　仮説にもとづく共分散構造分析の結果
$^{*}p<.05$, $^{**}p<.01$, $^{***}p<.001$

■ 概念モデルの範囲は十分？

交絡要因は含まれているのか？介入効果を考えるために十分な可能世界群をカバーしているのか？

「市民参加の催しを知らない」人を除外して良いのか？

■ モデルは本当に〞正しい〞の？

判断の規範が確証的因子解析やAICで本当に良いのか？

■ そもそも介入可能なのか？

この表明された『情報開示』は介入可能な概念なのか？

心理と現実はどのように交わりうるのか？

単なる記述統計だというなら何の不満もないけれど

介入を目的とした場合の外的/内的妥当性の規範とは一定の距離がありそう

理解／診断の役には立つとして，介入／治療の役には立つの？

まとめ：「統計学的因果推論ってよく分からない…」という方々へのメッセージ

- あなたが本当にやりたいことは『記述』『理の探求』『予想』『介入』のうちのどれですか？（＊排反ではない＊）

- 『介入』が目的なら統計的因果推論系の方法論と規範意識をぜひ身につけよう

- 『介入』という観点からあなたの研究を眺めてみるのも良いかも（例：再現性問題）

さいごに

「結局、人の心のことなんて分からない」

「結局、因果のことなんて分からない」

たしかに「心」も「因果」も形而上的側面を含むけれどもさ

何にも分からないわけじゃないから！！

丁寧に外堀のロジックを埋めていけば

分かることも面白いことも役に立つこともたくさんあるんだから！

…そんな想いこそが

『ぼくらが因果鉄道の旅にでる理由』

おしまい