

A force competition of predator on urban ecosystem

Kacharat Phromkhunathon

Wildlife Behavioural Ecology for Conservation Research Center

204/98 Village No. 3 Pathana Khan Road, Pak Prak Sub-district, Mueang Kanchanaburi District, Kanchanaburi, Thailand, 71000

kacharatp@gmail.com

Abstract

Definitely the fact, is an undeniable impact of habitat change and fragmentation in the urban ecosystem take effect to species loss causes population decline into local extinction. The results that emerged from habitat selection in ecology in this case study may suggest possible opportunistic of population turnover are caused by behaviour adaptive in the life-history of predators. And provides functional responses proportion aim for response to available exploit habitat. Though data imperfectly create approach sufficient of N assumes initial of each predator for testing and experiment theory empirical [$y = 2.4444$, $\text{Pr} (>F) = 0.002466$]. Moreover, consequences interspecific competition were determine nonhierarchical pattern by supposing Golden Jackal (species B) is dominant species in the community, show when encounter 1) Leopard Cat (species A) have $dN_{Aj}/dt = 1.821292$ [$\text{Pr} (>F) = 0.2261$] and competitive coefficient = 0.96797 [$\text{Pr} (>F) = 0.3961$] and 2) Common Palm Civet (species A) have $dN_{Aj}/dt = 4.777457$ [$\text{Pr} (>F) = 0.2261$] and competitive coefficient = 0.93647 [$\text{Pr} (>F) = 0.3961$]. That demonstrates plausible Golden Jackal discriminated occasion predominant obviously from the functional responses the robust. However, these results expect the one essence for estimating the population growth rate, especially from individual metabolic rate causes behaviour adaptive in template phase of spatial-temporal dynamics and predict carrying capacity free-bias improving. Effort understanding to mechanism complex before into broadly practical aims enhance the wildlife management and conservation probabilities.

Keyword Animal behaviour, Competition, Habitat selection, Predator, Urban ecosystem

1. Introduction

Undeniable, urban civilization development participate taken habitat decline both quantitative and qualities. Therefore, understanding dimensions complexity emphasize habitat selection in the ecology of how carnivore responses behaviour adaptive to habitat change configuration and what outcomes of competitive mechanism work for interpreting is intricate on the spatial-temporal dynamics. And why never incapable of reaching an equilibrium of carrying capacity. Often those ambiguous give rise to issues the potential combustible argument about wildlife management and conservation. Maybe because functional of many species lack information to support our understood, or data conclusive enhance within reasonable of occurrence. Such as population regulation and controls of coexistence, of species relative abundance patterns, and of diversity (Tilman et al. 2004). Understanding these mechanisms can enable us to better predict changes in biodiversity and

restore some ecological processes in urbanized landscapes with the ultimate goal of increasing the species richness and reducing homogenization effects (Jokimäki et al. 2011).

Here I effort searching expects probability of the population turnover from diminishing remain by behaviour adaptive intuitive of predators are cause obtain effect from habitat change and fragmentation in history. From behavioral trait have effect to competitive under the ongoing anthropogenic environmental change that often results in deterioration of the qualities of resources that are necessary for animals (Forsman and Kivelä 2021). Unfortunately, most tests of habitat selection theory have been incomplete and often inconclusive, also the relationship of the behavioral surrogate to fitness has seldom been empirically demonstrated (Morris 1989a). May cause the predator is assumed to control which it will visit and leave a habitat, that species' densities hover about the point of stable coexistence (Charnov 1976; Morris 2003). Because the competition coefficients represented by isoclines correspond to the average competition over all habitats occupied by population (Morris 2003). The key feature of such problems which most important source in many situations, is variation in animal abundance, N_i , because conventional thinking in capture-recapture problems is based on the notion of a capture probability defined conditional on presence, or occupancy among sites (Royle and Nichols 2003). The challenge, then, is to develop mechanistic models that begin from what is understood (or hypothesized) about the interactions of the individual units, and to use computation and analysis to explain emergent behavior in terms of the statistical mechanics of ensembles of such units (Levin et al. 1997). This conclusion depends critically on the relative slopes and intercepts of each habitat's fitness function (Morris 2011).

Effort expects to improve understanding from testing and experiment theory on the empirical urban ecosystem before extending broad into practical aims enhance the wildlife management and conservation strategies probabilities. Certainly, most communities are complex and each species may be engaged in many predator-prey interactions (Heithaus 2001). The implication of competition local coexists may cause diversification force which is correlated with changes in feeding strategy and behaviour (Dayan and Simberloff 2005). Behavioural responses to spatial elements can reflect real or perceived costs of living in a fragmented landscape at more matrix tolerant by resource competition with one or more coexisting species (Schluter 2000; Gehring and Swihart 2003). Thus, in the short-term, the most sensible approach may, therefore, be to concentrate research and protection efforts on species that are threatened or whose populations are declining, and for which human disturbance is implicated as a possible cause (Gill et al. 2001)

2. Materials and Methods

2.1. Study site

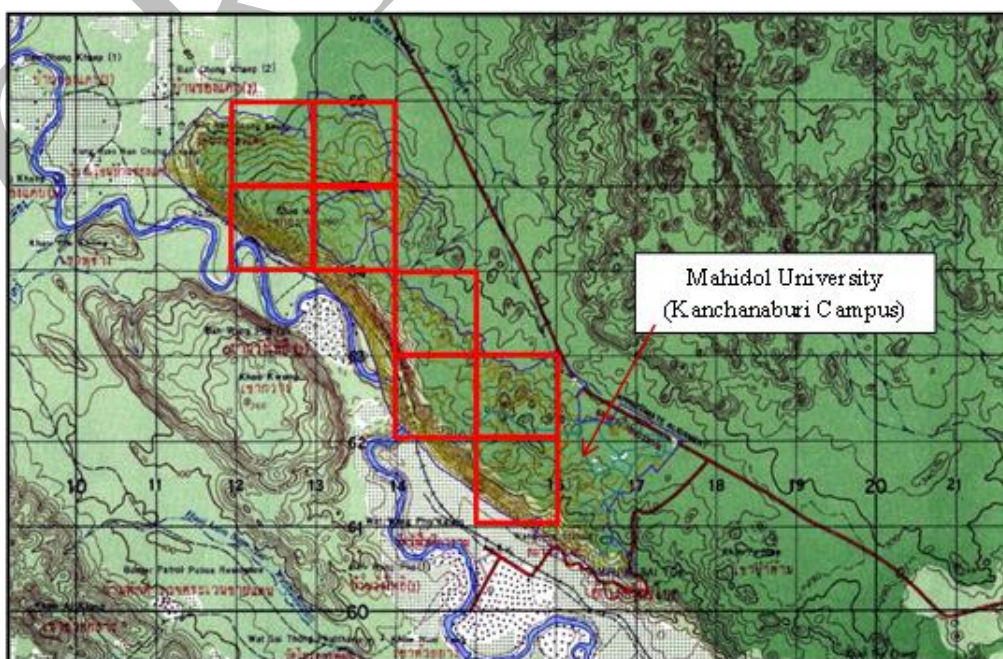
Mahidol University (Kanchanaburi Campus) have area boundaries of 937.5 ha located on latitude 14°07'46.20" N and longitude 99°09'34.69" E in the West of Thailand. Have completed synonym habitat types are urban forests, and the monospecific forest is mixed deciduous forest cover across limestone mountains. Even the forest structure criteria listed good condition is $LAI = 1.7138$ (1-10 % dieback) (Phormkhunathon 2020). Though habitat boundary restrained distribution in ecological are cause from habitat change and fragmentation on the urban landscape in history, otherwise have habitat niche incomplete

(lack riparian forest). These features, suitable anticipate on-field testing and experiment about habitat selection in the ecology of predator competition responses conditional such mentioned. Which may the key conceal are interaction important to forcible within mechanism system contribute sustaining biodiversity.

2.2. Habitat selection behaviour responses competitive under habitat niche incomplete

Significance resolves sampling data design ad hoc on the urban forest for analytical involves predators competitive correlated with occupancy. It is context circumstance difficult unbiased and accurate rely on appropriate analyze. The answers depend, in part, on the mechanisms that are relatively "invisible" to human observers of habitat selection on the trade-off involved in competitive fitness in the path tortuosity yardstick (Case and Gilpin 1974; Morris et al. 2000; Morris 2003; Mayor et al. 2009), on habitat incomplete. It is the switch in behaviour from selective to opportunistic use of habitat that may lead to the coexistence, not the actual location of the boundary to investigate the effect of the size of the sampling unit. (Křivan 1996, He and Gaston 2000; Morris et al. 2000). Therefore after carefully thoughts about sampling design free-bias providing fitness data underline competitive interaction based on limited of specific-area and recognize to applying suite to research progressive quality in long-term. I determined alternative used randomize sampling design total 8 grids study with camera trap (CT) 8 traps, which each grids scale 1x1 km on GIS Maps 1:50000. Each grid study is divided into quarters for CT point and translocation every month (30 days and nights). The CT set to function in hybrid mode and trigger 3 shots and operated 24 hrs for capture-recapture of carnivores available on their habitat per resource unit through March-June 2021 periods. This suggest that the method is reasonably robust to typical behaviour pattern that may violate underlying linear model assumptions (Rowcliffe et al. 2008).

Fig 1. Show a randomized sampling design of eight grids study on Mahidol University (Kanchanaburi Campus) area for predator available exploit habitat study under a force competition.



2.3. Imperfectly data management provides free bias from occupancy based on empirical randomized sampling

Habitat selection is one particular of animal behaviour in ecology, which many case studies apply to integrate with wildlife conservation and management. Due to it is logical of behaviour pattern to occur cause force competition response to available mosaic habitat size on the landscape for survival and reproductive on spatial-temporal dynamics. There are many reasons for wanting techniques that help us discern competitive interaction for solutions to spatial-temporal dynamics used the Lotka-Volterra-Gause competition equations for habitat selection patterns studies in the field (Rosenzweig and Abramsky 1985; Morris 1989b). Statistical models of habitat selection, such as resource selection functions, lack any explicit connection to the fitness mechanisms that shaped patterns of habitat use, in contrast, models such as the ideal free distribution (IFD), isodars, and ideal despotic distribution (IDD) are more mechanistic, being based on underlying principles from modern evolutionary theory (Morris et al. 2008). For problem empirical herein, impossible to reach out estimate fitness of population density each species in short-term. So this case study is unambitious for analytical involve population growth rate in both density-dependent and density-independent habitat selection. And define analytics as follow;

2.3.1. Simpson's Index

$$y = \frac{\sum n_i^2}{N^2} \quad (\text{Rosenzweig and Abramsky 1985})$$

where n_i is the census of a species on the i th grid, m is the number of grid, and $N = \sum n_i$

2.3.2. The Lotka-Volterra-Gause competition

$$dN_{Aj}/dt = r_{Aj}N_{Aj}[(K_{Aj}-N_{Aj}-\alpha_{ABj}N_{Bj})/K_{Aj}] \quad (\text{Morris 2003})$$

where N_{ij} is density of species i in habitat j

α_{ABj} is the competitive effect of Species B on Species A in Habitat j

r is the intrinsic growth rate

K is carrying capacity

3. Results

3.1. A force competition provides opportunistic with the population growth rate

Species competition has a robust linear mechanism for estimating the population growth rate in a community when N is assumed. This situation becomes even more interesting in a spatial context of nonhierarchical competition is in general of broad importance, as priority effects may determine competitive outcomes (Durrett and Levin 1998). Here rising for example 2 cases below by supposing Golden Jackal *Canis aureus* is dominant species in the community which predominant responses to available exploit habitat niche incomplete with Leopard Cat *Prionailurus bengalensis* and Common Palm Civet *Pardoxurus hermaphroditus*, respectively. Is dominant species reduced in the community.

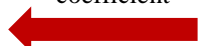
Case 1. Leopard Cat (A) Vs Golden Jackal (B); $dN_{A_j}/dt = 1.821292$ [Pr (>F) = 0.2261]

Leopard Cat *Prionailurus bengalensis*



Golden Jackal *Canis aureus*



competitive coefficient

 0.96797
 [Pr (>F) = 0.3961]


Case 2. Common Palm Civet (A) Vs Golden Jackal (B); $dN_{A_j}/dt = 4.777457$ [Pr (>F) = 0.2261]

Common Palm Civet *Paguma larvata*



Golden Jackal *Canis aureus*



competitive coefficient

 0.93647
 [Pr (>F) = 0.3961]

Both cases demonstrated apparent Golden Jackal discriminated occasion predominant obviously response to available exploit habitat where considering outcomes the values of dN_{A_j}/dt correlate with competition coefficients are positive. It demonstrated significant implicit suggests each predator opportunistic exploit habitat for population turnover unequally. The outcome represents linear interspecific competition. Account for plausible is the point might be ascent equilibrium before decline gradient again causes competitive. The one essence interesting critical involve behaviour adaptive are a response to available exploit habitat because suggestion about individual metabolic rate oscillates robust from cost-searching causes adaptive relevant through life-histories. Which alternative could be lead to an investigation estimates population growth rate from reproductive success provides carrying capacity. But while, however, this assumed initial from N less in the urban forest which has problems insight interpreted cases data imperfectly, is amount N of each species appeared in history both before-after of habitat change and fragmentation.

In particular, competition coefficients are found when species affect the local extinction or migration rates of each other (Levins and Culver 1971), depending on the relative magnitudes of the competition coefficients (May and Leonard 1975). Because

competition may be operating, but exclusion or displacement may be incomplete, or even impossible (Colwell and Futuyma 1971). Thus the number of species which can coexist competitively is limited mostly by the inequality of the interspecies competition coefficients and not appreciably by their magnitude (MacArthur 1969). Because having opportunity to displace through on principle prey-predator system, additional each species will be encountering the stressor factors cases environmental stochasticity stimulating adaptive under tolerance range aim for a survivor and reproductive (Phormhunthon 2020). To demonstrate that in the corresponding stochastic spatial system the behavior is much different (Durrett and Levin 1998). That fact can elucidate to infer highlights suggest involves adaptive behaviour might be divergence with spatial oscillation. By there is a limit to the similarity (and hence to the number) of competing species which can coexist, a number is reduced by unequal abundance of resources but increased by adding to the dimensionality of the niche (MacArthur and Levins 1967). Whether the underlying proximate mechanisms in these examples involve genetic divergence or adaptive phenotypic plasticity remains to be determined (Grether et al. 2009), this occurs depends on the nature of the functional response (Osmond et al. 2017).

For instance, Brown et al. (1999) was represent Rosenzweig and MacArthur's conceptual in 1963 is pioneer recognized propose to involve with behavioural responses of predator-prey dynamics, which elucidate demonstrated opportunities of population size saturation in N -driven systems, the killing of prey by the predators is the principle impact of predators on prey's fitness and population dynamics. Because they can be highly efficient predators at low population sizes but rapidly become inefficient predators as the population size of predators increases (Brown et al. 1999). It possibly causes predators to intake energy from consumption on prey yields fitness per capita probability where synthesize about fecundity rate associated with gamma (γ) and beta (β) species. In addition, the constraints of body size and its correlation increasingly predominate over the interspecific trade-offs in resource use, which are the more proximate determinants of species interactions and abundance (Tilman et al. 2004). Thus, it is possible that when population size is equilibrium or isocline is zero, that point will be a regression gradient to face local extinction. If plausibly exponential population growth rate will be relative with log-time series allowed spatial-temporal dynamics in the bell-shaped curve where $e = 2.71828$ (the natural logs). However, a spatio-temporal mosaic develops in which different regions oscillate out of phase (Durrett and Levin 1998).

3.2. Opportunity sustaining biodiversity where $r < 0$

Trending to population density fitness with habitat scale is interest from ecologists have been a long-time in a decade, and many arguments for investigating to the point this fitness. Due to may have any question dramatics ambiguous on population biology which is beyond understood, though not all the parameters are necessarily significant (Ayala et al. 1973). Its crucial wish answer realistic from testing and experiment theory can provide to properly the wildlife conservation and management strategies design for sustaining biodiversity in long-term. Among the war paradoxical of ecological Vs economics. Such the classical LVG model is based on the logistic theory of population growth and is subject to the same serious criticisms as the logistic theory since it does not take into account the age of

organisms, their sex, nor genetic differences between them, both intra- and interspecific, are linear (Ayala et al. 1973).

Undoubtedly, using r and K is an important parameter for predicting the population growth rate and finite rate of increases or even investigating population density fitness. For total or an average number of individuals present consideration at the size of the population sampled (N_i). (Ayala et al. 1973; Royle and Nichols 2003). A species will occupy more sites when its average r is high, and fewer when its average r is lower (Gaston et al. 2000). Of considerable interest in ecology is the special case of a nongrowing population, where $(dN/dt) = r = 0$, and there is a steady state between the rate of limiting resource supply in the environment and the rate of resource use by the population (Savage et al. 2004). Plausibly for a suitably large number of species a fluctuation in r will mean no species can invade at every season, and hence allow saturation (MacArthur 1969). In contrast, for instance here, taking break linear the prey density in this theory framework, it requires a better understanding of how abundance in turn over from predator functional response that links local extinction in short-term to long-term (Gillooly and Allen 2007), where $r < 0$. From life-history strategies for each species are the most relevant with parameters to study (Savage et al. 2004). When consequence initial this case study, it is possible to demonstrate each species might have number population $y = 2.4444$ [$N = 18$, $(Pr > F) = 0.002466$] occupancy on habitat boundary after habitat change and fragmentation in histories. It's significant indicate to the signal of possible trajectory local extinction of each species or not yet. These declines caused the collapse of the positive interspecific abundance-occupancy relationship (Gaston et al. 2000). Though each species is assumed, a priori, to have some finite probability of extinction depends on initially the most abundant (Case 1990). As there is no opportunity for niche partitioning, the only possible outcomes are competitive dominance or a priority effect (Amarasekare 2002). This result provide inferences functional forms if handle non-linear prey density and competitive influences coexistence from being costly to beneficial (i.e. trade-off between energy intake and mortality rate of prey) in habitat selection (Křivan 1997; Skalski and Gilliam 2001; Amarasekare 2002). One with regard interest about consequence emerges is an individual metabolic rate and the range of K can generate abundance from reproductive success from adaptive instinct responses to interference environment. Therefore species coexistence on effect of increasing local extinction and the rate of return in a fluctuating environment depends on the product of the eigenvalue (Levins and Culver 1971). These suggest logistic functional responses pattern per capita of predator would rather than habitat quality matching are causing adaptive instinct. Because of each species might exhibit interplay behavioral plastic trait adaptive which flexibility available to habitat and differences response tolerance levels by human-mediated changes in urban ecosystem (Morris 2011; Wong and Candolin 2015). The implication is that much of the variation in species coexistence is directly attributable to the kinetics of biochemical reactions and ecological interactions (Brown 2004).

4. Discussion

In developing priorities for the conservation of biodiversity, it becomes important to identify and understand the most fragile and critical components of ecological systems (Levin et al. 1997). Negligent give importance to behaviour adaptive responses functional proportion

in the predator-prey system obtained impact causes habitat change and fragmentation in the urban ecosystem. Any blind spot anonymous for creating approaching to synthesize about the population growth rate recognition coexists on fundamental to testing and experiment theory. It essence participate providing to maintain species diversity asymmetrical characteristics for sustaining biodiversity in the urban ecosystem. Therefore, given the complexity of the problem, it is necessary to endeavour to change not only wildlife behavior, but also human behavior (Takahata et al. 2014). The empirical evidence to be positive or negative allow both predation (top-down) and resource limitation (bottom-up) among habitat fragmentation (pattern) on species abundance are general much weak than the effects of habitat loss (Fahrig 2002, 2003; Sinclair et al. 2003). An indirect consequence of species loss is that it limits the potential number of ways a system can reorganize (Peterson et al. 1998).

Though understanding the processes underpinning this important relationship is undoubtedly growing and necessary theoretical development, but progress is slow (Levins and Culver 1971; Gaston et al. 2000). Such this case is studied and acceptable imperfectly. Because the parameter used estimate coexistence causes predator competition available exploit habitat niche incomplete, that limited for expects the population growth through spatial-temporal dynamics. A challenge poorly understood dramatics in decades for understanding progressive. Although the answer to this question is probably yes after the species is first detected, a population adopting the paradoxical data and detection probabilities must be assumed constant within the primary period (Maynard Smith and Parker 1976; Mackenzie et al. 2003). That demonstrated conclusive probable involves a population each carnivore species can turn over, because trophic species do not necessarily contribute equally to trophic elements in food-web size (Schoener 1989). Consumption rate is further determined by predator search rate for prey, and predator handling time of prey (time spent chasing and consuming prey) (Fortin et al. 2015), its functional form will depend on the type condition of selection for each environment pattern in space and time (Levins 1962). The result is coexistence of all species and densities that are almost constant when observed in boxes with sides that are a large multiple of the “correlation length” (Durrett and Levin 1998).

Finally, field experiments can be designed to test the response of gross predator behavior to resource availability at different scales (Charnov 1976; Peterson et al. 1998). Because of best evaluated not just by testing a single prediction, but rather by using a more holistic approach that evaluates all assumptions and predictions of the theory, as well as the logic behind the theory (Gillooly and Allen 2007). More importantly, perhaps, is the reality that adaptive traits and strategies are moulded by the dynamic interplay between ecology and evolution (Morris 2011). However, it is always difficult to infer process (extinction and colonization dynamics) from pattern (site occupancy); typically, many processes can produce any pattern (Mackenzie et al. 2003).

Acknowledgements

Special thank you to IDEA WILD for equipment funds support project achievement.

References

1. Amarasekare, P. (2002). Interference competition and species coexistence. *Proc Biol Sci*, 269, 2541-2550.
2. Ayala, F. J., Gilpin, M. E., & Ehrenfeld, J. G. (1973). Competition between species: theoretical models and experimental tests. *Theoretical Population Biology*, 4, 331-356.
3. Brown, J. S., Laundré, J. W., & Gurung, M. (1999). The ecology of fear: optimal foraging, game theory. *Journal of Mammalogy*, 80, 385-399.
4. Brown, J. H. (2004). Toward a metabolic theory of ecology. *Ecology*, 85, 1771-1789.
5. Case, T. J., & Gilpin, M. E. (1974). Interference Competition and Niche Theory. *PNAS*, 71, 3073-3077.
6. Case, T. J. (1990). Invasion resistance arises in strongly interacting species-rich model competition communities. *PNAS*, 87, 9610-9614.
7. Charnov, E. L. (1976). Optimal foraging, the marginal value theorem. *Theoretical Population Biology*, 9, 129-136.
8. Colwell, R. K., & Futuyma, D. J. (1971). On the measurement of niche breadth and overlap. *Ecology*, 52, 567-576.
9. Dayan, T., & Simberloff, D. (2005). Ecological and community-wide character displacement: the next generation. *Ecology Letters*, 8, 875-894.
10. Durrett, R., & Levin, S. (1998). Spatial aspects of interspecific competition. *Theoretical Population Biology*, 53, 30-43.
11. Fahrig, L. (2002). Effect of habitat fragmentation on the extinction threshold: a synthesis. *Ecological Applications*, 12, 346-353.
12. Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. *Annu. Rev. Ecol. Evol. Syst*, 34, 487-515.
13. Forsman, J. T., & Kivelä, S. M. (2021). Evolution of searching effort for resources: a missing piece of the puzzle in the ideal free distribution paradigm. *Oikos*, 00, 1-12.
14. Fortin, D., Buono, P. L., Schmitz, O. J., Courbin, N., Losier, C., St-Laurent, M. H., & et al. (2015). A spatial theory for characterizing predator-multiprey interactions in heterogeneous landscape. *Proc Biol Sci*, 282:20150973, 1-10.
15. Gaston, K. J., Blackburn, T. M., Greenwood, J. J. D., Gregory, R. D., Quinn, M., Lawton, J. H. (2000). Abundance-occupancy relationships. *Journal of Applied Ecology*, 37, 39-59.
16. Gehring, T. M., & Swihart, R. K. (2003). Body size, niche breadth, and ecologically scaled responses to habitat fragmentation: mammalian predators in an agricultural landscape. *Biological Conservation*, 109, 283-295.
17. Gill, J. A., Norris, K., Sutherland, W. J. (2001). Why behavioural responses may not reflect the population consequences of human disturbance. *Biological Conservation*, 97, 265-268.
18. Gillooly, J. F., & Allen, A. P. (2007). Linking global patterns in biodiversity to evolutionary dynamics using metabolic theory. *Ecology*, 88, 1890-1894.
19. Grether, G. F., Losin, N., Anderson, C. N., & Okamoto, K. (2009). The role of interspecific interference competition in character displacement and the evolution of competitor recognition. *Biol. Rev.*, 84, 617-635.
20. He, F., & Gaston, K. J. (2000). Occupancy-abundance relationships and sampling scales. *Ecography*, 23, 503-511.

21. Heithaus, M. R. (2001). Habitat selection by predators and prey in communities with asymmetrical intraguild predation. *Oikos*, 92, 542-554.
22. Jokimäki, J., Kaisanlahti-Jokimäki, M.-L., Suhonen, J., Clergeau, P., Pautasso, M., & Fernández-Juricic, E. (2011). Merging wildlife community ecology with animal behavioral ecology for a better urban landscape planning. *Landscape and Urban Planning*, 100, 383-385.
23. Křivan, V. (1996). Optimal foraging and predator-prey dynamics. *Theoretical Population Biology*, 49, 265-290.
24. Křivan, V. (1997). Dynamic ideal free distribution: effects of optimal patch choice on predator-prey dynamics. *The American Naturalist*, 149, 164-178.
25. Levins, R. (1962). Theory of fitness in a heterogeneous environment. I. The fitness set and adaptive function. *The American Naturalist*, 96, 361-373.
26. Levins, R., & Culver, D. (1971). Regional Coexistence of Species and Competition between Rare Species. *PNAS*, 68, 1246-1248.
27. Levin, S. A., Grenfell, B., Hastings, A., & Perelson, A. S. (1997). Mathematical and computational challenges in population biology and ecosystems science. *Science*, 275, 334-343.
28. Mackenzie, D. I., Nichols, J. D., Hines, J. E., Knutson, M. G., & Franklin, A. B. (2003). Estimating site occupancy, colonization, and local extinction when a species is detected imperfectly. *Ecology*, 84, 2200-2207.
29. MacArthur, R., & Levins, R. (1967). The limiting similarity, convergence, and divergence of coexisting species. *The American Naturalist*, 101, 377-385.
30. MacArthur, R. (1969). Species packing, and what interspecies competition minimizes. *PNAS*, 64, 1369-1371.
31. May, R. M., & Leonard, W. J. (1975). Nonlinear aspects of competition between three species. *SIAM Journal on Applied Mathematics*, 29, 243-253.
32. Maynard Smith, J., & Parker, G. A. (1976). The logic of asymmetric contests. *Anim. Behav.*, 24, 159-175.
33. Mayor, S. J., Schneider, D. C., Schaefer, J. A., & Mahoney, S. P. (2009). Habitat selection at multiple scales. *Ecoscience*, 16, 238-247.
34. Morris, D. W. (1989a). Density-dependent habitat selection: testing the theory with fitness data. *Evolutionary Ecology*, 3, 80-94.
35. Morris, D. W. (1989b). Habitat-dependent estimates of competitive interaction. *Oikos*, 55, 111-120.
36. Morris, D. W., Davidson, D. L., & Krebs, C. J. (2000). Measuring the ghost of competition: insights from density-dependent habitat selection on the co-existence and dynamics of lemmings. *Evolutionary Ecology Research*, 2, 41-67.
37. Morris, D. W. (2003). How can we apply theories of habitat selection to wildlife conservation and management ?. *Wildlife Research*, 30, 303-319.
38. Morris, D. W., Clark, R. G., & Boyce, M. S. (2008). Habitat and habitat selection: theory, test, and implications. *Israel Journal of Ecology and Evolution*, 54, 287-294.
39. Morris, D. W. (2011). Adaptation and habitat selection in the eco-evolutionary process. *Proc Biol Sci*, 278, 2401-2411.
40. Osmond, M. M., Otto, S. P., & Klausmeier, C. A. (2017). When predators help prey adapt and persist in a changing environment. *The American Naturalist*, 190, 83-98.

41. Peterson, G., Allen, C. R., & Holling, C. S. (1998). Ecological resilience, biodiversity, and scale. *Ecosystems*, 1, 6-18.
42. Phormkhunathon, K. (2020). The threshold of ecosystem services assessment in urban forest for learning outcomes in higher education: Mahidol University (Kanchanaburi Campus). *EcoEvoRxiv*. November 27. doi:10.32942/osf.io/wydm8.
43. Royle, J. A., & Nichols, J. D. (2003). Estimating abundance from repeated presence-absence data or point counts. *Ecology*, 84, 777-790.
44. Rosenzweig, M. L. (1981). A theory of habitat selection. *Ecology*, 62, 327-335.
45. Rosenzweig, M. L., & Abramsky, Z. (1985). Detecting density-dependent habitat selection. *The American Naturalist*, 126, 405-417.
46. Rowcliffe, J. M., Field, J., Turvey, S. T., & Carbone, C. (2008). Estimating animal density using camera traps without the need for individual recognition. *Journal of Applied Ecology*, 45, 1228-1236.
47. Savage, V. M., Gillooly, J. F., Brown, J. H., West, G. B., & Charnov, E. L. (2004). Effects of body size and temperature on population growth. *The American Naturalist*, 163, 429-441.
48. Schluter, D. (2000). Ecological character displacement in adaptive radiation. *The American Naturalist*, 156, 4-16.
49. Schoener, T. W. (1989). Food webs from the small to the large. *Ecology*, 70, 1559-1589.
50. Skalski, G. T., & Gilliam, J. F. (2001). Functional responses with predator interference: viable alternatives to the Holling Type II Model. *Ecology*, 82, 3083-3092.
51. Sinclair, A. R. E., Mduma, S., & Brashares, J. S. (2003). Patterns of predation in a diverse predator-prey system. *Nature*, 425, 288-290.
52. Takahata, C., Nielsen, S. E., Takii, A., & Izumiyama, S. (2014). Habitat selection of a large carnivore along human-wildlife boundaries in a highly modified landscape. *PLoS One*, 9, e86181.
53. Tilman, D., Hillerislambers, J., Harpole, S., Dybzinski, R., Fargione, J., Clark, C., & et al. (2004). Does metabolic theory apply to community ecology ? it's a matter of scale. *Ecology*, 85, 1797-1799.
54. Wong, B. M., & Candolin, U. (2015). Behavioral responses to changing environments. *Behavioral Ecology*, 26, 665-673.