So Many Zebras, So Little Time:

How Ecological Models May Aid Counterinsurgency Operations

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Overview

Pity the poor lions. If only they had a bit more time, they could finally rid the plains of the pesky zebra. There are just so many of them, though. Why don't the zebra just unite and finish off the lions? The zebras far outnumber them.

Obviously the issue is more complicated, but this story is example of a complex ecological interaction between predators and prey. The mathematics underlying the various strategies for survival on both sides have been worked out over the past 100 years, and we have a fairly good understanding of such relationships.

While not a perfect comparison, it strikes us that many of the mathematical models developed by ecologists may have considerable applicability to the field of counterinsurgency. Some preliminary analysis on our part suggests that this predator-prey model may be too simplistic for the more complicated issue of counter-insurgency, but there are other, more detailed ecological models that we feel capture the essence of the problem.

The purpose of this paper is not to provide a definitive answer to this problem, but to suggest a framework for other researchers to adapt – we could find no similar work in any literature – and to expand upon it. Indeed, many of the models discussed in this paper are common to both ecologists and economists. (The result of both sorts of modeling are quite similar: maximizing profits – money/food – at the least risk – bankruptcy/death.) From our preliminary work, we hope that others more adept at the use of these models will make significant contributions to the area of predictive ability in combating terrorism and understanding unconventional warfare.

Introduction: Ecology and Counterinsurgency

The climate of conflict during the early 21st century has lent itself to a reexamination of techniques and tactics used in counterinsurgency.[2] The complexity inherent to warfare and other complex systems can be modeled in similar ways. The interaction of competing and cooperating groups having differing goals, tendencies, and talents lends itself to mathematical analyses, which often result in predictions of ways to perturb systems to reach desired outcomes. Occasionally, these predictions are not intuitive.

Here, we explore the notion that ecological modeling of species interactions might approximate the interactions found in counterinsurgency. First, we found that relatively simple models of two animal species locked in a predator-prey relationship (what ecologists call “predation”), and similar models, were inappropriate because of over-simplicity, violation of critical assumptions, or both. Second, we discovered that models of between-species competition for resources approximated the struggle between insurgents and counterinsurgents for military and political control over a host nation’s population. Third, this set of models implies that various aspects of a counterinsurgency campaign – fighting insurgents, controlling crime, and winning popular support – are probably and perhaps favorably inseparable.

This paper is intended to stimulate thought and further work by using biological models and metaphors for predictive purposes in warfare. It is important to note that modeling of this sort can only provide insight – not answers. Using the initial framework outlined here, more extensive analysis, modeling, and simulation could be used to derive historical insights about past COIN campaigns and aid in planning future ones.

Biology as a mindset

Biology is more than a laboratory science; it is a way of thinking about the natural world. Biological metaphors provide powerful ideas about how the natural world functions, and many parallels between natural and man-made systems have been drawn in technical, policy, and popular literature.[3]

Within the field of military and war studies, biological metaphors are often used to convey powerful ideas about human behavior. For example, a very influential recent article by David Kilcullen uses the terms “adaptation,” “evolution,” “competition,” “ecosystem,” and “environment” to describe various things occurring during a counterinsurgency (COIN) campaign.[4] Notably, these words are all from the same subspecialty of biology.

The study of this subspecialty – commonly called ecology, evolution, and animal behavior or “EEB” – is more than merely observational. It is also mathematical and can sometimes be predictive. In practice, empirical and theoretical work is often performed simultaneously by one or more investigators in order to shine greater light on nature’s mysteries. Depending which comes first, experiments can be performed to test models, or new data can be used to inform new mathematical theory. This quantitative approach has been highly successful since the beginning of modern biology a century ago and continues in cutting-edge fields such as bioinformatics and genomics.

The similarities between biological ideas and observations of warfare raise the question: Might mathematical models of biological processes be useful for understanding – and perhaps predicting – certain aspects of warfare? Here, we investigate whether a number of ecological models might be relevant to the study and practice of COIN.

How the weak win wars

It has been posited that powerful modern nations – the U.S., the USSR, Great Britain, France – have only been beaten in battle or driven to stalemate via insurgent tactics. These include guerrilla warfare and terrorism, and typically have a large psychological operations (PSYOP) component. The general success of insurgencies warrants study. However, since the Vietnam era, relatively little intellectual or academic work has been performed within military/defense circles.[5]

What is "counterinsurgency"? Typically, the term COIN is meaningless without an initial insurgency. Generally speaking, COIN involves a rebellion ("R" – the insurgents) against an authority ("A" -- the counterinsurgents) for control of a population ("P" – everyone else).[6] The Rebellion or the Authority may be from the area where the action is taking place, or as is often the case, the Rebellion may find safe haven outside this area.

The literature has various definitions of what insurgency and counterinsurgency are. Below are three modern definitions [7]:

"Counterinsurgency: those military, paramilitary, political, economic, psychological and civic actions undertaken by a government to defeat a subversive insurgency"

"An insurgency is a struggle for power (over a political space) between a state (or occupying power) and one or more organized, popularly based internal challengers."

"An insurgency is a struggle for control over a contested political space, between a state (or group of states or occupying powers), and one or more popularly based, non-state challengers."

The first key point, in all three definitions, is that an Authority in the contested area is defending its right to control a territory against a Rebellion. The Rebellion is implicitly assumed to be smaller and less powerful, else they would be the governing Authority. The second key point, in the second and third definitions, is that the Authority and Rebellion are fighting over *political space*, which includes control of the "hearts, minds, and acquiescence of the general population" in the contested area. This is to be distinguished from battles over what is merely *physical space*, territory itself – a key distinction between this particular form of irregular warfare and traditional conventional warfare [8]. Inherent in this is that PSYOP and other non-kinetic techniques are at least as valuable as - if not more than - traditional kinetic techniques in winning these battles. Finally, the third and most inclusive definition takes into account the transnational nature of some contemporary insurgencies, noting that one or more states (Authorities) may battle one or more external or internal challengers (Rebels). This last definition, by David Killcullen, is probably the most useful.

In order to possibly use ecology models to understand COIN, at least one large generalization is necessary. That is, there are similarities that exist across most COIN environments. This assumption is particularly germane in light of recent discussions about the new “global insurgency” and its similarities and differences with “classical insurgencies.”[9] To some extent, there has been a shift in how insurgencies operate in the modern age. Communications have improved; financing is different. However, this does not mean that the “essence” of insurgency, or fighting it, has been significantly altered. If this is true – if there are generalities about COIN that we can understand at a fundamental level despite adaptational differences over the decades – then we can ask, is there a set of ecological models that addresses these similarities, and thus has the utility to be applied to different insurgencies in the past, present, and future? If so, what are those models?

Simple models: Us versus Them

The interaction of insurgents and counterinsurgents on an asymmetric battlefield resembles the perennial struggle between predator and prey. Mathematical models of predation are some of the oldest in the field of ecology and evolutionary biology and date back nearly a century to seminal work resulting in the influential Lotka-Volterra equations.[10]

On the surface, the simple metaphor of predator-prey interactions is appealing. Predators are suited in style to kill prey, and prey, in turn, are quite often adept at escaping their common predators.[11] When observed in nature, these “arms races” have resulted in at least a temporary equilibrium; where they have not, no interaction can be observed, and the prey have gone extinct. The symbolism is obvious.

Furthermore, observations from nature suggest numerous overt mechanisms by which prey avoid extinction.[12] They can reduce the kill rate by decreasing local prey density (therefore increasing predator search time) or increasing “handling time” (time taken to kill a prey item). Prey can also utilize strategies such as occupying territory within which predators can’t hunt (small rodent prey can burrow, for example) – prey can always persist at low densities in such spatial refuges. There may be a victim “carrying capacity” – a maximum number of kills per day (predators having eating limitations). Waning prey populations can be reinforced by immigrants from populations not being preyed upon. All of these scenarios have counterparts in human warfare.

The excellent verbal metaphor begs the question: Do mathematical models of predator-prey interactions among animal species have any relevance for understanding interactions during a counterinsurgency campaign?

Imagine a pyramid describing categories of people in the contested area of a COIN campaign (Figure 1). At the base of the pyramid is the general population – people who just want to go about their lives. The middle contains, in far lesser numbers, the criminal element of the population. These people are most likely not part of the Rebellion, but rather take advantage of a weak or distracted Authority in order to better themselves. Finally, at the top of the pyramid are the insurgents, or Rebellion. Historical data puts this group at about 0-1% of the population in the contested area.

In theory, one could separate these three groups with regard to counterinsurgency operations. That is, one group from the Authority could concentrate on political affairs (targeting the general population), another group could conduct policing (targeting criminals), and a final group could perform “hunter-killer” operations (against the Rebels). This is in contrast to single individuals/units performing a mixture of these three basic COIN functions. In this framework, a simple predator-prey model may be valuable for simulating what takes place during COIN at the top of the pyramid. An historical example of this would be Operation Phoenix during the Vietnam War.

Population models such as those used to describe systems of predator-prey interactions are systems of equations that allow us to measure differences in rates between two variables (mathematicians call these differential equations). The most widely influential predator-prey models are those originally constructed by Lotka and Volterra. In essence, the Lotka-Volterra predation model is a system of such equations describing the interaction between predator and prey. This interaction is commonly symbolized as (+, -) because the effect of the prey on the predator is positive (+), and the effect of the predator on the prey is negative (-).

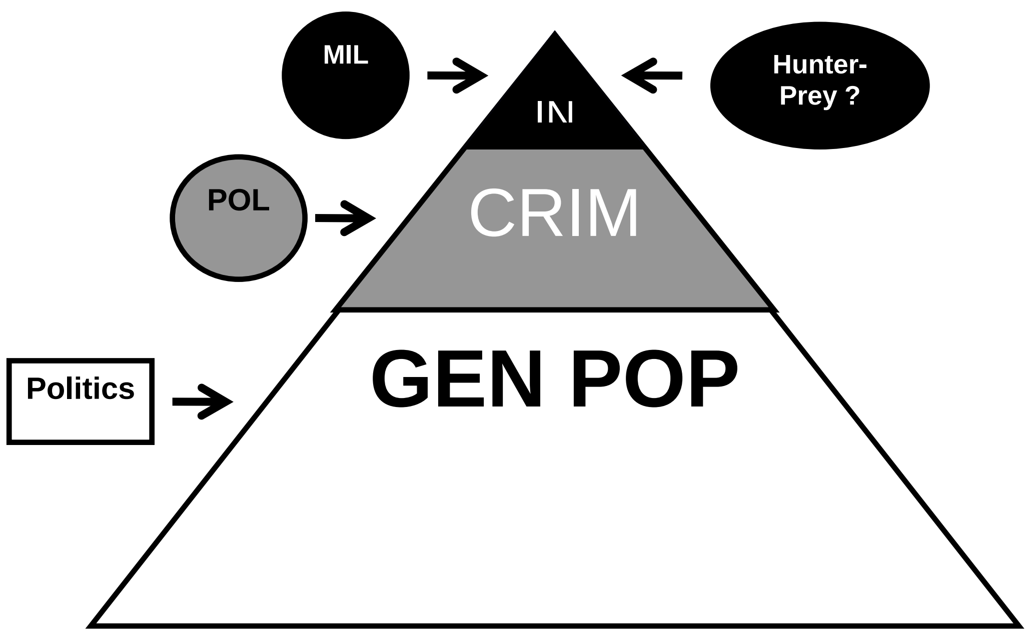

Figure 1. General population pyramid and its interactions during a counterinsurgency.

The Lotka-Volterra "growth" equations for Authority and Rebellion describe how predator and prey populations change in size based on natural birth and death rates and the interaction between predator and prey. The notion of predator and prey fighting to "win" is attractive on its surface. The key question is: Does this biological model accurately depict the interactions and relationships between Authority and Rebellion in a COIN ecosystem?

Numerous assumptions accompany the Lotka-Volterra predation model. Some are non-negotiable while others can be accounted for by making adjustments such as adding new variables. Five key assumptions are:

- Prey population growth is limited only by predation
- Predator is a specialist that can persist only in presence of prey
- Individual predators can consume an infinite number of prey
- Random encounters occur in an homogenous environment
- There is a closed system with no migration

In natural systems of animal predators and prey, these assumptions often hold true - at least insofar that their violation does not severely disrupt the outcome of the system. However, in COIN, the actors (Rebellion and Authority) most likely violate these assumptions to the point of the model not being effective. For example, the Rebellion population is probably limited in size by more factors than the Authority kill rate. Furthermore, the Authority population does not receive a genuine positive (+) benefit from killing Rebels (with regard to population size/growth) and indeed can persist without the Rebellion. There is most likely some degree of migration for the Rebellion and Authority in and out of the contested area (although this particular situation can be alleviated by modifying the model to account for this). Finally, the environments within which Rebellion and Authority encounter each other are always heterogeneous, and encounters are often non-random. To summarize, the ecological predation model framework is probably oversimplified and not very useful for understanding COIN.

The overarching problem with the relatively simple two-species interaction models (like predation interactions) is that they do not include the major aspect of COIN that distinguishes it from conventional warfare: the role of the general Population in the success or failure of the Authority and Rebellion. A successful COIN campaign is not won when the most Rebels are killed; rather, it is won when the most "political space" is controlled. The Authority does not "grow" when a Rebel is killed as the predation "growth" equations maintain. Both Authority and Rebellion can grow in some sense when they win the hearts, minds, and acquiescence of a member of the general Population (Figure 2). This individual will effectively "join their side" and increase their population size.

Another class of ecological models, competition models, take this into account and may be more useful for describing the complex conflict ecosystem of COIN.

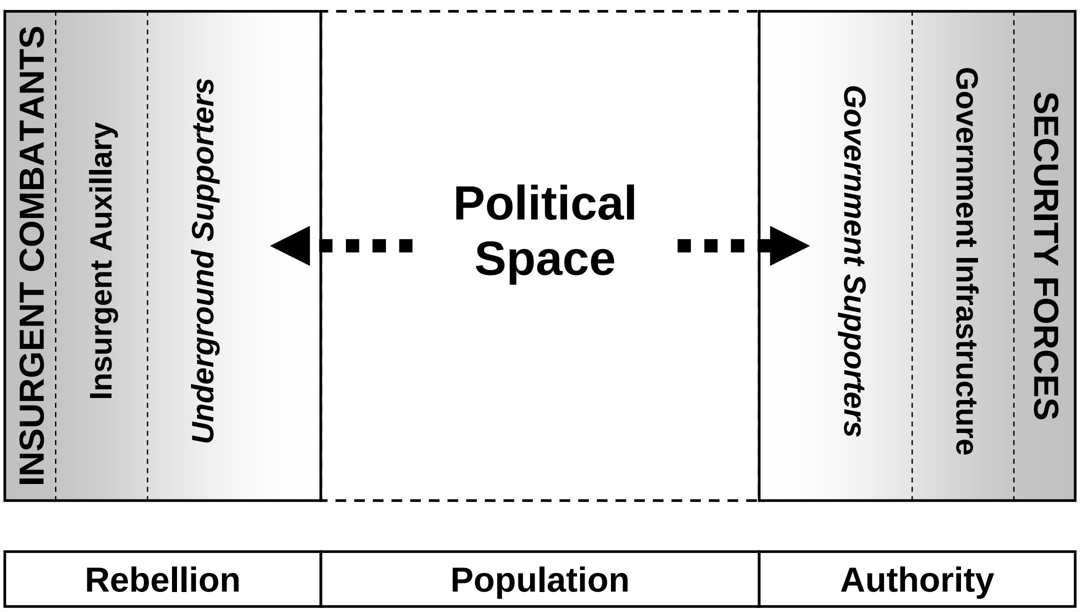

Figure 2. Competition between Authority and Rebellion over the Population.

Competition models: Parts of the whole

COIN is more than killing insurgents. Killing the enemy is not the primary objective; rather, it is to out-compete challengers to control political space made up of the general population's hearts, minds, and acquiescence (Figure 2). The Authority can be viewed as a coalition of Security Forces, Government Infrastructure that supports the Authority, and persons in the Population that firmly support the Authority. Similarly, the Rebellion can be seen as the group containing actual Insurgent Combatants, the Auxillary forces that directly support them, and Indirect Supporters in the Population make up the "Underground" movement that opposes the Authority but does not directly fight. In the middle are the undecided general Population.

Hence, access to and control of the general Population in the center of Figure 2 is what the competition between A and R is about. Luckily, there is another class of ecological models which may in fact be relevant and useful, however: models of competition for resources between two species.

Ecological competition models can be seen through the prism of COIN as more "inclusive," taking into account not only the insurgents and counterinsurgents but also the larger civilian Population within the contested area. Calculations based on historical COIN data suggest that insurgents and counterinsurgents as a percentage of the AO population is very small. Typically, reliable data from COIN is hard to come by, but, where information is available, insurgent combatants have comprised 0-1% of the overall population, and counterinsurgents or security forces amounted to 1-2% of the population. Hence, by ignoring 97% of the persons in the area of conflict – among other reasons – simple ecological models like those describing predator-prey interactions lose much of the realism contained within the unconventional warfare of COIN.

Competition in nature comes in a number of forms, and ecologists have developed different mathematical competition models to describe them. One example is "exploitation competition," described as the negative (-,-) interaction of two (or more) species over a limited resource within the environment. The species *indirectly* "harm" each other by using non-renewable resources that the other species needs. In nature, for example, this resource might be food – an item that can ultimately constrain the local population growth rate of each species. However, this common form of competition in nature does not accurately describe what occurs between the Authority and Rebellion during an insurgency, because the numbers of opposing forces do not grow in direct relation to how many "hearts and minds" are won over. Furthermore, the "Competitive Exclusion Principle" of competition states that (in a simple system with two species competing for a single resource in a homogenous environment with no other interactions) two species cannot compete for the same limiting resource for a long period of time.

A simple extension of exploitation competition is more realistic and applicable. Termed "interference competition," it occurs when species seeking a resource harm each other when gathering it, even if it is not in limited supply.[13] Here, there is indirect competition for a limited resource and direct competition between the competitors for access to the resource (the interference). A simple and amusing human analogy is a competition between a couple on a date sharing a milkshake with two straws. In an exploitation competition, the winner drinks more of the milkshake. In an interference competition, both people drink, but one person pinches the other's straw.

For our purposes, there are three "species" or actors involved – Authority (A), Rebellion (R), and Population (P). A preys on R, and both compete for access to P (a precursor to winning support: a means to an end). Such "competition for access" to P can be considered predation for the purposes of this model. After Okuyama and Ruyle's diagram,[14] this three-actor "food web" is depicted in Figure 3.

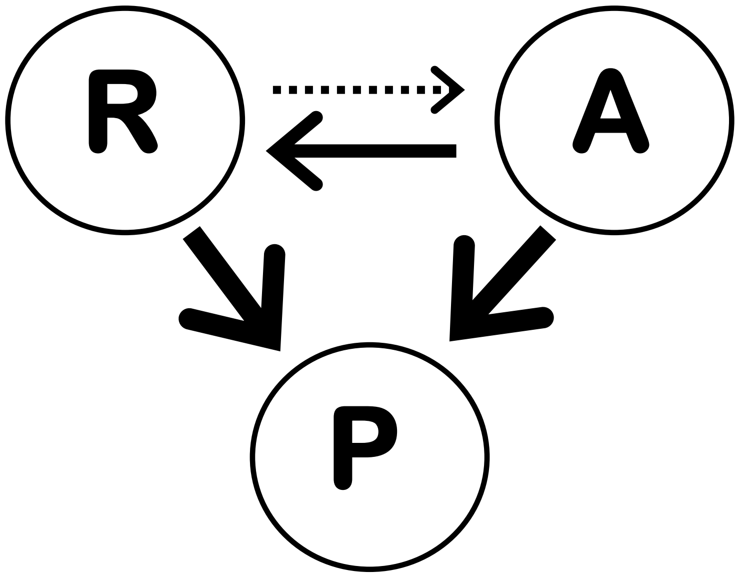

Figure 3. Ecological relationships in the Authority, Rebellion, and Population "food chain".

Generally speaking, the interference competition model is more realistic than others we have considered and dismissed because it more accurately describes the complicated "food web" of COIN. In interference competition, species are not classified strictly as a "competitor" or a "predator" but rather can play multiple roles across time and space. This is most likely the rule in nature, not an exception.

Unfortunately, from the standpoint of COIN, interference competition can allow, and even promote, coexistence of competitors on a shared resource. This is in contrast to exploitation competition, where in theory the Competitive Exclusion Principle would hold and one of the competing species would go extinct. In fact, with interference competition, assuming that the Competitive Exclusion Principle operates and that one species (Authority) is the "top predator" over the other competitive species (Rebellion) in order for coexistence to occur, the Rebellion must be better at competing for the resource. This is what we tend to see in COIN campaigns that lead to stalemate or loss for the Authority. Obviously, if the Authority is better at preying on the insurgency and is equally good at competing for the Population, the Authority will win.

There are some additional assumptions made in order for these types of interference competition models to work. One is that the resource being competed for is in limited supply; else, there would be no competition. This is a reasonable assumption for COIN, particularly when viewed at a smaller-than-nation scale (e.g., a district).

Another simplifying assumption of these competition models is that there is a "closed system". (This is an assumption of most every simple model.) In other words, the Authority and Rebellion receive no exogenous support. This is most likely violated in a majority of cases. Indeed, it has been wagered that rarely does an insurgency survive without exogenous support.[15] Such "migration effects" are also common to animal systems and can generally be accounted for with additional variables/factors (*i.e.*, migration rate of R in and out of the system) in the primary sets of equations. Migration, if it occurs, may not matter if its rate is low. It may also occur in some parts of the AO and not in others, allowing the model to be more accurate in some provinces than in others.

The reality of counterinsurgency – for example, the current war in Iraq – can certainly involve multiple actors (*i.e.*, multiple simultaneous Rebellions). Although outside the scope of this paper and more mathematically intensive, the three-way interaction outlined above (Figure 3, with A, R, and P) can be extended to *N* groups using matrices and can incorporate additional features.[16]

The above scenario relies on the simplifying assumption that the Authority preys on the Rebellion unidirectionally. This assumption is perhaps reasonable if we suppose that Authority manpower is easily replaced (or substantially more easily replaceable than that of the Rebellion). If this assumption is relaxed - if we allow the Rebellion to *substantially* prey on the Authority - the model becomes more complex. Of course, each "predator" cannot prey on the other equally, and thus one can assume for the sake of the model that A is the “top” predator in the system, and effectively R does not prey on A.

It is important to note that there can be benefits or costs to successful A predation on R. The key point is that in this competition model, the goal is to obtain access to the resource (P); A predation on R is only beneficial inasmuch as it increases access to P. Looking at Figure 3, there can be direct and indirect feedback to A due to direct predation on R.

All things considered, interference competition models from ecology are a relatively simple quantitative approach to modeling, understanding, and perhaps predicting COIN at a very simple, fundamental level. However, in order to make a more realistic model, many factors need to be changed or added, and it is still not clear that some of the fundamental assumptions (*e.g.*, logistic growth rates) are realistic or meaningful. In addition, all of the detailed mechanism of *how* predation and competition occur have been left out!

Luckily, some ecologists have felt the same way about their systems of study and have pondered the same issues, even though the Lotka-Volterra competition framework has been generally useful for decades. There is another more advanced and more newly developed class of ecological models that may be useful for COIN based in game theory.

Fight or Flight: Adaptive Dynamics

Modeling competition between species that also simultaneously prey on one another (“interference competition”) is complicated in comparison to simple competition without interference. Although many studies have observed interference competition in nature, formal models are still relatively rudimentary. One issue is that the individual behaviors that underlie the interference are quite varied and complex. Ecological population models, like the ones discussed above, do not take this array of behaviors into account.

These individual-level behaviors may have important influences on group behavior, something ecologists are only now coming to terms with. Similarly, differences in individual ability, competitiveness, experience, social interactions, and similar factors may have influences on overall group success.

An alternative approach to the Lotka-Volterra population models is based in the field of mathematics called game theory.[17] The key difference between ecological population models and game theory models for effectively modeling the same behaviors is that population models expend with biological detail for simplicity while game theory ignores underlying "genetic detail" (the "how" of behavior) but utilizes ecological realism to describe the system.

There are two new key incorporations beyond the competition model. First, individuals can be in different behavioral states at different times (e.g., searching, handling, fighting), incorporating a mechanistic reality into the model. These states and actions occur at certain frequencies, and the frequency at which one actor (say, Authority) is doing something ("searching for Population members to influence") may depend on the frequency with which the other actor (say, Rebel) is doing something else ("hunting for Authority troops"). Second, individuals weigh the gains and losses from each action (as much as that's possible) and then attempt to perform the optimum behavior based on their state and the state of an interacting individual.

"Adaptive Dynamics" is effectively a combination of game theory and population biology and is a relatively new area of study (~10 years old). It is now being used in ecology and other fields to study complex adaptive systems, involving a few moving parts and a discrete number of variables that when combined together have more complicated properties as a collective (so-called "emergent properties").[18] Such systems are those encountered both in nature and on a battlefield – some well-known examples of this are ants forming a bridge to cross a gap, and hundred of fish swimming in schools or birds flying in flocks.

A “decision tree” associated with this type of model is shown in Figure 4. The tree keeps track of all possible events and actions that could occur to a member of the Authority.[19] (The opposite can be done for events and actions of a Rebellion member.) In ecological competition, such trees are used to keep track of foraging behavior;[20] here, we modify this slightly. In our example tree (Figure 4), the Authority member is assumed to be in one of three distinct states: *searching* for a member of the Population to “consume” (*i.e.* win over to the Authority’s side), *handling* a member of the Population (*i.e.* talking to them, making deals, etc.), or *fighting over* a Population member with someone from the Rebellion (*i.e.* interference competition). This is an oversimplification but a useful one as it captures the general goals and strategy behind COIN.

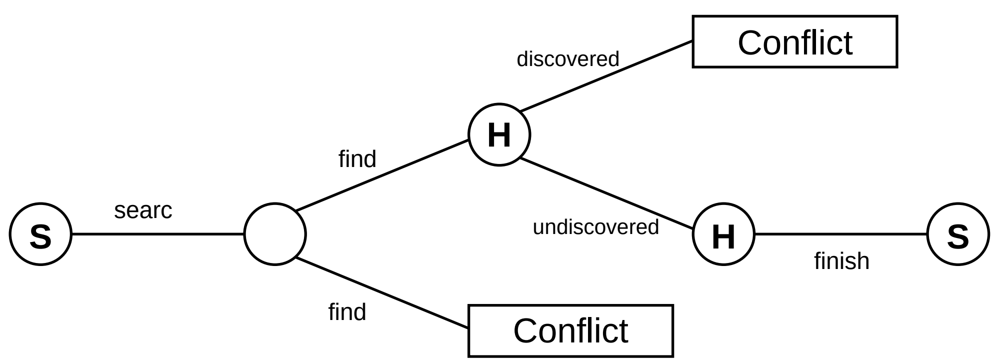

Figure 4. An example of a counterinsurgent’s game theory decision tree.

The states change according to events and choices that the Authority member faces. Sometimes the response to an event is predetermined, and sometimes an action requires a choice. Tradeoffs to decision choices include "energy" and "time", and so each decision has some consequence associated with it.

These decision trees intersect with game theory: For each decision, we know the costs and benefits associated with each choice/decision and the probability associated with each choice. From consequences and probabilities, a modeler can arrive at a "payoff function" that is associated with a given strategy. Generally, one follows a strategy which maximizes this payoff function.

For the purposes of mathematical analysis, these probabilities are variables. For example, the probability of being "discovered" by a Rebel while handling a Population member might be called κ; therefore the probability of not being discovered is $(1- \kappa)$, etc. In simulation studies, different reasonable values, hopefully based on actual field data, are tried for different variables, and in this way, a spectrum of outcomes can be determined from a number of variables.

In addition, within the "conflict boxes" shown in Figure 4, are "conflict decision trees" (not shown). Hence, the conflict box does not necessarily mean that a conflict occurs, only that it is possible for one to occur. Similar to the main decision tree, the Authority member can either "be careful" (*i.e.* avoid) or "dare" (*i.e.* threaten) the Rebel, and if a conflict ensues, it can either be won or lost. If won, the Authority can in theory continue to "handle" the Population member; if lost, the Authority is relegated back to searching (at best).

Because this type of model is essentially "designed around" the problem at hand, there are less assumptions to be violated by reality because there are more details incorporated into the model. However, these Adaptive Dynamics models also have their peculiarities. One, for example, has to do with the notion of a payoff. Every model of this type, even in ecology, must have some kind of short-term currency to approximate long-term cost or benefit of actions. In ecology and evolution, the payoff approximates reproductive “fitness,” which is the ultimate survival and reproductive power of a type of individual with a certain combination of genes, etc. In COIN, it is even harder to estimate the payoff associated with killing one Rebel or winning over one member of the Population to be pro-Authority. With regard to warfare, this is an area that must be given much careful thought.

Adaptive dynamics models, in the end, can offer predictions about the best strategies for providing the “highest payoff” when facing an opponent in a game who is expected to play a number of strategies with certain probabilities. It can predict consequences of various choices/actions and recommend strategies. This is conditional, of course, on the correct variables, states, and probabilities being included in the model.

Modeling war: what is it good for?

Models are, by definition, not reality. They are deliberate oversimplifications of reality constructed systematically to gain insight into how a complex system of interacting factors operates in principle. As in the theoretical study of complex systems and networks in, say, biology or economics, here we propose that models can serve as a (perhaps crude) framework for understanding fundamental components of COIN warfare.

Specifically, in this initial effort, we have borrowed a class of model from ecology called “interference competition” models, in which two species compete for a common resource while simultaneously one preys on the other, creating interference. On the surface, this closely resembles what we see in a COIN system – A conventionally powerful Authority (the “top predator”) competes with a Rebellion for access to political space comprised of control over the general Population, and at the same time, the Authority is directly preying on the Rebellion.

One general weakness with this kind of model is that biological realism of the behaviors involved is ignored for the sake of simplicity. For example, there is an assumption of interference without considering its mechanism or “adaptive value.” In nature, a given animal in one state might attack and in another state might flee. In this sense, individuals within species are treated like “aimless billiard balls” that randomly encounter each other and subsequently act aggressively. For many ecological purposes, this is okay; general insight about population dynamics can be gained while ignoring the realism of very complicated ecosystems. It is currently unclear how directly applicable this possibly useful model will be towards understanding the underpinnings of COIN.

As an alternative, we also considered a class of models based on game theory combined with population biology called “Adaptive Dynamics” models. This class of models is far more complicated but, as a worthy trade-off, also are more descriptive of the behaviors of individuals alone and during interactions than are the “Lotka-Volterra” models of competition (contrast Figures 3 and 4). While more difficult to work with, these models may in fact ultimately be better at describing the intricacies of COIN warfare. Ultimately, these Adaptive Dynamics models are most likely more useful. One caveat is that, unlike the century-old Lotka-Volterra competition models, Adaptive Dynamics models are a tenth the age and less developed and evaluated.

Neither of the proposed model frameworks is perfect. Assumptions are sometimes violated. Details are glossed over. Ties are drawn across vastly different areas of study. Metaphors are occasionally taken just a step too far. However, we think there is a good deal of value in this discussion. Our hope in introducing the topic of using ecological models to understand COIN is twofold.

One, we reason that “thinking like a biologist” can in itself provide food for thought with regard to studying and planning for COIN and other forms of warfare. Although comparing war fighters to foraging birds (for instance) may seem silly or juvenile on the surface, the problems that foraging animals face are literally life-and-death – they forage and find prey, or they die. Similarities between some forms of animal behavior and that of soldiers on patrol, for example, are striking, and therefore, there may be some genuine value in this line of thought.

Two, we believe that these models, or variations or derivations thereof, may be useful for sketching out the broad strokes of the behaviors that occur during unconventional warfare and can thereby capture some major elements of it, allowing for some general insights to be obtained. It is not immediately clear if a simple or complex model is best, nor is it clear whether descriptive and vague models or very specific models are the answer. It is furthermore not clear that there is "an answer."

There are additional, complicating issues with regard to utilizing ecology models in the study of unconventional warfare. These are not necessarily "problems" but things that should be taken into careful consideration before or during application of these models. One issue is "scale-dependence." The dynamics of interaction between A, R, and P depend on the scale one looks at. To some extent, there is also an issue of "density dependence", a complicating and common issue in population ecology. Some models may apply at one scale (town) but not at another (nation). Larger scales may also hold more heterogeneity, etc.

Another issue is "asymmetry of support." By this we mean that, in order to be judged as "successful", A and R require different levels of popular support. In ecological terms, R needs to consume less of P than A does to maintain equality. At present, it is not clear to us if or how a model needs to be modified to take this into account.

A final issue of note is "means versus will." The model only addresses the means to fight but ignores the reality of political will to keep fighting. This again may be asymmetrical with A finding it more difficult to maintain political will, particularly as an occupying force. Like asymmetry of support, it is not clear if this is a factor that can be ignored with regard to the models.

The general discussion of utilizing ecological models to model warfare leads to some other matters for discussion. One of these matters, with regard to COIN, is a debate about the proper or necessary ratio of Authority troops to those of the Rebels or, alternatively, those of the Authority to members of the Population in the AO. Both traditional and modern books and manuals recommend a ratio of 10-20:1 for A:R and 20-25:1000 for A:P.[21] This is largely based on experiences from previous COIN campaigns, which are generally dated. Additionally, historical data indicate that there is not necessarily a direct relationship between the ratios and relative success. It is possible that further quantitative analysis using models like the ones presented in this paper could shed light on this issue. We have no conclusions as of yet. However, the "validity" of using predator-prey vs. competition models, as explained above (see Figure 1), seems to suggest that "hunting insurgents", "policing criminals" and "political control" are not easily separable.

Through all of this, a key general issue is, how does one measure success in COIN? We ascertain that "access to the population" is a means to the end goal of "support of the population" via the cliché of winning their hearts, minds, and acquiescence. Within our ecological model of competition, this is represented as members of the Population effectively "joining" the Authority or Rebellion, thus increasing their population size.

In this paper, we have been asking how the study of warfare could benefit from ecology. But what about the reverse – Could the field of ecology benefit from the study of war? Hard science research often progresses in fits and starts by the whims of investigators' groupthink about what is "fashionable" (or fundable) at any given time. Often, the status quo remains until a tipping point occurs at which a majority of powerful scientists decide that a shift is in order. Some areas of ecological theory discussed in this paper are underdeveloped for no particular reason having to do with the usefulness of the models. More specifically, complicating factors such as adaptive behaviors, spatial heterogeneity, and prey refuges have generally not been incorporated into the theory and their effects on the system have not been well investigated. If these factors are critical to the understanding of COIN via ecology – and they well may be – initial work within the military community could stimulate ecologists to work on variants of these models, thus creating a circle of benefit for all involved.

There may be additional fields of study within the social sciences that can benefit from such work and may also contribute to it. One example is the recent thesis by Evans and Spies entitled, "Insurgency in the Hood: Understanding Insurgencies Through Urban Gangs." The authors suggest that it is very difficult to obtain unbiased, accurate data about insurgencies; it is easier to study organizations like gangs as a surrogate in order to gain insight to generalities of use to the war fighter. We further suggest that preliminary results from ecological models of COIN could be compared to data such as that from urban gangs which, at a fundamental level, operate somewhat like insurgencies.

Finally, we can consider these questions: What does modeling COIN using ecology mean for war fighters? Or war planners? Are the models useful for determining how to win, how not to lose, or how to avoid Pyrrhic victories? How should/could lessons from biology be incorporated into war fighter education, training, and doctrine? This paper has raised more questions than it has answered. Some of them are: Are the variables in the ecological models measurable in COIN? Is there accurate data, and is it specific to a single insurgency? What are the relevant outputs of these models? Will the outputs be descriptive, or prescriptive?

In the end, we return to the idea stated at the beginning of this paper – Biology is more than laboratory science; it is a way of thinking about the natural world. An increased emphasis on adaptation, evolution, behavior, metaphors, and models in these areas would have great benefits in the new climate of conflict in the early 21st century.[22]

Notes

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[2] See, for example, David Killcullen, "Counterinsurgency Redux," *Survival* (Winter 2006-07),Vol 48, No. 4, pp. 111-130, and "Twenty-eight Articles: Fundamentals of Company-Level Counterinsurgency," Joint Information Operations Center, Australian Army, Summer 2006, pp. 29-35.

[3] See for example, Raphael Sagarin, "Adapt or Die: What Charles Darwin can teach Tom Ridge about homeland security," *Foreign Policy* Sep/Oct 2003, pp. 68-69; Ori Brafman and Rod A. Beckstrom, *The Starfish and the Spider* (2006), Penguin Group, New York; Mark D. Drapeau, "Fishing for Terrorist Starfish," *The Washington Times* Commentary 31 July 2007, p. A16; Richard Dawkins, *The Selfish Gene* (1976). Dawkins' biological metaphors include the transmission of ideas (usually from human to human) in units called "memes," which are akin to the better known genes – which transmit hereditary information from parent to offspring. See also the very recent book, *The Black Swan: The Impact of the Highly Improbable*, by Nassim Nicholas Taleb (2007), Random House, New York.

[4] See "Counterinsurgency Redux," note 2. Some additional biological metaphors used it the paper are "self-synchronizing swarm[s] of cells," "the war of the flea," the notion of a "complex conflict ecosystem," and "competing entities [maximizing] survivability." Also, from the same author Killcullen (2006) Three Pillars of Counterinsurgency, remarks delivered at the U.S. Government COIN Conference, Washington DC, 28 Sept 2006, there are terms such as "model," "environment," "survivability," "evolving," "adapting," and "predator."

[5] See the very interesting commentary on this by John A. Nagl, 2002 (2005: 2nd ed.), *Learning to Eat Soup With a Knife: Counterinsurgency Lessons from Malaya and Vietnam*, The University of Chicago Press, Chicago, IL. The title is partly a quotation from *Seven Pillars of Wisdom* by T. E. Lawrence ("Lawrence of Arabia") – "To make war upon rebellion is messy and slow, like eating soup with a knife."

[6] Nathan Leites and Charles World, *Rebellion and Authority*.

[7] The first quotation is from the Australian *Joint Services Glossary*; the second from Gordon McCormick of the Naval Postgraduate School (2007), Things Fall Apart: The 'Endgame' Dynamics of Internal Wars, RAND paper; and the final quotation is from David Killcullen (2006) Three Pillars of Counterinsurgency, remarks delivered at the U.S. Government COIN Conference, Washington DC, 28 Sept 2006.

[8] The U.S. Defense Department's 2006 Quadrennial Defense Review (QDR 2006) notes that transforming the DoD to a state in which it is prepared for unconventional warfare is a major priority.

[9] See "Counterinsurgency Redux," note 2.

[10] Alfred J. Lotka (1925), *Elements of physical biology*, Williams & Wilkins Co., Baltimore, MD. Vito Volterra (1926), Variazioni e fluttuazioni del numero d'individui in specie animali conviventi. Mem. R. Accad. Naz. dei Lincei. Ser. VI, vol. 2.

[11] See for example, Toshinori Okuyama and Robert L. Ruyle (2003) Analysis of adaptive foraging in an intraguild predation system, *Web Ecology* 4: 1-6, and note 24.

[12] See for example, Nicholas J. Gotelli, *A Primer of Ecology* (1995), Sinauer Associates Inc., Sunderland, MA, Chapter 6.

[13] James T. Quinlivan, 1995, Force Requirements in Stability Operations, *Parameters* Winter 1995, pp. 59-69. Accessed August 2007 at: http://carlisle-www.army.mil/usawc/Parameters/1995/quinliv.htm.

[14] This is also often called "intraguild predation," or IGP. The most simple definition is probably, "a form of competition that involves a fight or other active interaction among organisms," from:

http://www.biochem.northwestern.edu/holmgren/Glossary/Definitions/Def-I/interference_competition.html(accessed 2 Aug 2007).

[15] See Figure 1 of Toshinori Okuyama and Robert L. Ruyle (2003), note 23.

[16] G. A. Polis, C. A. Meyers, and R. D. Holt. 1989. The ecology and evolution of intraguild predation: potential competitors that eat each other. *Annual Review of Ecology and Systematics* 20: 297-330; M. Arim and P. A. Marquet. 2004. Intraguild predation: a widespread interaction related to species biology. *Ecology Letters* 7: 557-564.

[17] See Nagl (2002), note 5, p. xvi.

[18] See http://en.wikipedia.org/wiki/Lotka-Volterra_inter-specific_competition_equations/, accessed July 30, 2007.

[19] See also Toshinori Okuyama and Robert L. Ruyle (2003), note 23, for incorporating the “antipredator behavior” of prey into interference competition models.

[20] Wouter K. Vahl, G. Sander van Doorn, and Franz J. Weissing, “unpublished manuscript”, Ch. 6 in Wouter K. Vahl, Ph.D. dissertation, University of Groningen. See also, F. Huntingford and A. Turner, 1987, *Animal Conflict*, London: Chapman and Hall.

[21] See also P. H. Crowley (2000), Hawks, doves, and mixed-symmetry games. *Journal of Theoretical Biology* 204: 543-563.

[22] Jaap van der Meer and Bruno J. Ens, 1997, Models of interference and their consequences for the spatial distribution of ideal and free predators. *Journal of Animal Ecology* 66: 846-858.