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To facilitate military operations in a megacity, it is first important to understand how congested and densely populated environments react when predators disturb their ecosystem in search of resources. This research explores the megacity by extrapolating key concepts from invasion biology and social science to explain how resource dependency affects the ability of external predators to invade densely populated environments. In section one, a literature review provides the reader evidence that resource constraints in a megacity have the propensity to perpetuate conflict. Section two uses invasion biology and agent based modeling to observe and describe the interconnectedness that exists between a megacity's population, resources, and predators, which seek to exploit those resources. Section three expands on the overall conclusion from section two, which is that densely populated environments and the complex networks that support resource allocation and distribution to the population exist in a delicate, symbiotic balance. Section three also introduces the reader to a proposed operational concept. T

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Executive Summary

Title: Symbiotic Warfare: Resource Competition and Conflict

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Thesis: Densely populated and congested environments rely on robust resource allocation networks and distribution pathways that future agglomeration populations (predators) will attempt to disrupt in order to exploit resources. The military's future role in megacity warfare is to provide undisrupted flow of resources to the population in order to neutralize predation threats.

Discussion: Future conflict is likely to erupt as the result of a competition for resources between actors. Relating back to the basics of supply and demand, those without sufficient abundance of supply will target and exploit others to gain access to resources. If worldwide demographic trends continue, actors struggling for resource demands are likely to find themselves doing so in a megacity. The congested and densely populated environment of the megacity requires more than just analysis of infrastructure and urbanization if the military plans to conduct effective operations. Defined as predators, agglomeration populations use violence and disruptive means to acquire resources. These predators, which have no political motivation, seek only to control and manipulate resource allocation networks and distribution pathways to achieve their ends. The population itself is just maneuver space. However, predators that seek to exploit or harvest resources within a megacity face an enormous challenge. Concepts extrapolated from invasion biology and ecology prove that the best means for neutralizing predation threats in densely populated environments is by leveraging the local population itself. If predators aim to use the population as maneuver space, then leveraging the population to destabilize a predator's maneuver becomes the objective. A secondary objective in order to neutralize predators is for the military to ensure the population retains its access to resources. Scientific studies prove any disruption to resource allocation networks or distribution pathways will destabilize the community and afford predators the opportunity to nest, disperse, and ultimately invade.

Conclusion: A thorough literature review and the use of adaptive behavior modeling proves two hypotheses: 1) the host population affords the best mechanism for neutralizing resource predation threats, and 2) mapping the invasion pathway affords military planners the ability to identify critical vulnerabilities in the population, resource allocation networks and distribution pathways, and within the predators themselves. Proposing a new operational concept titled, the Symbiotic Warfare Operating Concept , the SWOC affords community and military planners the ability to identify and exploit intervention points for tactical and/or strategic gain while providing military planners a capability assessment to identify deficiencies for conducting operations within a megacity.

DISCLAIMER

THE OPINIONS AND CONCLUSIONS EXPRESSED HEREIN ARE THOSE OF THE INDIVIDUAL STUDENT AUTHOR AND DO NOT NECESSARILY REPRESENT THE VIEWS OF EITHER THE MARINE CORPS COMMAND AND STAFF COLLEGE OR ANY OTHER GOVERNMENTAL AGENCY. REFERENCES TO THIS STUDY SHOULD INCLUDE THE FOREGOING STATEMENT.

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Abstract

To facilitate military operations in a megacity, it is first important to understand how congested and densely populated environments react when predators disturb their ecosystem in search of resources. This research explores the megacity by extrapolating key concepts from invasion biology and social science to explain how resource dependency affects the ability of external predators to invade densely populated environments. In section one, a literature review provides the reader evidence that resource constraints in a megacity have the propensity to perpetuate conflict. Section two uses invasion biology and agent based modeling to observe and describe the interconnectedness that exists between a megacity's population, resources, and predators, which seek to exploit those resources. Section three expands on the overall conclusion from section two, which is that densely populated environments and the complex networks that support resource allocation and distribution to the population exist in a delicate, symbiotic balance. Section three also introduces the reader to a proposed operational concept. Titled the Symbiotic Warfare Operating Concept (SWOC), the SWOC suggests the best mechanism to neutralize external predation threats comes from understanding that a predator's survival depends on its ability to use the local population as maneuver space. Thus, the objective of the military in a third party intervention role becomes protecting resource allocation networks and distribution pathways to ensure those networks and pathways remain open to the population. Section three concludes with a military capabilities assessment, which reveals the military is doctrinally, technologically and tactically ill-equipped to operate within the megacity.

Section One: How Constraint Perpetuates Violence

Introduction

Most research on future war analyzes conflict at the macro level using empirical evidence of recent conflicts to suggest that future war will continue between states against non-state actors.[1] While macro-level analysis may be useful in trending patters of conflict over time, the research fails to address the obvious and overwhelming demographic trends that will change the landscape of future battlefields.

Megacities and their congested environments present new challenges for the military. Densely populated and congested environments rely on robust resource allocation networks and distribution pathways in order to meet the resource demands of the megacity population. Thus, military planners cannot ignore the delicate balance that exists between the population and resources within a megacity. Only through a micro-analytical approach can military and civilian planners adequately determine intervention points to neutralize external predation threats. Thus, whether future threats manifest themselves by non-state actors or by state actors becomes entirely irrelevant, as the battlefield on which actors will conduct operations will be the megacity.

Problem/Puzzle

While most research proposes concepts and frameworks that characterize the social and environmental aspects of cities,[2] this literature review explores the marriage between ecology and sociology to describe the interdependencies that exist between city populations and their urban ecosystems. Researching how populations behave when adversaries (which are defined as state or not state actors who disrupt a community's ecosystem to exploit resources) affords

military planners the ability to identify and exploit intervention points for tactical and/or strategic gain.

Literature Review

According to William Catton, "natural systems have limits of tolerance that produce an ensemble of interacting constraints on human action."[3] In his essay, Catton argues that collective behavior theory, when coupled with an understanding of ecosystems, explains how people and societies respond (behave) when faced with urban resource deficits. For Catton, the potential for conflict increases in conjunction with a state's increase in the use of legal governance as a means to regulate competitive consumption of natural resources. Thus, scarcity of resources will drive individuals and entire societies (beyond states) to engage in networked exchanges as a method of adapting to anticipated competitive encounters.[4] According to Catton, as urbanization increases the demands on natural resources, urban societies will confront an eventual scarcity of resources derived from indispensable biological systems (such as forests, cropland, grazing lands, and fisheries).[5] Acting collectively, states and individuals within a society will seek to justify their actions to control and harvest resources. Such 'pre-emptive' aggression manifests itself as competition grows because of resource capacity deficits.

Violence may arise at the state or city-level if panic occurs. For clarification, social science defines panic as "the aggregation of how groups behave when demoralization occurs due to events departing radically from culturally instilled expectations."[6] Panic ensues due to either perceived or actual resource deficiencies.[7] If panic occurs, individual actions cease to be concerned with group interests and individuals become preoccupied with self-preservation.[8] The normal mode of panic manifests itself in the form of crowds, which occur when individuals congregate collectively to express individual interests.

Depending on which social science theory one subscribes to, crowds behave either rationally or irrationally. For sake of argument, sociologist N. J. Smelser's "value-added process" theory of collective behavior promotes a sound argument that not all crowds act irrationally.[9] According to Smelser, and complemented by Catton, crowds (even rational crowds) may resort to violence due to an increase in panic that manifests itself when strain manifests. Strain, in an urban setting, arises when commercial and governance mechanisms do not aggregate enough resources to sufficiently relieve strain. Thus, strain, whether actual or perceived, can lead to violence if the strain on a particular system (in this case, resource system) is not relieved. According to Smesler, and promoted by Catton, a containing entity can only relieve panic by ensuring routes of escape from threat are identified, left completely open, or are perceived to remain open to the public. Thus, a perceived or actual strain on an urban ecosystem will cause panic, which may manifest violence if a controlling entity or governance system cannot alleviate or contain the strain on resources. In a megacity, strain is the result of resource scarcity. In an urban context, scarcity includes strains on whatever commodities are essential to daily living (money, groceries, and fuel).[10] Thus, strain on resources from an actual or perceived threat may lead a population to resort to violence as a matter of self-preservation. Violence will disrupt the resource allocation networks and distribution pathways controlled by the city and state. If the networks and pathways become vulnerable to attack, primary and opportunistic "predation" of resources may occur.

Predation of resources in a densely populated environment may increase the propensity of violence against civilians. The trend of increasing civilian violence may continue. For example, social scientists, such as Monika Heupel and Berhard Zangl offer macro-level analysis of how warring parties have increasingly propagated violence against civilians over the last few

decades.[11] Heupel and Zangl explore validating the hypothesis that fragmentation of warring parties and the economization of their war motives facilitate the application of brutal violence against civilians.[12] Thus, new wars are different from old wars in that agglomeration populations act as warring parties and wage wars against states. In contrast, old wars were characterized by a state waging war against another state—even if done by proxy. Still seeking an overall political objective, Heupel and Znagle categorize agglomeration populations by their economy, motives, and strategy. Their research uses case studies from Cambodia, Afghanistan, Angola, Somalia, and Sierra Leone to characterize how warring parties conduct violence. Heupel and Zangl's conclusions suggest ideological and identity-based motives of warring parties generally did not disappear, but increasingly merged with economic motives. Furthermore, their study reveals a troubling trend. Drawn from empirical and case study evidence using several of the aforementioned case studies, agglomeration populations operating in densely populated environments have increasingly relied on strategies that entail brutal violence against civilians.

Thus, drawing parallels between densely populated societies and megacities makes for an easy transition. Under the megacity scenario, warring parties would commit an intentional disruption of the ecosystem to acquire/and or control resources and related commodities. Regardless of their motives or claims of legitimacy, warring parties in a megacity will operate amongst and within the population in an effort to disrupt the balance of the ecosystem and manipulate the resource allocation networks and distribution pathways that supply a city. Based off this analysis, a definition for the term "predation" reveals itself. Predation is an act committed by agglomeration populations (termed predators), which seek to control or exploit a community's resources.

In a predation scenario, predators will increase violence targeted at civilians. Referring back to the aforementioned empirical study, the propensity towards civilian violence occurs for three reasons. First, agglomeration populations that either maintain criminal war economies[13] and/or heavily rely on other criminals are more likely to employ brutal warfare strategies because activities (such as looting and blackmailing) normally entail violence against the local population. Second, with the shift toward economic (resource) motives, agglomeration populations will no longer fight for interests of the local population, lowering the agglomeration population's inhibitions to commit violence. Third, as an agglomeration population loses the ability to control individual factions, brutal violence against the local population caused by the fragmentation of the agglomeration population itself.[14]

Other scenarios that threaten urban ecosystems beyond predation require analysis and mention. For example, natural disasters illicit a different social network response when their community is threatened. Interestingly enough, research illustrates that people and nations are likely to react as a "disaster community" exhibiting the same types of behaviors as communities and societies that experience imposed (intentionally manipulated) resource constraints. [15] For example, in times of resource instability caused by natural disasters, initial behavior can be characterized by reacting in a brief stage of "immobility" where people respond in a way that they "under react to the event, failing to comprehend its magnitude" followed by an emphasis of "activity for activity's own sake."[16] In such a situation, cities, communities, groups, and/or nations that may potentially suffer consequences resulting from the natural disaster may become easy targets for outside predators seeking to exploit resources.[17] Whether through direct predation or caused by natural disaster, ecosystem analysis when coupled with collective

behavior theories affords civil and military planners the ability to predict behaviors of megacity populations when an internal or external threat disrupts a community's access to resources.

Understanding predation in a megacity context requires military and civilian planners to understand the megacity conflict environment, which according to Dr. David Kilcullen, is the result of three main drivers: urbanization, littoralization, and connectedness. Kilcullen describes connectedness by characterizing coastal cities as networked, connected, and linked. [18] Using demographics and incidents in Somalia to reinforce his claims, Kilcullen suggests that networks are neither licit nor illicit and that "people self-organize in networks and engage in a complex hybrid of illicit and licit behavior that rides the connectedness of coastal urban areas."[19]

Zoning in on connectedness, Kilcullen's essay brings up several interesting points. First, he offers a conceptual framework model that one can use to visualize the interdependencies of and connectedness between a city's periurban areas and key transportation nodes. In his concept, Kilcullen defines periurban areas as "the slums and townships around the margins of growing cities that account for a high proportion of new immigrants from the countryside." [20] Kilcullen also defines transportation nodes as "airports, intermodal logistics hubs, container terminals, free trade zones, and seaports." [21] Transportation nodes are usually located in periurban areas. Transportation network workers also live in periurban areas. Furthermore, periurban areas experience weaker governance, increased crime, poverty, and unemployment, and often suffer greater shortages of food, fuel, electricity, and water.[22] Fusing Kilcullen's argument with Catton's, Smelser's, and Huepel and Zangl's theories, conflict could spark violence if panic and/or resource capacity deficits grow and/or predators exploit transportation nodes. [23]

Categorizing future threats, Kilcullen comes to the same conclusion as Catton and Smelser suggesting future predation threats will manifest from both irregular actors and methods.

The gravest future threats will come from irregular actors (agglomeration populations) who avoid direct confrontation with military and police forces. These non-state armed groups (predators) will employ stealth, operate in small teams, and combine tactical initiative with local knowledge. [24] In this type of scenario, the population becomes maneuver space itself.

Furthermore, manipulation of networks (whether social, transportation, or economic) will be the source of hybrid threats.[25] While all of these threats require some level of manipulation of activities within a megacity, governments (like the United States) must clarify legal distinctions between warfare and law enforcement in order to promote enhanced cooperation. Kilcullen suggests capabilities that combine policing, administration, and emergency services with sufficient military capability to deal with well-armed non-state adversaries are likely to be more effective than military or constabulary efforts alone.[26] Of note, Kilcullen also claims networks will be "nested" in the complex urban littoral environment, avoiding detection "by remaining beneath the clutter of urban development and overpopulation."[27] Thus, in addition to redefining roles and relationships of the military and constabulary, the military must adopt an operating concept that accounts for the symbiotic nature of the megacity population in relation to its resources. Only by holistic analysis can military and civilian planners determine intervention points available to assist a community effort aimed at neutralizing predation.

Kilcullen proposes three types of intervention points in his essay. First, he identifies and classifies supply-side interventions as those that ameliorate drivers of rabid urbanization and ease pressure on infrastructure. Second, he suggests demand side interventions, which are those that improve a city's resiliency to cope with pressures on its systems. Third, he categorizes framing-system interventions, which are those that alter the context of how the city develops, changing its interaction with national and transnational systems.[28] Operations and efforts targeted towards

intervention points provide planners a proactive versus reactive response. This proactive method supports Catton's claims and other social science research that illustrates how a resource controlling entity can manipulate a population's behavior by controlling resource allocation networks or distribution pathways. For military planners, intervention points are synonymous with resource critical vulnerabilities. As in nature, predation and the predation process is synonymous with invasion processes. Thus, military planners must map the invasion process to determine resource intervention points in order to assist communities in neutralizing predation.

Conclusion

Ecology and sociology research suggests that violence will erupt when resource constraints motivate a collective population (group, crowd, or warring party) to mobilize in order to manipulate control of networks directly related to resource allocation and distribution. Understanding how populations behave when internal or external threats disturb their ecosystems (intentionally or unintentionally) affords planners the ability to identify critical vulnerabilities in resource allocation networks and distribution pathways. These critical vulnerabilities serve as intervention points for military planners to use when attempting to neutralize a resource predation threat.

Redefined Problem Statement

Whether military planners generate operations to quell violence or strive to prevent it, planners must identify vulnerabilities in resource allocation networks and distribution pathways to ensure densely populated and congested communities have access to essential resources. Observing the invasion process via the use of agent-based modeling allows planners to draw conclusions about predation and the invasion process as it naturally occurs.

Section Two: When Predators Become Prey: Observing Characteristics of Invasion

The purpose of this case study is to use invasion biology agent-based models to observe the effects invasive species have on a community's (ecosystem) resources, infrastructure, and native population. Doing so allows researchers to draw parallels between biology and military science in order to conceptualize how an invasion of a megacity might occur. Invasion biology, which explores densely populated, congested environments, affords researchers numerous examples of how invasion affects a community.[29] Whether caused by invasive pathogens or intraspecific predation, invasion biology affords researchers the ability to study how populations in congested environments react to predators in the hope that a pattern of the invasion process will reveal itself.

Building on the previously conducted literature review, which concluded megacity warfare will occur due to a competition for limited resources, this case study uses the biological understanding of intraspecific competition (competition for resources between the same species) to draw conclusions about how adventive species (predators) may invade a megacity for the control of or manipulation of resources. This case study then summarizes the observations drawn from both empirical studies of invasion ecology as well as agent based modeling to illustrate how a community (a function of native population and habitat) responds to an invasion. Such conclusions may prove useful to military planners seeking to identify intervention points in order to assist a community in neutralizing predation threats.

Introduction to Empirical Study Review

Invasion biology expands beyond the study of the natural distribution patterns of living organisms to examine how non-native (adventive) species are introduced, spread, and interact with native species in an ecosystem.[30] In the study of invasion biology, most adventive

organisms are introduced to a receiving ecosystem as a result of human action.[31] Furthermore, the native population of an ecosystem historically maintains a competitive advantage over ecosystem resources resulting in the failure of an adventive species to establish occupancy.[32] Thus, the success of an invasive species is directly dependent on the ability of the native population (community) to control resources and/or prevent the adventive species from acquiring resources. Translating this to a megacity concept, this case study affords researchers the ability to test the hypothesis that the ability of the native population (community) to retain access to resources and deny those resources to predators directly correlates to a megacity community's ability to resist invasion from agglomeration populations (predators), which seek to exploit resources.

General Observations of Invasion Behavior

Biology affords numerous examples of why invasion (defined as the ability of predators to extort resources) succeeds or fails.[33] Scientists have proven that the vulnerability of a community's ecosystem is more crucial in determining whether invasion succeeds or fails more so than the biological characteristics of the predators themselves.[34] For example, studies illustrate that environments that are geographically and historically isolated; contain a low diversity of native species; exhibit high levels of natural disturbance or human activities; and illustrate an absence of co-adapted enemies (to include competitors, predators, parasites, and disease) are more susceptible to invasion.[35]

Ironically, the vulnerability of the adventive organism in relation to the ecosystem's native population explains why most invasions fail. For example, "established species with a substantial geographical range are sustained in part by the positive feedback effects of dispersal on local population dynamics."[36] Unless the local population permits an adventive organism

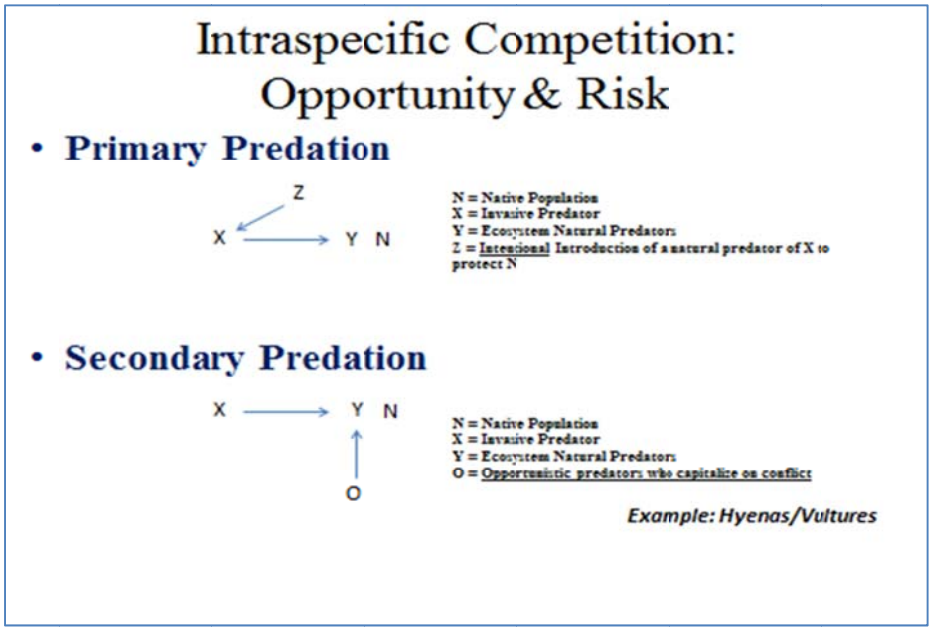
(predator) to disperse, the adventive species is subject to extinction.[37] As is the case with islands, which are the most vulnerable of ecosystems to invasion, an adventive, invasive species will "exploit the entire range of resources and habitats." [38] In order for invasion to be successful, an adaptive, invasive species must determine its capacity to exploit a particular resource against the spectrum of resources obtainable in the new habitat.[39]

Most observation and theoretical studies regarding the process of invasion emphasize the traits of the invaded community or habitat vice focusing on traits of the invasive species.[40] There is good reason for this. An invasive, adventive organism is only successful if it can "displace the native species or use empty or underused niches to establish occupancy."[41] Resource availability (the ability to control or gain access to resources) is the main limiting factor in the ability of a predator to invade. In a megacity scenario (as illustrated by invasion pathology, microbiology, and ecology), invaders target both vulnerable populations and pathways. Where the local population and resources are most vulnerable is where invasion is likely to occur.[42]

Scientists have also studied the effects of resource levels on invasion. Studies conducted by scientists such as Burke and Grime and Hueneke et al.[43] illustrate that as the native population's dependence on resources increases, the threat of successful predation actually decreases.[44] Notably, a community's codependency on and proximity to resources significantly impeded an adventive species ability to invade.[45] Thus, in a megacity where there exists a high density of population and a high codependence of resources, the determining factor for a predator's success relies in the predator's ability to control and desegregate the population from resources. Therefore, it is more advantageous to explore a community's vulnerabilities in resource allocation networks and distribution pathways more so than analyzing the characteristics of and targeting the predators themselves.

Interestingly, research has shown that natural or introduced (manipulated) predators have the potential to serve as a deterrent against an invading species. For example, one study proved that lizard predators impeded the establishment of spiders on islands and thereby deterred an adventive, invasive species from acquiring the resources necessary to establish a habitat.[46] In this study, the invasive species (predator) became the prey and the probability of invasion success was limited.[47] Translating this to a megacity concept, a third party or introduced natural enemy of the predator may prove successful if the local population embraces the third party and the introduction of the third party does not result in disruptive effects on the megacity's natural functioning (access to resources).

The graphic below illustrates the differences between natural and introduced predators into an ecosystem. Note that this case study limits itself to exploring intraspecific competition between natural and introduced predators that migrate to a habitat. This study does not attempt to analyze secondary, opportunistic predators that may come from within or introduce themselves to a habitat to capitalize on an adventive species invasion already underway.



Introducing more variables into invasion research, Miller et al. discovered that a variety of factors (migration, predation, and resource availability) influenced invasion capability of similar protozoans.[48] They manipulated resources available, accounted for the natural predators within a given ecosystem in relation to the invasive species, and introduced additional non-native predators to the ecosystem.[49] Their results validated the hypothesis that the probability of successful invasion is dependent on an ecosystem's resource availability, species interactions, ease of invasive species dispersal, and the invasive species' ability to react in the new habitat when third parties are introduced to counter the predation threat.[50] Drawing on parallels, in a megacity scenario, the probability of successful invasion by external predation correlates directly with a megacity's ability to provide resource control, target invaders through the use of native predators (such as law enforcement) as well as use introduced, welcomed predators (such as a third party intervention) to limit predator dispersal.

Predator-Prey Population & Models—NETLOGO (Wolf vs Sheep Manipulated Scenario)

If researchers regard the megacity as complex ecosystem and conclude that its ecosystem is susceptible to invasion by adaptive predators that possess the capacity to exploit resources, then researchers can further explore predator-prey interactions. By modifying both predator and prey variables and coefficients using NETLOGO software and applications, researchers can model predator-prey interactions with multiple variables. Predator-prey models, such as the Volterra-Lotka model of predator-prey interaction (logistics growth model), allow biologists to analyze how two interacting populations either grow or decline over time in the same habitat.[51] In normal predator-prey models, researchers observe a native population in a given habitat and then introduce a natural predator of that population to observe effects. Researchers commonly use a sheep (prey) versus wolf (predator) model to study predator-prey interactions. Using

NETLOGO software and applications, researches manipulate population of both predator and prey as well as observe the effects of predation when the amount of resources (grass) is increased and decreased.

One notable study extrapolated data from the wolf-sheep predator-prey model to foster a better understanding of guerilla warfare. Specifically, Michael Intriligator and Dagobert Brito analyzed intraspecific competition of predators by adapting the Volterra-Lotka logistics growth model.[52] By using a system of differential equations to account for population variables (the number of predators "x" at time t, the number of natural predators to combat "x" at time t, and the size of the prey population controlled by "x" at time t), they effectively adapted predator-prey model into a guerilla warfare model. In their study, they reassigned some of the native sheep populations to assume the role of a predator competitor against the wolf predator. Additionally, they set up a control that neither the reassigned sheep (predator population) nor wolf (secondary, invasive predator) would "feed" directly on the other but would grow in relation to its own population. In their model, they attributed fluctuations in wolf (invasive predator) populations to both manipulated recruitment and loss rates.[53]

The model effectively illustrated that the rule of thumb that uses the ratio of soldiers to guerilla forces as criterion for controlling predation success was flawed.[54] According to results, the ratio of natural predators (predator sheep) to the native, sheep (prey) population controlled by the wolves (invasive predators) must be above a certain value. This implied that the targeted variable for manipulation was not the population of the invaders or the natural predators designed to target the invaders, but that of the native population.[55] The ability of the predators (guerilla forces) to segregate the population from resources and limit soldiers' ability to secure resources for the population proved instrumental to the guerilla forces' success. Ultimately, their

study illustrated the important role both the native population and resource access plays in predation.

Using NETLOGO to observe the dependency of resources as a variable of predator-prey populations, this researcher extrapolated the predator-prey wolf-sheep model to observe how those interactions would take place in a resource-constrained environment.[56] In this model, the population of both predator and prey fluctuated dramatically in proportion to the amount of grass available for sheep consumption. Under stable conditions of the ecosystem, predator-prey populations fluctuated at a predictable rate; however, the introduction of resource depletion (as illustrated by burning the grass in the model) resulted in a rapid growth of predator to prey populations. Observing interactions, this researcher concluded that increased competition for resources between the predator and prey populations directly influenced the ability of the predator to disperse and increase its population size. Translating this to a megacity scenario, the research proves that a native population's drive to maintain control over resources directly limits the ability of predators to successfully invade.

To observe the behavior of predator-prey ecosystems when secondary (third party) predators introduce themselves to an ecosystem, this researcher explored a different NETLOGO model.[57] In this study, birds (predator) and bugs (native population) wander randomly around a landscape. Each step costs both species energy and both birds and bugs must consume resources (bugs must eat grass and birds must eat bugs and other introduced invaders) to replenish their energy. Grass grows at a fixed rate, and when eaten, this researcher deducted a fixed amount of resources from the resource patch. This researcher introduced mice (secondary predators) as invasive species to represent indirect competitors of the bugs. This researcher also introduced other disruptions, such as simulating a disease to remove a portion of the bug population or

burning down grass to remove the food source for bugs and invasive species. Overall, this researcher observed the natural population and the third party predators were successful in neutralizing the invasive threat of the unwanted predators as long as the third party predators did not disrupt resources necessary for the native population. The conclusions derived from this modeling event support general, empirical observations as well as other predator-prey and intraspecific competition results previously mentioned.

A summary of the conclusions drawn from previous research as well as this researcher's own studies in regards to both predation and invasion are mentioned in the bullet points below.

- The ability of the native population (community) to control resources directly correlates to the megacity's ability to resist invasion by an adventive species (predator).
- Environments that are: geographically and historically isolated; contain a low diversity of native species; exhibit high levels of natural disturbance or human activities; and illustrate an absence of co-adapted enemies (to include competitors, predators, parasites, and disease) are more susceptible to invasion.
- Invaders target both vulnerable populations and pathways. Where the local population and resources are most vulnerable is where invasion is likely to occur.
- It is more advantageous to explore a community's vulnerabilities more so than analyzing the characteristics of the predators themselves.
- A third party or introduced natural predator to counter an invasive species may prove successful if the host community embraces the third party.
- The probability of successful invasion by external predators correlates directly with the megacity's ability to provide resource control, target invaders by the use of native predators

(law enforcement) as well as use introduced, welcomed predators (such as a third party intervention) in order to limit predator dispersal.

- An opposing force should consider targeting and vying for control over the natural population vice seeking to capture or destroy invasive predators.
- The ability of the native population to maintain control over resources is directly dependent on the ability to mitigate the dispersal of predators.

Interdependency of Three Key Variables

All three models suggest a direct relationship exists between the ecosystem resources (proximity dependent), prey populations, and predator populations. Manipulating one variable proves to have dramatic consequences on the others. Therefore, researchers must take a holistic approach to understanding invasion.

When analyzing invasion, researchers must consider all three components: the predator, native population, and resources as dependent variables. The native population and resources (as well as the infrastructure essential to ensure the delivery of resources) combine to form a community. Researchers should think of the community as a habitat. A community resilient to predation is a community that ensures the natural population remains in control and in direct proximity to the resources essential to sustaining it.

In a megacity, where resource proximity and infrastructure are critical to ensuring the stability of a population, the determining factor for invasion is the community population. Therefore, military and law enforcement should focus efforts on securing the local population and protecting resources versus solely targeting or hunting predators. Participation of the local population and reducing vulnerabilities that exist in resource allocation networks and distribution pathways, ultimately affects predation success.[58] As invasion studies and modeling illustrate,

predators ultimately become the natural prey of the community in resource-constrained environments. The more densely populated the community, the harder it is for an adventive species to survive.

Section Three: Symbiotic Warfare Operating Concept

The Concept of Predation in Relation to Future Warfare

Future conflict is likely to erupt as the result of a competition for resources between actors.[59] Relating back to the basics of supply and demand, those without sufficient abundance of supply will target and exploit the supply of others. If worldwide demographic trends continue, actors struggling for resource demands are likely to find themselves doing so in a megacity environment. The congested and densely populated environment of the megacity requires more than just analysis of infrastructure and urbanization if the military plans to conduct effective operations. Actors on the losing side of the supply scale can be state or non-state actors, but ultimately these agglomeration populations have one strategy objective in mind: use the population as maneuver space itself in order to gain access to resources.

Defined as predators, agglomeration populations use violence and disruptive means to acquire resources. These predators, which have no political motivation, seek only to control and manipulate resource allocation networks and distribution pathways to achieve their ends. The population itself is just maneuver space. However, predators that seek to exploit or harvest resources within a megacity face an enormous challenge. Concepts extrapolated from invasion biology and ecology prove that the best means for neutralizing predation threats in densely populated environments is by leveraging the local population itself. If predators aim to use the population as maneuver space, then leveraging the population to destabilize a predator's maneuver becomes the objective. A secondary objective to support neutralization is the ability of the military to provide the population access to resources. Studies prove any disruption to resource allocation networks or distribution pathways will destabilize the community and afford predators the opportunity to disperse, scatter, and ultimately invade.

Overview

The Symbiotic Warfare Operating Concept (SWOC) describes how the future Joint Force will shape the megacity operating environment and neutralize threats acting as a complementary extension to an already existing, networked community infrastructure. The SWOC guides future force development by identifying capabilities the services will need to conduct operations in a megacity. To conduct operations in such an environment, the SWOC requires platforms and capabilities that must 1) facilitate military maneuver in congested and potentially contested environments in order to secure resource networks and distribution pathways vital to the population, and 2) minimize disruption to those resource networks and distribution pathways. Therefore, the SWOC vision of future warfare explores how the military will work in parallel with the local population and public service networks to ensure the uninterrupted flow of resources and services to the population. As a result, the SWOC serves as both a ways and means of securing resources and neutralizing predation threats that seek to disrupt flow.

Symbiosis and the Character of Megacity Conflict

The title, *Symbiotic Warfare Operating Concept*, emphasizes the importance of maintaining a holistic view when conducting operations in a congested environment such as a megacity. Densely populated environments and the complex networks that support resource allocation and distribution to the population exist in a delicate, symbiotic balance. Thus, the SWOC affords community and military planners the ability to identify and exploit intervention points for tactical and/or strategic gain. The primary objective of the SWOC is to neutralize external threats by ensuring resource allocation networks and distribution pathways remain secure and open to the population. The neutralization of predators is a secondary effect of the military's efforts at keeping resource distribution networks and pathways open to the

community. In such a scenario, the community targets and neutralizes the predator(s) themselves, not the military.

The SWOC also serves to describe the interdependence and connectedness that must exist between the military, public services, and local population. Similar to military operations on urbanized terrain (MOUT) doctrine and counterinsurgency (COIN) doctrine, symbiotic warfare considers geography, population, and the adversary as interdependent variables. However, the military is only successful in achieving the main objective in the SWOC by effectively using the local population and local infrastructure as maneuver space itself. For the military, the objective in the SWOC is not the neutralization of predators, but to keep the resource pathways open to the population in order for the population, working with law enforcement, to neutralize predators.

The SWOC <u>is not</u> siege warfare...

The SWOC attempts to stabilize and minimize disruption in the megacity differentiating itself from siege warfare. The DoD defines siege warfare as the employment of combat forces to physically occupy and control a designated area.[60] A tactical mission, the Army and Marine Corps define seize as a military force taking possession of a designated area using overwhelming force or clearing a designated area to obtain control of it.[61] The SWOC is geographically agnostic in the sense the military objective is to control resources within the terrain and minimize infrastructure damage in order to avoid disruptions in the daily operations of the community. Furthermore, the use of overwhelming force or dispersal of the population because of military operations will disrupt distribution pathways and networks, and stress the capacity of civil services to provide sustenance for personnel. Therefore, symbiotic warfare operations require the military to act as an augmentation force to the local community with the military's primary objective to ensure resource allocation networks and distribution pathways remain open.

The SWOC <u>is</u> a synthesis of Urban Warfare, COIN, and Irregular Warfare

Symbiotic warfare encompasses urban warfare and military tactics associated with military operations on urbanized terrain (MCWP 3-53.3 *Military Operations on Urbanized Terrain* and JP 3-06 *Joint Urban Operations*) doctrine and counterinsurgency (COIN) doctrine.[62] By definition, MCWP 3-53.3 and JP 3-06 outline the tactical and capability options available to a commander in an urban environment. [63] Explicit in describing the street, sub terrain, and air battle space, urban doctrine takes into consideration that "the basic principles of combat in built-up areas have essentially remained unchanged in this century."[64]

Where the SWOC and urban operations doctrine agree are on the importance of maneuver warfare and combined arms philosophies in the urban environment.[65] Where the SWOC and urban operations doctrine disagree are on the factors that will have an impact on the manner in which military forces, to include the Marine Corps, conduct urban warfare. For example, MCWP 3-53.3 uses historical examples of warfare to suggest the critical factors that contribute to effectiveness are intelligence, surprise, and combined arms. Combined arms, according to MCWP 3-53.3, require essential categories of weapons in association with: 1) infantry, 2) armor, 3) artillery, 4) mortars, 5) antiaircraft artillery, and 6) aviation. [66] While these types of weapons and capabilities were essential in 1998, technology advancements of the US military and our adversaries require the US update doctrine to account for operational concepts, tactics, and new types of tactical lethal and nonlethal weapons required to conduct operations.

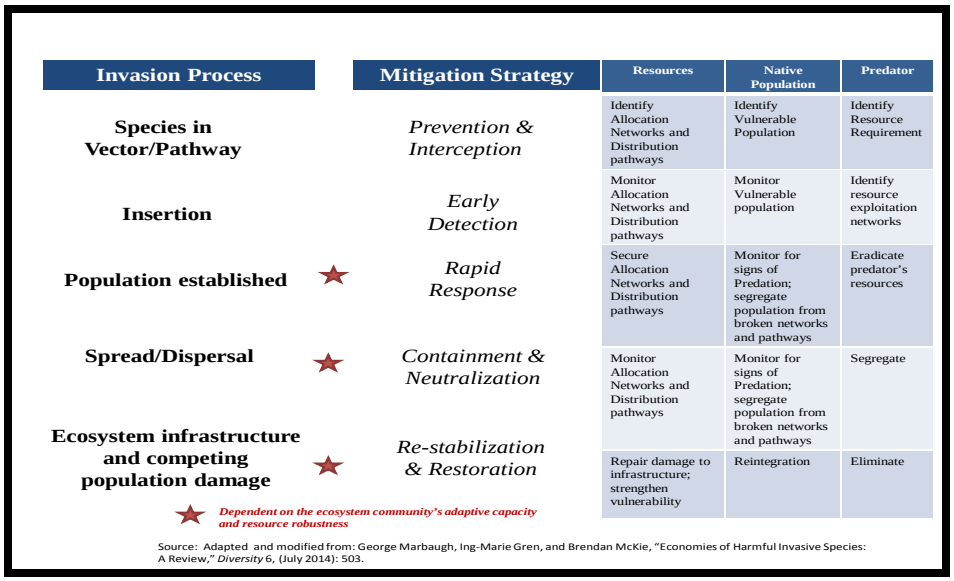
Additionally, JP 3-06's discussion of the urban operating environment does not take in account the interconnectedness between densely populated environments and access to resources. As the previous literature review illustrated, panic ensues when populations become

segregated from resources they view vital to sustenance (such as food, water, power, fuel, cyber, money). If the future of conflict manifests out of a competition for resources, than the military must prepare the intelligence preparation of the battle space (IPB) by defining the populations' critical resource requirements, mapping out the resource allocation networks and distribution pathways that provide those critical resources, and assessing those networks and pathways for vulnerability. Securing and ensuring the integrity of resource networks and pathways becomes the military's primary responsibility.

Proposed Model for Mapping Predation Intervention Points

Although the SWOC is geographically agnostic in the sense the military's objective is to control resources within the terrain and minimize infrastructure damage in order to avoid disruptions in the daily operations of the community. Intelligence preparation of the battlespace requires military and civilian planners to identify critical vulnerabilities that exist in resource allocation and network distribution pathways as a preventative measure against predation. Using biological science and studies to map predator invasion process, a proposed model to identify military intervention points may prove useful.

The table grpahic below adapts physical and biological sciences to complement the SWOC in an effort to provide military and civilian planners a proactive method of analyzing the symbiotic, delicate balance between a community's population and resources.



Invasion Process	Mitigation Strategy	Resources	Native Population	Predator
Species in Vector/Pathway	*Prevention & Interception*	Identify Allocation Networks and Distribution pathways	Identify Vulnerable Population	Identify Resource Requirement
Insertion	*Early Detection*	Monitor Allocation Networks and Distribution pathways	Monitor Vulnerable population	Identify resource exploitation networks
Population established ★	*Rapid Response*	Secure Allocation Networks and Distribution pathways	Monitor for signs of Predation; segregate population from broken networks and pathways	Eradicate predator's resources
Spread/Dispersal ★	*Containment & Neutralization*	Monitor Allocation Networks and Distribution pathways	Monitor for signs of Predation; segregate population from broken networks and pathways	Segregate
Ecosystem infrastructure and competing population damage ★	*Re-stabilization & Restoration*	Repair damage to infrastructure; strengthen vulnerability	Reintegration	Eliminate

★ *Dependent on the ecosystem community's adaptive capacity and resource robustness*

Source: Adapted and modified from: George Marbaugh, Ing-Marie Gren, and Brendan McKie, "Economies of Harmful Invasive Species: A Review," *Diversity* 6, (July 2014): 503.

While each predator and community is unique, the qualities of neither the predator nor the population actually serve as the center of gravity in symbiotic warfare. Predators exploit resources and the vulnerabilities that exist in resource allocation and distribution networks and pathways. Neutralizing the threat requires cohesive efforts between the civilian community, metropolitan police forces, and the military. In the SWOC, the military only takes direct action when metropolitan police forces require augmentation or when defending resource allocation networks and/or distribution pathways. Thus, the identification of intervention points proves useful for military planners who seek to commit military assets and capabilities to assist in predation neutralization.

Differences between Symbiotic Warfare and Insurgency

COIN defines an insurgency as "the organized use of subversion and violence to seize, nullify, or challenge political control of a region."[67] The SWOC adopts a similar definition for its use of the term "predator," delineating insurgents from predators primarily by their objective. For example, in an insurgency, the insurgent uses "a mixture of subversion, sabotage, political, economic, psychological actions, and armed conflict to achieve its political aims." [68] Predators,

which also use a mixture of subversion, sabotage, political, economic, psychological, and armed conflict, seek to control or exploit resources. The predator's objective is not political by nature. Furthermore, the hearts and minds of the population is not an objective for predators or for a military, which is charged with assisting a community in neutralizing a predation threat. Predators use the population itself as maneuver space to gain access to resources. Thus, military planners must determine where populations are most vulnerable to help the community determine where predators may temporary nest.

The SWOC also adopts several concepts from COIN doctrine. For example, similar to COIN,[69] symbiotic warfare is a comprehensive civilian and military effort designed to neutralize predators and address the root causes of resource instability that led to predation. Similarly, symbiotic warfare is population centric. The development of proper symbiotic warfare tactics starts with the acceptance of the population's role in identifying and neutralizing the threat. A metropolitan police force may prove fully capable of securing the population; thus, the military will assume only an enabling and complementary role with capabilities such as intelligence, surveillance, and reconnaissance (ISR), counter electromagnetic warfare.

Critical Factors in Urban Operations

The factors the SWOC determines critical to urban operations are intelligence, combined arms, and civil military operations. Combined arms breaks down essential categories of weapons to: 1) offensive and defensive air, sea, and cyber forces, 2) security forces (infantry and SOF), 3) electromagnetic weapons, and 4) nonlethal fires. The SWOC uses the existing infrastructure and resources within the megacity to target and neutralize the threat to the greatest extent possible. Military operations in the support of the SWOC are to fill infrastructure capability and capacity

gaps and strengthen the vulnerabilities of networks and pathways that provide resource allocation and distribution.

Offensive and defensive air, sea, and cyber forces require the US military to reassess its current platforms for viability in a megacity environment. For air and cyber assets, the services could consider using ISR micro air vehicles (MAVs) to swarm and scatter the megacity. Low cost ISR MAVs, using a C-130 as a delivery mechanism, can deploy in an uncontested air space and transfer via flutter, hover, an loiter in a contested air space for up to ten days.[70] Their less than 1.5 inch profile and light weight allows for a C-130 to deploy up to 10,000 during one air delivery. The uses of ISR MAVs prove critical to monitoring resource allocation networks and distribution pathways.

Furthermore, the military could also use MAVs to set up virtual command and control (C2) nodes. MAVs equipped with dual transmit capability, similar to ISR MAVs, can also carry a unique IP address. Deploying 10,000 during one launch not allows for network and transmit capability for military forces, but also permits for reestablishing connectivity after a cyber or electromagnetic attack. To assist in neutralizing predation threats, the military and civilian law enforcement can use network mirror imaging to set up a network noose to track predator movements and transmissions. This also opens the virtual C2 environment to facilitate robust information operations campaigns to include those launched by intelligence planners who seek to employ deception tactics.

Fires, while important, play a minor role to the IPB planning, MAV ISR and virtual C2 nodes. While small diameter bombs may prove precise, it is important to remember that the concept of symbiotic warfare is to minimize disruption to infrastructure within a megacity-

especially to resource allocation networks and distribution pathways that the predators themselves will seek to exploit.

Capability Assessment

Today's Joint Force cannot meet the challenges of megacity warfare. While MCWP 3-53.3, JP 3-06, and JP 3-24 are starting points for doctrine reassessment, capabilities require a technology refresh if the Joint Force wants to remain impervious and invulnerable while defending, securing, and protecting a megacity's resource allocation networks and distribution pathways. The purpose of the capability assessment is not to seduce the Joint Force with technology, but counter twenty-first century technological threats that leave megacity resources and communities vulnerable to predation.

Regarding potential threats that leave resource allocation networks and distribution pathways vulnerable, the SWOC recommends the development of the following capabilities and tactics. Rethinking how the Joint Force uses its current capabilities and tactics could not come at a more relevant time. The lag time in acquisition and proper RTD&E places 2015 as the right time to consider 2025's future needs. The following is a list of current capability, platform, and concept shortfalls:

- Capabilities
    - Terrain and Subterrain Loiter, Hover and Flutter ISR
    - Terrain and subterrain counterelectromagnetic warfare
- Platforms
    - ISR and network-capable Micro Air Vehicles and drones which provide loiter capabilities and those that can flutter, scatter, and swarm to counter an electromagnetic threat, reopen networked lines of communication, provide

network noose capabilities to monitor predator activity and exploit information exchanges for intelligence gathering,

- Concepts
    - Virtual "Cloud" C2 in order to 1) minimize military footprint on a community's resources and 2) remain elusive to predators
    - Scatter, swarm, and disperse tactics to counter electromagnetic attack[71] and track a predator's capability to use the population as maneuver space

The graphic below depicts the SWOC and highlights capability, platform, and concepts the Joint Force must acquire and embrace to remain relevant in future megacity warfare.

Megacity Warfare

Central Idea

Use the Joint Force to protect and secure resource allocation networks and distribution pathways using the local population and resources to neutralize predation threat(s).

Joint Force must be equipped and capable to respond to…

Primary predators targeting resources (individuals, groups, states) and/or opportunistic predators (individuals, groups, states) which seek to exploit vulnerabilities of populations suffering from damaged resource pathways or networks. Damage to resource networks and pathways may be the a result of natural disasters or unexpected damage to infrastructure.

	Army	*Air Force*	*Navy*	*Marine Corps*
Operational Concept		Symbiotic Warfare		
Functional Concept	Logistics Support Packages (tailored HA/DR); Stand up Mobile and Virtual C2 nodes	Air and Cyber Maneuver; swarm, scatter, dispersal tactics; electromagentic counter air; virtual C2 nodes	Logistics Support Packages;	Operating from virtual C2 nodes; IPB/intel mechanism for providing security of resource pathways and distribution networks
Deficiency assessment:	Capacity and capability for virtual and mobile C2	Loiter and hover platforms, use of micro air vehicles and drones for shallow/deep penetration (terrain and subterrain); SWARM and SCATTER clouds for connectivity	Hover and delivery platforms in congested/contested environments.	Compressed terrain and subterrain corridor maneuver platforms.

Conclusion

Densely populated and congested environments rely on robust resource allocation networks and distribution pathways that future agglomeration populations (predators) will attempt to disrupt in order to exploit resources. The military's future role in megacity warfare is to provide undisrupted flow of resources to the population in order to neutralize predation

threats. In and of itself, symbiotic warfare is nothing more than a hybrid of urban warfare, insurgency and irregular warfare. Based off scientific research and adaptive modeling of how densely populated species behave when predators attempt to exploit resources, symbiotic warfare provides the intelligence community a map of the predation invasion process, affording military intelligence community the ability to identify points of intervention useful in neutralizing predation threats.

Furthermore, symbiotic warfare, and the follow on symbiotic warfare operating concept, focuses on the interdependencies that exist between resources, population, and the predators that seek to disrupt the integrity of resource allocation networks and distribution pathways. Doctrine analysis reveals obvious oversights in these considerations and still relies on fires as a primary means of threat neutralization. If megacity warfare becomes a reality, then the military needs to prepare for it. Current platforms and capabilities, which they deliver, fall short in meeting heavy ISR demands and networking capabilities. Furthermore, the ability of platforms to maneuver freely within the megacity do not currently exist. If nothing more, this research provides the military a sobering reality that future warfare may not require direct action and fires as much as it will require the military to deliver and secure essential services for a population.

[1] Monika Heupel and Bernhard Zangl, "On the Transformation of Warfare: a Plausibility Probe of the New War Thesis." *Journal of International Relations and Development* 13, (2010): 26-58.

[2] William Catton, Jr., "Probable Collective Responses to Ecological Scarcity: How Violent?" *Sociological Perspectives*, 27, no 1, (January 1984): 3. *See Also.* David Kilcullen, "The City as a System: Future Conflict and Urban Resilience." *The Fletcher Forum of World Affairs* 36, no. 2, (Summer 2012): 19-39.

[3] William Catton, Jr., "Probable Collective Responses to Ecological Scarcity: How Violent?" *Sociological Perspectives*, 27, no 1, (January 1984): 3.

[4] William Catton, Jr., "Probable Collective Responses to Ecological Scarcity: How Violent?" *Sociological Perspectives*, 27, no 1, (January 1984): 7. *See Also.* William H. McNeill, *The Pursuit of Power* (University of Chicago Press: Chicago, IL, 1982).

[5] William Catton, Jr., "Probable Collective Responses to Ecological Scarcity: How Violent?" *Sociological Perspectives*, 27, no 1, (January 1984): 3.

[6] William Catton, Jr., "Probable Collective Responses to Ecological Scarcity: How Violent?" *Sociological Perspectives*, 27, no 1, (January 1984): 8.

[7] William Catton, Jr., "Probable Collective Responses to Ecological Scarcity: How Violent?" *Sociological Perspectives*, 27, no 1, (January 1984): 8.

[8] William Catton, Jr., "Probable Collective Responses to Ecological Scarcity: How Violent?" *Sociological Perspectives*, 27, no 1, (January 1984): 8.

[9] N. J. Smelser, *Theory of Collective Behavior*. (New York: Free Press, 2010).

[10] William Catton, Jr., "Probable Collective Responses to Ecological Scarcity: How Violent?" *Sociological Perspectives*, 27, no 1, (January 1984): 8.

[11] Monika Heupel and Bernhard Zangl, "On the Transformation of Warfare: a Plausibility Probe of the New War Thesis." *Journal of International Relations and Development* 13, (2010): 26-58.

[12] Monika Heupel and Bernhard Zangl, "On the Transformation of Warfare: a Plausibility Probe of the New War Thesis." *Journal of International Relations and Development* 13, (2010): 26-58.

[13] For a thorough discussion of war economies and shadow economy networks, see Michael Pugh and Neil Cooper, *War Economies in a Regional Context: Challenges of Transformation*. Boulder, Colorado: Lynne Rienner Publishers, Inc., 2004.

[14] Monika Heupel and Bernhard Zangl, "On the Transformation of Warfare: a Plausibility Probe of the New War Thesis." *Journal of International Relations and Development* 13, (2010): 34.

[15] For a detailed discussion on disaster communities and the behavior of social networks established by communities in response to natural (and imposed disasters) see Alan Kirschenbauam, "Generic Sources of Disaster Communities: A Social Network Approach." *International Journal of Sociology and Social Policy* 24, no. 10/11, (2004): 95-129.

[16] William Catton, Jr., "Probable Collective Responses to Ecological Scarcity: How Violent?" *Sociological Perspectives*, 27, no 1, (January 1984): 14.

[17] For further discussion, see: William Catton, Jr., "Probable Collective Responses to Ecological Scarcity: How Violent?" *Sociological Perspectives*, 27, no 1, (January 1984): 14.

[18] According to Kilcullen, urbanization is clustered in littoral (coastal) areas. “Coastal cities are networked internally, connected to the rural binterland, and linked with ethnic diaspora populations and global networks” (24). David Kilcullen, “The City as a System: Future Conflict and Urban Resilience.” *The Fletcher Forum of World Affairs* 36, no. 2, (Summer 2012): 19-39.

[19] David Kilcullen, “The City as a System: Future Conflict and Urban Resilience.” *The Fletcher Forum of World Affairs* 36, no. 2, (Summer 2012): 25.

[20] David Kilcullen, “The City as a System: Future Conflict and Urban Resilience.” *The Fletcher Forum of World Affairs* 36, no. 2, (Summer 2012): 24.

[21] David Kilcullen, “The City as a System: Future Conflict and Urban Resilience.” *The Fletcher Forum of World Affairs* 36, no. 2, (Summer 2012): 24.

[22] David Kilcullen, “The City as a System: Future Conflict and Urban Resilience.” *The Fletcher Forum of World Affairs* 36, no. 2, (Summer 2012): 28.

[23] For additional definition of nodes beyond tangible assets, see Jacob Apkarian et al, “Hierarchy in Mixed Relation Networks: Warfare Advantage and Resource Distribution in Simulated World-Systems.” *Journal of Social Structure* 14, no. 1, (2013): 1-17. The article provides mathematical framework for validating the theory that societal evolution is really co-evolution and that the exigencies that confront a single society will push that society to adapt to the problems it faces. Therefore, low power actors benefit by being excluded from coercive relations while high power actors inevitably suffer. Furthermore, regardless of whether or not an actor is high or low power, exclusion from exchange is always detrimental.

[24] David Kilcullen, “The City as a System: Future Conflict and Urban Resilience.” *The Fletcher Forum of World Affairs* 36, no. 2, (Summer 2012): 29. Kilcullen suggests using Mumbai as a case study to analyze the networks and study irregular actors and methods. China, where more than fifty-one percent is urbanized, also makes a good case study to understand how greater connectedness affords civilian populations greater access to advanced technologies enhancing civilian population’s military potential.

[25] David Kilcullen, “The City as a System: Future Conflict and Urban Resilience.” *The Fletcher Forum of World Affairs* 36, no. 2, (Summer 2012): 19-39.

[26] David Kilcullen, “The City as a System: Future Conflict and Urban Resilience.” *The Fletcher Forum of World Affairs* 36, no. 2, (Summer 2012): 32.

[27] David Kilcullen, “The City as a System: Future Conflict and Urban Resilience.” *The Fletcher Forum of World Affairs* 36, no. 2, (Summer 2012): 33. Note: The recent example of operations to extradite Christopher Coke to the US exemplifies how nested networks complicate operations in a megacity environment. Overall, the operation led to 500 arrests and 73 lives lost in the efforts to extract a single crime boss from one urbanized, networked, littoral environment.

[28] David Kilcullen, “The City as a System: Future Conflict and Urban Resilience.” *The Fletcher Forum of World Affairs* 36, no. 2, (Summer 2012): 37.

[29] For further justification of modeling ecological systems, see also: S. Pickett, M. Cadenasso, J. Grove, C. Nilon, R. Pouyat, W. Zipperer and R. Costanza, “Urban Ecological Systems: Linking Terrestrial Ecological, Physical, and Socioeconomic Components of Metropolitan Areas.” *Annual Review of Ecology and Systematics* 32 (2001): 127-157.

[30] Jannike Falk-Peterson, Thomas Bohn, and Odd Terje Sandlund, “On the numerous concepts in invasion biology.” *Biological Invasions* 8 (July 2005): 1409.

[31] Jannike Falk-Peterson, Thomas Bohn, and Odd Terje Sandlund, "On the numerous concepts in invasion biology." *Biological Invasions* 8 (July 2005): 1411.

[32] Thomas E. Miller, Jamie M. Kneitel and Jean H. Burns, "Effect of Community Structure on Invasion Success and Rate." *Ecology* 83 no. 4 (2002): 898.

[33] For the analysis and summary of over 45 conducted studies, see: Dov F. Sax and James H. Brown, "The paradox of invasion." *Global Ecology and Biogeography* 9 (2000): 363-371.

[34] Thomas E. Miller, Jamie M. Kneitel and Jean H. Burns, "Effect of Community Structure on Invasion Success and Rate." *Ecology* 83 no. 4 (2002): 898.

[35] Dov F. Sax and James H. Brown, "The paradox of invasion." *Global Ecology and Biogeography* 9 (2000): 363.

[36] Dov F. Sax and James H. Brown, "The paradox of invasion." *Global Ecology and Biogeography* 9 (2000): 365.

[37] Dov F. Sax and James H. Brown, "The paradox of invasion." *Global Ecology and Biogeography* 9 (2000): 364.

[38] Dov F. Sax and James H. Brown, "The paradox of invasion." *Global Ecology and Biogeography* 9 (2000): 367.

[39] Dov F. Sax and James H. Brown, "The paradox of invasion." *Global Ecology and Biogeography* 9 (2000): 366-367.

[40] Thomas E. Miller, Jamie M. Kneitel and Jean H. Burns, "Effect of Community Structure on Invasion Success and Rate." *Ecology* 83 no. 4 (2002): 898.

[41] Thomas E. Miller, Jamie M. Kneitel and Jean H. Burns, "Effect of Community Structure on Invasion Success and Rate." *Ecology* 83 no. 4 (2002): 898.

[42] J.H. Brown, "On the Relationship between Abundance and Distribution of Species." *American Naturalist* 124 (1984): 255-279.

[43] Thomas E. Miller, Jamie M. Kneitel and Jean H. Burns, "Effect of Community Structure on Invasion Success and Rate." *Ecology* 83 no. 4 (2002): 899.

[44] Thomas E. Miller, Jamie M. Kneitel and Jean H. Burns, "Effect of Community Structure on Invasion Success and Rate." *Ecology* 83 no. 4 (2002): 899. *See Also.* C. Elton, *The Ecology of Invasions by Animals and Plants*, (Methuen and Co: London), 1958. *See Also.* T.J. Case, "Invasion Resistance Arises in Strongly Interacting Species-Rich Model Competition Communities," *Proceedings of the National Academy of Science USA* 87 (1990): 9610-9614.

[45] T.J. Case, "Invasion Resistance Arises in Strongly Interacting Species-Rich Model Competition Communities," *Proceedings of the National Academy of Science USA* 87 (1990): 9610-9614.

[46] Thomas E. Miller, Jamie M. Kneitel and Jean H. Burns, "Effect of Community Structure on Invasion Success and Rate." *Ecology* 83 no. 4 (2002): 899.

[47] Thomas E. Miller, Jamie M. Kneitel and Jean H. Burns, "Effect of Community Structure on Invasion Success and Rate." *Ecology* 83 no. 4 (2002): 899.

[48] Thomas E. Miller, Jamie M. Kneitel and Jean H. Burns, "Effect of Community Structure on Invasion Success and Rate." *Ecology* 83 no. 4 (2002): 899.

[49] Thomas E. Miller, Jamie M. Kneitel and Jean H. Burns, "Effect of Community Structure on Invasion Success and Rate." *Ecology* 83 no. 4 (2002): 899.

[50] Thomas E. Miller, Jamie M. Kneitel and Jean H. Burns, "Effect of Community Structure on Invasion Success and Rate." *Ecology* 83 no. 4 (2002): 904.

[51] A.J. Lotka, *Elements of Mathematical Biology* (Johns Hopkins Press: Baltimore, MD), 1956.

[52] Michael D. Intriligator and Dagobert L. Brito, "A Predator-Prey Model of Guerrilla Warfare." *Synthese*, 76, no. 2 (Aug 1998): 235-244.

[53] Michael D. Intriligator and Dagobert L. Brito, "A Predator-Prey Model of Guerrilla Warfare." *Synthese*, 76, no. 2 (Aug 1998): 235-244.

[54] Michael D. Intriligator and Dagobert L. Brito, "A Predator-Prey Model of Guerrilla Warfare." *Synthese*, 76, no. 2 (Aug 1998): 235-244.

[55] Michael D. Intriligator and Dagobert L. Brito, "A Predator-Prey Model of Guerrilla Warfare." *Synthese*, 76, no. 2 (Aug 1998): 235-244.

[56] U. Wilensky, "NetLogo Wolf Sheep Predation Model." http://ccl.nortwestern.edu/nelogo/models/WolfSheepPredation. Center for Connected Learning and Computer Based Modeling, Nowrthwestern University, Evanstan, IL, 2009.

[57] M. Novak and U. Wilensky, "NetLogo Bug Hunt Predators and Invasive Species model," http://ccl.northwestern.edu/netlogo/models/BugHuntPredatorsandInvasiveSpecies. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL, 2011.

[58] Of note, the effects of damage to ecosystem infrastructure were not modeled in this case study. In other words, models that illustrate how damage to resource infrastructure may lead to crowed pathways resulting in the ultimate breakdown of ecosystem function should be considered by future analysts who seek to elaborate on these concepts.

[59] For more information on the environment and security, see: Thomas F. Homer-Dixon, "Environmental Scarcities and Violent Conflict: Evidence from Cases," *International Security 19*, No. 1 (Summer, 1994): 5-40. http://www.jstor.org/discover/10.2307/2539147.

[60] Field Manual 1-01, *Operational Terms and Graphics*, (Headquarters, Department of the Army: Washington, DC), 2004: 1-168.

[61] Field Manual 1-01, *Operational Terms and Graphics*, (Headquarters, Department of the Army: Washington, DC), 2004: 1-168.

[62] MCWP 3-53.3, *Military Operations on Urbanized Terrain*, (Department of the Navy, Headquarters United States Marine Corps: Washington, DC), 1998. *See Also*. Joint Publication 3-06, *Joint Urban Operations*, (Headquarters Joint Staff: Washington, DC), 20 November 2013. *See Also.* Joint Publication 3-24, *Counterinsurgency*, (Headquarters Joint Staff: Washington, DC), 22 November 2013.

[63] MCWP 3-53.3, *Military Operations on Urbanized Terrain*, (Department of the Navy, Headquarters United States Marine Corps: Washington, DC), 1998: 1-2. *See Also.* Joint Publication 3-06, *Joint Urban Operations*, (Headquarters Joint Staff: Washington, DC), 20 November 2013: I-2 thru I-7.

[64] MCWP 3-53.3, *Military Operations on Urbanized Terrain*, (Department of the Navy, Headquarters United States Marine Corps: Washington, DC), 1998: 1-8. *See Also*. Joint Publication 3-06, *Joint Urban Operations*, (Headquarters Joint Staff: Washington, DC), 20 November 2013.

[65] MCWP 3-53.3, *Military Operations on Urbanized Terrain*, (Department of the Navy, Headquarters United States Marine Corps: Washington, DC), 1998: 1-12. *See Also*. Joint Publication 3-06, *Joint Urban Operations*, (Headquarters Joint Staff: Washington, DC), 20 November 2013.

[66] MCWP 3-53.3, *Military Operations on Urbanized Terrain*, (Department of the Navy, Headquarters United States Marine Corps: Washington, DC), 1998: 1-13-15. *See Also.* Joint Publication 3-06, *Joint Urban Operations*, (Headquarters Joint Staff: Washington, DC), 20 November 2013.

[67] Joint Publication 3-24, *Counterinsurgency*, (Headquarters Joint Staff: Washington, DC), 22 November 2013: I-1.

[68] Joint Publication 3-24, *Counterinsurgency*, (Headquarters Joint Staff: Washington, DC), 22 November 2013: I-1.

[69] By definition, "COIN is a comprehensive civilian and military effort designed to simultaneously defeat and contain insurgency and addresses its root causes." Joint Publication 3-24, *Counterinsurgency*, (Headquarters Joint Staff: Washington, DC), 22 November 2013: I-1.

[70] David J. Blair and Nick Helms, "The Swarm, the Cloud, and the Importance of Getting there First: What's at Stake in the Remote Aviation Culture Debate." *Air & Space Power Journal* 27, no. 4, (2013): 14-38. http://search.proquest.com/docview/1465234115?accountid=14746.

[71] For detailed explanation of "swarm" and "scatter" as tactics to counter electromagnetic threats, see: David J. Blair and Nick Helms, "The Swarm, the Cloud, and the Importance of Getting there First: What's at Stake in the Remote Aviation Culture Debate." *Air & Space Power Journal* 27, no. 4, (2013): 14-38. http://search.proquest.com/docview/1465234115?accountid=14746.

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