# Utilizing Biological Models to Determine the Recruitment of the Irish Republican Army

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***Abstract*—**Sociological models (e.g., social network analysis, small-group dynamic and gang models) have historically been used to predict the behavior of terrorist groups. However, they may not be the most appropriate method for understanding the behavior of terrorist organizations because the models were not initially intended to incorporate violent behavior of its subjects. Rather, models that incorporate life and death competition between subjects, i.e., models utilized by scientists to examine the behavior of wildlife populations, may provide a more accurate analysis. This paper suggests the use of biological models to attain a more robust method for understanding the behavior of terrorist organizations as compared to traditional methods. This study also describes how a biological population model incorporating predator-prey behavior factors can predict terrorist organizational recruitment behavior for the purpose of understanding the factors that govern the growth and decline of terrorist organizations. The Lotka-Volterra, a biological model that is based on a predator-prey relationship, is applied to a highly suggestive case study, that of the Irish Republican Army. This case study illuminates how a biological model can be utilized to understand the actions of a terrorist organization.

***Keywords*—**Biological Models, Lotka-Volterra Predator-Prey Model, Terrorist Organizational Behavior, Terrorist Recruitment.

## I. Introduction

ONE of the primary missions in the War against Terror has been to examine the participants, actions, and funding mechanisms of terrorist organizations. This process has allowed analysts to identify and interpret clues to determine whether and when an impending terrorist act is going to occur, and has guided the development of policies for the purpose of preventing future attacks.

When studying organizational behavior, analysts most often utilize models developed by sociologists. Research has also indicated that these are the models of choice when studying the behavior of terrorist organizations [1]. However, sociological models were originally intended to study the behavior of non-violent organizations. Analysts looking at terrorist organizations had to adjust these models to account for the individuals who have no regard for conventional social mores.

What most analysts forget is that there are models available which were developed to incorporate competition between organizations and individuals, as well as fighting and organized warfare. They are the models utilized to describe interactions between biological populations. The data analysis is used to predict which individual in a population is most virulent and which population will succeed in a competition over resources and shared habitats. These models were built with the expectation that populations will die off and be replaced by others.

This study discusses the current models used for the analysis of a terrorist organization – social network analysis, small-group dynamic, and gang – and suggests that models used to study the interactions between biological populations might be a better alternative. To support this theory, this study demonstrates how one particular biological model, the Lotka-Volterra predator-prey model, can accurately analyze the recruitment of a terrorist organization, the Irish Republican Army.

## II. Current Modeling Efforts

Understanding the behavior of terrorist organizations can help determine if current policies for combating terrorism are effective and aid in the development of more successful policies. There are very few analysts examining the behavior of terrorist organizations. The Center for Nonproliferation Studies completed a literature search looking for resources studying the behavior of terrorist cells; the result was that there are very few resources available [2]. Our own research also identified the same lack of resources and we believe we identified why this is the case.

There are three types of sociological models commonly used to examine the dynamics of terrorist organizations: social network analysis (SNA) models; small-group dynamic models; and gang models. Social theorists utilize SNA models to understand human group dynamics; specifically, they have attempted to use these models to describe the behavioral structure of terrorist organizations [3]. However, these models are typically used to describe organizations that have stable social structures and engage in non-terrorist activities, e.g., cleaning beaches, running corporations, and raising money for cancer research. Terrorist organizations do not follow the normal group dynamics motivated by philanthropy and

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generosity that one would find at a fire department or Rotary club. Their organizational behavior is driven by a need for their message to survive and ensure their enemies do not. The differences between terrorists and other organizations are significant enough to suggest that SNA models might not be the most appropriate method for predicting the actions of terrorist organizations.

Due to the secretive nature of terrorist organizations, researchers have had difficulties understanding terrorist group dynamics; as a result, social scientists have also attempted to utilize small-group dynamic models to aid in the understanding of terrorist group dynamics [4]. However, as with SNA, utilizing models meant for small-groups is not the most appropriate method for understanding terrorist organizations. These models are only appropriate when the organization divides itself into small entities; the models provide a through analysis of the smaller groups but not the organization as a whole. This, therefore, is not an effective method for determining the intent of an entire terrorist organization for the purposes of policy development.

At first, gang models seem like a good alternative. Some analysts have applied gang models to terrorists because the actions of both of these populations are not ruled by morals and both exhibit behavior which is considered to be violent. However, social disorganization theory – the backbone of gang models – is not as effective when applied to terrorist groups because gangs and terrorist organizations have a very different organizational structure [5].

## III. WHY USE BIOLOGICAL MODELS TO PREDICT THE BEHAVIOR OF TERRORIST ORGANIZATIONS?

The study of organizational behavior has become a very popular method of understanding how a group of individuals interact to reach a common goal. Methods from sociology, political science, economics, psychology, and anthropology have been used to develop this discipline. With influences from both the science and mathematical fields, many different models have been developed to analyze organizations.

Why then are so few scientists examining terrorist organizational behavior? Perhaps it is because the models currently being utilized do not offer accurate predictions or complete analyses. This consideration instigated this investigation of other types of models. During this study, the similarities among terrorist organizations and wildlife populations became evident. As described by Charles Darwin in his Theory of Natural Selection, wildlife populations survive because they are “fit” enough to pass their genes onto their young. Wildlife fitness is a “measure of the selective quality of genes” or their ability to reproduce [6]. Populations which are better “fit” than others will have a better chance of their genes surviving in the future. Fitness is dependant on feeding behavior, eating the correct food, and knowing where, when, and how to search for food. It is also dependant on their sexual behavior, choosing the appropriate mating strategy (monogamy or polygamy), and finding the appropriate mate(s). Finally, fitness is dependant on territorial behavior; this includes choosing an appropriate location and size for their territory, and an effective defensive strategy to protect their home [7]. In a similar way, terrorist organizations also have a specific strategy to increase their own “fitness.” This initial similarity was sufficiently strong enough to consider using models meant to describe wildlife populations to analyze terrorist organizations.

More importantly, though, is that these models include violent behavior as an existing component. Competition between individuals and species are explicit in the models used by ecologists and behaviorists. For example, models have examined how successful weapons are in defending one species against their enemy [8]; estimated the time when one species will successfully kill off another [9]; determined which species will have control of the local habitat [10]; and verified which individual in a group will dominate the others [11]. Considering biological models already incorporate dynamics similar to those that exist between terrorist organizations and their victims, it solidified the decision that biological models may be an effective means to helping understand the dynamics of terrorist organizations.

For years, biologists have used models to examine community dynamics: social structure; selection of habitats and mates; relationships with prey; time of food consumption; and recruitment. Wildlife managers, facing the extinction of many different species, have used models to predict trends (e.g., how a population disperses into a new habitat) or to understand the factors which influence or hinder the population growth, recruitment, and competition within a population. Wildlife managers make predictions knowing the current environment and what factors influence the population size of a species; they use the results from their modeling to determine the type of management required to reestablish a population, particularly common in recovery plans.

Population models are used to describe population dynamics, examine interactions among species, predict population sizes, and aid in population management, especially those species which are in jeopardy of going extinct. This activity has helped prevent the extinction of higher-order animals, e.g., the gray wolf and the Florida panther.

Most of these modeling activities concentrate on wildlife populations; species which are believed to be driven by instincts of survival alone without the influences of a human-like thought process. It was thought by some that biological models are ineffective for understanding human population dynamics because they don’t take into account humans’ additional mental capacity – especially the ability to use emotions and manipulate their surroundings. They felt that because humans are not governed by the same rules as less intelligent organisms, biological models are ineffective at describing the relationship between fighting human populations. As a result, many of the models developed to understand human behavior during times of war are sociological, not biological.

However, there has been success using a biological model in the study of conventional warfare. During WWI, Frederick Lanchester developed a model to help understand the relationship of power between opposing forces, mainly combating forces. He used a predator-prey model to help determine who would be able to inflict maximum damage to an enemy [12]. The model is so successful, it has even been used outside of the military realm [13].

Just as biologists have developed models that predict population trends in wildlife, basic population models can be used to demonstrate the effectiveness of a terrorist organization in predicting recruitment, i.e., population trends of the organization. The Lotka-Volterra (L-V) predator-prey population model may be particularly effective for this purpose. The L-V model describes population dynamics, particularly between two competing populations. It is a basic, supply and demand type model, where the population of one preys on another, and the size of each population has an impact on the size of the other population [14]. Figure 1 is a graph of the deaths of the members of the British Army (BA) and the Irish Republican Army (IRA). After examining this data and the dynamics of the two main participants in the Thirty-Years War, the L-V model was selected to analyze the relationship between the BA and IRA.

By examining and understanding the population dynamics of an organization, one can determine its maturation and phase of evolution. For example, is the organization in a recruitment phase? Is it losing membership and support? Is it stable or is it going through significant change? By overlapping the dynamics with current events, the organizations' behavior may be well understood.

## IV. THE MODEL: LOTKA-VOLTERRA PREDATOR-PREY MODEL

The L-V model was developed in the 1920s and 1930s independently by two individuals, Alfred Lotka and Vito Volterra. It is utilized to describe the fluctuating population sizes of two competing species. While there are many variations to this model, a simple supply and demand equation drives the model.

There are some basic assumptions associated with the model:

- "Prey will grow in an unlimited way when predators do not keep them under control.
- Predators depend on the presence of their prey to survive.
- The rate of predation depends on the likelihood that a victim is encountered by a predator.
- The growth rate of the predator population is proportional to food intake (rate of predation) [15]"

The creation of this model, consistent with these assumptions, leads to the following two equations:

$$\frac{dx}{dt} = ax - bxy \qquad (1)$$

$$\frac{dy}{dt} = -cy + dxy, \qquad (2)$$

where,

$x$ =prey population;
$y$ =predator population;
$a$ = growth rate of the prey when predators are absent;
$c$ = net death rate of the predators when prey are absent;
$xy$ approximates the likelihood that an encounter will occur between both species if they move randomly and are distributed uniformly throughout their habitat; and
$b/d$ describes the efficiency of predation, converting a unit of prey into a unit of predator [16].

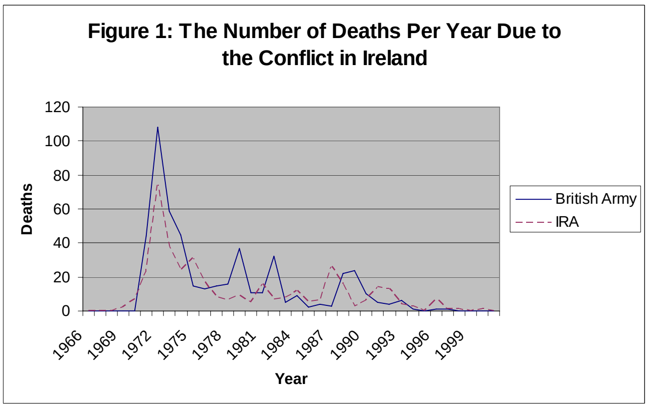


Fig. 1 The Number of Deaths per Year Due to the Conflict in Ireland

The relationship between the lynx and the snowshoe hare are two species which can help explain the dynamics of this model: the lynx, which preys on hares, converts the energy they gain from eating the hares into producing young. As a result of more reproductive energy, the lynx population expands, increasing their consumption of hares. As the hares are preyed upon by the lynx, there are fewer hares to support the lynx population; this decreases the amount of energy available for reproduction and results in a decrease in the lynx population. As the lynx population decreases, the hare population recovers. As the hare population recovers, there is more food available for the lynx, and the cycle starts again. Because of the nature of their relationship, neither population will go extinct due solely to the interaction between the two. Other outside forces, such as a loss of habitat, introduction of disease, or a cause other than the variables of the predator-prey relationship, are significant factors that can impact the survivability of the two species.

The basic L-V equation has been modified by many scientists to describe the interactions between different organisms [17]. This model has been widely accepted by biologists who use it to examine the relationship between foxes and pheasants, moose and wolves, and spiders and flies.

As described above, the models currently used for analyzing terrorist organizations have not been able to adequately describe one of the unique phenomena of terrorist groups, i.e., the use of terrorist cells [18]. These cells help terrorist organizations maintain their status when they go into hiding, enabling them to sustain their allegiance to their organization while remaining hidden from their enemies. In essence, they are the low population of "hares" that always remain in the population. Because of their limited visibility, they are difficult to "hunt." Their population is sufficient to secretly recruit individuals and maintain a low level of activity. Once the pressure from the government – the lynx – is reduced, they begin to openly recruit individuals again, a phenomena seen in the IRA, providing another level of support for the L-V model.

## V. THE KEY MODELING DECISION – SINN FÉIN VERSUS THE BRITISH ARMY

The terrorist organization selected for study in this thesis is the Irish Republican Army. The fighting in Ireland did not just consist solely of two groups; there were a number of organizations involved, including the British Security Forces, Republican Paramilitary Groups, Loyalist Paramilitary Groups and Irish Security Forces. One might feel it would be difficult to determine the direct effect of one group on another; however, when the number of IRA members (the number of Provisional and Original IRA members) killed by different organizations are analyzed, one clearly identifies the BA as its biggest "predator".

The L-V model mimics nature, where the predator drives the population of the prey. The pivotal event which determined who should be the predator and who should be the prey is the infamous Bloody Sunday. This event triggered the IRA to resume an active campaign against the British [19]. Thus, the predator for this model is considered the BA. The prey, whose population sizes are dependant on the predator, is the IRA. It is difficult to distinguish an offset cyclical-wave relationship between the two groups when the population of the BA and the IRA are compared. This is because of the BA's unique population dynamic. The army, as described above, is a static population because the army is set to a predetermined size. (Everyone in a platoon has a set job; if someone leaves that post, another person replaces that individual.) The size of the BA changed as the number of platoons in Ireland changed, with little to no impact from the number of casualties [20].

## VI. KNOWN POPULATION NUMBERS

The BA and the Royal Ulster Constabulary intelligence reports revealed the IRA was organized in cell structures, making it difficult to ascertain the actual size of the membership [21]. After a thorough examination of the available information, the best estimate of the membership of the IRA was that it peaked around 1,500 in the mid-1970s. This number decreased to roughly 500 members during the 1994 ceasefire, coinciding with the adoption of a new organization of the IRA in 1979 [22].

Because the population numbers were not readily available, a different method was required to determine the rough population estimate of the IRA for the model. Sinn Féin (SF) was the political arm of the struggle of the Catholic Irish; therefore, the numbers of individuals voting to support SF gives a rough estimate of those in support of the IRA. Consequently, for the purpose of this study, public support of SF was considered the population of the IRA. Because of SF voting abstention until 1982, this study was limited to the last 20 years of the conflict [23].

The number of BA troops in Northern Ireland was not available for all years, for the years that data was not known, the numbers were interpolated by taking averages of the surrounding years [24]. The same procedure was performed to obtain number of votes for SF in the years where no voting occurred.

## VII. THE MODEL

Because the two populations, the BA and SF were not within the predetermined assumptions of the canonical L-V model (Section IV), the model was modified to meet the anomalies. The first adaptation introduced a term placing a limit on the size of the population, called the carrying capacity [25]. The carrying capacity is the maximum size a population can reach taking into account the environment's ability to sustain a maximum number of individuals. With no other factors impacting a population, after the carrying capacity is reached, the population will slightly increase, then, quickly decline, see-sawing above and below carrying capacity but remaining stable. The carrying capacity is calculated by making the growth rate dependant on the density. As individuals compete for food, habitat and other limited resources during crowded conditions, an increase in the net population mortality is observed. The effects are most pronounced when there are increasing encounters between individuals. Therefore, the new L-V formulas have a term which contains a term of self-regulation.

$$\frac{dx}{dt} = \frac{ax(K-x)}{K} - bxy, \tag{3}$$

$$\frac{dy}{dt} = -cy + dxy \tag{4}$$

where,

*(the same parameters as equation 1&2)*

$K$= the carrying capacity.

In the case of terrorist groups, limiting factors would be such components as money, housing, arms, communication, etc.

The model was altered to incorporate how the predator's population changes over time. When an individual dies in the BA, that person is replaced by another soldier, so the population remains static unless the number of platoons is changed; this creates a difference of 30 soldiers at a time as opposed to one.

Using the actual number of troops for the predator and the parameters listed below for (5) and MatLab Version 7.0.1.24704 (R14) Service Pack 1, the number of prey was determined.

$$dx = xc - xAb - \left(\frac{x^2 e}{K}\right) \qquad (5)$$

*Parameters:*
$A$ = BA population
$b$ = 0.005 = the hunting efficiency of the BA
$c$ = 100 = the recruitment rate of the IRA
$e$ = 500 = rate at which the IRA reaches carrying capacity
$K$ = 400,000 = the carrying capacity of the IRA

Figure 2 shows the comparison of the actual number of votes for SF versus the predicted number of votes. Visual inspection demonstrates that although the numbers are different, the trends are consistent. Visual inspection of the data is important, but it is also valuable to conduct statistical analyses to indicate the strength of the similarities between the observed data and the expected or predicted data. A Kolmogorov-Smirnov test on the data indicated that the data was consistent with a log normal distribution [26]. Therefore, a base 10-log transformation was applied to the data. After the transformation, it was found that the chi-square value of the data was 0.999907 and had a p value > 0.1, thus there are no described differences between the actual and predicted data.

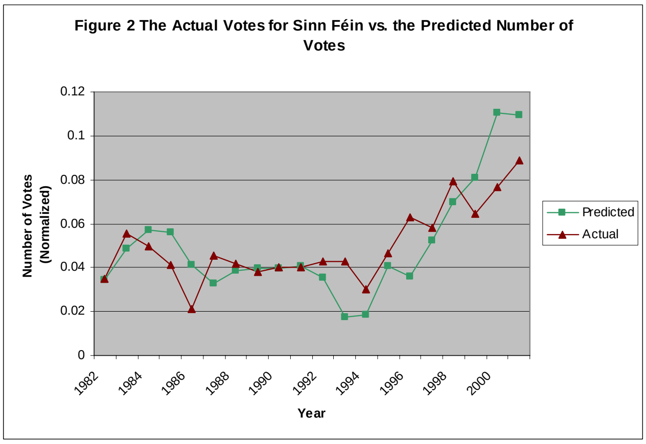


Fig. 2 The Actual Votes for Sinn Fein vs. the Predicted Number of Votes

Pearson's R and Spearman's R are two additional tests used to describe the correlation between the two datasets. Pearson's R for the non-transformed data is 0.8077 and the Pearson's R for the transformed data is 0.6835. The Spearman's R for the data ranked into ordinal numbers is 0.609.

Analyses of the data prove that the population of support for SF is consistent with the output of the model. Changing the parameters does not have a significant impact on the model; changes cause the distribution to shift to the right or left, but the general trends of the model remain the same. When comparing the modeled population to the actual voting population, there are many similarities. As terrorist activity decreased in Northern Ireland and the IRA maintained their ceasefire, the BA decreased the presence of the army in the region; this eased tensions and allowed the BA to increase the army presence in areas which needed a stronger military presence [27]. The decrease in the number of army personnel (the predator) resulted in a drastic increase in SF votes in the latter years, particularly the late 1990s; this phenomenon was predicted by the model.

A final way to analyze the model's effectiveness is to the correlate the data with the history of the war in Northern Ireland (which also supports that the model is accurate). The decrease in support in the mid 1980s occurred when the Anglo-Irish Agreement, (strengthening the relationship between the British and Republic of Ireland) was not a republican agenda [28]. As demonstrated by the populous voting data, the unionist block increased as votes for the nationalists decreased. The decrease in support in 1994 was probably due to a cease-fire; SF and IRA both promised that there would be no ceasefire, yet the Army Council voted to support a four-month ceasefire [29]. The model diverges from the actual data from 1997 to the present; this is expected because the IRA agreed to a ceasefire, changing the dynamics between IRA and the BA.

One of the greatest limitations of testing the validity of this model is the inability to identify the actual membership data of the IRA. The authors expect that, even with a security clearance, it would be difficult to determine the actual membership. Without this data, another means of calculating membership data was determined. The authors feel that SF, a political party in support of the actions of the IRA, was a good selection because their elections are open and individuals can freely elect whom they desire to support.

Due to data constraints, the model itself cannot predict the number of individuals in support of the IRA in a particular year, but rather, it can be used to predict the trends of support, and, more specifically, *popular* support. Popular support influences recruitment efforts, the size, and the impact of the actions taken by the IRA.

Though the L-V model cannot be performed for every terrorist organization; this study demonstrates that trends of support can be determined by analyzing how the population numbers of the BA changed over time. This indicates preliminary support to the original hypothesis – terrorist organizations are working under the same stressors as wildlife populations. An adaptation of this model may help governments analyze the trends seen in these organizations and assist in determining their approach to eliminating terrorism. Further research, such as greater analysis of social organization, is necessary; however, this is a good first step to identifying the drivers of the "terrorist" social organization. Future modeling should be developed to recognize trends and help identify how governments may counteract these organizations. The success of this model to predict past trends of the interaction of SF and the BA also indicates that biological models are available as another tool for understanding terrorist population dynamics.

## VIII. CONCLUSION

Governments use the output of models to create and implement policies to fight the War on Terrorism. In order for them to succeed in this war, it is important for models to be developed that accurately describing their subject's behavior. A review of the current literature demonstrates that there are not many studies that successfully examine the dynamics of terrorist organizations. This may be because analysts depend on models which are not appropriate for understanding terrorist organizational behavior, as current models are either utilizing non-violent models or incorporate violent behavior vectors into their formulas.

Biological models were applied to terrorist organizations because they incorporate the dynamics that exist between terrorist organizations and their victims, as well as provide the population dynamics of a selected population. For the case study, this study utilized a Lotka-Volterra predator-prey model to describe the recruitment behavior of a terrorist organization. Even though the examination was relatively simple and preliminary, it was successful in describing the trends seen in the case study population.

The authors anticipate that this is not the only behavior of terrorist organizations that can be explained by biological models. Examination of the literature demonstrates that other types of biological models may be modified, exactly as described in this study, to aid in the analysis of other aspects of terrorist organizations. Additional research should focus on identifying and developing these models to help fight the War on Terrorism.

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