Diversity: The Biological Perspective Position Statement

Carol Taylor
University of Idaho
Computer Science Department
Moscow, ID 83844-1010
208-885-0680
ctaylor@cs.uidaho.edu

ABSTRACT

Maintaining some minimum level of biological diversity is critical for the proper functioning of global ecosystems. While there are still many unknowns about the relationships between species within an ecosystem, a number of processes are known to affect diversity. Specifically, predator/prey relationships, competition and extinction plus spatial and temporal disturbances influence the number and distribution of species. Currently, most computer diversity strategies are implemented without any attempt to model the processes that influence diversity. We believe that a broader mapping of diversity concepts which include these processes will present a more complete view of computer security dynamics and perhaps suggest novel defensive approaches.

1. INTRODUCTION

Analogies between the computer and biological world have a long history in computer security. Programs that could self-replicate and transfer themselves between computers became known as viruses. Computer defense strategies were successfully modeled after the human immune system. Multiple versions of software, hardware or network protocols were implemented for defense since greater diversity has been known to increase survival in biological systems.

The role of diversity in computer security is the topic of this panel. In this position statement we will discuss the role of diversity in biology and suggest an expanded view of diversity that includes ecological relationships. This could be of benefit in defining computer/attacker and program-to-program interactions.

2. DIVERSITY AS BIOLOGY

Diversity in nature occurs as the result of factors that influence individual species such as competition and predation plus environmental factors like geography and climate. For long-term survival, species must be capable of adaptations to take advantage of new niches or escape from hunting or competition pressures.

NSPW 2005 Lake Arrowhead CA USA

Eventually, new species are formed from the old species if enough genetic changes occur and the sub-species become isolated.

While an increase in diversity through individual species formation is interesting, it is not the best analogy for computer system diversity which appears closer to ecosystem diversity. At the ecosystem level, diversity is known to strongly influence ecosystem function. Darwin and Wallace in the 1800's first stated the observation that an intact, diverse community is more stable and functions better than communities that have lost species [4]. Experimental evidence generally supports this idea by showing that logging, fishing and trapping frequently remove key organisms which leads to ecosystem degradation.

Species removal taken to an extreme is the single species monocultures of modern day agriculture. These systems are highly susceptible to catastrophic failure since one disease or insect pest can devastate the entire crop. This is the most frequently cited analogy to the technological diversity that currently exists in our "cyber ecosystem" [1, 2, 3]. Many in computer security and the popular press have stated that our current systems are vulnerable because they lack diversity and have become too homogeneous. For similar reasons in agriculture, monocultures in the computer world serve a purpose in that they are easier to manage and take less effort to administer.

That both agriculture and cyber ecosystems benefit equally from more diversity has not actually been proven. In agriculture, research has found that interspersing even a few species can significantly reduce the spread of disease. However, showing that higher computer diversity offers protection against the spread of viruses and worms, is not as straightforward [5]. Unfortunately, unlike the biological world where genetic adaptation is large, the number of potential OS's is comparatively small as is the number of possible applications. Another problem with constructing diverse systems from existing OS's is that all known OS's contain vulnerabilities, so that replacing monoculture systems with equally vulnerable systems does not necessarily increase overall system security. Schell noted this problem in his "flying pigs" article and criticized current security practice that tends to construct systems from multiple insecure components and then claims that the overall system is secure [5].

3. DIVERSITY PROCESSES

In nature, species co-exist and all organisms exist in a network of relationships to other organisms. These relationships may be positive which assist species with survival as in the case of symbiotic relationships[3], or negative as in the case of predators that hunt a prey species to extinction.

In considering diversity for computer security it may be useful to expand our view to include some of the biological processes and other factors that are considered when evaluating diversity in nature. For example, the following brief list includes processes known to affect biological diversity along with a suggested mapping to computer security:

- Predator/Prey Models
  - Predators could be viewed as attackers either collectively or as separate species based on their skill level or other characteristics
  - Prey could be subdivided into OS species (Windows , MAC or Linux) or by system type (Mail Server, Web Server, Desktop)
- Spatial/Temporal Dimensions
  - Instead of viewing the entire Internet as one ecosystem, could impose spatial dimensions in order to group either attackers or systems
    - Actual geography or some other distinguishing feature that divides the Internet into ecological regions
  - Computer systems could be seen to evolve like species over time in response to threats or market pressure. This concept may suggest better methods for incorporating defensive traits into computers as adaptive characteristics.
- Other concepts to consider that relates to diversity include species competition and extinction, ecosystem stability and symbiotic relationships among others.

During the panel discussion these ideas will be presented in more detail. Discussion from NSPW participants should help determine the overall merit of these and other ideas relative to computer diversity.

5. REFERENCES

[1] Bain, C., D. Faatz, A. Fayad, D. Williams. Diversity as a defense strategy for information systems. Mitre Corp., 2000.

[2] Forrest, S., A. Somayaji and D.H. Ackley. Building diverse computer systems. In *Proc. 6th Workshop Hot Topics in Operating Systems*, 1997, pp. 67-72.

[3] Geer, D. et al. Cyber Insecurity: the cost of monopoly, how the dominance of Microsoft products poses a risk to security. Computer & Communications Industry Association Report, 2003.

[4] Loreau, M., Naeem, S., and Inchausti, P. **Biodiversity and Ecosystem Functioning.** Oxford University Press, New York, 2002.

[5] Schell, R. Information Security: Science, Pseudoscience, and Flying Pigs. In Proc. ACSAC 2001.

[3] Symbiotic relationship is where one species is dependent on another for survival but the non-dependent species also benefits