UNIVERSITY OF ALBERTA
folio

Volume 44 Number 17 Edmonton, Canada April 27, 2007

http://www.ualberta.ca/folio

# Mathematician breaks down mob mentality

## Model explains behaviour of schools of fish, flocks of birds

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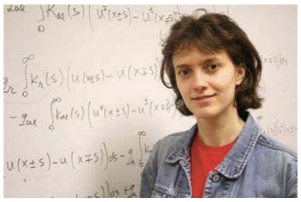

U of A grad student Raluca Eftimie has found a formula for the united movement of flocks of birds and schools of fish.

A University of Alberta study is showing that 'mob mentality' in the animal kingdom is the product of a series of individual communications.

There is a scene in the animated blockbuster Finding Nemo in which a school of fish makes a rapid string of complicated patterns - an arrow, a portrait of young Nemo and other intricate designs. While the detailed shapes might be a bit outlandish for fish to form, the premise isn't far off. But how does a school of fish or a flock of birds know how to move from one configuration to another and then reorganize as a unit, without knowing what the entire group is doing?

New research by U of A scientists shows that one movement started by a single individual ripples through the entire group - a finding that helps unravel a mystery that has plagued scientists for years.

"It is known that there is a connection between the signals animals use to communicate with each other and their behaviour," said Raluca Eftimie, a graduate student in the U of A's Centre for Mathematical Biology. "But until now, the connection between the complex spatial group patterns that we can see in nature and the different ways animals communicate has not been stated explicitly."

For decades people have puzzled about how animals - fish schools, locust swarms, large flocks of birds - form large, complex, dynamic groups. It is clear individuals in the group are only communicating with nearby neighbours, but then the groups somehow emerge spontaneously with complicated patterns. Eftimie and her co-authors - Dr. Mark Lewis and Dr. Gerda de Vries, also from the Centre for Mathematical Biology - used a one-dimensional mathematical model to describe the formation and movement of animal groups. The work is published in the prestigious journal, Proceedings of the National Academy of Sciences.

"Every individual in the group is influenced by the movement of the individuals in its neighbourhood," said de Vries. Conversely, the individual's movement can influence the movement of the entire group.

"It turns out that the entire group can respond indirectly to a single individual, as each individual's movement response is a signal to its next neighbour," said Lewis, the Canada Research Chair in Mathematical Biology. "By this method, signals are passed quickly from individual to individual. So for example, one fish turns, causing the next one to turn, then the next one, and so on.

This produces the complex collective behaviours - swarm formation, zig-zag group movements - that emerge from the 'bottom up,' simply based on interactions between neighbours."

Until Eftimie's work, these complex emergent patterns could not be connected clearly to simple rules for the small-scale communication between individuals.

People have had some success in proposing rather complex and detailed explanations for how specific species form into groups, says Lewis.

"What Raluca's work does is show that very simple and straightforward sets of rules can produce the complex kinds of patterns seen in nature," said Lewis. "Her work has stripped out the unnecessary detail to the core elements of communication that give rise to the patterns found in large scale groups."

In particular, the researchers looked at the direction from which animals can receive signals from their neighbours.

"For example, some species of birds use directional communication, and therefore, we may assume that in this case the behaviour of an individual will be influenced by the signals received from those con-specifics that face towards this individual," said Eftimie. "Based on these observations, we come up with some simple rules that can describe the different ways animals communicate. Then we incorporate these rules into the mathematical model, and check what kind of movement patterns we get."

The team came up with 10 complex patterns. Some are classical, such as stationary pulses, ripples or traveling trains, but they also describe new patterns that have not been reported before, such as zig-zag pulses, feathers and traveling breathers.

This model doesn't apply to specific species, says Eftimie. "However, we can think of those flocks of birds that fly in one direction, and then suddenly change direction 180 degrees, and compare this with the zig-zagging type of pattern shown by the numerical simulations. Or we can think about the anti-predatory behaviour exhibited by some schools of fish - when a predator is nearby, the school contracts in a tight aggregation, to expand again when the predator is gone. And we can try to compare this behaviour with the breather pattern described in our paper."

The results of the model suggest that if we want to better understand the aggregations we see in nature, says Eftimie, we should take a look at how these animals communicate.

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