New theorem determines the age distribution of populations from fruit flies to humans

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Drosophila sp fly. Credit: Muhammad Mahdi Karim / Wikipedia. GNU Free Documentation License, Version 1.2

The initial motivation was to estimate the age structure of a fruit fly population, the result a fundamental theorem that can help determine the age distribution of essentially any group.

This emerging theorem on stationary populations shows that you can determine the age distribution of a population by looking at how long they still have to live.

The mathematical discovery can help produce data with a wide range of implications, from predicting rates of infectious diseases, such as West Nile virus spread by mosquitoes, to anticipating the health care needs of an aging population.

"The idea is you can't look at an insect and say: How much longer are you going to live?" said Dr. James R. Carey, entomologist at the University of California, Davis. "If you understand the age structure of the population, you can better understand the risks and needs," said Dr. Arni S.R Srinivasa Rao, a mathematical modeler at the Medical College of Georgia at Georgia Regents University. "If there are more children, you need to worry about schools; if there are more older people, you need to worry about health benefits." Rao noted that while many countries, including the United States, have good population data generated by regular surveys, others, including some European and many Third World countries, still don't.

The new theorem is published in the *Journal of Mathematical Biology* and *Notices of the American Mathematical Society*.

The work began about a decade ago, when Carey deduced that by keeping tabs on how long a large fruit fly population lived in captivity, he could determine the age structure - how many flies are how old - of the general fruit fly population. It's called Carey's Equality.

Figuring that out without knowing the age of the fruit flies at capture was Carey's eureka moment.

Flash forward to a mathematical demography meeting last year at The Ohio State University Mathematical Biosciences Institute where Carey was explaining his observation and Rao was listening.

"I saw a pattern in what he observed," Rao said, and within 45 minutes, he had put together the complex mathematics behind it, helping prove the relationship, and making it more readily transferrable to diverse populations, from humans to the mosquito population they are now studying. He presented the math to his new colleague the next day.

"We went back a few more steps and said how is this true; what are the biological factors; what are the symmetries; what are the patterns in biology," Rao said.

In fact, putting two graphs - one depicting the usual course of individual fruit flies from birth to death and the other charting how long flies lived after capture -back-to-back creates a symmetrical mountain that starts at the peak of one day of life and trails off at the base at about 60 days of life on either side.

Their theorem can be applied to human and non-humans in stationary populations - meaning the birth and death rate and age composition are stable and similar - such as the fruit fly or more dynamic populations like China.

In terms of broader application beyond age distribution, instead of farmer's guesstimating how many wolves are needed to keep their elk population in an ideal range and vice versa in Montana, they can apply this theorem.

"It's not about how many wolves there are; it's about what is needed to make them both live together," said Rao. "We need to know at what rate wolves are killing elk and how many elk are dying." The age structure of the wolves and elks also yields evidence of how many are in their reproductive years. Taking it to the next step, how much food do the elks need to live, Rao said.

Back to the mosquito, "Understanding age structure in these insect populations is a huge deal worldwide because it's the older mosquitoes that vector the West Nile fever, malaria, yellow fever, and so forth," Carey said.

Biochemical and gene expression studies to collect age data are crude and don't reveal much, and programs to capture, mark, release, then recapture often yield too few recaptures, Carey noted.

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