Independent evolutionary origins of complex sociality in marine life

March 31 2017

Heterocarpus ensifer. Credit: NOAA

In the world of evolutionary research, scientists studying the evolution of eusocial societies have traditionally relied on information gathered from studying terrestrial insects. A group of Columbia researchers, however, has just added to that knowledge base, publishing a new study that sheds light on how the complex social system evolved in the sea.

The study reveals that, in snapping shrimps, eusociality - a social system characterized by cooperative care of juveniles; reproductive division of labor, where many group members are temporarily or permanently sterile; and overlap of generations - only seems to have evolved from pair-forming species and not through intermediate forms of social systems. Although being phylogenetically and ecologically distinct from insects, it turns out that the evolution of eusociality in snapping shrimps follows the so-called "subsocial route" first proposed for insects nearly 50 years ago.

"Our study shows that there is really only one way to become eusocial in shrimps—by forming a family group where parents and offspring live together," said Solomon Tin Chi Chak, lead author on the study and a postdoctoral research scientist in the lab of Associate Professor Dustin Rubenstein in the Department of Ecology, Evolution & Environmental Biology. "Communal species of shrimps where unrelated individuals live together in a large group have never transitioned into eusocial species."

Shrimps and many other animals can be grouped into three general categories of social organization: simple, pair-forming species, in which reproducing pairs of males and females live together; communally breeding societies, in which reproduction is more or less evenly distributed among group members that are often unrelated; and complex, eusocial societies, where reproduction is dominated by a single female and nonbreeding individuals fulfill roles caring for the young or protecting and providing for the group. How simple groups transition evolutionarily to more complex societies has remained unclear. Competing hypotheses based largely on research on terrestrial insect species, such as ants, bees, wasps and termites, suggest that eusociality and communal breeding are either alternative evolutionary endpoints, or that communal breeding is an intermediate stage in the transition from pair-forming to eusociality.

To test the hypotheses in a marine population, the researchers looked to the bottom of the ocean.

Snapping shrimps in the genus Synalpheus are the only known marine genus that has evolved eusociality. Living in the canals of marine sponges, the majority of these snapping shrimps live in simple pairs. This genus, however, has mysteriously also developed the two other, more complex forms of social organization. While researchers have observed all three forms of social organization in other animals, snapping shrimps are rare in that all three forms exist in a single genus, leaving researchers questioning how eusociality evolved in the marine environment.

To find answers, Chak and his colleagues began by analyzing a large collection of snapping shrimps amassed over nearly 30 years from the Caribbean. Based on population characteristics of the more than 30 shrimp species, the researchers found that they ultimately clustered into pair-forming, communal and eusocial group categories. The team then attempted to determine which type of society is a more likely precursor to eusociality.

Further analyses, published in *Nature Ecology & Evolution*, suggested that eusocial and communal species are discrete evolutionary endpoints that evolved independently from pair-forming ancestors along alternative paths. This model parallels observations in insects and vertebrates and the current study confirms that, in marine snapping shrimps, the model also applies - eusociality happens only when hatchlings remain close to home, rather than dispersing to other sponges or parts of the sea, as separating from the "family" makes it impossible to form a family group.

The finding affirms the importance of kin selection - a backbone of social evolution theory for the last half century - in driving social

evolution and suggests a general model of animal social evolution, Chak said.

"This work helps us understand the evolutionary history of eusocial and communally breeding social systems, which are socially more complex than pair-forming," he added. "If we want to know more about how complex social systems evolved more broadly in other species of animals, we now have information from a broader range of taxonomic groups that reinforces patterns seen in more commonly studied groups. Our results suggest that communal and eusocial species evolve along their own path. They are actually two very distinct social organizations and they may have evolved for different reasons. Understanding the ecological and genetic basics of how and why pair-forming species transition to communal and eusocial species will be important to our future work."

More information: Solomon Tin Chi Chak et al, Evolutionary transitions towards eusociality in snapping shrimps, *Nature Ecology & Evolution* (2017). DOI: 10.1038/s41559-017-0096

Provided by Columbia University