Functional roles of prey behaviors in the prey-predator interactions: a study using littoral cladocerans and odonate larvae.

博士論文（要約）

Functional roles of prey behaviors in the prey-predator interactions: a study using littoral cladocerans and odonate larvae.

（捕食者-被食者の相互作用における被食者行動の機能的役割:
沿岸性ミジンコとトンボ幼虫を用いた研究）

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Predation is a fundamental factor affecting the life histories and population dynamics of all the organisms. To avoid or reduce the adverse effects of competition among congeneric species and predation by predatory species, animals have evolved various traits, including feeding habits and behaviors and antipredator defenses. Odonate larvae are commonly found in freshwater habitats and prey on a variety of small invertebrates, including cladocerans. In this thesis, I examined predator-prey interactions between odonate larvae and littoral cladocerans for understanding the functional roles of their feeding and antipredator behaviors for the coexistence of these organisms in aquatic habitats.

In the first chapter, I analyzed the larvae's feeding habits of multiple odonate species to clarify why these species could appear in the same habitats, since it was not necessarily clear if there is a dietary separation among the larvae of different odonatan species. For this object, I collected different species of odonate larvae in different seasons at various sites on the floating mat of Mizorogaike Pond in Kyoto, Japan. Then, I examined the abundance and gut contents of the dominant species. My analyses showed that habitat and seasonal abundance of the odonate larvae did not significantly overlap between most pairs of the dominant species. Moreover, the degree of dietary overlap was not related to larval biomass in microhabitats. These results suggest that, although larval food habits were similar among odonate species, various vegetation types on the floating mat allowed many odonate species to inhabit Mizorogaike Pond.

Littoral cladocerans such as Chydoridae and Macrothricidae are found on the surface of macrophytes and sediment. Although these micro-habitats are places where they can efficiently feed on algae attached and detritus accumulated, few studies have examined functional roles of the bottom sediments from the viewpoint of predator avoidance. The bottom substrate may affect these cladocerans' behaviors, which, in turn, changes their vulnerabilities to predators like odonate larvae. Therefore, I conducted laboratory experiments to examine the movement of three littoral cladoceran species, *Chydorus* and *Alona*, *Ilyocryptus*, and tested if their vulnerabilities to predation by odonate larvae changed depending on presence or absence of bottom sediments. I observed that when sediments were available, *Ilyocryptus* crawled into the sediments and ceased movement. But in the containers without sediments, they continuously swam or crawled. On the other hand, the movement of *Chydorus* and *Alona* did not change regardless of the presence or absence of sediments. In predation experiments with and without bottom sediments, *Alona* was the most vulnerable to predation by odonate larvae, followed by

Chydorus, whose strategy was to increase movement. In the containers without sediment, *Ilyocryptus* was preyed on by odonate larvae as often as *Chydorus*. However, they were not consumed by this predator when containers had sediment. These results indicate that behavior and vulnerability to predation of littoral cladocerans are species-specific and change depending on the sediments' availability.

The death feigning behaver has been often reported in a variety of animals, including microcrustaceans such as littoral cladoceran species. However, the effectiveness of such a behavior as an antipredator defense has not been quantitatively examined. In the last chapter, therefore, I examined the death feigning behaviors of two littoral cladocerans, *Chydorus* and *Oxyurella*, and assessed the effectiveness of the behavior as an antipredator defense against odonate larvae of *Sympetrum frequens*. I first examined how the odonatan larvae detected the preys, and found that the odonate larvae consumed live cladocerans even under a dark condition but not consumed anesthetized cladocerans, indicating that the larvae catch the prey using mechanical cues such as vibration currents caused by the prey individuals. Then, I observed behavioral events of odonate larvae and prey cladocerans in a small container containing 5 to 25 cladocerans and a single odonatan larva using a video-record system. I also checked and counted the number of cladocerans showing the escape swimming behaviors and the death feigning behaviors when the odonatan larvae failed to capture the cladocerans by the first attack and estimated how many cladocerans exhibiting these behaviors were consumed through the second attack by the odonatan larvae. I observed a total of 1099 behavioral events in the prey-predator interactions. On average, the odonate larvae pursued 63% (247 events) of the cladocerans encountered (399 events), attacked 89% (218 events) of the cladocerans pursued, but successfully captured only 29% (65 events) of the cladocerans by the first attack. Among the cladocerans that were not captured (153 events), 38% (59 events) of the individuals continually swam, but 62% (94 events) cased to move and exhibited the death feigning behaviors. The capture rate of odonatan for cladocerans exhibiting the death feigning behaviors (4 out of 73 individuals) was significantly lower than that of cladocerans that were continually swimming (13 of 59 individuals). These results showed that the death feigning behavior of littoral cladocerans is indeed competent to reduce predation risk by such a predator that detect prey using vibration currents.

In summary, I showed that behavior of littoral cladocerans changes depending on environmental conditions such as availability of the bottom sediments and that their behavioral response to predators like odonate larvae that detect preys using mechanical cues caused by the preys are crucial to reduce their predation risks. In this study, I highlighted the death feigning behavior as an actual example of lowering the predation rate by larvae of an odonate species. In a study examining the prey-predator interactions, functional roles of prey organisms' behavioral response to predators have often been overlooked. This study showed that context-dependent behaviors of prey organisms such as digging into sediment and death feigning are prime factors determining the strength of prey-predator interactions.