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Development of Educational Materials using Shrimps with Consideration for Animal Welfare

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Abstract: We developed ideal education material with animal welfare considerations based on the Pacific white shrimp *Penaeus vannamei*, a globally mainstream farmed shrimp. As its name indicates, the body of this shrimp becomes white when it dies. When alive, however, it is transparent and its internal structure could be readily visible without the need for dissection. In this study, the visual appearance of the internal organs, including the stomach, hepatopancreas, heart, and intestines, was evaluated by volunteers ranging from 20 to 60 years old, comparing the Pacific white shrimp and the kuruma shrimp *Marsupenaeus japonicus*. The volunteers were divided into two groups: those in their 20s (n = 21), who were primarily university students, and those in their 30s to 60s (n =14), who were primary school teachers and professionals involved in the fisheries industry. A greater number of volunteers concluded that the stomach, hepatopancreas, heart, and intestines of the Pacific white shrimp were easier to visualize compared with those of the kuruma shrimp. Volunteers in their 20s tended to be more cautious in their responses to the visibility of the stomach, intestine, and heart, but only those in their 30s to 60s were cautious regarding the visibility of the hepatopancreas. This suggests that the ability to observe is not the same based on the observer's age and/or the organ under observation. Taken together, the Pacific white shrimp is a preferred educational tool for observing internal organs in a living state without requiring dissection.

Keywords: Pacific white Shrimp, Internal anatomy, Educational materials, Animal welfare

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Introduction

Aquaculture for sustainable food production is increasing worldwide. Shrimp farming is robust and the most successful based on the Pacific white shrimp *Penaeus vannamei* (Dugassa and Gaetan, 2018). Production of this shrimp has increased nearly 53% in five years, from 3803.6 thousand tons to 5812.2 thousand tons between 2015 and 2020, and accounts for 51.7% of total shrimp production (Pedrazzani *et al.*, 2023). The increase in shrimp farming has been accompanied by the concept of animal welfare to maintain sustainable food production. There has been a movement to develop animal welfare protocols for Pacific white shrimp (Wright, 2016; Pedrazzani *et al.*, 2023). In particular, eyestalk ablation promotes shrimp maturation (Uawisetwathana *et al.*, 2011); therefore, the farming of Pacific white shrimp using eyestalk ablation has become a widely discussed issue (Wright, 2016; Pedrazzani *et al.*, 2023).

The "3Rs alternatives" have been widely adopted in research and education. They were first described by Russell and Burch (1959) and refer to the Replacement, Reduction, and Refinement of animals used in research, teaching, testing, and exhibition. In 1985, the Council for International Organizations of Medical Sciences published the International Guiding Principles for Biomedical Research Involving Animals, which define the ethical standards for animals used in medical and biological experiments. Based on these guidelines, educational material for invertebrates is needed to supplement the study of vertebrates for school education. Experiments using animals that are commercially farmed for human consumption are not included in the scope of regulations under the 3R principle, as long as their life is treated ethically. Therefore, the use of these animals also corresponds to the "Replace" tenet of the 3Rs, and the availability of these animals would enable a more active implementation of experiential education. In addition, carefully planned and managed aquaculture has benefits in terms of conserving natural resources and reducing the impact on the environment. Therefore, farmed shrimp is a useful material from an educational perspective.

We developed educational material that considers animal welfare based on the Pacific white shrimp, a globally mainstream farmed shrimp. Our focus was on the transparency of their body when alive, which enables one to view the internal organs without dissection (Figs. 1A, B). We asked volunteers ranging from 20s to 60s years old to observe the Pacific white shrimp and its close relative, the kuruma shrimp *Marsupenaeus japonicas* (Figs. 1C, D), and assess the visibility of the stomach, hepatopancreas, heart, and intestine in a living state.

Materials and Methods

Shrimp

The Pacific white shrimp *Penaeus vannamei* and the kuruma shrimp *Marsupenaeus japonicus* were purchased from a commercial vendor in Japan. They were used for an experiment in which the internal organs were visually observed after rearing at a water temperature of 20°C for one week. Two different growth stages of Pacific white shrimps of approximately 14 and 19 cm in total length were evaluated (Figs. 2A, B). The former was used in the present study because of its higher transparency. The total length of the kuruma shrimp was 15–16 cm.

Volunteers

There were 21 volunteers in their 20s who participated in the survey, which included students from Kanazawa University and Bunkyo University. There were 3 volunteers in their 30s, 5 in their 40s, 4 in their 50s, and 2 in their 60s who also participated. The volunteers in this age range included primary school teachers and fishery workers.

Survey on the visibility of the internal organs in Pacific white shrimp and kuruma shrimp by volunteers

The internal organs of the shrimp were explained to the volunteers using Figure 3. Thereafter, the

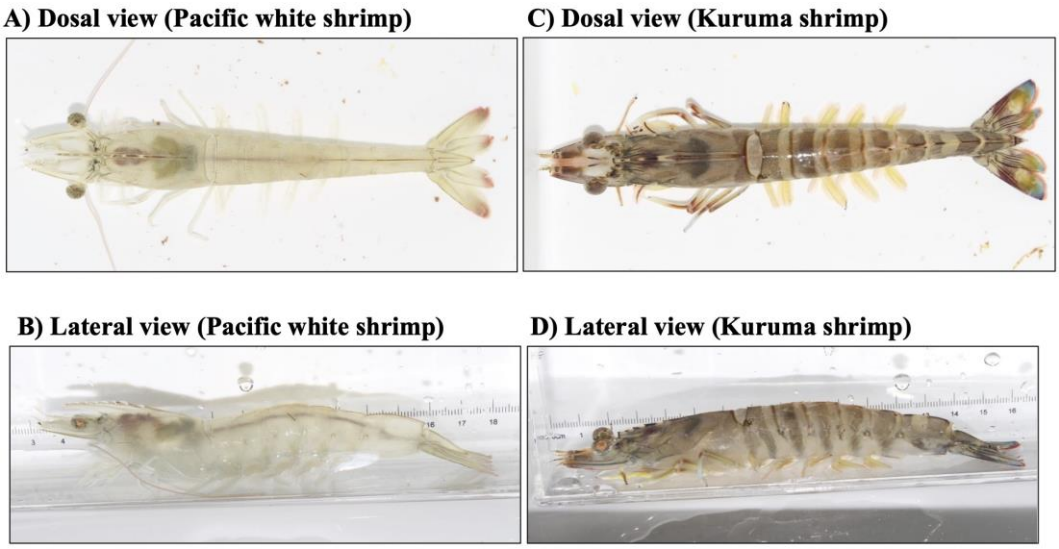

Fig. 1: Photographs of the Pacific white shrimp (A: dorsal view; B: lateral view) and kuruma shrimp (C: dorsal view; D: lateral view).

Fig. 2: Lateral view of the Pacific white shrimp showing changes in transparency according to the growth stage of approximately 14 cm (A) and 19 cm (B) in length.

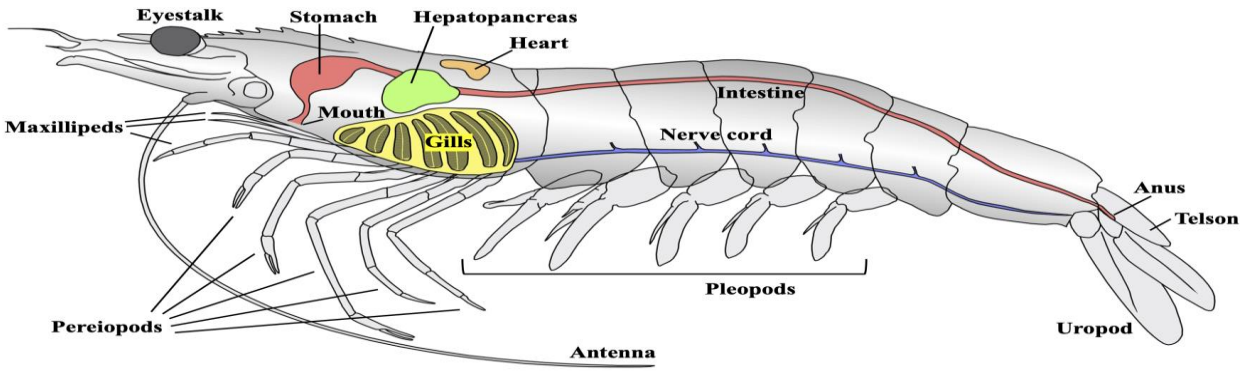

Fig. 3: Schematic diagram of the shrimp.

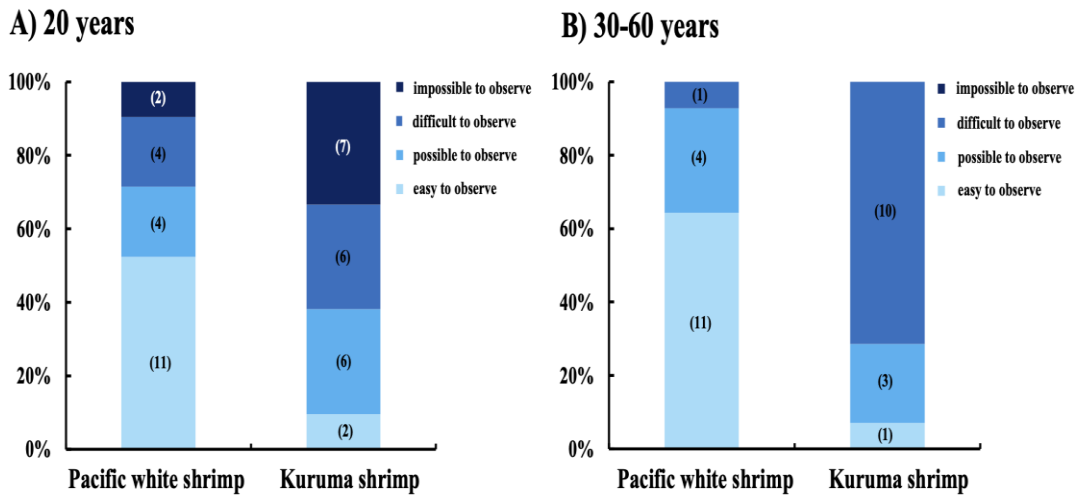

Fig. 4: Results of a questionnaire on the visibility of the stomach in the Pacific white and kuruma shrimps by volunteers. The volunteers evaluated the visibility of the stomach on a graded scale. Numbers inside the bars indicate the number of respondents.

volunteers, except students at Bunkyo University in Saitama prefecture, were asked to observe the living Pacific white and kuruma shrimp at their leisure and answer a questionnaire. Students at Bunkyo University were shown photographs of Pacific white shrimp and kuruma shrimp (Fig. 1) and two videos (Video 1: Pacific white shrimp; Video 2: kuruma shrimp; https://ijzi.net/Vdo-Heartbeat.html) of their beating hearts before answering the questionnaire.

The internal organs include the stomach, hepatopancreas, heart, and intestines. The volunteers evaluated the visibility of these internal organs on a graded scale (1: easy to observe, 2: possible to observe, 3: difficult to observe, 4: impossible to observe).

Results

Visibility of the stomach of Pacific white shrimp and kuruma shrimp by volunteers

The results are indicated in Figure 4. For the Pacific white shrimp, most volunteers in their 20s (71.4%) and 30s–60s (93.8%) could easily observe the stomach. In the kuruma shrimp, less than 40% of the 20s and 30s–60s groups could easily or possibly observe this organ. Volunteers in their 20s tended to be more careful in answering questions on the visibility of the stomach.

Visibility of the hepatopancreas in Pacific white shrimp and kuruma shrimp by volunteers

The results are indicated in Figure 5. For the Pacific white shrimp, most volunteers in their 20s (95.2%) and 30s–60s (85.7%) could easily observe the hepatopancreas. In the kuruma shrimp, volunteers in the 20s (81.0%) and 30s–60s (71.4%) groups indicated that it was easy or possible to observe. Volunteers in their 30s–60s tended to be more careful in answering questions on the visibility of the hepatopancreas. One 64-year-old volunteer indicated that the hepatopancreas of the kuruma shrimp was not visible.

Visibility of the heart in Pacific white shrimp and kuruma shrimp by volunteers

The results are indicated in Figure 6. For the Pacific white shrimp, all volunteers in the 20s and 30s–60s groups indicated that it was easy or possible to observe the heart. In the kuruma shrimp, the 20s (57.1%) and 30s–60s (92.9%) indicated that it was easy or possible to observe. Volunteers in their 20s tended to be more careful in answering questions on the visibility of the heart.

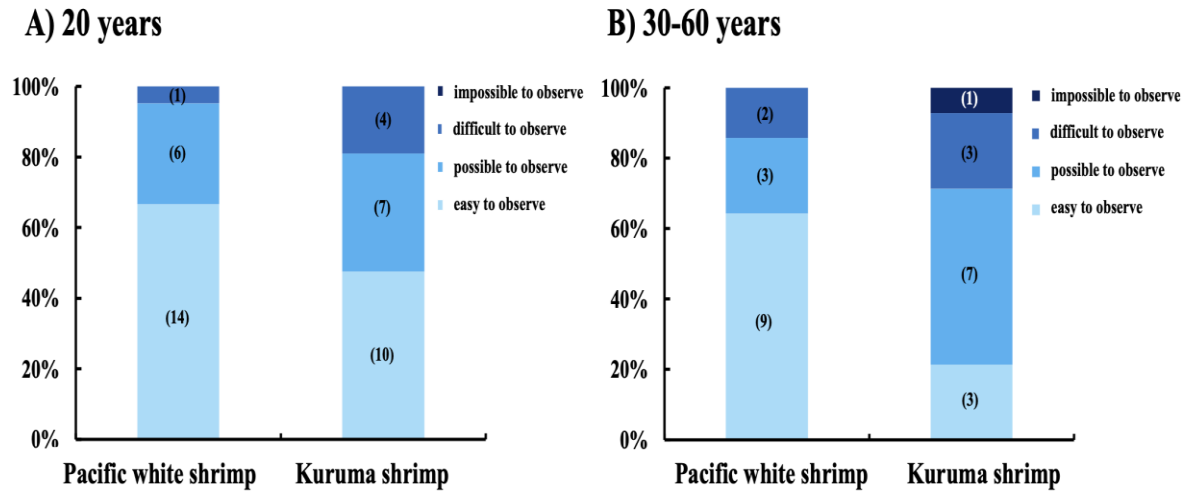

Fig. 5: Results of a questionnaire on the visibility of the hepatopancreas or midgut gland of the Pacific white and kuruma shrimps by volunteers. The volunteers evaluated the visibility of the hepatopancreas on a graded scale. Numbers inside the bars indicate the number of respondents.

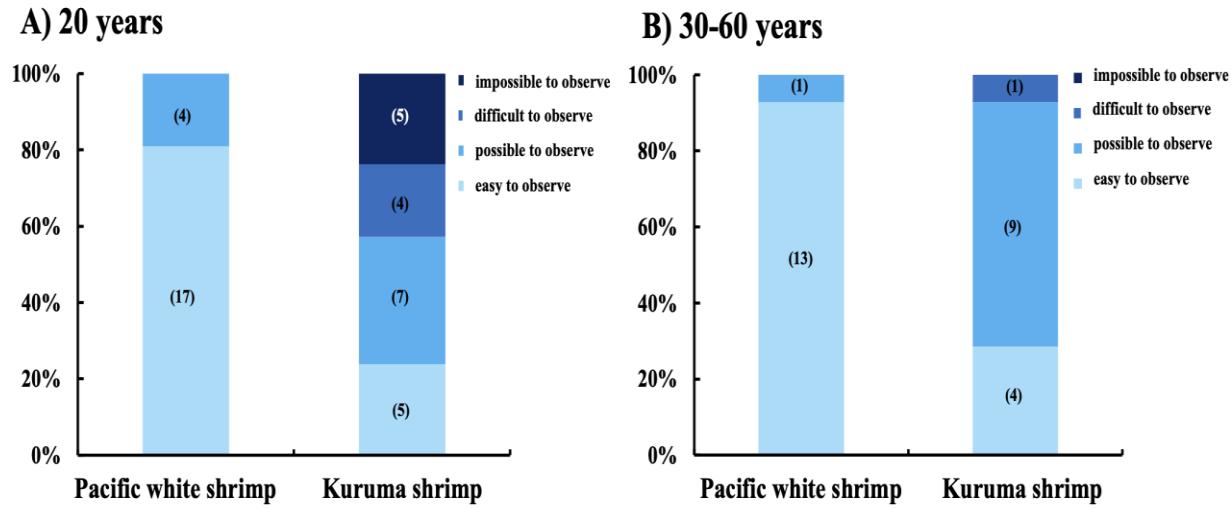

Fig. 6: Results of a questionnaire on the visibility of the heart of the Pacific white and kuruma shrimps by volunteers. The volunteers evaluated the visibility of the stomach on a graded scale. Numbers inside the bars indicate the number of respondents.

Visibility of the intestine in Pacific white shrimp and kuruma shrimp by volunteers

The results are indicated in Figure 7. For the Pacific white shrimp, most volunteers in their 20s (95.2%) and 30s–60s (100%) indicated that it was easy or possible to observe the intestine. In the kuruma shrimp, 20s (33.3%) and 30s–60s (50.0%) indicated that it was easy or possible to observe. Volunteers in their 20s tended to be more careful in answering questions on the visibility of the intestine.

Discussion

Advantages of the Pacific white shrimp

The results of this study indicate that the Pacific white shrimp is more useful than the kuruma shrimp for viewing the internal organs. Once introduced into an educational program, this will provide information on the basic anatomy of the animal, including the digestive and vascular systems, and an understanding of the specific body plan of the shrimp.

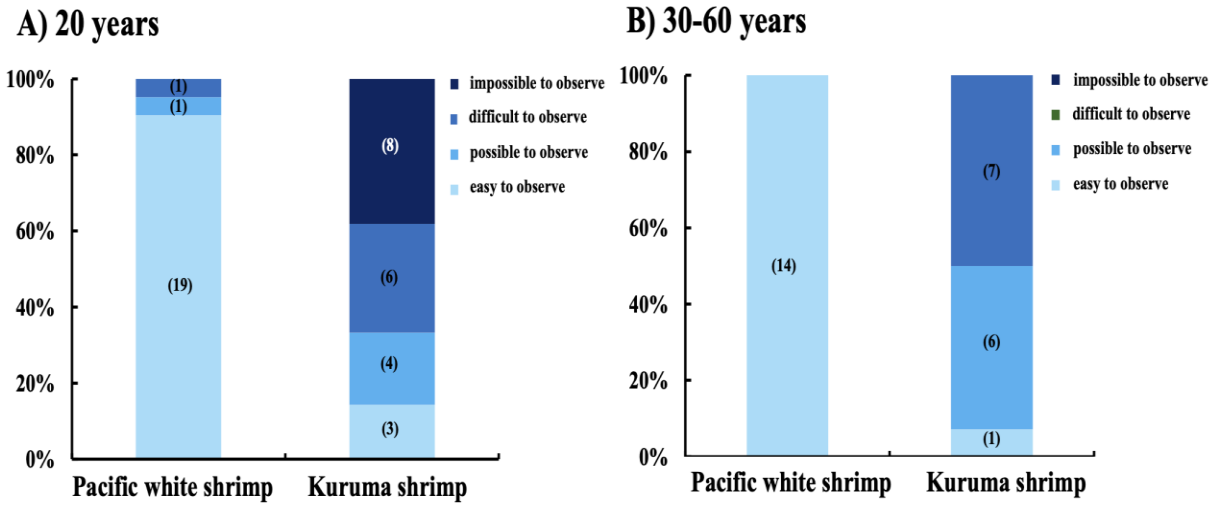

Fig. 7: Results of a questionnaire on the visibility of the intestine of thePacific white and kuruma shrimps by volunteers. The volunteers evaluated the visibility of the intestine on a graded scale. Numbers inside the bars indicate the number of respondents.

The ability to visualize the stomach and intestine can confirm what the shrimp has eaten and is useful for examining the digestive system of the animal. Food enters the mouth, followed by the stomach. It is digested in the hepatopancreas and is further processed in the intestines. In crustaceans, the coloration of the digestive system can provide information about the type of diet and health status. For example, feeding trials on the swimming crab *Portunus trituberculatus* indicated that the color of the hepatopancreas changes from pale white to red when the type of food is changed (Guo *et al.*, 2022). The hepatopancreas is an original aspect of the crustacean digestive tract that is used for the storage of nutrient reserves (Ceccaldi, 1998), which are used during the intermolt phase of each molt cycle to build new tissues. Therefore, Pacific white shrimp are an excellent model animal to explain the hepatopancreatic function of crustaceans.

The beating hearts of the Pacific white shrimp were more easily observed compared with that in the kuruma shrimp (Video 1: Pacific white shrimp; Video 2: kuruma shrimp; https://ijzi.net/Vdo-Heartbeat.html). Shrimps have an open vascular system, with a hole in the heart (ostium) through which the blood lymph also flows. The Pacific white shrimp is an excellent model animal to explain not only the location of the shrimp's heart but also to examine the open vascular system with ostium without dissection.

Potential educational programs involving the Pacific white shrimps

Because animal welfare is becoming an issue, the Pacific white shrimp is an excellent model that allows easy observation of its internal organs without dissection. We found that volunteers in their 20s tended to be more cautious in their responses to the visibility of the stomach, intestine, and heart (Figs. 4, 6, 7), but only the identification of the hepatopancreas was considered cautious in the 30s–60s group (Fig. 5). Therefore, the ability to observe these organs is not the same based on the age of the observer and/or the organ under observation. In the future, it will be necessary to construct shrimp education programs optimized for school-age and attainment goals. This shrimp model may not only be used for university students but also for elementary, junior high, and high school students to understand the functions of the internal organs and the animal's anatomy.

Decapods, including shrimp, are an important part of the marine ecosystem. The Norwegian lobster *Nephrops norvegicus* has been shown to break down marine plastic into small fragments in

their stomachs and excrete finer microplastics through their intestines (Cau *et al.*, 2020). Studying the digestive system of the shrimp will not only provide insight into the animal's anatomy but will serve as an effective model for understanding environmental issues.

Ethical Statement

This study was in accordance with the Guidelines proposed by Institute of Noto Satoumi Education and Studies, Ogi, Noto-cho, Ishikawa 927-0553, Japan

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Conflict of Interest

The authors declare no conflicts of interest.

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