

Duke of Edinburgh Prize to:

Katsumi TSUKAMOTO
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for “The Fundamental Studies on Fish
 Migration, especially the Discovery of
 the Eel Spawning Area in the Pacific”

***Outline of the work:***

Migratory fishes have long been attracting people’s interest. Therefore, migratory fishes have not only been for research objects and food animals, but also the subjects of legends and belief, or symbolic creatures that help connect humans with nature. Prof. Katsumi Tsukamoto has contributed to establishing the field of fish migration studies by being engaged in research on migratory fishes for 40 years. Among his achievements, the discovery of spawning events of the Japanese eel in the western Pacific by collecting their eggs deserves special mention. He published about 600 original papers or book chapters including three papers in the journal *Nature* that were highly regarded internationally. In addition, he published many educational and general public books, and especially his recent essay entitled “Pursuing the mystery of the eel”, which is included in the Japanese language textbook for the 4th grade of elementary schools, is making a deep impression on children.

1. Fish Migration Study

Prof. Tsukamoto chose three species that migrate between the sea and freshwater, the anadromous masu salmon, amphidromous ayu and catadromous freshwater eels, as model species for his migration studies. First, using intensive field surveys of masu salmon, he also found that the aquatic plants along riverbanks played an important role for the wintering and survival of juvenile salmon before their downstream migration to the sea. Furthermore, extensive mark recapture experiments showed that the early growth rate in the river was an important determinant for the differentiation of migratory types, such as migrants or residents.

By investigating the mechanism of upstream migration in juvenile ayu, he found an important principle of the migratory ecology of the ayu in which the fish born earlier in a spawning season migrated earlier at a younger age with a smaller body size, but with a higher growth rate. This finding led to discovery of an interesting phenomenon of a migratory-type of “large ayu” with larger size at maturity inhabiting in the inlet rivers of Lake Biwa that switched at each generation every year between resident-type “small ayu” with much smaller size at maturity that inhabit the lake throughout their life. This alternating life history strategy called “Switching Theory” was highly regarded internationally as a first example in fish ecology.

Secondly, he revealed that a surge of thyroid hormone was the necessary condition before upstream migration, and that as the final step for triggering the initiation of migration, an elevated internal drive level in the brain caused by exogenous environmental factors such as a rise in water temperature or fish density and changes in light condition, or endogenous physiological factors such as starvation and circadian rhythm are likely needed. His work on ayu migration was a comprehensive and integral model research that included various approaches from ecology, physiology and behavior to be a pioneer work in the field of fish migration.

2. Discovery of the Japanese Eel Spawning Area

At the beginning of the 20th century, the Danish oceanographer Johannes Schmidt found the spawning area of the Atlantic freshwater eels in the Sargasso Sea of the North Atlantic. This discovery ended 2,400 years of superstition and confusion about eel spawning after the ancient Greek naturalist Aristotle suggested that eels spontaneously originated from the guts of the earth. But Schmidt could only outline the possible range of the estimated spawning area of these eels as being as wide as millions of square kilometers by collecting their small eel larvae, because he did not determine any sites where their spawning behavior had actually occurred by collecting adult eels or their eggs in his estimated spawning area.

Prof. Tsukamoto has participated in more than 20 research cruises in the western North Pacific searching for the spawning area of the Japanese eel for 40 years since 1973. He has organized many international collaborative research cruises on eel spawning areas since 1986. In the summer of 2009, he and his colleagues succeeded in collecting 31 Japanese eel eggs using large plankton nets along the southern end of the West Mariana Ridge to the west of Guam, which was a moment when human beings could finally see wild eel eggs and, thus revealing the mystery of eel spawning for the first time since the age of Aristotle. This success was reported in the journal *Nature Communications* in a paper entitled “Oceanic spawning ecology of freshwater eels in the western North Pacific” in February 2011.

This discovery was derived from two main hypotheses, the Seamount Hypothesis and the New Moon Hypothesis. These hypotheses were proposed based on the distribution data of all eel larvae of this species ever collected in the North Equatorial Current, together with the ocean bottom topography and the oceanic current patterns, as well as data on the hatching dates of larvae from their otolith (ear stone) daily growth rings. The two hypotheses predicted the area and timing of eel spawning event by proposing that eels will spawn near the seamount areas of the West Mariana Ridge during the darkness of the new moon period of each month within their spawning season. The new findings obtained by Prof. Tsukamoto’s team about the wild eel eggs and their apparent spawning depths confirmed both hypotheses and are the only comprehensive view of oceanic eel spawning in the world.

3. Applied research

The basic studies on fish migration by Prof. Tsukamoto have contributed greatly to the advancement of applied science such as conservation biology and fisheries science. Research on migratory type differentiation of fishes such as masu salmon residents gave important information for their conservation and ecology. The information on eel spawning ecology by Prof. Tsukamoto have provided better understanding of eel biology and life history, which can facilitate conservation efforts to prevent further declines in populations of these remarkable fishes that are increasingly endangered globally. He has organized the East Asia Eel Resource Consortium (EASEC) since 1997 for a better understanding of the state of eel resources and the conservation of the international shared resource of the Japanese eel in East Asia. An Eel Sanctuary “Eel River” has also been designated in each country of Taiwan, China, Korea and Japan, and scientists have started the monitoring of glass eel recruitment, which also helps to stimulate the awareness of the endangered eels by the public.

As mentioned above, the original and extensive research on fish migration by Prof. Tsukamoto has contributed greatly to both the academic world and the conservation of organisms and natural environment. Therefore, Prof. Tsukamoto deserves to be a laureate for the Duke of Edinburgh Prize of the Japan Academy.

List of Primary Publications:

【Original Papers】

1. TSUKAMOTO, **Katsumi**, Seinen CHOW, Tsuguo OTAKE, Hiroaki KUROGI, Noritaka MOCHIOKA, Michael J. MILLER, Jun AOYAMA, Shingo KIMURA, Shun WATANABE, Tatsuki YOSHINAGA, Akira SHINODA, Mari

- KUROKI, Machiko OYA, Tomowo WATANABE, Kazuhiro HATA, Shigeo IJIRI, Yukinori KAZETO and Hideki TANAKA: Oceanic spawning ecology of freshwater eels in the western North Pacific. **Nature Communications**, 2 February, 2011.
2. **TSUKAMOTO, Katsumi**: Oceanic migration and spawning of anguillid eels. **Journal of Fish Biology**, 74, 1833-1852, 2009.
 3. **TSUKAMOTO, Katsumi**, Yoshiaki YAMADA, Akihiro OKAMURA, Toyoji KANEKO, Hideki TANAKA, Michael J. MILLER, Noriyuki HORIE, Naomi MIKAWA, Tomoko UTOH and Satoru TANAKA: Positive buoyancy in eel leptocephali: an adaptation for life in the ocean surface layer. **Marine Biology**, 156, 835-846, 2009.
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 11. **TSUKAMOTO, Katsumi**: Discovery of spawning area of the Japanese eel. **Nature**, 356, 789-791, 1992.
 12. **TSUKAMOTO, Katsumi** and Kazuo UCHIDA: Spacing and jumping behaviours of the ayu, *Plecoglossus altivelis*. **Fisheries Science**, 56, 1383-1392, 1990.
 13. **TSUKAMOTO, Katsumi**, Shinji MASUDA, Minoru ENDO and Tsuguo OTAKE: Behavioural characteristics of the ayu, *Plecoglossus altivelis*, as predictive indices for stocking effectiveness in a river. **Fisheries Science**, 56, 1177-1186, 1990.
 14. **TSUKAMOTO, Katsumi**: Recruitment mechanism of the eel, *Anguilla japonica*, to the Japanese coast. **Journal of Fish Biology**, 36, 659-671, 1990.
 15. **TSUKAMOTO, Katsumi**, Yasuo SEKI, Tadamichi OBA, Machiko OYA and Masao IWAHASHI: Application of otolith to migration study of salmonids. **Physiology and Ecology Japan**, Special Vol.1, 119-140, 1989.
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【Books, Book chapters】

22. **TSUKAMOTO, Katsumi**: Migration. *The Basic Ecology of Fishes*. (ed. K. Tsukamoto), Koseisya-Koseikaku, 57-72, 2010.
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