Division of Seasonal Biology (Adjunct)

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Animals living outside the tropics adapt various physiology and behavior to seasonal changes in the environment. For example, animals restrict breeding to specific seasons to maximize survival of their offspring in temperate zones. As animals use changes in day length and temperature as seasonal cues, these phenomena are referred to as photoperiodism and thermoperiodism, respectively. We use comparative approaches to understand these mechanisms. Medaka fish provides an excellent model to study these mechanisms because of their rapid and robust seasonal responses. In this division, we are trying to uncover the underlying mechanisms of seasonal adaptation.

I. Underlying mechanism that defines the critical photoperiod

It is well established that the circadian clock (i.e., an internal biological clock with a period of approximately 24 hrs) is somehow involved in seasonal time measurement.

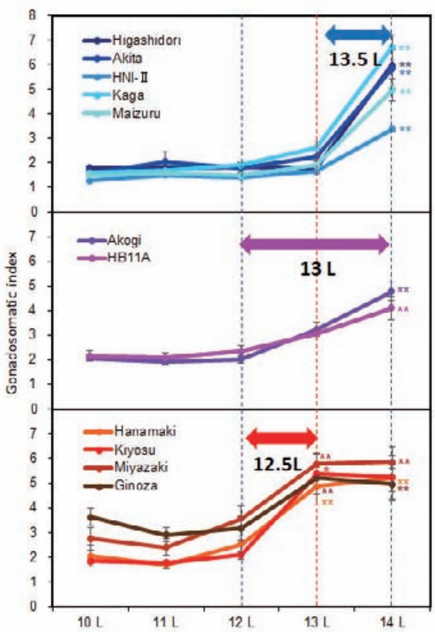

Figure 1. Different critical day length between Medaka from higher and lower latitudes.

However, it remains unknown how the circadian clock measures day length. It has been reported that Medaka populations that were caught at higher latitudes have more sophisticated responses to day length (Sawara and Egami, 1977). For example, Medaka fish caught in Hokkaido have a longer critical day length (i.e., duration of photoperiod required to cause a response) than those caught in Okinawa. To uncover the underlying mechanism of seasonal time measurement, we are currently performing a forward genetic analysis in Medaka populations collected from various latitudes all over Japan.

1-1 Variation in critical photoperiod with latitude in Medaka fish

To perform a forward genetic analysis, we have obtained 11 populations including wild populations, closed colonies, and inbred strains from all over Japan. We have examined the effects of changing day length to determine the critical day lengths that will cause seasonal responses in the gonad. In winter, fish were subjected to 10, 11, 12, 13, and 14 h day lengths with warm temperatures. Then gonadal development was examined to determine the critical day length. As a result, we found differences in the critical day length among Medaka populations. That is, Medaka from higher latitudes required longer day length while those from lower latitudes required shorter day length (Figure 1).

1-2 Quantitative trait loci (QTL) analysis of critical day length

To identify the genes regulating critical day length, quantitative trait loci (QTL) analysis was conducted using F_2 medaka derived from crosses between Northern and Southern populations. As a result, we identified significant QTLs using Restriction-site Associated DNA (RAD) markers (Figure 2). We are now performing whole genome re-sequencing using various Medaka strains that show different critical photoperiods.

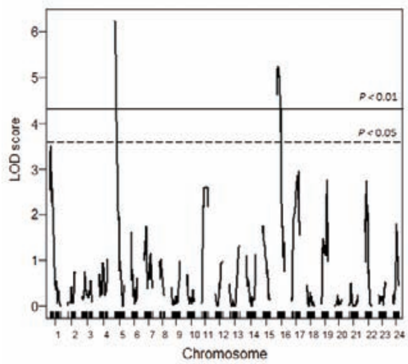

Figure 2. Result of QTL analysis for critical day length.

II. Mechanism that determines seasonal breeders and non-seasonal breeders

Animals that reproduce year-round (e.g., human beings and laboratory mice) are so-called non-seasonal breeders. In contrast most animals living outside of tropical zones reproduce only during a particular period of the year. Therefore, they are called seasonal breeders. However, the underlying mechanism that determines seasonal breeders and non-seasonal breeders remains unknown. To uncover this mechanism, we performed a forward genetic approach.

2-1 Geographic variations in the responses to short day stimulus

When we transferred Medaka fish from summer conditions to winter conditions, we noticed that Medaka from lower latitudes do not regress their gonads even under short day conditions. Accordingly, we next examined the responses to short day conditions using 19 populations derived from various latitudes. As a result, populations from higher latitudes showed gonadal regression, while populations from lower latitudes did not regress their gonads (Figure 3).

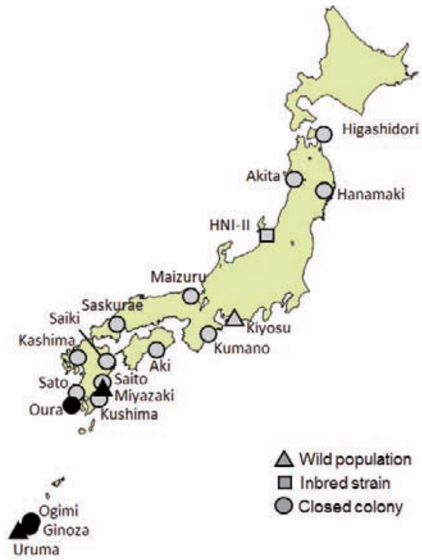

Figure 3. Medaka from lower latitudes (Solid black symbols) do not regress their gonads even under short day conditions.

2-2 QTL analysis of genes determining seasonal breeders and non-seasonal breeders

To identify genes that determine seasonal breeders and non-seasonal breeders, we performed QTL analysis using F_2 generations and identified a significant QTL that determines seasonal breeders and non-seasonal breeders. We are currently trying to identify responsible genes (Figure 4).

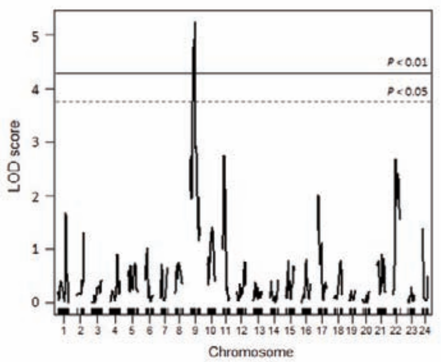

Figure 4. Result of QTL analysis that determines seasonal breeder and non-seasonal breeder.

III. Transcriptome analysis of seasonality in Medaka fish

In addition to the forward genetic approach, we have performed genome-wide transcriptome analysis of brain, eye, and liver of Medaka fish to understand the underlying mechanism of seasonal adaptation. Results of the eyes revealed dynamic seasonal changes in expression of genes encoding photopigments and the downstream phototransduction pathway. Functional analysis suggested that seasonally regulated plasticity in the phototransduction pathway is critical for the emergence of seasonally regulated behavior.

Publication List:

〔Review articles〕

- Ikegami, K., and Yoshimura, T. (2016). Comparative analysis reveals the underlying mechanism of vertebrate seasonal reproduction. Gen. Comp. Endocrinol. *227*, 64-68.
- Nishiwaki-Ohkawa, T., and Yoshimura, T. (2016). Molecular basis for regulating seasonal reproduction in vertebrates. J. Endocrinol. *229*, R117-R127.