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Review

Omics of the marine medaka (*Oryzias melastigma*) and its relevance to marine environmental research

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A B S T R A C T

In recent years, the marine medaka (*Oryzias melastigma*), also known as the Indian medaka or brackish medaka, has been recognized as a model fish species for ecotoxicology and environmental research in the Asian region. *O. melastigma* has several promising features for research, which include a short generation period (3–4 months), daily spawning, small size (3–4 cm), transparent embryos, sexual dimorphism, and ease of mass culture in the laboratory. There have been extensive transcriptome and genome studies on the marine medaka in the past decade. Such omics data can be useful in understanding the signal transduction pathways of small teleosts in response to environmental stressors. An omics-integrated approach in the study of the marine medaka is important for strengthening its role as a small fish model for marine environmental studies. In this review, we present current omics information about the marine medaka and discuss its potential applications in the study of various molecular pathways that can be targets of marine environmental stressors, such as chemical pollutants. We believe that this review will encourage the use of this small fish as a model species in marine environmental research.

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1. Introduction

Current aquatic ecotoxicological studies of experimental animals have mostly focused on freshwater organisms. Marine organisms have been used sparingly. Biomonitoring with sentinel organisms and risk assessments of the health of aquatic ecosystems are key to ensuring a safe and habitable environment (van der Oost et al., 2003). Standardized and developed model species are important for effective biomonitoring and environmental risk assessment (ERA). In recent years, omics databases have been evaluated for the development of useful and accessible ERA and prediction tools (Piña and Barata, 2011). One of the most important steps in conducting omics-based marine ecotoxicological and environmental studies is finding an appropriate marine model organism that can be used to elucidate the underlying molecular mechanisms that are affected by marine and estuarine pollutants.

New technologies for next-generation sequencing (NGS) with bioinformatics, widely used in personalized medicine, have also been applied to marine environmental research (Bourlat et al., 2013). Marine ecotoxicologists and environmental scientists are eager to apply NGS to develop model marine species that can lead to a better understanding of underlying molecular mechanisms, which has already been done in freshwater model species (Fent and Sumpter, 2011).

Fish are the most diverse marine vertebrates. Therefore, diverse fish species are necessary for evaluating pollutant toxicity and understanding the mechanisms of action underlying this toxicity. Fish can also be useful as model species to study early warning signals for the effects of anthropogenic substances (Heath, 1995). Two fish model species, medaka and zebrafish, are unique for their versatility in diverse research areas. One of the advantages of both species is the availability of whole genome information and mutant lines (Kasahara et al., 2007; Howe et al., 2013). Although recent sequencing projects in other teleosts have offered valuable insights into genetics, evolutionary biology, and developmental biology, the medaka and zebrafish still hold distinct advantages as model species (Roest Crollius and Weissenbach, 2005; Mehinto et al., 2012; Schartl, 2014). Medaka and zebrafish are considered ‘piscine mice’ and have been widely used in functional genomics studies involving transgenesis, antisense oligonucleotide (morpholino)-triggered knockdowns, and large-scale mutagenesis (Grunwald and Eisen, 2002; Wittbrodt et al., 2002; Taniguchi et al., 2006; Lieschke and Currie, 2007). The development of credible fish models for omics-based marine environmental research is also important for ecosystem risk assessment of marine pollution. Marine scientists need ecologically relevant fish species to better understand molecular mechanisms involved in detoxifying marine pollutants. In the past few decades, molecular biomarkers in fish that respond to freshwater environmental pollution have been extensively utilized to monitor the health of aquatic ecosystems (Heath, 1995; van der Oost et al., 2003). However, the use of single or multiple biomarkers might be limited by a lack of sensitivity and specificity in response to chemicals.

An analysis of the published research on the marine medaka reveals that it has had limited use in omics research (Fig. S1). Valuable insights have been obtained from the use of the latest omics tools in risk assessment research on marine pollutants (Bourlat et al., 2013; Brander et al., 2013). The application of microarrays and/or RNA-seq-based ecotoxicogenomic techniques has allowed the evaluation of early molecular responses to environmental contaminants rather than just a single endpoint. In addition, omics platforms can help researchers understand the responses of biota to marine pollutants (Van Aggelen et al., 2010). However, there is a need for the development of robust model species in marine ecotoxicological research in order to effectively deploy omics capabilities. In the quest for such a model, we present a critical appraisal of the marine medaka, with special reference to its omics and its applications in marine ecotoxicology and environmental risk assessments.

2. Taxonomic background

There is some ambiguity about the taxonomic position of the marine medaka *Oryzias melastigma* (synonyms: *Oryzias dancena*, *Oryzias melastigmus*, *Oryzias melanostigma*). The fish was initially named *Cyprinus dancena* by Hamihon (1822) without any original morphometric description. Day (1877) identified this species from India and reported it as *Haphochilus melastigma*. Subsequently, Jordan and Snyder (1906) characterized the species from India and renamed it *O. melastigma*. The species name *O. melastigma* was also used to refer to the brackish *Oryzias* species in Japanese literature (Yamamoto, 1975; Uwa et al., 1983; Iwamatsu et al., 1985; Uwa and Magtoon, 1986; Uwa and Parenti, 1988; Hamaguchi, 1996), and the fish was registered at the Laboratory of Freshwater Fish Stocks BioScience Center of Nagoya University (Nagoya, Japan) (Iwamatsu et al., 1993). However, this species was renamed by Roberts (1998) as *O. dancena* based on analysis of morphometric parameters. Phylogenetic analysis using *Oryzias* mitochondrial DNA sequences revealed that *O. dancena* (like *O. melastigma*) has a sister relationship with the basal species *Oryzias javanicus* (Naruse, 1996; Takehana et al., 2005). Thus, several scientific names are available for the brackish *Oryzias* species. Because previous specimens have been named *O. melastigma* or *O. dancena* from India and Thailand and show slightly different phenotypic characteristics in dorsal-fin rays, anal-fin rays, pelvic-fin rays, or fin shapes (Magtoon and Termvidchakorn, 2009), studies are needed to appropriately name the species. In this study, we used the fish name *O. melastigma*, and sequenced and registered its mitochondrial genome information under this name (Hwang et al., 2012). The *O. melastigma* used in the genome analysis was provided by Dr. Doris W.T. Au (from the stock culture of the State Key Laboratory in Marine Pollution, City University of Hong Kong, Hong Kong SAR, China) in August 29, 2009 and has been maintained at the aquarium facility of the Department of Biological Science, Sungkyunkwan University (Suwon, South Korea).

3. Advantages of using the marine medaka

The marine medaka can be easily raised in laboratory aquatic culture conditions, as the species requires similar husbandry conditions to those of the Japanese medaka and zebrafish with respect to water quality, temperature, feeding, and light cycles. However, they require a different salinity. Japanese medaka tolerates a wide range of temperature fluctuation (10–40 °C) (Wittbrodt et al., 2002), while there is only limited information on temperature tolerance of the marine medaka. A recent study using *O. melastigma* larvae exposed to 12–32 °C for 7 days showed that cumulative mortality significantly increased at 12 °C (81.7%) and 32 °C (23.3%) (Li et al., 2015). In the case of adults (both sexes), the fish showed no mortality in slow acclimation to 10 and 35 °C for 10 days (unpublished), suggesting that the marine medaka has strong thermal tolerance at both low and high temperature ranges.

The marine medaka is an egg-laying fish that produces transparent embryos with a diaphanous chorion (Chen et al., 2009). The marine medaka eggs become attached to the female body using attachment filaments that allow easy identification of reproductively active females for subsequent studies. The marine medaka has several promising characteristics for experimental research, which include small size (3–4 cm), ease of maintenance and breeding under laboratory conditions, and responsiveness to