RESEARCH ARTICLE

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Dynamic Changes in the Sperm Quality of *Mytilus galloprovincialis* Under Continuous Thermal Stress

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SUMMARY

Global warming is an increasingly serious problem underlying ecological change in marine flora and fauna. *Mytilus galloprovincialis* is an intertidal species that colonizes coasts in moderate and warm climates, and can thus withstand extreme climatic conditions; however, it successfully reproduces only within a certain temperature range. The effects of prolonged exposure to 28°C, a temperature unsuitable for breeding activity, on sperm quality were evaluated in this study. Such heat stress induced the following: a significant reduction in concentration; a biphasic pattern of motility and mitochondrial membrane potential that first increased, and then collapsed; a decrease in the intracellular calcium concentration; a rapid increase in lipid peroxidation that was normalized after the third week of heat stress; an increase in DNA fragmentation after the third week of heat stress; and atypical morphology (i.e., sperm with a globular head, asymmetrical tail, and acrosome loss). Currently, these elevated-temperature conditions are achieved along the Mediterranean coast during the late summer, when the reproductive activity of *M. galloprovincialis* is suspended after massive spawning in the spring. The increasing global temperature, however, may shift their breeding season, thus significantly impacting marine ecosystems and mussel production.

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INTRODUCTION

Global warming is an increasingly pervasive occurrence that is altering environmental conditions and biogeochemical processes of marine ecosystems (Hoegh-Guldberg and Bruno, 2010; Munday et al., 2013). Shifts in species ranges and changes to phenology, abundance, life-history traits, and physiological performance have all been identified and attributed to shifts in the climate (Poloczanska et al., 2013). A major goal of climate-change research is determining the future of individual populations. Experimental studies have provided crucial insights into the responses of various marine species to higher temperatures (Portner and Farrell, 2008), thus alluding to how organisms might respond to the present and future climate, but fundamental knowledge gaps remain (Kelly and Hofmann, 2013). Furthermore, projections of a species' persistence within marine habitats preclude the role of evolution and the ability of organisms to adapt (Munday et al., 2013).

Mytilus spp. are well-studied organisms widely used as bioindicators in monitoring programs, such as Mussel Watch, which integrates chemical analyses with the use of biomarkers to track the molecular, biochemical, and cellular effects of pollutants (Livingstone, 1993). The current biogeographic distribution of *M. galloprovincialis*, for example, appears to be related to water temperature: it is a temperate-to-warm water animal that lives in habitat that starts in the Mediterranean and extends northward to the coast of France, Russia, and the United Kingdom (Sanjuan et al., 1997). *M. galloprovincialis* also represents