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Mucus as a mediator of gametogenic synchrony in the sea cucumber *Cucumaria frondosa* (Holothuroidea: Echinodermata)

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The data presented here demonstrate that the sea cucumber *Cucumaria frondosa* secretes a biologically active mucus that helps maintain gametogenic synchrony among conspecifics. Either a whole mature individual or a sample of its freshly collected mucus was able to initiate gametogenesis in conspecifics that were in the gametogenic recovery stage when other environmental conditions, including daylength, were maintained constant. Similar results were obtained when the mucus was kept in seawater for less than 3 h prior to its use, whereas after 6 h in seawater, the mucus had lost its inducing properties. Laboratory experiments showed that the mucus was produced in lesser amount during late summer and autumn; the production rapidly increased in early January to reach a peak a few months before the June spawning, in 1992 and 1993. The increment of mucus production was concurrent with the initiation of gametogenesis. Synthesis of mucus was maximal in individuals having attained gametogenic maturity and minimum in individuals with less developed gonads. At first relatively stable in seawater, the mucus gradually lost its integrity within a period of 3–5 h, suggesting that the mucus may be carried over long distances by currents, thus allowing a transfer of information before its complete degradation. This phenomenon was observed in the field where streams of mucus could be followed by SCUBA divers as far as 20–30 m away from the secreting animal. The data presented here are the first evidence of the important role played by mucus secretion during the gametogenic processes of an echinoderm.

INTRODUCTION

A number of interactions between organisms involve chemical agents rather than physical contact, and the study of these interactions has been termed chemical ecology. Interspecific chemoreception is thought to prevail mainly in food and predator detection. Nevertheless, pheromones are presumed to play a role during conspecific recognition, search of suitable colonizing area, spawning, courtship, moulting, aggregation and communication of potential threat among invertebrates (see reviews by Leroy, 1987; Agosta, 1992; Hay, 1996).

Although reports remain scarce and often speculative, the study of chemical communication in echinoderms has received some degree of attention in recent years. Run et al. (1988) proposed that sex-specific contact chemoreception could partially explain sex recognition in the starfish *Archaster typicus*. Ormond et al. (1973) and Beach et al. (1975) showed that an active component released by the gonad of *Acanthaster planci* induced reproductive behaviour and spawning in nearby mature adults. Chaet (1966) and Kanatani & Shirai (1968) suggested that a chemical substance released into the seawater by starfish could stimulate the spawning in neighbouring individuals. More recently, Hamel & Mercier (1995a) indicated that chemical communication seemed to play a role in the synchronization of gametogenesis during aggregative behaviour in the starfish *Leptasterias polaris*, mostly during the last stages of gamete maturation, before spawning. The paired mating of the sea star *Neosmilater georgianus* was also presumed to be regulated by chemical mediators (Slattery & Bosch, 1993). Miller (1989) studied the periodic presence of a long-lived bioactive sex-specific substance in natural seawater during the reproductive season of starfish. He suggested that benthic invertebrates may communicate their sexual identity and readiness to spawn by means of waterborne pheromones. To our knowledge, no description of the exact mode of action or identification of the chemical compounds involved have been provided for echinoderms (see review by Giese et al., 1991).

In a recent study, we have demonstrated that photoperiod was not the only factor controlling the onset and evolution of gametogenesis in *Cucumaria frondosa* (Hamel & Mercier, 1996a). Laboratory experiments showed that gametogenic processes were significantly asynchronous in individuals maintained separately under natural environmental conditions for more than a year. Conversely, animals kept in groups showed gametogenic synchrony. Gametogenic activity was induced in less mature individuals by exposure to more developed ones, even without the photoperiod cue. These results clearly demonstrated that chemical communication was playing a major role during gametogenesis, in synergism with the increment of daylength, temperature and food supply, allowing an optimal synthesis of gametes to ensure the success of spawning (Hamel & Mercier, 1996a).

The goal of the present work was to determine the origin of the chemical mediator and its annual seasonal cycle in *C. frondosa*. We also aimed at determining its ecological significance in benthic ecosystems, especially among dense populations of sea cucumbers found at all