

Reproductive differences between cultured and wild corals

Taiwan's National Museum of Marine Biology & Aquarium (NMMBA) has focused on the artificial propagation of corals for years. In 2014, natural spawning of gametes of various cultured corals was officially recorded after 8 years culturing. Since then, the researchers of NMMBA have been able to study a variety of cultured corals, such as *Oxypora* sp and *Echinopora* sp. Thanks to the stable environment created by NMMBA for the artificial propagation of corals, the nearly synchronised spawning of cultured and wild corals occurs every year during spawning season and is a spectacle that has been receiving news coverage since 2015. Presently, the NMMBA is the only known research institution worldwide that is able to breed corals for natural spawning of these corals in large water tanks, and conduct scientific research using the coral gametes including sperm and eggs. Natural spawning of gametes in cultured corals is extremely difficult. During propagation, environmental factors must fulfil the growth needs of corals, such as amount of light exposure, temperature, amount of nutrient salt provided, culture conditions, water flow, and water quality. Only when all the required conditions are fulfilled can researchers create an environment for corals to spawn. The spawning of cultured corals indicates that their health and the propagation environment have reached a desirable status. However, no study has compared the differences between the eggs produced by cultured corals and those produced by wild corals in terms of morphology, characteristics, and physiological and biochemical properties.

This study aimed to clarify the reproductive differences between cultured and wild corals and provide a foundation for relevant research to promote the technological development of artificial coral propagation and cryopreservation. The study results revealed substantial differences between the eggs produced by cultured corals and those produced by wild corals, particularly with respect to egg size, thickness of microvillus layers, lipid and yolk contents, and density of *Symbiodinium* (plant cells that have a symbiotic relationship with corals) in parent corals, and chlorophyll content. The eggs of wild corals are larger possibly because food resources are more abundant in the wild, allowing wild corals to feed on small plankton in seawater. By contrast, the seawater in the environment constructed by the NMMBA has been filtered.

Studies have proven that larger eggs are conducive to successful reproduction because the larger volume enables these eggs to store more nutrients. This leads corals to spend more time in the egg stage and is also beneficial for embryonic development following fertilisation. Larger eggs can provide more nutrients to the embryo and help the embryo grow into a larger adult coral. The microvilli across the surface of a coral egg are pivotal because they promote nutrient absorption and affect the fertilisation process. These membrane protrusions are the key to successful fertilisation, maturation, and offspring reproduction. This study discovered that cultured corals had a thicker microvillus layer than did wild corals. Such specialisation occurred probably because the cultured corals attempted to adapt themselves to an artificial 'adversity' (i.e., an environment in which the conditions are less favourable than those of a natural environment). Transmission electron microscope observation revealed complex structures of yolk and lipid in coral eggs, indicating that they have yolk materials with various properties. We determined that yolk and lipid

contents were higher in the eggs produced by human-grown corals, possibly because of physical changes induced by the propagation environment. Studies have reported that when food resources are insufficient, *Symbiodinium* in the coral body is subjected to the nitrogen deficiency effect, also known as deficiency of nitrogen fertiliser (i.e., one of the three major nutrients for plant growth). Such 'adversity' changes the physiological metabolism of *Symbiodinium*, leading to higher levels of production and accumulation of yolk materials, which is delivered to coral by *Symbiodinium* and stored in eggs. Alternatively, this study revealed that in an artificial environment where food was insufficient, corals tended to synthesise more lipid and delivered the lipid to their eggs when necessary.

Finally, this study measured the density of *Symbiodinium* and content of chlorophyll in parent corals because the most remarkable mystery of corals is how they are able to keep plants (i.e., *Symbiodinium*) within themselves and live on these plants. The relationship between corals and *Symbiodinium* represents unique mutualism between animals and plants. Such mutualism with *Symbiodinium* is crucial and indispensable for hermatypic corals to maintain their health. Some studies showed that deep-water corals have higher *Symbiodinium* density and chlorophyll content compared with shallow-water corals because they must enhance their sunlight absorption efficiency. This explains why *Symbiodinium* and chlorophyll contents are higher in cultured corals than in wild corals.

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