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Modeling the transport of coral larvae within the Singapore Straits reveals potential external source reefs for the Southern Islands of Singapore

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Is gene flow rare in *Isopora brueggemanni*? – Inference from the genetic assignment methods

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The scleractinian coral *Isopora brueggemanni*, which is distributed throughout the Ryukyu Archipelago (Okinawa Island, Miyako Island, and the Yaeyama Islands), is a hermaphroditic brooder. However, only a few planulae were released intermittently from colonies kept in running seawater tanks and no apparent periodicity of planula release was observed. Histological study suggests that some planulae might be produced through self-fertilization. Although this coral forms colonies with short stout branches, asexual reproduction via fragmentation occurs frequently under natural conditions.

Our previous study showed that the clonal structure and genetic diversity of each population of *I. brueggemanni* were very different, and that there was significant genetic differentiation among the populations. This is probably because gene flow via planulae dispersion is low due to low dispersal capacity of planulae or to predominance of asexual reproduction via fragmentation.

In this study, to estimate the extent of gene flow (connectivity) among populations of *I. brueggemanni*, we performed genetic assignment methods to detect migration over far shorter timescales using microsatellite markers.

We sampled *I. brueggemanni* from 19 populations at three sites in the Ryukyu Archipelago (three from the Kerama Islands, three from Miyako Island, three from Ishigaki Island, and ten from Sekisei Lagoon). A total of 313 colonies were genotyped using four microsatellite markers, IbTC2, IbTC13, IbAAT6 and IbAAT12. The number of genetically differentiated *I. brueggemanni* populations, K , was estimated by employing a Bayesian approach, implemented in the program *Structure* (Pritchard *et al.* 2000). F_0 immigrants in populations were estimated by employing a Monte Carlo resampling method, implemented in the program *GeneClass 2* (Piry *et al.* 2004) using data of genotyping.

The result of the genetic assignment methods indicated that there were very few numbers of immigrants at all sites (Kerama Islands; 3, Miyako Island; 4, Sekisei Lagoon; 17). Most populations were constructed by original members of the populations and most of the immigrants at Kerama Islands and Miyako Island have originated from Sekisei Lagoon. Although three populations of Kerama Islands were very close to each other, no immigrants originated from the neighboring populations were detected. The low number of immigrants among populations and maintenance of each population by its original members might be due to the unique mode of reproduction of the coral, though the direction of Kuroshio Current may also contributed to the isolation of the populations.

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Singapore's coral reefs have experienced significant anthropogenic impacts for at least three decades, mostly resulting from land reclamation activities. Nevertheless, the species richness of scleractinian coral communities around the Southern Islands is comparable to other more extensive reefs in the region. Little has been done, however, to protect the remainder of these reefs, which support a diverse array of marine life. Ongoing reef restoration efforts that are labour and cost-intensive may not be sustainable in the long run if there is no natural recruitment to replenish the populations. The nature of the marine environment provides many opportunities for exchange of genetic material between conspecifics of different

populations, this is especially true for broadcast spawners such as most scleractinian corals. Knowledge of the intricate processes of reef dynamics and connectivity, which can be identified using hydrodynamic-advection and individual-based models, is important for reef management decisions.

A two-dimensional hydrodynamic, flexible mesh model (MIKE 21) coupled with a Lagrangian particle tracking module was used to simulate larvae distribution within the Singapore Straits and the South Channel after known coral mass spawning events in Singapore, and predicted spawn times on the northern coasts of Pulau Batam and Pulau Bintan in Indonesia. In each simulation, neutrally buoyant, passive particles representing the generally passive coral planulae were released during the mass spawn times in years 2003, 2005 and 2007. Findings indicate that most of the coral larvae released from Singapore are carried away during the peak settlement competency periods, and therefore do not contribute to seeding the local reefs, while larvae from Pulau Batam are brought towards Singapore. This means that, in order to effectively protect Singapore's reefs, conservation strategies need consider external source reefs which may necessitate reef management collaborations with Indonesia.

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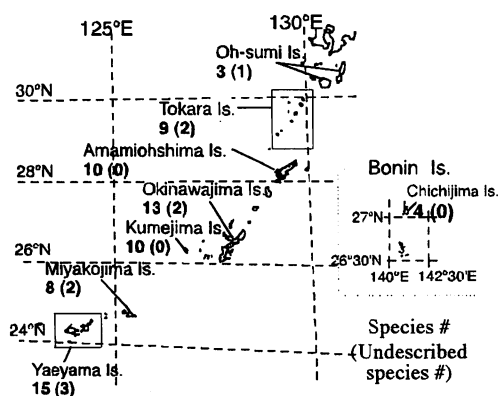
Overview on the biogeography of photosymbiotic ascidians in Japan with new records from some islands in the Ryukyu Archipelago, Japan

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Obligate photosymbioses have been known in some colonial ascidians of the family Didemnidae. The photosymbionts are always prokaryotic algae; *Prochloron* in many of the host species, *Synechocystis* in some *Trididemnum* spp., and/or unknown cyanophytes. The host ascidians are exclusively distributed in tropical and subtropical waters, probably due to the susceptibility to low temperature of the photosymbionts. Recently, we started the biogeographic survey of the photosymbiotic didemnids in the Ryukyus to record the current status of their distribution, because they would be potential indicators for the increase of seawater temperature due to the global warming.

In the 20th century, only five photosymbiotic species were recognized mainly in the Ryukyu Archipelago, probably because not many taxonomical surveys had been carried out in Japan. To date, we surveyed the distribution of the photosymbiotic ascidians in the several continental islands belonging to the Ryukyu Archipelago and Chichijima Island, an oceanic island, belonging to the Bonin Island, and 15 or more photosymbiotic species are so far known to be distributed in Japan. In the present study, we reported the new records of the photosymbiotic ascidians from Miyakojima Is., Kurimajima Is., Kumejima Is., Yakushima Is., and Tanegashima Is., and reviewed the biogeography and taxonomy of the photosymbiotic didemnids in the Ryukyus.



In the Ryukyu Archipelago ranging from about 24°N to 31°N, the species number of the photosymbiotic species tended to be larger in the islands of lower latitude, and gradually decreased toward north: 15 species and three potentially undescribed species were recorded from Yaeyama Islands, the south-most island group in the Ryukyus, as three species and one undescribed species were recorded from Oh-sumi Islands, the north-most island group. Therefore, for many photosymbiotic species, the north limit of the distribution range lies within the archipelago, suggesting that the photosymbiotic didemnids can be a potential indicator for the warming of seawater. On the other hand, only 4 species were recorded from Chichijima Island, whereas the latitude is rather

lower than that of Amamiyoshima Island where 10 species were recorded. It would have been difficult for the ascidian larvae to reach the oceanic islands from other areas, causing the fewer numbers of the photosymbiotic species. The survey should be extended to the mainland of Japan in future study.

We described two photosymbiotic *Diplosoma* species as new species in 2005: *D. ooru* Hirose et Suetsugu and *D. simileguwa* Oka et Hirose. Later, the two species were respectively recorded in Palau and Heron