

A case study of the northernmost distribution limit shift of a soft coral *Dendronephthya* sp. in the East Sea of Korea

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수지맨드라미류의 동해 서식 북방한계선 북상에 관한 연구

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Abstract

The migration of diverse organisms both on land and under the waters is highly affected by climate change which has several effects on human life. While there are sufficient amounts of papers touching upon the subject of migration for species on land, there is a need for more studies on the migration of marine organisms. Especially in urgent need are observations of the coral migration in the East Sea of Korea, which is reported to have a fast sea temperature rise. The East Korean Warm Current (EKWC) has the potential to help the migration of diverse coral species to settle in the East Sea, which would bring unimaginable impacts. Whether these impacts would be positive or negative still needs to be assessed, and therefore, the objective of this paper was first to report scientific evidence of the settlement of the *Dendronephthya* sp. in the East Sea, Wangdol Reef, to be specific. This indicates that the northernmost distribution limit of the *Dendronephthya* sp. shifted up to the East Sea of roughly 200km. We hypothesize that the small ones would have settled in 2021 when the EKWC was the strongest and the sea temperatures were the highest compared to the past ten years. For the biggest colony found in the middle summit, we speculate that it has been around for at least more than two years, as the size was approximately 40cm. The reason why it has succeeded in settling only in the Wangdol Reef and whether it will stay around still remains as a question. Nevertheless, the observation itself provides a new platform for numerous amounts of new discoveries to be made in the rapidly growing field of coral ecology in Korea.

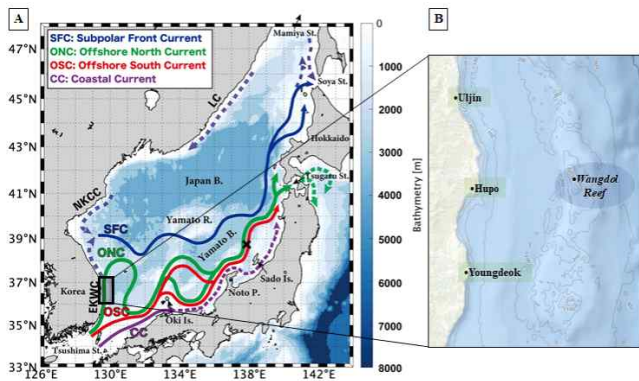
1. Introduction

Ever since the industrial revolution, climate change has never been faster, and this rapid change is causing diverse impacts on almost every organism on earth [1,2]. The most evident impact would be the migration of species due to the destruction of habitats which also has an immense effect on human life [2,3]. As such, there are a number of papers discussing and monitoring the migration of organisms on land, e.g., insects, trees, and animals [3].

Unfortunately, the number of studies observing the migration of ocean organisms is lacking. Even short are the observations of the migration of corals which support more than ¼ of all marine organisms [4]. Especially the number of studies touching upon this subject in Korea is even hard to find even though the northernmost limit of the sea temperature has moved up between 50 to 100km for the last 25 years in Korea, showing a fast sea

temperature rise rate in the world [5]. This temperature rise makes it a habitable environment for new coral species to migrate into the Korean Seas, which needs careful monitoring. Studying corals are in an immediate need in Korea as the economic benefits of corals have been discussed worldwide for more than a century [6]; however, not so much in Korea.

Thus, the objective of this paper was first to report scientific proof of the migration of a soft coral species, *Dendronephthya* sp., up in the East Sea of Korea. A total of four sites, Munam (Goseong), Osan (Uljin), Wangdol Reef (Hupo), and Deajin (Youngdeok), were selected and investigated based on the path of the East Korean Warm Current [fig.1, Munam is not indicated in the figure: more detail in section 2.1]. Results showed that several *Dendronephthya* sp. has successfully attached to Wangdol Reef for at least one to two years, indicating a shift of the northernmost distribution limit from 35.00°N to 36.43°N (approximately 200km apart) of these species [7].



[Fig. 1] (A) Map of the East Korean Warm Current (EKWC) in detail [8] and (B) a close up view of the three sites investigated: Osan (Uljin, 36.88°N), Wangdol Reef (Hupo, 36.43°N), and Deajin (Youngdeok, 36.56°N).

2. Materials and Methods

2.1 Site selection

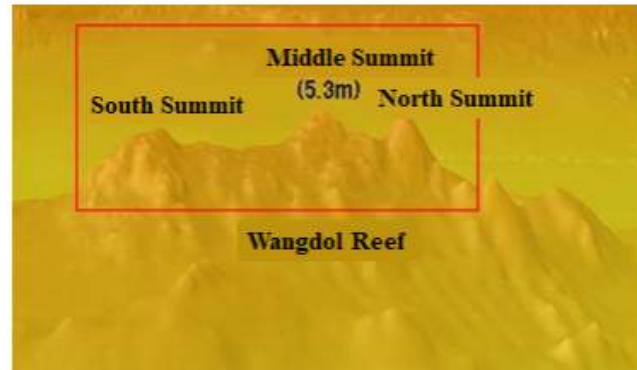
Four sites along the East Sea of Korea were selected among areas under the effect of the East Korean Warm Current (EKWC) path: Munam (Goseong, 38.30°N), Osan (Uljin, 36.88°N), Wangdol Reef (Hupo, 36.43°N), and Deajin (Youngdeok, 36.56°N). Investigated sites in Munam, Osan, and Deajin were within 5km from the shore, while Wangdol Reef was approximately 23km offshore. Munam was selected to test whether the effects of the EKWC reached all the way up north of Korea (38.30°N). The other three areas were selected as they are under the constant effect of the EKWC [fig.1], especially the Offshore North Current (ONC) indicating the highest possibility for the soft coral *Dendronephthya* sp. to migrate with the current and attach successfully.

2.2 Data Collection

Field data were collected by scuba diving photography in August and September 2022. A team of three to four divers surveyed the selected areas for approximately 40 minutes at least two times per site. Wangdol Reef was inspected a total of four times as it had the highest probability for the *Dendronephthya* sp. to be observed due to its geological characteristics [9]. The depth and temperature data were collected where the *Dendronephthya* sp. was found.

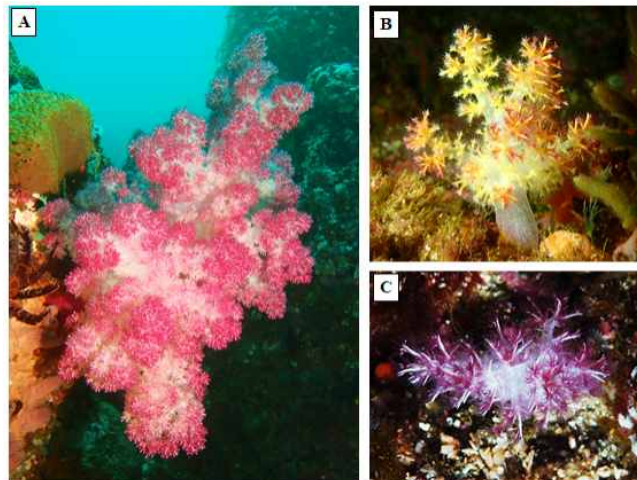
3. Results

The *Dendronephthya* sp. was found in one site out of the four investigated, Wangdol Reef [fig.2], while the *Dendronephthya* sp. was not visible in the other three sites. In Wangdol Reef, several different colonies (*Dendronephthya* sp.1, sp.2, sp.3, and several more not shown in this paper) were found attached throughout the area of the middle and north summits [fig.3A-C].



[Fig. 2] Seafloor map of the Wangdol Reef in Hupo, South Korea provided by the Korea Hydrographic and Oceanographic Agency.

The biggest colony, sp.1, was found in the middle summit of Wangdol Reef, with a size of around 40cm [fig.3A]. It was found at a depth of 20.8m, and the temperature was 13°C. Several other smaller colonies, sp.2 and sp.3 were found in the north and middle summit at a depth of around 16m at the same temperature [fig.3B-C].



[Fig. 3] Photos of (A-B) the *Dendronephthya* sp. 1 and sp.2 in the middle summit and (C) *Dendronephthya* sp. 3 in the north summit of Wangdol Reef.

4. Discussion

As the first scientific paper to report the northernmost distribution limit shift of the *Dendronephthya* sp., only several assumptions prevail for when and why the *Dendronephthya* sp. was successful in migrating only to the Wangdol Reef. Here, we have hypothesized two possible explanations that could lead to further investigations on this topic.

First, to answer the question ‘when,’ we hypothesized that the small *Dendronephthya* sp. colonies (sp.2 and sp.3 and several more) would have attached in the year 2021 as the temperature was recorded to be the highest compared to the past ten years in the East Sea indicating that the EKWC was also the strongest [10]. The powerful current would have allowed the soft coral to disperse up north with ease, and the prevailing high temperatures during the summer would have given the *Dendronephthya* sp. enough time to attach successfully. For the biggest colony, sp.1 (40cm), we suggest that it would be at least more than two years old, considering that the *Dendronephthya* sp. grows approximately 3cm on average for a two-month period [11]. As the number of days of high temperatures in the East Sea continues to rise, there is a possibility for more and more corals to migrate and form a coral community. The impacts of these new formations need to be assessed to determine whether they would bring positive or negative outcomes to Korea.

Second, for the reason why *Dendronephthya* sp. has only attached to the Wangdol Reef, we suggest that the geological characteristics of the Wangdol Reef are ideal for a soft coral to settle compared to the other sites selected. While the other sites are relatively close to the shore, meaning the area would be more subjected to anthropogenic influences, Wangdol Reef is 23km away from the closest port allowing it to be free from most human impacts. In addition, according to a paper by Kim and Park (2014) [9], the geological properties of the reef are favorable for the soft coral *Dendronephthya* sp. to attach and thrive. There are three shallow summits between the depth of 6 to 9m surrounded by scattered underwater reefs between the depth of 5-40m covering an area of approximately 15km² providing plenty of space for new corals to attach [9]. More data on the marine ecology characteristics such as biotic and abiotic information are in need to better determine and predict the future of the coral migration up north to the East Sea of Korea.

In conclusion, the northernmost distribution limit shift is currently ongoing and has the possibility to continue to move up north as long as a favorable environment exists for new coral species. Information on these migrations is highly limited in

Korea and therefore is in immediate demand for studies based on the topic of coral migration in Korea. Deciphering the origin and the migration routes of these new colonies would be the first task to solve by identifying these species within the near future.

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