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Impacts of Offshore Wind Turbine Operation on Selected Mariculture Species, an in-situ Study

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Abstract

China is the fastest-growing offshore wind energy country and the largest mariculture country. Considering the demand for water area with the development of both industries in China and other countries, it will be more congestion in coastal water, and integrating the operation of both industries might be a solution. A 69-day in-situ experiment was conducted by comparing the growth of selected important mariculture species at two sites to study the potential negative impacts of the wind turbine operation. One site was within 30 meters of operating 4-MW offshore wind turbines, and the other was 1.5km away in the mariculture zone. The testing organisms included four important mariculture species: abalone, sea cucumber, and two seaweed species. All these organisms grew healthy during the experiments. The organisms near the wind turbine even reached higher growth rates than the control groups due to better water flow near the wind turbines. This study provides in situ data on the growth of selected mariculture species under wind turbine operation. The results showed that the operation of wind turbines did not negatively impact the growth of these species. With proper management and further development of technologies, these two industries might share ocean space in common.

Keywords: Offshore Wind Turbine; Mariculture; Sea cucumber; Abalone; Seaweed

Introduction

Wind energy is considered one of the most promising renewable energy and is rapidly developing globally [1-3]. It is also considered a practical solution to reduce greenhouse gas emissions. Offshore wind farms (OWFs) are developing even faster than the other renewable resources, taking advantage of not occupying existing land resources and significant wind potential [4-6]. As Europe remains the largest OWF market as a whole, China is the fastest-growing market. In 2018, China installed and connected more offshore capacity (1.8 GW) than any other country and became the world's 3rd largest in installed offshore wind capacities [7]. The rapid expending of OWFs occupies a considerable amount of offshore space, which might cause a conflict with other marine activities (fishing and shipping, e.g.).

In China, the development of OWFs is causing more realistic conflicts with another mature industry – mariculture (marine aquaculture). Compared to relatively limited commercial mariculture in the European countries and North America, China produced around 60% of the world's mariculture output and is the largest mariculture country globally, reporting a total production of over 18 million tonnes in 2017 [8]. Chinese mariculture is also much more diverse than other countries regarding farmed species (over 200) and farming systems/methods [8]. China is promoting mariculture to meet the future demand for aquatic products and alleviate pressure from terrestrial food production systems. Seaweed, which can be integrated into multi-trophic systems with nutrient-extractive function, is particularly promising. In 2020, China's mariculture demanded over 25 400 km^2 of coastal waters, and over 60% were used for shellfish farming [9].

With the fast development of both OWFs and mariculture, it could be predicted that there will be more conflicts between these two industries in the future. The operation of OWFs is considered to cause marine environmental issues and negatively impact marine organisms by increasing the noise level and introducing additional electromagnetic fields, etc. [10]. There are already laboratory and field-based ecosystem and environmental studies on the impacts of OWF operation on wild marine organisms, including marine mammals, zooplankton, fish, birds, and various benthic invertebrates [10-16]. The noise and electromagnetic radiation from the OWF operations may have cumulative impacts on the physiology and ecology of these marine lives. Their crops' fast and healthy growth during the harvest cycle is critical for the mariculture industry. However, there was minimal information on the direct environmental impacts of OWFs on mariculture. This research conducted *in-situ* comparison research on the impacts of OWF turbine operation near an important mariculture area for over two months. The growth of four important mariculture species with high economic value, including shellfish, seaweed, and echinoderms, was studied.

Methods

The experiments were conducted in Nanri Island in Fujian Province, China, which is an important mariculture area, farming shellfish (abalone, etc.), seaweed (kelp and *Gracilaria*, etc.), and other high-value seafood species (sea cucumbers, etc.). Mariculture was primarily operated in near-shore rafts and cages, and the products reached 0.18 million tonnes in 2018. One of China's largest OWF has been planned on the east coast of Nanri Island with 100 wind turbine units since 2015. In 2018, 4 4-MW Siemens SWT-4.0-130 wind turbine units were operating as the first stage of the wind farm construction, about 1km to the edge of the mariculture zone (Figure 1).

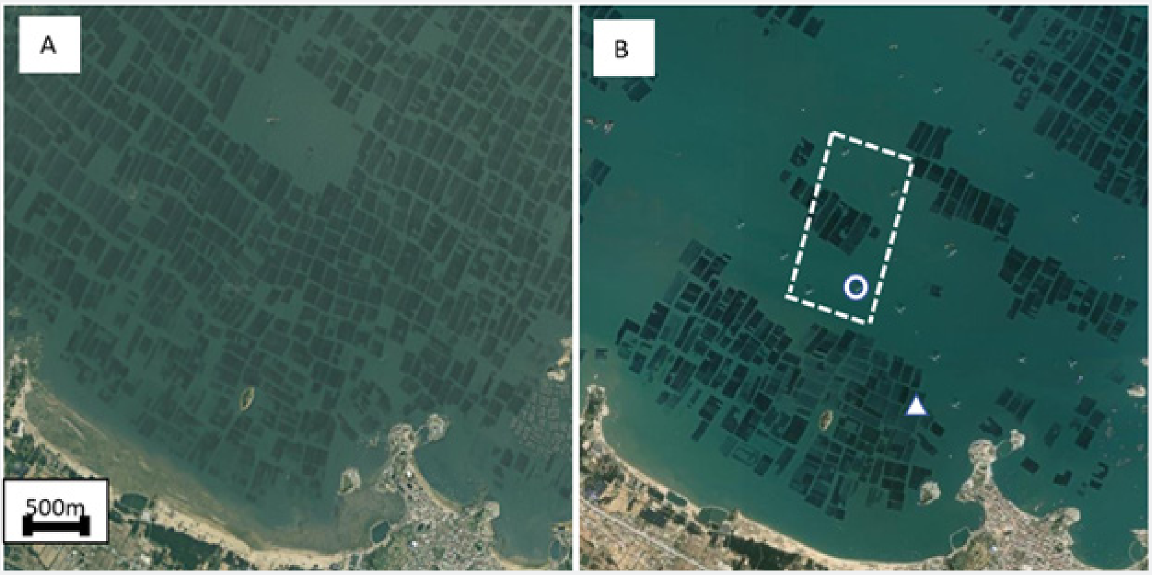

Figure 1: The mariculture zone before (A, 2015) and after (B, 2020) the offshore wind farm construction on the northwest coast of Nanri Island. At this experiment (2018), only four offshore wind turbines were built and operating (in the rectangle area). One of the testing rafts was located near one of the wind turbines (circle); the control raft was in the mariculture area. (Source of the satellite images: Google Earth).

There are four local mariculture species: abalone (Haliotis discus hannai), sea cucumber *(Apostichopus japonicus)*, seaweed *Saccharina japonica*, and *Gracilaria lemaneiformis*, were chosen to study the impacts of wind turbine operation on the growth of these species. A mariculture raft was permitted to be anchored within 30 meters from one operating wind turbine unit. The control groups were set in a mariculture raft about 1.5 km away from the wind turbine units in the mariculture zone. Groups of abalone and sea cucumber were cultivated in standard plastic cultivation cages in the water. Thirty abalones were grown in each cage, and 3 cages were set in each raft, respectively. Three sea cucumbers were cultivated in each cage, and three cages were placed in each raft, respectively. Seaweed was cultivated using hanging ropes attached to the rafts. The seaweed was pre-seeded to the rope onshore and carried to the sea. Three ropes of each seaweed were set in each raft. All the experimental species were gotten from the local farms and cultivated using the typical methods in the area.

The experiments were conducted between Mach 4th and May 11st. The wet weight of the experimental species was weighted biweekly. The abalones and sea cucumbers were taken out of the cage and weighted with a digital weight scale (Meile MT201, China). The seaweed was weighted with the rope and minus the weight of the wet ropes. The width and length of the kelp blades were also measured. The abalones and sea cucumbers were fed with fresh seaweed at 100-150% of their wet body weight in the cages weekly or every 10 days. Water temperature was also measured with a handhold YIS Pro+ multimeter.

The specific growth rates (SGRs)of each species were calculated as follows:

$$SGR\% = 100 \times [\ln(Wt2 / Wt1)] / \Delta t$$

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where W_{t1} is the initial weight at day t_1, and W_{t2} is the weight at day t_2. Δt is the number of days between t_2 and t_1. t-test analyses were conducted (SigmaPlot 14.0) to compare the growth rates of the 2 treatments.

Results

There was no extreme weather (e.g., typhoon) during the experiment period. At the end of the experiment, the surface seawater temperature increased from ~12.4°C in early March to an average of 16.5°C in April and 23.5°C on May 11th. There was no mortality on sea cucumber, and 3 of 90 abalones were lost during the 69-day experiment. The weight and size of all species increased (Figure 2). Sea cucumbers near the wind turbine grew from an average of 141.7g to 198.3g per cage at a specific growth rate of 0.49%, compared to from 139.7g to 190.3g per cage at SGR 0.46% in the control cages off the wind turbine. Abalones near the wind turbine grew from an average of 56g to 193.3g per cage at SGR 1.82%, compared to 55.7g to 190g per cage at SGR 1.81% in the control cages off the wind turbine. Kelp near the wind turbine grew from an average of 1029 g to 3319 g per rope at SGR 1.72%, compared to 1221 g to 2785 g per cage at SGR 1.21% in the control cages off the wind turbine. Gracilaria near the wind turbine grew from an average of 2533g per rope to 7383.3g at SGR 1.58%, compared to 2389g per cage to 4933g at SGR 1.07% in the control cages off the wind turbine. There were no significant differences between the growth rates near the wind turbine and the controls for sea cucumbers and abalone ($P>0.05$). However, both kelp and Gracilaria grew significantly faster near the wind turbine than the controls ($P<0.05$).

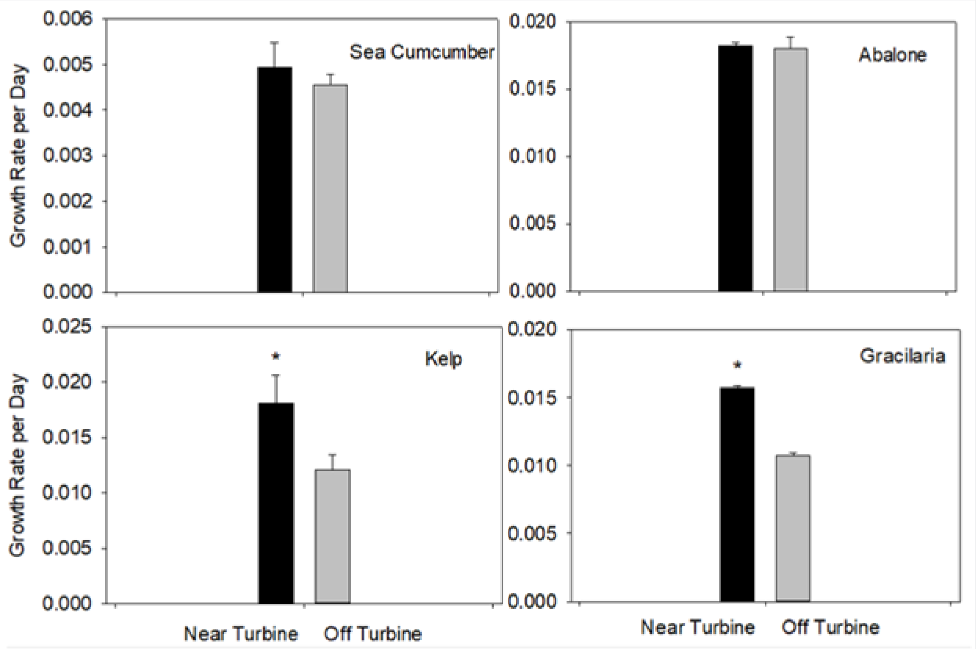

Figure 2: The specific growth rate (per day) of 4 experimental species (sea cucumber, abalone, kelp, and Gracilaria) in raft ~30 meters near the operating wind turbine (Near Turbine) and 1.5 km away from the wind turbine (Off Turbine) from March 3rd to May 11th. The "*" indicates the P-value ≤ 0.05.

Discussions

The growths of tested species

The growth rates of abalones were in the high range of growth rates in the peer-reviewed literature [17,18]. The growth rates of sea cucumber were similar to Namukose et al. [19] and higher than Gunay et al. [20]. These growth rates suggested both the abalones and the sea cucumbers were healthy growing during the experiment period. The growth of seaweed near the wind turbine is faster than in the mariculture zone, which suggests other factors (i.e., water motions) might be more important on the growth of seaweed [21, 22]. As the mariculture zone was crowded with rafts and cages, and there was only one raft near the wind turbines, the smooth water flow could support better seaweed growth near the wind turbines. This study suggested there was no negative impacts of operating wind turbines observed on the growth of these species. Although there have been concepts, models, protocols, and social-economic assessments on the co-location of OWF and mariculture for more sustainable usage of marine space [23-28], there is scant information about field research on the impacts of operating offshore wind turbines on mariculture. Even this study was conducted in natural sites with complex environmental factors, it still provides valuable information for future mariculture and OWF development.

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Co-existing of offshore wind farms and mariculture

Although the ocean covers about 70% of the earth and seems to have unlimited space, the use of ocean space is distance sensitive for both construction and operation aspects, which also directly links to cost. Coastal waters are precious and limited resources for transportation and all kinds of marine activities. The expansion of existing usages (i.e., mariculture), as well as the introduction of new uses of OWFs (Figure 3), are expecting more congestion in coastal water (2010-2020). In this case, Nari Island local government has to pay the mariculture farmers to withdraw their lease where the water space was zoned for OWFs. A significant part of the mariculture zone was occupied by OWFs, as no farming activity was allowed at least 200 meters from the wind turbines (Figure 1).

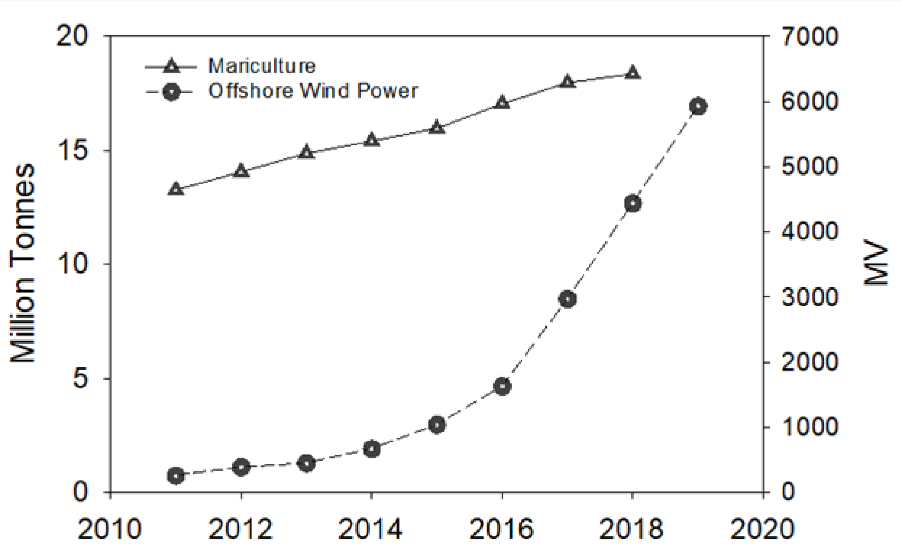

Figure 3: China's mariculture production (Million Tonnes) and offshore wind power (Million Volts, MV) development in the recent decade. Data from China Statistical Yearbook (2010-2020).

Considering the expansion demand for water areas with the development of both mariculture and wind farm in China and other countries in the following decades [29], it might be an option to integrate the operation of both industries. With proper management and further development of technologies, these two industries might use ocean space in common. More pilot zone should be set for mariculture in the OWF area. The co-existing could maximize the value of the sea area and benefit the interest of both farmers and wind farm companies [30-32]. Especially when the modern mariculture industry is, at least partially, moving or testing to move to more remoted offshore water using larger scale platforms, renewable energy sources from the sea (i.e., wind energy) might be a good source of energy to replace the diesel generators for electrical power [30]. The concept of a "Multi-purpose Platform" integrating wind power and model offshore mariculture structure is being developed, although it may be at a very early stage [26]. This study provided first handed information for the risk assessment for potential environmental impacts of wind farm unites on selected important farming species [33,34].

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