Evaluation on the influence that offshore wind power generation facilities give to underwater creatures

- An Example in Setana Port -

E.Naruse, Coastal Institute of Technology(CDIT), Sumitomo Hanzomon Bldg. 6F, 3-16, Hayabusa-cho Chiyoda-ku Tokyo, 102-0092, JAPAN
tel:+81-3-3234-5862, fax:+81-3-3234-5877, E-mail:naruse@cdit.or.jp;
M.Miyoshi, CDIT; K. Shimada, Metocean Environment Inc.; T.Shigaki, Metocean Environment Inc.;
K.Sumida, Daioh Construction Co., Ltd.; S.Dohata, Setana Town Office;

This research attempted to understand the characteristics of offshore wind farm's sound pressure level and the impact that offshore wind farm's foundation works on aquatic community. The method was survey on the sound pressure level and frequency analysis, and survey on aquatic community. The results are summarized as below:
i. The wind speed was 0－10 m/s and underwater sound pressure level was 109 ～ 140dB.
ii. Underwater sound pressure level's frequency was 6 － 10Hz, in strong winds. This frequency is a strong resemblance to wave disturbance. So, this is attributed to the fact that wave disturbance was made by strong wind and breakwater.
iii. The species number of fish community did not show any difference between 2003 and 2004,while individual number increased in 2004.

1. Introduction

In Japan, most of wind energy projects are land-based, with a few exceptions of near-shore/offshore operations. Compared to inlands, port/coastal areas enjoy relatively stable wind conditions in general, with higher wind speed and less wind fluctuations. As wind-favored inland sites are less and less available within the limited bounds of the nation, extensive development of port/coastal windmills has been called for (Fig.1).

Yet, the construction of wind power facilities in port/coastal areas may involve different types of impacts on the environment from the case of onshore installation. It is expected to give rise to the need of assessment of impacts on the environment unique to port/coastal areas.

In this research, survey was conducted to understand the characteristics of offshore wind farm's sound pressure level and the impact that offshore wind farm's foundation on aquatic community, for the purpose of gaining insights into impacts of offshore wind farms, which will be constructed in increasing numbers, upon port/coastal areas.

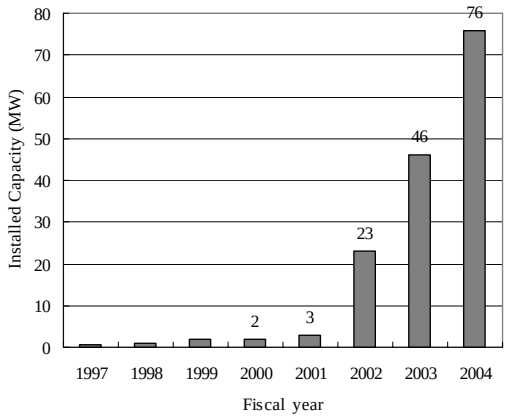

Fig.1: Development of Installed Capacity in Ports and Harbors Areas (including onshore installation; as of March, 2005)

2. Methodology

To understand the characteristics of offshore wind farm's sound pressure level and impacts on aquatic community arising from the operation of wind farm, we studied sound pressure level (hereinafter referred to as the sound pressure survey) as well as aquatic community (referred to as the aquatic community survey).

Both surveys were conducted on an offshore windmills (two 600kw units) situated within an eastern breakwater in Setana Port, Setana Town, Hokkaido, as shown in Fig. 2 and photo 1.

Fig.2: Location of Setana town

Photo.1: Windmills of Setana port

(1) Outline of the sound pressure survey

The survey was conducted from 12:00, August 16 to 12:00, August 17, 2004, with the focus on the sound pressure and the dominant frequency underwater vs. the sound pressure and the dominant frequency in the air around the offshore windmills. Fig. 3 shows a total of six measurement points, two points on the foundations of the windmills (St. 1 and St. 4), two points at 50 meters away from the windmills (St. 2. and St. 5), and two points at 200 meters away from the windmills (St. 3 and St. 6), respectively.

A 24-hour measurement was taken, with the data of sound pressure level collected every 10 minutes. The data was examined compared to the operation status of the windmills (running or stopped) and the wind speed, coupled with frequency analysis, to characterize the underwater sound around the windmills.

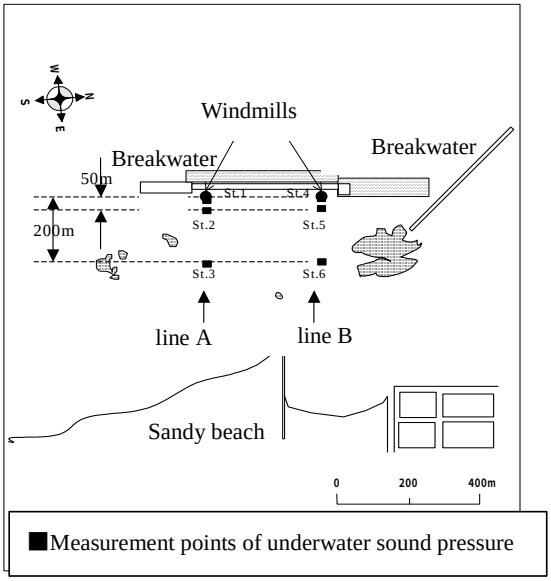

Fig.3: Measurement points of underwater sound pressure

For frequency analysis, 1 minute-stepwise data was used, and the wind speed data was collected with the use of existing anemometers on the windmills. In analyzing the frequency, analysis was made for representative periods of time on conditions varying in wind speed and wind direction, as shown in Table1.

Table 1: Conditions under frequency analysis

Conditions	Line A (St.1～St.3)	Line B (St.4～St.6)	Purpose
Under strong wind (over 7m/s)	Case 1-1	Case 1-2	To compare the strong wind with the weak wind
During stopped operation	Case 2-1	Case 2-2	
Sea wind (about 4m/s)	Case 3-1	Case 3-2	To compare the difference of the direction of the wind
Land wind (about 4m/s)	Case 4-1	Case 4-2	

(2) Outline of the aquatic community survey

The survey was conducted on August 18 and 19, 2003 prior to the construction of the windmills as well as on August 15, 2004 upon completion, focusing on the habitat of fish. As shown in Fig.4, there were a total of six measurement points, two at the foundations (St. 1 and St. 4), two at 200 meters away from the windmills (St. 3 and St. 6), one at a natural shore reef near the windmills (St. 7), and one at the breakwater near the windmills (St.8), respectively. Divers observed and made a record of aquatic life within about 10-meter radius from each measurement point, so that the data for the two years were compared.

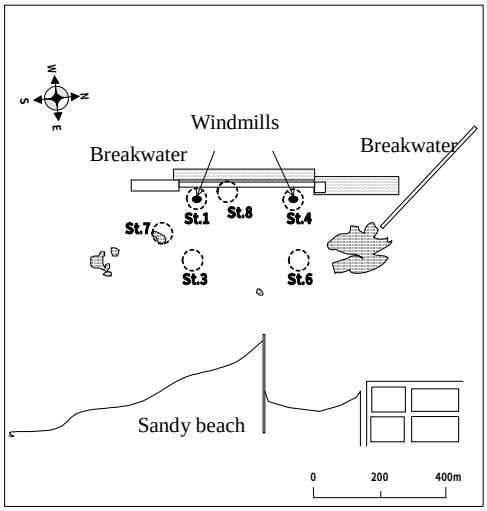

Fig.4: Observation points of aquatic community

3. Findings and Consideration

(1) The sound pressure survey

(a) Correlation between sound pressure level and wind speed

Fig 5 shows the maximum value of sound pressure level and the mean wind speed for ten minutes after every hour. The analysis excluded the affected periods of time with higher sound pressure level due to fishing boats and ships passing nearby.

The wind speed during the survey ranged from 0 to 10 m/s. In the beginning of the survey (12:00) up to around 15:00, a wind stronger than 7m/s was recorded. Later on, it became less windy over time, as weak as 2.0 m/s by 21:00. Then, the wind direction changed, from a sea wind (westerly) to a land wind (easterly), at a varying speed of 2.0 to 4.0 m/s.

The changing sound pressure level was within the range of 109dB to 140dB. A relatively higher level was recorded on the foundations (St. 1 and St. 4) at a windy period of time (12:00-14:00), but even for a less windy period of time at 3m/s (6:00-7:00), nearly 134 dB was recorded, which shows no significant correlation between the strength of the wind and the fluctuating sound pressure level.

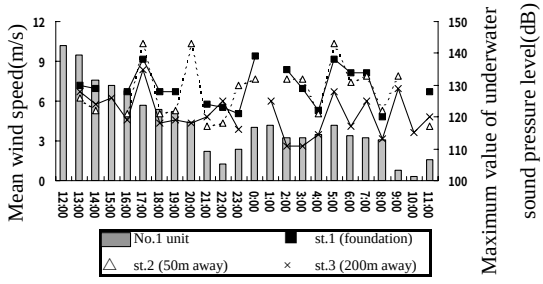

Fig.5(1): Correlation of wind speed vs. underwater sound pressure level (measurement line A)

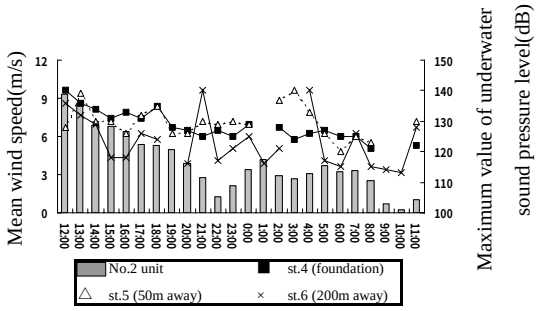

Fig.5(2): Correlation of wind speed vs. underwater sound pressure level (measurement line B)

(b) Frequency analysis (under strong wind vs. during stopped operation)

The results of the frequency analysis for Case 1-1 (measurement line A under strong wind) and Case 1-2 (measurement line B under strong wind) are shown in Fig. 6. For Case 1-1, the foundation (St. 1) had a peak at a 6-10Hz bandwidth, while no significant peaks appeared at the 50-meter point (St. 2) nor the 200-meter point (St. 3). In Case 1-2, the foundation (St. 4) showed a peak at a 6-10Hz bandwidth, while both the 50-meter point (St. 5) and the 200-meter point (St. 6) tended to be slightly higher at a bandwidth of 6-10Hz.

Fig. 7 shows the results of the frequency analysis for Case 2-1 (measurement line A during stopped operation) and Case 2-2 (measurement line B during stopped operation). The foundations (St. 1 and St. 4) and the 50-meter points (St. 2 and St. 5) share a similar pattern of frequency, whereas the 200-meter points (St. 3 and St. 6) show some difference in frequency pattern. Comparison between the measurements under strong wind (Case 1-1 and Case 1-2) and the ones during stopped operation (Case 2-1 and Case 2-2) suggests that, with peaks observed at a 6-10Hz bandwidth under strong wind, factors related to the wind strength might cause changing sound pressure in this bandwidth.

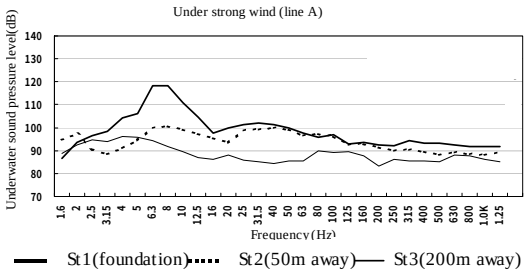

Fig.6(1): Frequency analysis: under strong wind (Case 1-1)

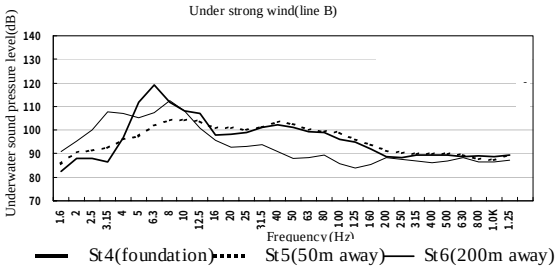

Fig.6(2): Frequency analysis: under strong wind (Case 1-2)

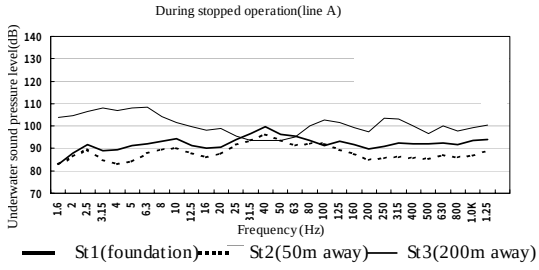

Fig.7(1): Frequency analysis: during stopped operation (Case 2-1)

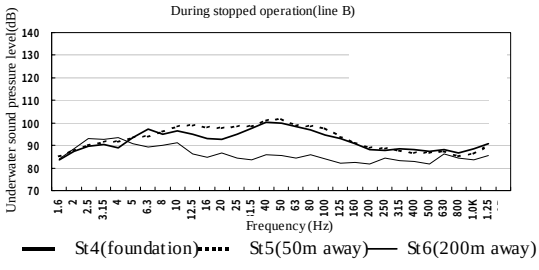

Fig.7(2): Frequency analysis: during stopped operation (Case 2-2)

(c) Results of frequency analysis (sea wind vs. land wind)

The results of analysis for Case 3 (sea wind) and Case 4 (land wind) are given in Fig. 8 and Fig. 9.

In both wind directions, the foundations (St. 1 and St. 4) showed peaks at a 6-10Hz bandwidth, respectively. For the 50-meter points (St. 2 and St. 5), peaks appeared at the same bandwidth many times. There was no apparent peak observed for either of the 200-meter points (St. 3 and St. 6).

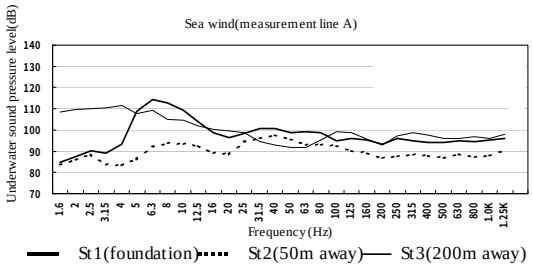

Fig.8(1): Frequency analysis: sea wind (measurement line A)

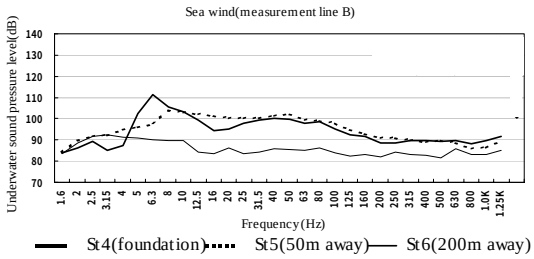

Fig.8(2): Frequency analysis: sea wind (measurement line B)

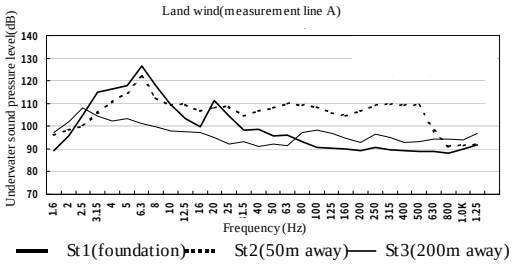

Fig.9(1): Frequency analysis: land wind (measurement line A)

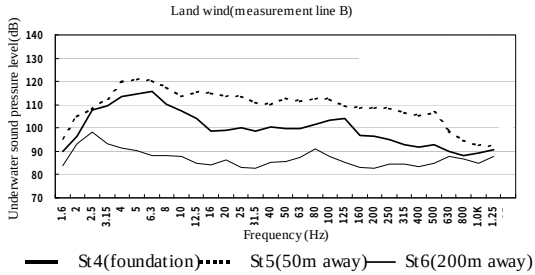

Fig.9(2): Frequency analysis: land wind (measurement line B)

(d) Summary of the sound pressure survey

The following outcomes are derived from the survey:

-At a wind speed of 0-10 m/s, the sound pressure level was within a range of 109-140 dB, and there was no marked fluctuation in underwater sound pressure depending on different wind speeds.

-The frequency analysis of underwater sound pressure showed frequency characteristics with a peak at 6-10Hz under strong wind.

As to the frequency characteristics of the source of underwater sound, reference data are available as shown in Fig. 10. In this research, the sound pressure level tended to get higher at 6-10Hz, which has a strong resemblance to the frequency pattern of noise caused by wave disturbance as shown in Fig. 10. It is assumed that the strong wind disturbed waves in the waters under study, which in turn affected the sound pressure level.

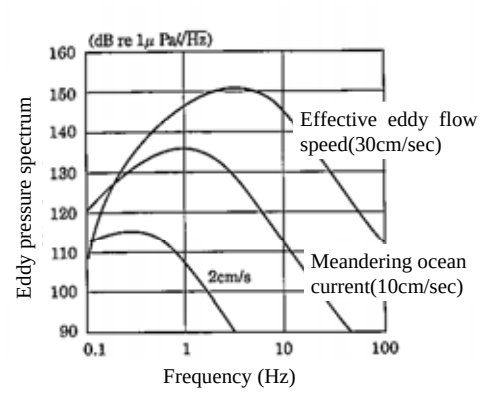

Fig.10: Eddy pressure spectrum

(2) The aquatic community survey

The findings from a survey conducted in 2004 are shown in Table 2, compared to the previous year in Table 3.

For the south foundation, Hexagrammos otakii, Cottidae, and Pleuronectidae were observed in both 2003 and 2004. The count in 2004 exceeded the previous year in individual number as well as species number.

For the north foundation, Hexagrammos otakii and Ditreme temmincki were observed in both years. It was higher in individual number in 2004 than 2003.

In the neighboring survey points (natural reef, breakwater), almost the same species were observed for both years, while the year of 2004 had more individual number than 2003.

As shown above, there is no marked difference between 2004 and 2003 in species observed at the foundations, with higher individual number identified in 2004 than 2003. However, it is still too early to derive a conclusion from these research findings only, because aquatic habitats undergo a natural process of change dynamically. Follow-up survey and monitoring of aquatic community is required on a continued basis.

Table 2: Aquatic community survey: 2004

Scientific name	st.1 Southern foundation (0m)	st.4 Northern foundation (0m)	st.7 Reef	st.8 Breakwater	st.3 Southern point (200m)	st.6 Northern point (200m)
Hexagrammos otakii	8	4		4		
Oplegnathus fasciatus		8				
Sebastes thompsoni	40					
Ditrema temmincki	30	10	50	50		
Cottidae	3			4		
Pleuronectidae	1				1	3
Stephanolepis cirrhifer	1	1				
Takifug niphobles					3	25
Sparidae				4		
Stichaeidae				1		
Callionymidae						1
Pterogobius zacalles			20			

Table 3: Aquatic community survey: 2003

Scientific name	Southern foundation (0m)	Northern foundation (0m)	Reef	Breakwater
Hexagrammidae				1
Hexagrammos otakii	5(1)	2		1
Pleuronectidae	1	2		1
Pleuronectes schrenki (Schmidt)		1		
Ditrema temmincki		1		2
Cottidae	2(1)		1	2
Stichaeidae				1
Pterogobius zacalles			1	
unknown		many		

4. Conclusion

From this research, it is found that the offshore wind farm power operation has not caused fluctuations in sound pressure level or impacts on the aquatic community. The main findings are as follows:

(1) The wind speed was within a range of 0-10 m/s during the survey, and the underwater sound pressure level fell within 109-140dB.

(2) The underwater pressure showed frequency characteristics peaking at 6-10Hz under strong wind, which is similar to the bandwidth specific to noise arising from wave disturbance. This similarity suggests that the waters under survey significantly disturbed by the adjacent breakwater under strong wind in turn affected the underwater sound pressure to a large extent.

(3) The number of fish species observed in the water around the off-shore windmill showed no significant change from 2003 to 2004, while the individual number increased in 2004 from the previous year.

References:

[1] Ports and Harbors Bureau, Ministry of Land, Infrastructure and Transport, Japan: The Status of Wind Power Farms in Ports and Harbors (http://www.mlit.go.jp/kowan/index.html)

[2]Basic and Applied Marine Acoustics, compiled by the Marine Acoustics Society of Japan, Seizando-shoten, 2004)