Effects of offshore wind farms on the early life stages of *Dicentrarchus labrax*

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Abstract

Anthropogenically generated underwater noise in the marine environment is ubiquitous, comprising both intense impulse and continuous noise. The installation of offshore wind farms across the North Sea has triggered a range of ecological questions regarding the impact of anthropogenically produced underwater noise on marine wildlife. Our interest goes out to the impact on the ‘passive drifters’, i.e. the early life stages of fish which form the basis of fish populations and are an important prey for pelagic predators. This study deals with the impact of pile-driving and operational noise generated at offshore wind farms on *Dicentrarchus labrax* (sea bass) larvae.

1. Introduction

Offshore wind farms are being installed across the North Sea, including the Belgian part, in which a concession zone is designed for the production of renewable energy and will host seven offshore wind farms (Fig. 1). Three types of foundations have already been used, i.e. gravity based foundations, monopiles and jackets requiring four pinpiles. The latter two are driven into the seabed and have comparable single strike sound exposure level (SELss) which varies between 145 and 168 dB re 1 μPa^2 s @ 750 m, but different number of strikes and amount of piling time (Norro et al., 2013).

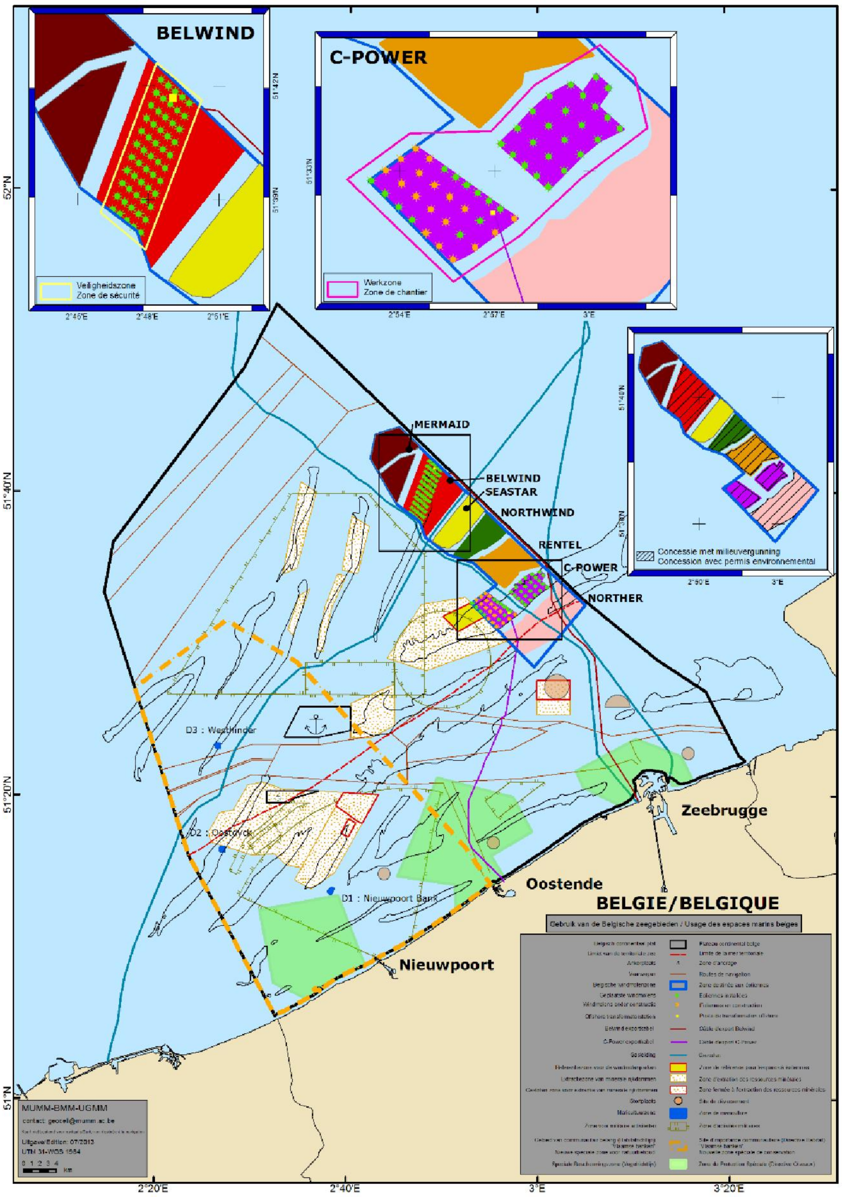

Figure 1 Belgian part of the North Sea with the offshore wind farm area. At the moment, C-power at the Thorntonbank, Belwind at the Blighbank and Northwind at the Lodewijckbank are installed or under construction (reproduced from [Vigin et al., 2013] with permission from Management Unit of the North Sea Mathematical Models (MUMM)).

Especially the construction phase of offshore wind farms raises questions about the possible impact it might have on the marine wild life. Pile-driving generates low and mid-frequency impulsive noise. At the moment, a growing body conducts research on marine mammals and fishes. Possible effects are mortality, external and internal tissue damage, temporary hearing loss and permanent hearing loss, physiological stress and the disturbance of natural behavior and distribution (Popper & Hastings, 2009). The differences in species-specific hearing capabilities, as well as vulnerability between fish species, fish sizes, and life stages complicate this bioacoustics research.

Research is moving towards defining the biological impact related to the single strike and cumulative sound exposure level (SELss and SELcum, respectively) and number of impulses (Halvorsen et al., 2012). SELcum of 210 dB re $1\mu Pa^2s$ was defined as the threshold for onset of injury for Chinook Salmon, but such levels only occur close to the piling source (Casper et al., 2012; Halvorsen et al., 2012). Practically no knowledge exists on the sound levels which cause mortality or injury to fish eggs, larvae, and fry. Given that their transport is mainly current-based (Bolle et al., 2005), they are condemned to endure any underwater noise present in the water column. Accordingly, it is very important to determine the threshold sound levels causing any disturbance.

The ecological importance of fish eggs, larvae, and fry to maintain a healthy population size, and their nutritional value in the pelagic food web only emphasizes the urgent need to establish these levels (Bos et al. 2009). Prins et al. (2009) made a first assumption about the impact of pile driving on fish eggs and larvae: '100% mortality of fish eggs and larvae in a radius of 1 km around the piling source'. This assumption was based on very little information (current patterns, dispersal, ecological value…). After the laboratorial experiment in Bolle et al. (2012), a revision of this assumption was recommended. However, no field experiments have yet validated the lab experiments or the assumption, exposing a crucial gap in this research area which needs urgent attention.

The introduction of long-term continuous noise into the marine environment receives far less attention even though it is also a concern in aquaculture. The operational phase of the offshore wind farms causes higher background sound pressure levels for the next 20 years (Norro et al., 2011). At the offshore wind farm on the Blighbank, wind turbines on monopiles elevate the background underwater sound pressure level with ~20 dB re 1 μPa (Norro et al., 2010). It is suggested that an increase of the background noise can interfere with the foraging behavior and communication of fish and induce stress in fish (Hastings & Popper, 2005; Thomsen et al., 2006; Walhberg & Westerberg, 2005; Mueller-Blenkle et al., 2010). However, the impact on the early life stages of fish remains relatively unknown.

2. Objectives

A multidisciplinary study combining biology, acoustics, physiology and biochemistry has been designed to examine the impact of the construction and exploitation of offshore wind farms on early life stages (eggs, larvae, and fry) of fish in Belgian waters. *Dicentrarchus labrax* (European sea bass) has been chosen as the model species for round fish. The first work package (WP1) of the project deals with the impact of pile-driving noise, and tackles the impact assessment from different angles. (1) The worst case scenario (close range) is analysed on board of the piling platform Neptune (Northwind NV and its contractor GeoSea). (2) The impact at 500 m is examined on board of a research vessel. (3) In parallel, noise exposure experiments will be carried out under controlled conditions in the lab.

The second work package (WP2) of the project deals with the chronic effects of operational noise on the development of fish eggs, larvae, and fry. These experiments are carried out under controlled conditions in the lab.

3. Target Species

Dicentrarchus labrax is a commercially important round fish species, as well in the fisheries as in the aquaculture industry. Dicentrarchus labrax is a well-studied species, in particular the larval growth, development, and skeletal formation (Zouithen et al., 2011). In addition, the year-round availability of the eggs, larvae, and fry in the Ecloserie Marine de Gravelines (France) is rather exceptional for marine fish species. Consequently, Dicentrarchus labrax is frequently used in experiments and is used here as a model species for round physoclist fish (Pickett & Pawson, 1994).

4. Work Packages

4.1 WP1

The general aim of the first work package is to assess the impact of pile-driving on eggs, larvae and fry of *Dicentrarchus labrax*. (1) An experiment on board of the piling platform Neptune (Northwind NV and its contractor GeoSea) at 43 m from the sound source analyses the worst case scenario (fig. 2). *D. labrax* is exposed to pile-driving noise for a complete piling event of one monopile at 2.5 m depth in 500 ml vials and the results are compared to a control group on land with no handling stress and a control group which undergoes the same handling as the exposed group. Simultaneously, the sound pressure and particle velocity is measured. Immediate and delayed mortality is observed during and after the experiment. Physiological stress is determined by measuring the whole-body cortisol, analyzed with a cortisol RIA kit and by calculating the respiration, determined by difference in oxygen level at the start and end of the experiment in the vials. 10 % of the surviving larvae are stored on 7% formaldehyde for histological analysis and the rest are transported back to the lab for further monitoring of their development.

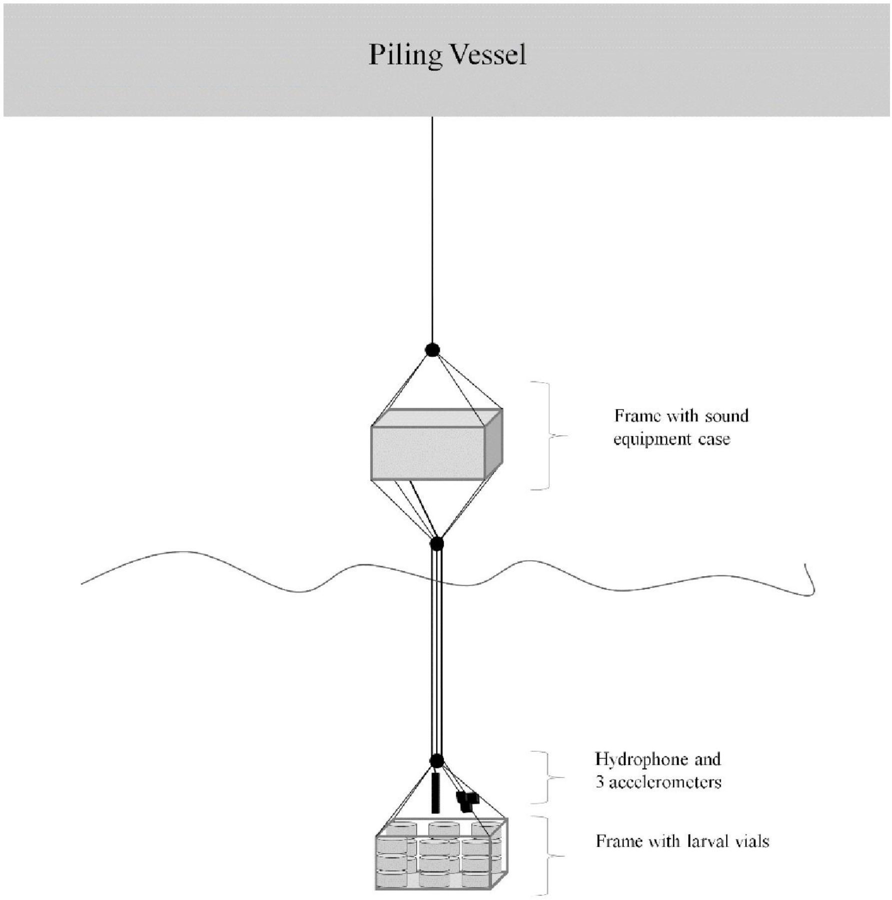

Figure 2 Experimental set-up to conduct the experiment on board of the piling platform. The structure exists of one frame above the sea surface, holding the sound equipment case with recorder and amplifier, and holds 4 m below in the sea a second frame which contains the 500 ml vials with *D. labrax*. The hydrophone and three-axis accelerometer are mounted just above the larval frame in the sea and are connected to the amplifier in the sound equipment case.

(2) The impact at 500 m is examined on board of a research vessel and has the same experimental set-up and approach as the experiment on board of the piling vessel.

(3) In parallel, noise exposure experiments are carried out under controlled conditions in the lab and have the same experimental set-up as the field experiments. A SIG Sparker Electrode submerged in a 40 000 L reservoir shoots every second 3000 Volts at 300 Joule and generates low frequency impulsive noise, mimicking the sound pressure levels of pile-driving noise between 70 m and 500m from the piling source. The advantage of this experiment is the considerably reduced handling stress compared to the field experiments. Results are to be compared.

4.2 WP2

Chronic effects are examined during and after exposure of *D. labrax* eggs and larvae to the playback of the operational noise recordings for one month. The experimental design exists of four groups: (1) silent group; (2) group only exposed during embryonic development; (3) group only exposed during larval development; (4) continuously exposed group during both embryonic and larval development. Embryonic development, hatching percentage, time of hatching, diameter yolk sac are giving information about their viability and fitness. Larval development, yolk sac resorption, growth, symmetry, skeletal development and chronic stress (Hsp70) are monitored.

5. Output

This paper presents the design of this doctoral thesis and no results are provided in this paper. Results which will be obtained in WP1 and WP2 will serve several purposes. The US Fisheries Hydro-acoustic Working Group formulated interim criteria for the maximum noise levels that fish could be exposed to without causing non-auditory tissue damage. The interim criterion for maximum SELcum for fish lighter than 2 grams, was set at 183 dB re 1$\mu Pa^2 s$. The results of WP1 can contribute in the re-examination of these interim criteria. In addition, the experiment on board of the piling vessel in WP1 will allow validating the assumptions of Prins et al. (2009) and the results of Bolle et al. (2012) (cf. supra). WP1 and WP2 deals with both underwater noise indicators: (1) low and mid frequency impulsive noise and (2) ambient noise, determined by the European Commission Directive 2008/56/EC in the Marine Strategy Framework Directive Good Environmental Status (MSFD-GES)

(Van der Graaf et al., 2012). These data are relevant to a scientifically based implementation of MSFD-GES.

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