

CHAPTER

1



Offshore wind farms significantly alter fish community structure - Aggregation of Atlantic cod and pouting

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The numerous wind turbine foundations being constructed in the North Sea influence the ecosystem functioning and local biodiversity. Interactions within and between these artificial hard substrates and the surrounding soft substrate occur. In this study we assess the anticipated environmental impact on benthopelagic fish species. Catch per unit effort data was combined with length-frequency distributions to gain insights in the fish community structure near wind turbine artificial reefs. Atlantic cod and pouting dominate the community structure and show clear seasonal patterns in presence. Specific age groups are attracted to the wind turbine foundations.

INTRODUCTION

The marine environment is being intensively used by mankind for offshore activities and exploitation of marine resources. One of these activities is the development of offshore wind farms (OWFs) and in recent years they are arising all across the North Sea. The numerous wind turbine foundations add a substantial amount of artificial hard substrates to the marine environment, having an influence on local biodiversity and ecosystem functioning (Andersson et al., 2009; Wilhelmsson et al., 2006). Benthopelagic fish species are likely to be affected by the environmental changes and hard substrates have been reported to attract and concentrate fishes (Bohnsack, 1989; Leitao et al., 2008; Pickering and Whitmarsh, 1997). Several fish species such as pouting (*Trisopterus luscus*), Atlantic cod (*Gadus morhua*), mackerel (*Scomber scombrus*) and horse mackerel (*Trachurus trachurus*)

have been observed in close proximity of wind turbine foundations (Leonhard et al., 2011; Reubens, 2013). The aggregation behaviour can be explained by several mechanisms (see chapter 14): 1) food availability and feeding efficiency, 2) increased shelter against currents and predators, 3) provision of nurseries and recruitment sites, 4) stress mediators.

In this chapter the anticipated impact will be assessed through the investigation of the benthopelagic fish community structure near wind turbine artificial hard substrates. Hereby we will focus on:

- Changes in the fish species community
- Abundance information (catch rates) of Atlantic cod and pouting
- Age structure of Atlantic cod and pouting





Line fishing, with fishing rod near the wind turbines

SAMPLING STRATEGY

We combined catch per unit effort (CPUE) data with length-frequency distributions of fish to gain insights in the fish community structure. To relate the community structure at the wind turbine artificial reefs to the surrounding marine environment, this habitat is compared with hard substrate (i.e. shipwrecks) and soft substrate (i.e. sandy areas) control areas (box). Data was gathered in the period 2009 – 2012 on a two-weekly to monthly basis.

Line fishing, with a fishing rod (hooks: Arca nr 4, bait: lugworm *Arenicola marina*), was performed at the different sites to

quantify the CPUE data. Sampling was restricted to daytime hours and standardized as $CPUE = N_f / (N_p * T)$; with N_f the number of fish caught (ind), N_p the number of fishermen (fm) and T the duration of fishing in hours (h).

Length-frequency distributions were used to assess the age structure in the population. It allows to separate the cohorts present. Age-length keys help to correctly assign the cohorts to their age group (table 1 and 2).

BOX: Sampling strategy

- **Wind turbines**

Thorntonbank, WGS 84: 51°33'N – 2°56'E
Hard substrates made by gravity based foundation and surrounding scour protection of rocks and pebble

- **Shipwrecks**

Kilmore, WGS 84: 51°23'N – 2°30'E
LCT 457, WGS 84: 51°25'N – 2°44'E
Hard substrates made by iron wrecks

- **Sandy areas**

Thorntonbank, WGS 84: 51°31'N – 2°52'E
Gootebank, WGS 84: 51°27'N – 2°52'E
Soft substrates composed of medium sand



DATA OVERVIEW

Fish community structure at different habitats in the Belgian part of the North Sea

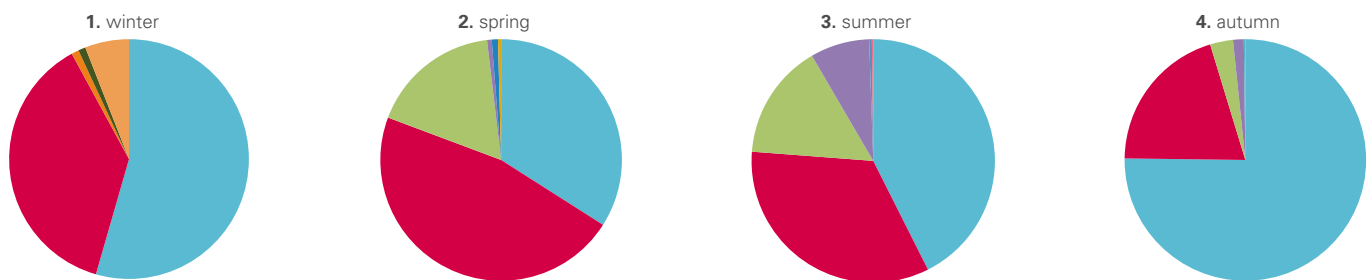
In total 19 fish species were encountered (from three types of sampling sites) (Figure 1). Comparable numbers of species were observed at all three sites, with 12, 11 and 12 species at the wind turbines, shipwrecks and sandy areas respectively. However, differences in species composition were found between the sites. Poor cod (*Trisopterus minutus*), saithe (*Pollachius virens*), black seabream (*Spondyliosoma cantharus*) and dragonfish (*Callionymus lyra*) were encountered only at the wind turbines, while dogfish (*Scyliorhinus canicula*), European flounder (*Platichthys flesus*) and common sole (*Solea solea*) were solely caught at the sandy areas. Sea bass (*Dicentrarchus labrax*) was present only at the shipwrecks.

The community structure clearly differed between the habitats. In general, across all three habitats, horse mackerel and mackerel are species typically present in our regions in late spring and summer, while whiting and dab are typical for autumn and winter. The wind turbines were characterized

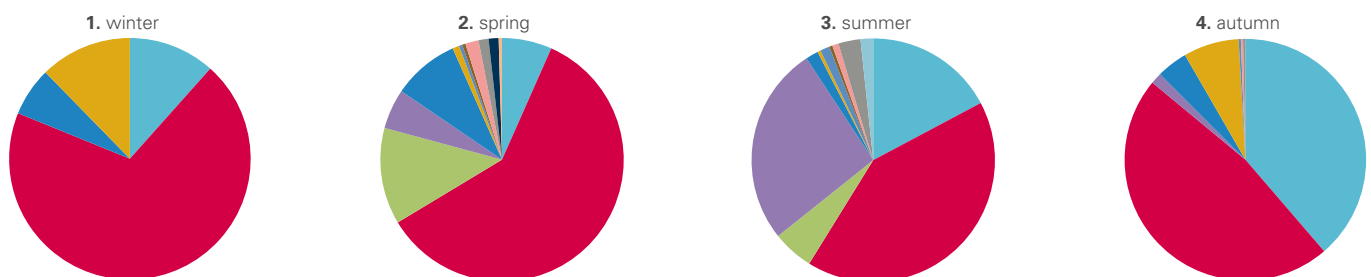
by Atlantic cod and pouting. At the shipwrecks, Atlantic cod, pouting and mackerel dominated the catches, while at the sandy areas mainly dab (*Limanda limanda*), whiting (*Merlangius merlangus*) and mackerel were caught.

Clear seasonal changes in community structure were observed at all habitats. At the wind turbines Atlantic cod and pouting dominate throughout the year, while in winter also bull rout (*Myoxocephalus scorpius*) is an important species while in spring and summer horse mackerel and mackerel contribute to the community. At the wrecks Atlantic cod dominates. Pouting contributes in summer and autumn, while mackerel and horse mackerel are mainly caught in spring and summer. Whiting has some importance in autumn and winter. At the sandy areas whiting and dab are dominant in all seasons except in summer, then mackerel takes over. In autumn pouting contributes to the community as well.

Wind turbines



Wrecks



Sandy areas

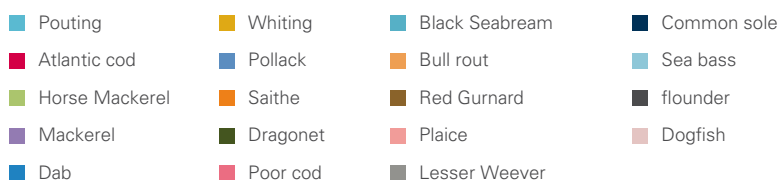
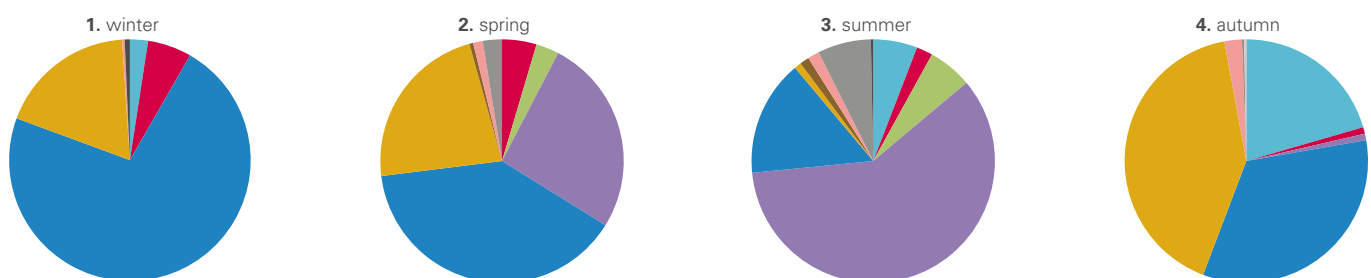


Figure 1. Fish community structure at the different habitats and between seasons. 1 winter (Jan-Mar), 2 spring (Apr-Jun), 3 summer (Jul-Sep), 4 autumn (Oct-Dec).

Temporal patterns in abundance of Atlantic cod and pouting

As Atlantic cod and pouting are species with a high commercial value and both were encountered in high numbers at the wind turbines, it was decided to investigate the catch rates of these species at the different habitats in closer detail to unravel whether they are attracted to a specific habitat.

Catch rates were compared for the period 2009 – 2012 and averaged (\pm standard deviation) per month. For Atlantic cod, much higher CPUE values were observed at the wind turbines compared to the other habitats (Figure 2). The catches were 2 to 12 times higher compared to the wrecks, and up to more than a 100 times higher compared to the sandy areas. Atlantic cod was seldom encountered at the sandy areas. At the wind turbines a clear seasonality in catches was observed. From December until April CPUEs were low ($1.3 \pm 0.3 - 2.5 \pm 4$ ind $h^{-1} fm^{-1}$) while from May until November CPUEs were elevated ($3.2 \pm 1.7 - 12.5 \pm 13.4$ ind $h^{-1} fm^{-1}$) with a peak in July. At the shipwrecks similar, yet less obvious trends were observed. Similar results were obtained for pouting. Highest CPUE values were found at the wind turbines, with catches 3 to more than 30 times higher and 9 to more than a 100 times higher compared to the shipwrecks and sandy areas respectively. Almost no pouting were present at the shipwrecks and sandy bottoms in the first half of the year, while from September

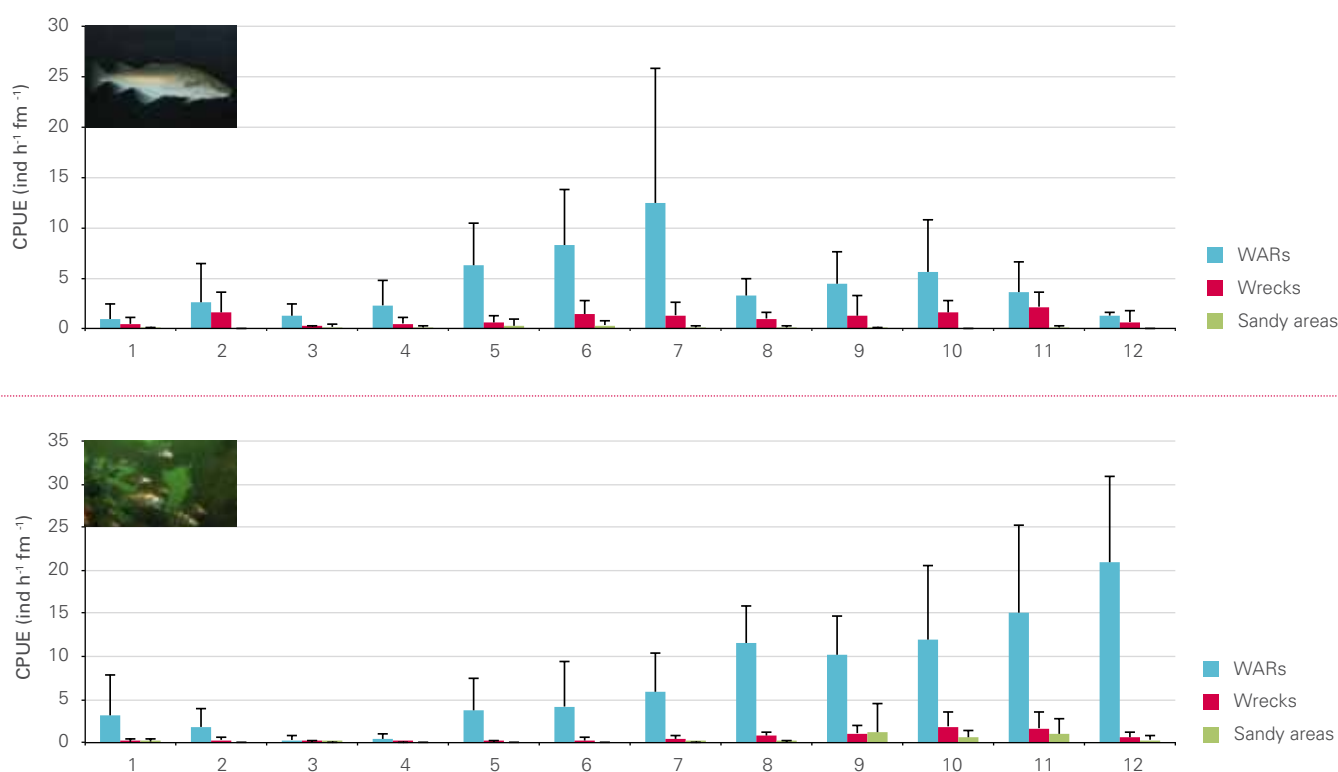
until December some pouting were encountered. At the wind turbines a seasonal pattern in catch rates was found. In winter and spring (January until June) low numbers were caught ($0.3 \pm 0.4 - 4.2 \pm 5.2$ ind $h^{-1} fm^{-1}$) while from July until December catches increased and peaked in December ($5.8 \pm 4.5 - 20.9 \pm 10$ ind $h^{-1} fm^{-1}$). At the shipwrecks a similar, but less obvious trend was observed.

These seasonal patterns in CPUE are probably related to life-history characteristics (i.e. reproductive behaviour of adults). Both species are known to spawn in winter and early spring (Alonso-Fernández et al., 2008; Mello and Rose, 2005) during which they migrate to distinct spawning areas outside the study area. In this period, CPUE was very low at the different habitats in the Belgian part of the North Sea. Late spring to late autumn is the feeding and growing period for both species. During this period, much higher CPUE, especially at the wind turbines, was observed. Both types of artificial reefs are home to a diverse and abundant epifaunal community with many potential prey species for Atlantic cod and pouting (see also chapters 12 and 14). Local factors, such as the availability of prey species, predator pressure, habitat complexity and refuge possibilities likely contributed to the differences in aggregation between the habitat types.

Figure 2. Average monthly catch per unit effort (CPUE) (with standard deviation) of Atlantic cod, *Gadus morhua* (upper panel) and pouting, *Trisopterus luscus* (lower panel) per habitat type. Data from 2009-2012. CPUE is defined as the number of fish caught in one hour by one fisherman.



Left side, school of pouting at a shipwreck; right side, Atlantic cod



Age structure of Atlantic cod and pouting

For Atlantic cod, the length-frequency distribution at the OWFs clearly revealed that the I-group was present year round (Figure 3); some II-group individuals were present as well, although in much lower numbers and mainly during the first half of the year. Thereafter, they were only sporadically encountered. At the shipwrecks the same trend was observed and some III-group cod were caught in winter and spring as well. At the Gootebank only few Atlantic cod were caught and their distribution was scattered over the year. Most of them belonged to the I-group. As only few fish were caught, clear length distributions could not be obtained.

For pouting, both the 0- and I-group were observed at the wind turbines (Figure 3). The first sightings of the 0-group were in August/September. The I-group was present year round, though was only well represented from May until October. The 0, I and II-group pouting were observed at the shipwrecks. In winter (January – March) the II-group was encountered, while the I-group was present from June onwards. The first 0-group pouting were observed in August/September. At the Gootebank pouting was mainly observed from September until December and only the 0-group was encountered.

Although not represented in the catches, other age groups may be present as well at the different habitats. Diver observations for instance, revealed the presence of juvenile Atlantic cod (0-group) at the wind turbines in May-June (sampling campaigns of 2011-2012). The individuals had an estimated average length of 5 cm. Pouting as small as 10 cm were also observed at the wind turbines. This suggests that other age groups are present but not efficiently caught using hook and line. Line fishing is a selective fishing technique and type and size of bait, hook design, fishing strategy and fish ecology all may influence the species and size selectivity (Løkkeborg and Bjørndal, 1992). Prey preferences of fish are related to prey size, thus size of bait and hooks will influence the fish size caught. The size of the hook induces a lower and upper limit of fish sizes able to be caught. For small fish the hook may be too big, while big fish may no longer be efficiently hooked.

	Q1	Q2	Q3	Q4
0 year			16.8 (6)	19.9 (71)
1 year	26.5 (39)	29.7 (173)	35.2 (127)	43.3 (715)
2 year	49.3 (184)	51.0 (925)	53.2 (262)	54.6 (594)
3 year	64.1 (180)	68.3 (283)	65.0 (13)	61.2 (687)

Table 1. Average length-at-age per quarter for Atlantic cod, based on data from the ICES area IVc in the period 2009-2012. Age was determined by otolith analysis. Values are expressed as total length (cm). Q1 = Jan-Mar, Q2 = Apr-Jun, Q3 = Jul-Sep, Q4 = Oct-Dec. The numbers between brackets indicate the number of fish available for age determination.

	Male	Female
0 year	20.7	21.4
1 year	27.5	26.8
2 year	31.5	33.1
3 year	35.6	38.2

Table 2. Average length-at-age for pouting (for both sexes). Data are based on Merayo and Villegas (1994) and expressed as total length (cm). Values refer to length at the end of the year. Regression from standard length (SL) to total length (TL) is based on Hamerlynck and Hostens (1993); $TL = 2.35 + 1.102 SL$.

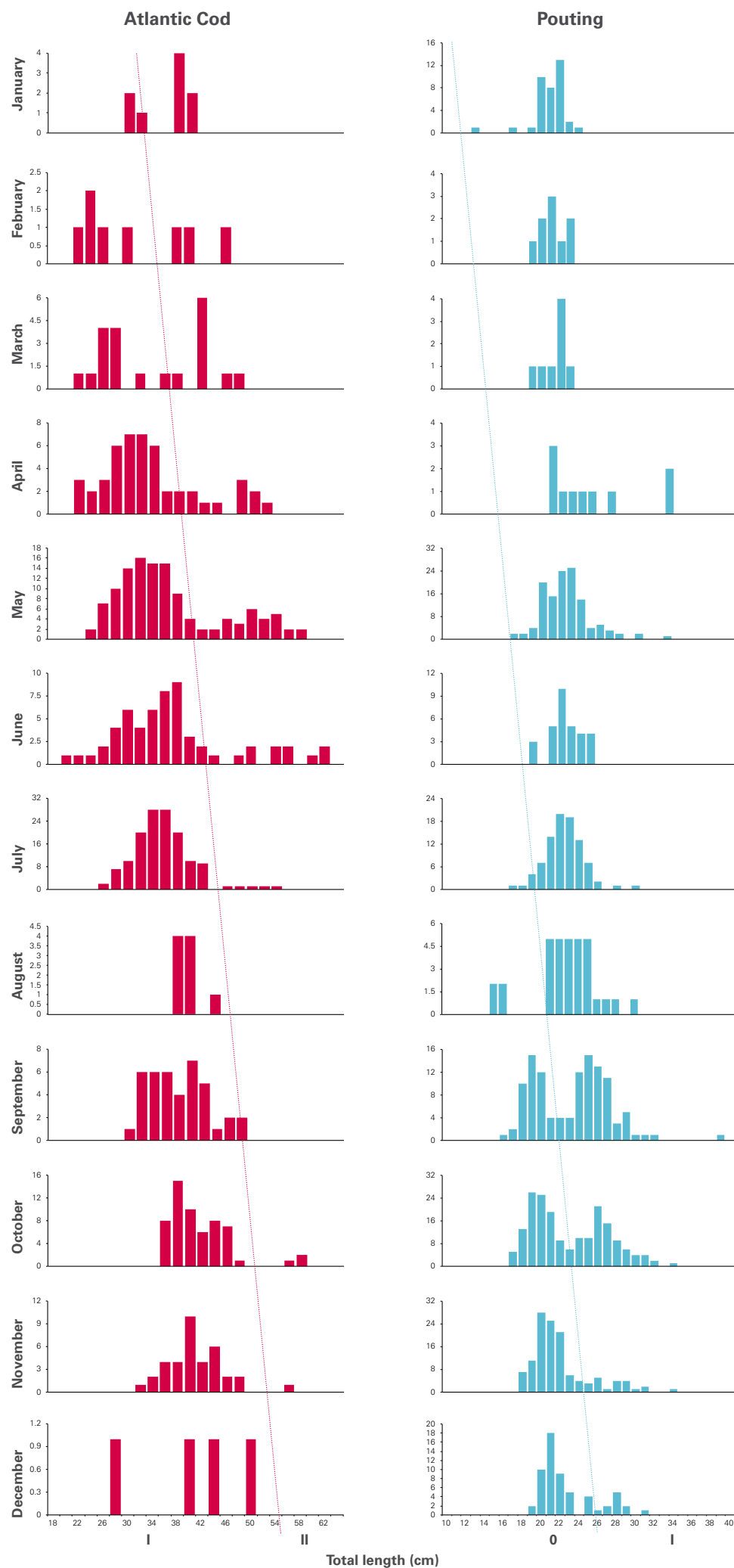


Figure 3. Length-frequency distribution of Atlantic cod, *Gadus morhua* and pouting, *Trisopterus luscus* at the OWFs with indication of the age groups. Values are expressed as total length (cm). Mind the differences in scale.

Take home messages

- Specific fish communities are observed at the different habitats (wind turbines, shipwrecks and sandy areas), with seasonal variability in the community structure.
- Atlantic cod and pouting are strongly attracted towards the wind turbines, but with a seasonal variation in numbers.
- Specific age groups are attracted towards the wind turbines
 - * Atlantic cod: I and II group
 - * Pouting: 0 and I group

FUTURE MONITORING

- Every type of fishing gear has a species-specific selectivity. The use of different fishing techniques will reflect the true community composition. For community composition estimates at the wind turbine artificial hard substrates, we suggest to combine line fishing with the placement of gill nets and diver observations. This will result in detailed information concerning the small-scale distribution and population structure of fish near wind turbines
- In this study, gravity based foundations (GBFs) were investigated as this was the only type present in the BPNS when the research started. Recently, monopiles and jacket foundations are implemented at several OWFs. Differences in reef effects are expected for the different foundation types. Jackets for instance, usually don't have a scour protection layer at the bottom. Varying hydrodynamic conditions and different fish behaviour are expected in comparison to the GBFs. Monopiles consist of steel, having different settlement characteristics for epifauna in comparison to the concrete foundation of GBFs; in addition do monopiles normally have a smaller scour protection.

fishing nets

