Investigating spatio-temporal patterns in co-occurrence of the European seabass, the Atlantic cod and cetaceans by means of two types of acoustic technologies

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Our capacity to track the presence and movement of animals has grown in an unprecedented rate over the recent decades, induced by increasing human disturbance of natural environments. This has allowed us to protect specific areas, such as foraging, stopover and breeding sites, which are important for the key stages in the life cycles of animals. The value of ecosystem-based management approaches has led to studies of species co-occurrences vital in maintaining ecological community structures (Tulloch *et al.*, 2018). Several species co-occurrence studies were motivated by the direct impact of anthropogenic activities on species commercially targeted for removal, and its indirect impact on non-targeted species such as cetaceans, which are protected under international conservation laws such as the EU Habitats Directive (1992/43/EC). Cetaceans as top predators are a key element of ocean health such that diminishing populations adversely affect ecosystem functioning (Lewison *et al.*, 2014). In this study, we explored the feasibility of investigating the spatiotemporal distribution and potential co-occurrence of the European seabass and Atlantic cod, two commercially valuable fish species, and cetaceans in the Belgian part of the North Sea (BPNS) using data acquired from two acoustic technologies—a passive acoustic monitoring (PAM) logger and an acoustic receiver jointly installed under the LifeWatch project. This is the first study to combine analyses from two different types of acoustic technologies. Different analyses were applied to identify patterns in occupancy and/or co-occurrence at different spatiotemporal scales. We found that seabass, cod and dolphins all co-occur with a porpoise within an hour-period within the 200 m detection range of the receiver/PAM logger. Dolphins had the highest proportion of detection positive hours (DPH) in co-occurrence with the harbour porpoise. Using logistic regression models, the probability that when a species/species group is present, another species/species group would be co-occurring, was predicted. In these models, significance of seasonal, diel and locational effects was tested. We found that during the colder seasons at night, when a cod or seabass is present, there is a higher probability of a harbour porpoise co-occurring at the same hour. The probability that when a dolphin is present, a porpoise would be co-occurring, is higher in stations close to the French border and during the night. Generally, the seasonal distributions of co-occurrence at finer temporal scales (hourly) agree with previous studies. By utilizing data from two types of acoustic networks already operational in the BPNS, we were able to demonstrate the potential of studying species co-occurrence with our present acoustic technologies. We conclude that developing these long-term monitoring networks while considering species co-occurrences would be a huge added value to the data we acquire from these technologies. Taking co-occurrence in mind when investigating species is a step towards an ecosystem-based management of our oceans wherein management is geared towards protecting the ecosystem as a whole.

Keywords
Acoustic Telemetry; Passive Acoustic Monitoring; Cetaceans; Harbour Porpoise; Dolphins; European Seabass; Atlantic Cod; Ecosystem-based Management; Species co-occurrence