

2 Technological developments (ToR d)

2.1 Burrow emergence rhythms of *Nephrops norvegicus*: UWTV, surveying biases and novel technological scenarios

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The occupancy assumption “one burrow system, one animal” (Sardà and Aguzzi, 2012) raises a number of generic research questions concerning the true occupation of burrows in many *Nephrops* stocks. The burrow system acts as the centre of a strong territorial rhythmic behaviour (Rice and Chapman, 1971; Farmer, 1975) leading the adults' lobsters to evict subordinates from burrows in a dominance hierarchy framework (Sbragaglia et al., 2017); indeed, two wild adult lobsters are rarely found in the same shelter (Cobb and Wang, 1985). Other studies showed evidence that no spatial segregation occurs between juveniles and adults (Maynou and Sardà, 1997) achieving the establishment of adult-juvenile complexes (at least 1 adult and 1 juvenile per burrow), which become separated as juveniles grow (Tuck et al., 1994). Moreover, *Nephrops* burrows systems could also be inhabited by other benthic crustacean species (e.g. *Munida* sp.) or may remain empty and intact for an unknown period of time after animals' death (Sardà and Aguzzi, 2012). These factors still create uncertainties about the true numbers of animals occupying burrow systems, representing an important issue when providing a relative or absolute index for determination of *Nephrops*' stock status (i.e. Harvest Rate; Sardà and Aguzzi, 2012).

For a better tuning of the occupancy assumption “1 burrow system, 1 animal”, an accurate temporal description of burrow emergence rhythmicity should be provided. The diel rhythm of burrow emergence can be subdivided in three different phases (Aguzzi et al., 2003, 2007): full emergence, full retraction and door-keeping (i.e. an intermediate period in which individuals wait at the burrow entrance; Sbragaglia et al., 2015). In Aguzzi et al. (submitted) more than three thousand video transects reporting densities by depth of full emergence and door-keeping animals and burrow systems collected in past decades around Ireland waters, are analysed. All density data were grouped per depth ranges based on both the available ones and the previous knowledges from trawl catch patterns (Aguzzi et al., 2003) as nominal: 15-50, 51-100, 101-160 and 340-570 m. A waveform analysis on UWTV survey data were conducted to describe averaged full emergence and door-keeping behavioural rhythms over the 24-h within the established depth range. Such an analysis indicate that *Nephrops* full emergence varied from nocturnal toward midday hours with increasing depth of sampling, while door-keeping behaviour coincided with full emergence only on the upper shelf (15-50 m depth) and the shelf-break (101-160 m depth). To further improve the analysis GAM models for emergence and door-keeping behaviours by depth range were developed as well. The statistical model result by GAM revealed an overall pattern of full emergence and door-keeping behaviour similar to that found by the previous waveform analysis. The emergence behaviour is predominantly dusk and dawn-oriented above 50 m, bimodal and tending to be diurnal between 50 and 100 m, temporally diffused between 101 and 160 m, and finally fully diurnal between 340 and 570 m. The door-keeping behaviour is

only temporally defined above 50 m (being nocturnal) and bimodal with a nocturnal increase between 100–160 m. Finally, estimated densities of visible animals engaged in both emergence and door-keeping behaviours (i.e. all individuals) were compared with burrow system counts and derived density estimates, to provide evidence putative biases to the standard stock assessment assumption that “1 burrow system is occupied and maintained by one animal” (Leocadio et al., 2018). A temporally integrated chart of all waveform and GAM results shows an average of about 1 visible individual per 10 burrows, at most, suggesting that a high proportion of the population remains cryptic even during periods of peak emergence.

In last years, the novel technologies have become increasingly common in fish-stock assessment using video imagery from worldwide cabled observatory networks (Aguzzi et al., 2020; Del-Rio et al., 2020). The novel scenarios allow to collect observations on visible *Nephrops* individuals as well as their burrows through cabled observatory instrumented fields for ecological monitoring of fishery resources (e.g. OBSEA-www.obsea.es; and SmartBay Observatory-<https://www.smartbay.ie/>). Hence, the next steps for fishery-independent assessment calibration should be focused on new advanced imaging packages used on autonomous robotic platforms (e.g. crawlers, AUVs and stand-alone cameras) to tune the fishery-independent assessment equation “1 burrow-1 animal”.

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2.2 Creel fishing and acoustic tracking trials in the No-Take zone off Palamós-Roses (Northwestern Mediterranean Sea) at 350-420 m depth.

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Marine Protected Areas (MPAs) have proven to be useful tools for conservation (Day et al., 2019), and they can offer many other benefits such as improving commercial fish stocks, including habitat restoration (Kerwath et al., 2013; Langton et al., 2020). In the context of the Spanish research project called RESNEP (CTM2017-82991-C2-1-R, “Marine no-take areas as a tool to recover iconic Mediterranean fisheries in decline: the case of *Nephrops norvegicus*”), a pilot marine reserve was established in an overfished ground at 350-400 m depth in the NW Mediterranean Sea, where Norway lobster (*Nephrops norvegicus*) dominated the target species fished by local and regional fisheries (BOE-A-2020-9015). Norway lobster constitutes an iconic fishing resource for European fisheries (Leocádio et al., 2012), whose landings have diminished the last two decades, especially in deep-water overfished benthic Mediterranean ecosystems (García-De-Vinuesa et al., 2020; Piroddi et al., 2020). The main objective of this marine no-take reserve, established on 2017, was to recover the population of Norway lobster as well as the recovery of the benthic assemblage and the habitat state.