Acoustic tracking of *Nephrops norvegicus* by networked moored hydrophones in a deep-sea no-take reserve of the North Western Mediterranean Sea

Ivan Masmitja, Spartacus Gomariz, Joaquim del Rio; Universitat Politècnica de Catalunya (UPC), Barcelona, Spain.
ivan.masmitja@upc.edu, spartacus.gomariz@upc.edu, joaquin.del.rio@upc.edu

Joan Navarro, María Vigo, Jacopo Aguzzi, Nixón Bahamón, José Antonio García, Guiomar Rotllant, Joan B. Company; Institut de Ciències del Mar (ICM-CSIC), Barcelona, Spain.
joan@icm.csic.es, m.vigo@csic.es, jaguzzi@icm.csic.es, n.bahamon@csic.es, guio@icm.csic.es, jagarcia@icm.csic.es, batista@icm.csic.es

Abstract. - Knowing the displacement capacity and mobility patterns of fished marine resources is pivotal to establish effective conservation management strategies in marine ecosystems. Accurate behavioral information of deep-sea fished ecosystems is necessary, but currently scarce, to establish the sizes and adequate locations of marine protected areas within the framework of large international societal programs (e.g. European Community H2020, as part of the Blue Growth economic strategy). A breakthrough in the autonomous capability of mobile platforms to deliver data on animal behavior beyond traditional fixed platform capabilities (e.g. cabled observatories) is overcoming these limitations. Here, we present useful example of that potential in relation to the implementation of autonomous underwater vehicles (AUVs) and remotely operated vehicles (ROVs) as an aid for acoustic long-baseline localization systems for autonomous tracking of Norway lobster (*Nephrops norvegicus)*, one of the key resources exploited in European waters. We reported the outcomes of that monitoring in combination with seafloor moored acoustic receivers to detect and track the movements of 33 tagged individuals at 400 m depth over more than three months. We identified best procedures to localize both the acoustic receivers and the tagged-lobsters, based on cutting-edge algorithms designed for off-the-self acoustic tags identification. These procedures represent an important step forward for prolonged, *in situ* monitoring of deep-sea benthic animal behavior at meter spatial scales.

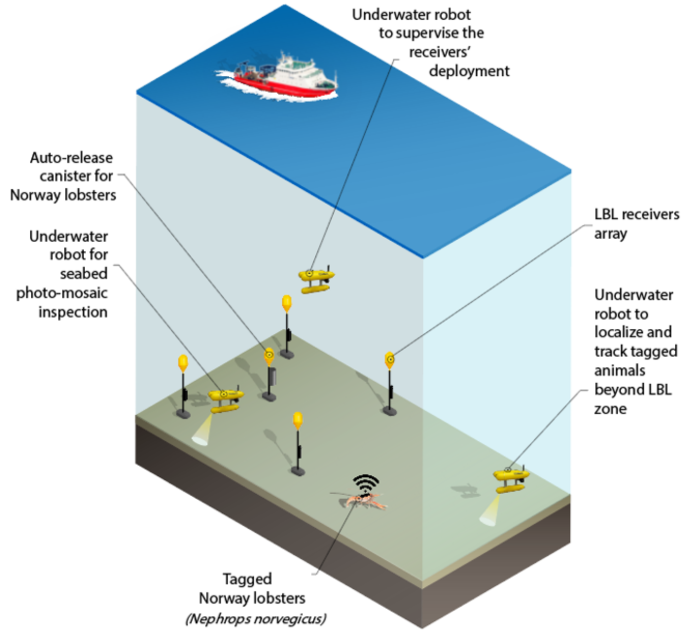

Figure 1. The strategy designed to track Norway lobsters (*Nephrops norvegicus*) is represented. Four receivers created an acoustic LBL localization system, where each one was in self-recording mode and was not accessed in real time. The tags transmitted periodically an acoustic ping, which was recorded by the static receivers and the underwater vehicles; both systems were used to track the lobsters' movements.

Static receivers for tracking purposes

The development of in situ, autonomous and permanent monitoring technologies delivering complex environmental information on habitat and species are being implemented worldwide (Aguzzi et al., 2019), serving the needs of policy decision (Danovaro et al., 2017) and the monitoring needed oriented to the fishery-independent stock assessment (Aguzzi et al., 2020). Acoustics monitoring of individuals play a major role in restoration via repopulation techniques, measuring home ranges and activity. For this purpose, tagged animals were deployed in June 2018 at 350-420 m depth, in a no-take reserve off Palamós-Roses coast (Figure 2A). Specifically, 33 *Nephrops* individuals were tagged with VEMCO transmitters connected by cyanoacrylate on the upper part of the cephalothorax (Figure 2B). The deployment area was equipped with 4 mooring lines, each holding a receiver for tracking signal presence (emergence)-absence (burial) and for triangulating animals' movement and efficiency in restoration procedures (i.e. tracking displaced ranges tom better tune the no-take zone surface area). The receiver's self-localization and clock's synchronization were computed using time of arrival (TOA) techniques. After these procedures, each tagged individual was localized using time difference of arrival (TDOA) methods. We tested different algorithms in order to characterize their performance and find the greatest (Masmitja et al., 2020). For example, in Figure 2C, the root mean square error (RMSE) position of a moving tag is presented, where the simulations were conducted using four static receivers. The figure shows the performance of the following algorithms: particle filter (PF), maximum a posteriori estimation (MAP), maximum likelihood (ML), weighted least square (WLS), and yet another positioning solver (YAPS).

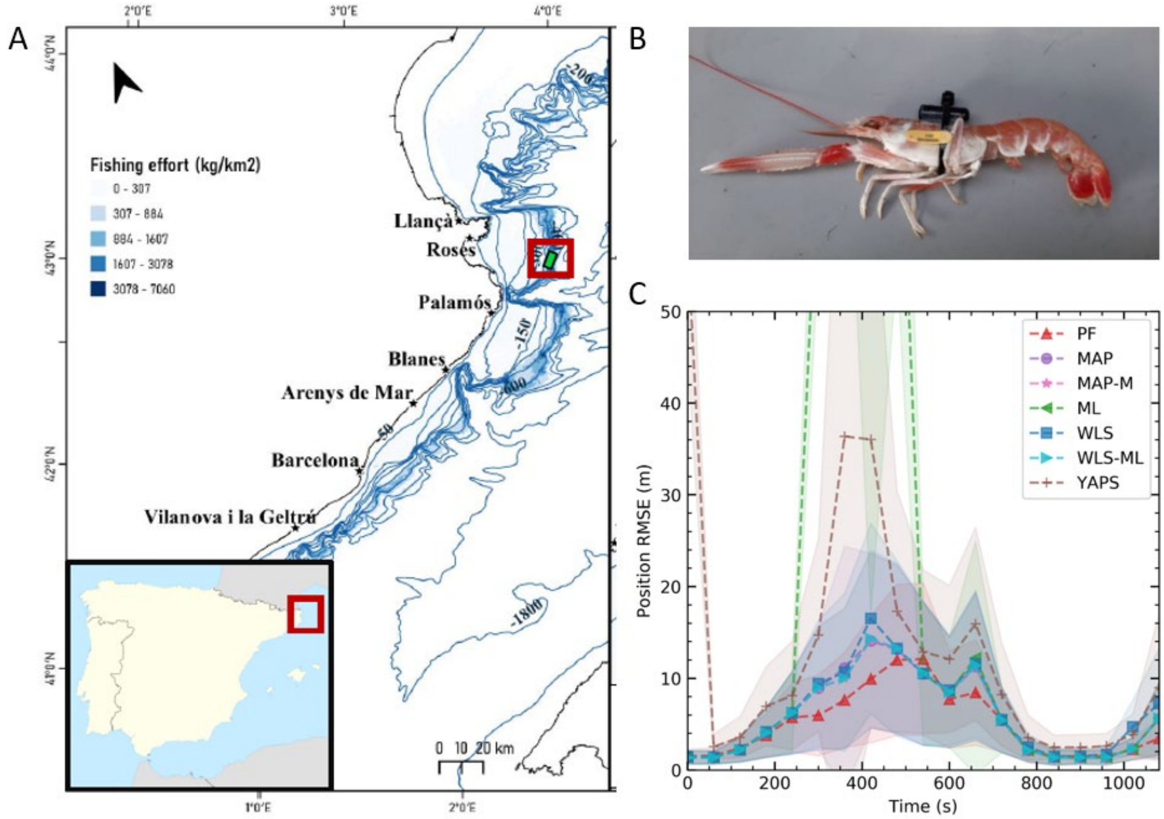

Figure 2. (A) Map of the study area in roses continental slope, northwestern Mediterranean Sea, where the Norway lobsters were tracked. The blue gradient indicates the accumulated catches of Norway lobster between 2006-2019. (B) a tagged Norway lobster showing the VEMCO tag glued on its superior portion of the cephalothorax. (C) Performance of different algorithms to track acoustic tags using TDOA.

Underwater vehicles for tracking purposes

Moreover, we deployed an AUV and an ROV to also localize and track the tagged Norway lobsters. The flexibility of these vehicles overcome the limitations of traditional static receivers. To do so, we developed an innovative area-only target tracking (AOTT) method by the use of particle filter algorithms (Masmitja, et al. 2019). The AOTT method was characterized and tuned in order to obtain the greatest performance analytically and through simulations. In addition, different field tests were conducted previously to the Norway lobster campaign, at OBSEA observatory (www.obsea.es) (Del Rio, et al. 2020) in Barcelona (Spain), and at Monterey Bay Aquarium Research Institute (MBARI) in Moss Landing (CA, USA), Figure 3A and 3B respectively.

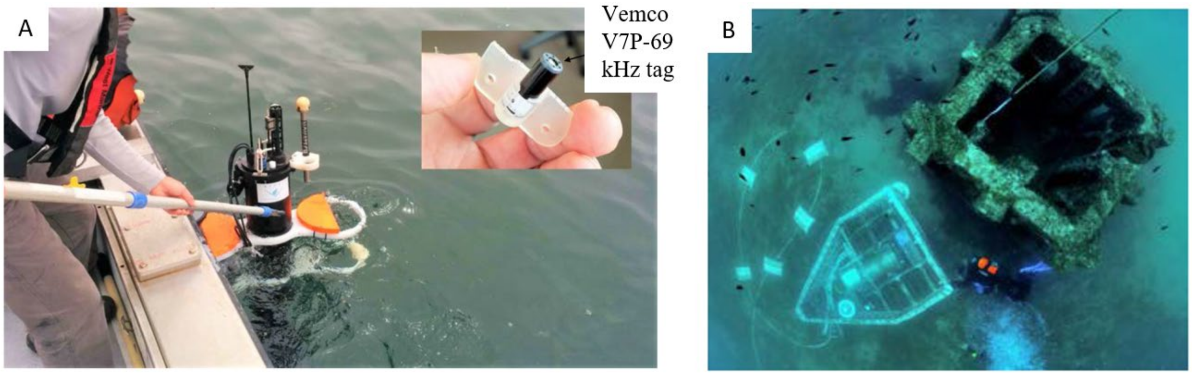

Figure 3. (A) Tests conducted at MBARI (Moss Landing, CA, USA). (B) OBSEA cabled observatory test site at 20 m depth, off Vilanova i la Gertrú (Barcelona, Spain).

The vehicles used during the campaign were the Super Mohawk II ROV and the Girona 500 AUV, Figure 4A and Figure 4B respectively. Finally, some of the results can be observed in Figure 4C, where the tracks conducted by both vehicles and the detected tags (T0…3) are represented.

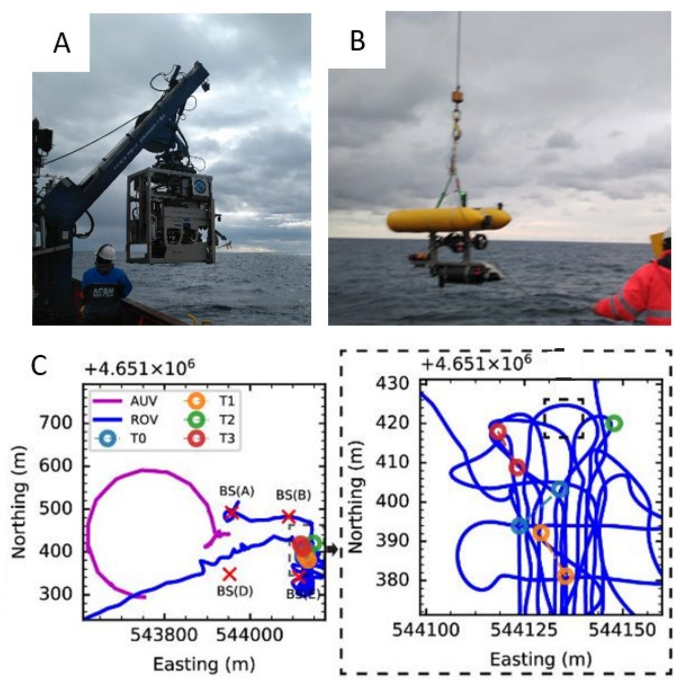

Figure 4. (A) Super Mohawk II ROV. (B) Girona 500 AUV. (C) tracks conducted by the vehicles and the detected tags (T0…3). The red crosses indicate the localization of the four moored Vemco receivers (BS)

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