

IN SITU RARE LONG TERM OBSERVATIONS OF THE DOGTOOTH GROUPEP *EPINEPHELUS CANINUS* IN ARTIFICIAL REEFS RECENTLY IMMERSSED IN THE NATIONAL PARK OF THE CALANQUES (NORTH-WESTERN MEDITERRANEAN SEA, FRANCE)

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Abstract – In winter 2017, biomimetic designs of porous concrete artificial reefs (Ragues® modules of 3 m in height for 12 tons in weight) targeting different high-value and apex rocky species such as groupers were immersed between -19 and – 22m in the National Park of the Calanques (French Mediterranean coast - 43° 12.679' N / 5° 23.485' E) as part of an experimental ecological restoration project called REXCOR. Still ongoing, the main objective of the REXCOR project is to evaluate the capacity of innovative designs of artificial reefs to restore altered ecological functions of the rocky coastline (shelter, breeding, feeding, nursery grounds) historically impacted by the sewage outflow of the city of Marseilles (second largest town in France). During the first summer after their deployment, one specimen of the Dogtooth Grouper, *Epinephelus caninus*, (Valenciennes, 1843) estimated to 65 cm was observed by scubadivers during three consecutive months (June, July and August 2018) and then in December 2018 inside the artificial reefs. Thanks to photoidentification and to the analysis of the different morphologic characteristics, it was determined as a unique individual. The specimen was a gravid female estimated between four to more than eight years old. To our knowledge, this is the first documented record of high site-fidelity (at least 7 months) for *E. caninus* found in North-western Mediterranean coastal habitats. This could represent a first positive cue to undertake a larger project of ecological restoration. It is also the first record in the National Park of the Calanques since its creation in 2012 and the first record in artificial reefs in France, especially at such a low depth despite the presence of others important artificial reefs sites in this area.

1. Introduction

Groupers (Perciformes: Serranidae) represent one of the most emblematic Mediterranean fish. Due a high market value both for recreational and commercial fisheries, grouper populations are declining and some species such as *Epinephelus marginatus* are now considered as locally threatened [1]. As a keystone species, the study and the protection of groupers directly benefits associated coastal ecosystems. The long-term presence of such high trophic level species is considered as a good indicator to evaluate the health of a

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Mediterranean reef and the efficiency of management measures such as the creation of Marine Protected Areas [2]. Consequently, important efforts are undertaken in order to improve the scientific knowledge and the management of groupers populations. Seven species are found in the Mediterranean sea but some of them are still poorly described in terms of biology, ecology, stock structure, distribution, conservation and management plan. Among the 163 grouper species evaluated through the global IUCN Red List assessment, 50 species were classified as Data Deficient (DD) and this reflects the lack of accurate information [3,4].

Available published data on the Dogtooth Grouper, *Epinephelus caninus* (Valenciennes, 1843) in the Western Mediterranean sea is particularly scarce (5, 6, 7). The intrinsic vulnerability index calculated by Fishbase (<http://www.fishbase.org>) according to the species life history associated to fishing vulnerability is particularly high (87/100), with 100 being the most vulnerable score). Widely distributed in the Eastern Atlantic from Portugal to Angola, this sub-tropical species is uncommon in the Mediterranean Sea especially in its north-western shore. It is mostly found in deep areas from 30 to 300-400 m occurring on both sandy mud and hard substrates [5, 6, 7, 8, 9]. As most of the groupers, *E. caninus* is a protogynous hermaphrodites and it is expected to be bottom-dwelling lie-in-wait predators that ambush their prey as it passes nearby [5, 10]. These predatory fish mostly feed on small fishes and crustaceans [5,9,10,11]. Morales-Nin et al. [12] described a specimen of 164 cm of total length and weighed 57 kg. Examinations of the otoliths of this fish reveal that *E. caninus* could reach 55 years old, a similar longevity observed in other grouper species such as *E. marginatus* [5]. Reproductive biology and behavior are still unclear for the Dogtooth Grouper. Some coastal lagoons of the southern shore of the Mediterranean Sea are described as potential nursery grounds for *E. caninus* [13]. Known to occur in French Mediterranean waters [14], only few published deep records (two ROV observations between -183 m and -189 m [9]) and unpublished data [6] are available.

Table 1 – Summary of informations for the Dogtooth Grouper *Epinephelus caninus* extracted by Fishbase (<http://www.fishbase.org>).

IUCN Status (Mediterranean)	Depth range (m)	Maximum size (cm)	Trophic level	Intrinsic Vulnerability Index
EN	30 - 400	164	3.8 ±0.55	87/100

2. Materials and Methods

With 873 716 inhabitants in 2021 the city of Marseilles is the second largest in France. Until 50 years ago, effluents were discharged directly into the sea without treatment. Various investments to improve the quality of wastewater treatment have been made between 1987 and 2008 so as to become one of the most efficient wastewater treatment plants in the Mediterranean (Geolide – 1 860 000 Population Equivalent) which drastically improve the water quality as 90 % to 95 % dissolved and suspended solids are removed (Boissery com. pers.).

After almost ten years, this decrease in anthropogenic pressure was not associated to the restoration of different historical biogenic habitats such as rocky reefs and *Posidonia*

oceanica seagrass beds. Thus, the study of the resilience, here the capacity of this degraded area to host again the associated biocenosis, especially the high trophic level rocky species, and the description of the ongoing restoration trajectory, was not possible. This motivated local authorities, national agencies and the Marine Protected Area to intend an experimental artificial reefs restoration program.

On winter 2017, four replicated villages of artificial reefs were immersed between -19 and -22 m in the French National Park of the Calanques (French Mediterranean coast - $43^{\circ} 12.679'N / 5^{\circ} 23.485'E$) as part of an experimental ecological restoration project called REXCOR. Still ongoing, the main objective of the project is to study the capacity of innovative designs of artificial reefs to study the restoration of the main altered ecological functions of the rocky coastline (shelter, breeding, feeding, nursery grounds) historically impacted. The four 4 villages (A, B, C, D) were settled at a different distance of the discharge from the wastewater treatment plant at respectively 170 m, 700 m, 1000 m and 1500 m.

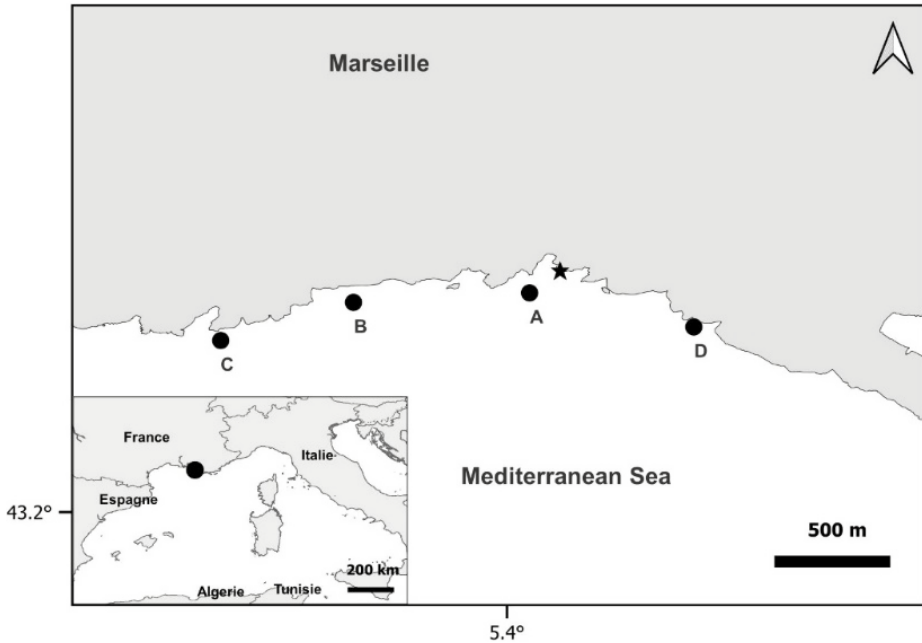


Figure 1 – Study area of the experimental ecological project REXCOR project (National Park of the Calanques). A, B, C and D represent the four artificial reefs villages. The star represents the discharge of the wastewater treatment plant.

Biomimetic designs of concrete artificial reefs 3 m high and weighing 12 tons (Ragues ®) were specifically developed to create new hard substrata and narrow cavities of different dimensions and shape targeting different high-value and rare rocky species such as lobsters, seabreams and groupers but also sessile species such as gorgons and corals.

Different monitoring programs were launched and are still ongoing including scubadiving surveys to study the mobile fauna (summer and autumn), photoquadrats studies to study sessile communities successions (summer and autumn), acoustic surveys (spring, summer and winter) to study the wildlife noise by night and technical surveys (summer and autumn) to study the integrity of innovative artificial reefs designs.



Figure 2 – The REXCOR project host different monitoring programs in order to study the resilience of the local rocky ecosystem inside an around the artificial reef villages in the impacted area of the National Park of the Calanques (left: Ragues ® module monitoring, center: acoustic surveys, right photoquadrats studies).

3. Results and discussion

In 2018, during the first year after the deployment of the villages, nine scuba diving campaigns were led by different scientific teams in order to realize the monitoring programs. On four occasions, one specimen of *Epinephelus caninus* was observed inside the cavities newly created by the artificial reefs immersed at around 1 km west of the discharge area. To our knowledge, this is the first record ever of *E. caninus* in the National Park of the Calanques since its creation in 2012 and the first record in French waters at such a low depth (< 25 m) by scubadivers. Interestingly, 400 other artificial reefs were immersed in 2008 in a nearby (but deeper) area from 25 to 31 m at less than 10 km away [15, 16]. Thoroughly monitored for ten years, no *E. caninus* were observed in the artificial reefs of the Prado (Le Direach, com. pers.). The design and/or the site selection could have played a major role in the efficiency of artificial reefs to shelter high trophic level species [17].

Thanks to photoidentification and video analysis, the different characteristic dark bands of the dog tooth grouper radiating posteriorly from the eye and associated cephalic blotches were studied as previously suggested [18]. We determined that the same individual (approximately 65 cm) was sheltered inside the artificial reefs for at least 7 months. Strong site fidelity has already been described in other grouper species such as *E. marginatus* [19,20] but not for *E. caninus*. Site fidelity is a good indicator of the production effect of artificial and natural reefs [21, 22, 23]. This suggests that local food resources and habitat provided by artificial reefs and natural surrounding areas probably allowed to meet the different ecological needs (shelter, feeding) of such a high trophic level species. If an “attraction vs production” debate still exists, many studies are now available to clearly describe the interest of artificial

reefs for some benthic species to shelter a whole ecosystem from primary producers to high trophic level species [24,25]. Moreover, the abdominal cavity of this potential sexually mature female (estimated between four to eight years old according to different authors [12,26]) seemed to be full of eggs during the summer and very close to spawn. Artificial reefs could have played a key function during the last days before the reproduction of this individual.

Our preliminary results suggest that the historical degraded area studied in 2018 in the national park of the Calanques could now support again important ecological functions for rocky species such as groupers. The water quality does not seem to limit at least the long-term presence of this high trophic benthic-demersal fish species and potentially the associated food web.

Using biomimetic artificial reefs to create new hard substrates in degraded coastal areas targeting benthic fish species seems to be efficient at least to study the potential of restoring a degraded area and to evaluate the local policies and stakeholders new policies and actions. Some design of artificial reefs could also play an important role for endangered and unknown species such as the Dogtooth Grouper supporting ecological functions including reproduction, shelter and food resources for such species.

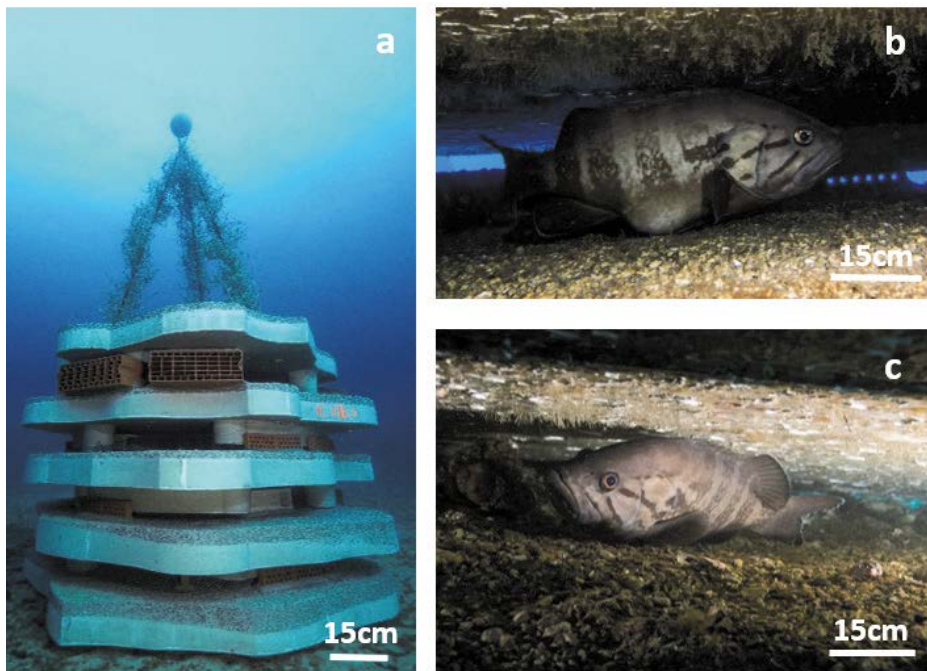


Figure 3 – Illustrations of the Ragues artificial reef (a) and the individual of the dogtooth grouper *Epinephelus caninus* observed inside of these modules in 2018.

4. Conclusion

The settlement of biomimetic artificial reefs showed that after one year in an historically degraded urban area, a rapid colonization and a high residency for at least one individual of the Dogtooth Grouper was possible. This suggests that this high trophic level species was able to reside on the area of the newly settled artificial reefs and that the water quality is not anymore an ecological filter to support important ecological functions (shelter, feeding, breeding...), but maybe the availability of healthy hard substrate is still missing locally. Further studies are needed to better quantify the long-term movements of resident species between natural and artificial reefs and how spatial and temporal patterns could differ between species. The interest of artificial reefs as a tool of the potential of recovery and restoration of an historical degraded area to recover its trophic structure through habitat restoration still need more considerations in prevention of larger scale restoration projects.

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