Institut Català de Recerca per a la Governança del Mar

A proposal for estimates of equivalent fishing effort reduction through sustainability measures

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In 2019, the Western Mediterranean MultiAnnual Plan (WMMAP) was established with the objective of contributing to reaching and maintaining MSY for the target stocks, to implementing landing obligations, and to provide a fair standard of living for those who depend on fishing activities. Shortly after, a simulation exercise on the fishing effort reduction necessary to reach F_{MSY} for the European hake in 2025 showed that the bottom trawl fleet would need to work only 50 to 66 days a year, depending on the segment (ICATMAR 20-07, Martín et al. 2019). Seeing as this scenario would not be compatible with the socioeconomic sustainability of the western Mediterranean fleet, ICATMAR brought forward a two-way strategy focused on providing the most accurate and extensive information for use in management decisions tailored to the particularities of the northern GSA 6 fisheries. On one hand, an exhaustive revision of stock assessment methods and input parameters was initiated, including analyses of population structure, with the objective of refining and improving the representation painted by the stock assessment models (ICATMAR 24-06, 23-08, 22-05). On the other hand, studies were carried out to explore measures beyond reduction of fishing days for the recovery of the exploited populations and the ecosystems they inhabit, i.e., the use of low-contact otter boards, the improvement of gear selectivity, and the establishment of permanent closure areas. While the effectiveness of these measures has been contrasted and presented in different forums over the years (e.g., Bahamon et al. 2024, ICATMAR 23-06, 21-05, Tuset et al. 2021, Sala-Coromina et al. 2021, Gorelli 2017, Puig et al. 2012), the text of the WMMAP is centered around the reduction of fishing effort, and so alternative measures have only been implemented as compensation mechanisms, with meager results up to date (ICATMAR 24-07, 23-09).

In an attempt to provide useful information for decisions regarding the application of the WMMAP, the present report is a practical exercise in the quantification of these alternative fisheries management measures in terms of equivalent reduction of fishing effort in the northern GSA 6 (from here on, N GSA6), i.e., the reduction is not an actual decrease in fishing days but rather an equivalent reduction achieved through a combination of management measures, as indicated in Table 1. Using size frequency distributions, biological parameters, landings, and spatial data, we estimated the equivalent effect in fishing effort reduction of the following measures:

- Implementation of gear selectivity in coastal and deep-sea fisheries (45 and 50 mm square mesh codend, respectively).
- Permanent fishing closures (currently 3.8% of total fishable area, with the objective to reach 5%)
- Spatial closure for bottom trawling beyond 800 m depth.
- Protection of hake spawners through temporary closures on small-scale fisheries.

The use of low-contact otter boards throughout the fleet is a key measure proposed by ICATMAR for the recovery of the ecosystems, but it is not part of the present report since it is not quantifiable in terms of reduction of fishing effort. For ease of reference, all results are summarized in Table 1.

Table 1. Summary of results of the quantification exercises for the fisheries management measures proposed in N GSA6. ARA: blue and red shrimp (*Aristeus antennatus*); HKE: European hake (*Merluccius merluccius*). Due to the difficulties in gathering official information on the number of assigned days by métier for the present year, reduction equivalent is referred to the number of worked fishing days per métier in 2023.

	Proposed measure		**Quantification** % Reduction equivalent	Reduction equivalent in fishing days (reference 2023)	**Species of reference**
1	Gear selectivity	50 mm square mesh in deep-water fisheries	22% reduction of current fishing days	1563 total fishing days 7.3 days per vessel*	ARA
		45 mm square mesh in coastal fisheries	24% reduction of current fishing days	6914 total fishing days 32 days per vessel*	HKE
2	Permanent fishing closures		7.3% of total catch in individuals are inside closures	399 total fishing days 2 days per vessel*	HKE and other WMMAP species
3	Spatial closure beyond 800 m depth		10.3% reduction in surface from previous fishable area	254 total fishing days 1.3 days per vessel*	ARA
4	Protection of hake spawners through temporary closures on small-scale fisheries		7.1% reduction in weight in hake spawners catch in small-scale fisheries	1000 total fishing days (2.5 months closure) 3.6 days per vessel*	HKE
5	Use of low-contact otter boards		Non-quantifiable		All species in habitat

(*) Since vessels can operate in both coastal or deep-sea métiers within the same year, the equivalent number of total fishing days was distributed to the total number of vessels in the bottom trawl fleet (202 vessels as of 2023) or small-scale fisheries fleet (277 vessels in 2023) to obtain the equivalent number of days per vessel. For instance, in the case of blue and red shrimp, where only 50 vessels belong to the deep-sea fisheries métier, the calculations in number of individuals stem from only these 50 vessels, but the resulting estimate of equivalent fishing days has been distributed throughout the entire fleet. The question of whether to distribute the total equivalent days to all vessels in the fleet or to keep them only within each métier will eventually have to be determined.

1. Improvement in gear selectivity

Using length frequency distribution data from ICATMAR monitoring program and daily landings data for the years 2019 to 2023, we estimated the total number of individuals caught per year with commercial codend mesh sizes (40 mm square mesh) in the N GSA6, following the rising method described in ICATMAR 24-06. The species analyzed were European hake (*Merluccius merluccius*) as the main target species for coastal fisheries, and blue and red shrimp (*Aristeus antennatus*) as the main target species for deep-sea fisheries. The size frequency distributions obtained for both species are comparable with official data for the GSA 6 from the EU Data Collection Framework, as presented in ICATMAR 22-05. Then, length frequency distribution data were treated with selectivity vectors generated by Bahamon et al. (2024) to estimate the total number individuals that would be caught per year with the more selective gears proposed (45 mm square mesh for coastal fisheries, 50 mm square mesh for deep-sea fisheries; Figures 1 and 2). The difference between both numbers is the potential reduction in individuals caught by the application of selectivity measures.

The total number of days fished by year and métier in the N GSA6 was obtained from 2023 daily landings data. We obtained a catch ratio in individuals per day by dividing the total number of individuals caught by the number of days fished. Finally, the potential reduction in number of individuals for each species was divided by the catch ratio to obtain the equivalence of this reduction in the catch in terms of fishing days for the entire bottom trawl fleet.

For hake, the potential reduction of the catch with the implementation of a 45 mm square mesh size codend throughout the fleet would be equivalent to reducing 32 days per vessel in average, or 24% of the total days worked in 2023 for the entire N GSA6 bottom trawl fleet (almost 200 fishing vessels). For blue and red shrimp, the potential reduction of the catch with the implementation of a 50 mm square mesh size codend throughout the fleet would be equivalent to reducing 7.3 days per vessel in average, or 22% of the total days worked in 2023. Since vessels can operate in both coastal or deep-sea métiers within the same year, the equivalent number of total fishing days was distributed to the total number of vessels in the bottom trawl fleet (202 vessels as of 2023) to obtain the equivalent number of days per vessel. For instance, in the case of blue and red shrimp, where only 50 vessels belong to the deep-sea fisheries métier, the calculations in number of individuals stem from only these 50 vessels, but the resulting estimate of equivalent fishing days has been distributed throughout the entire fleet. The question of whether to distribute the total equivalent days to all vessels in the fleet or to keep them only within each métier will eventually have to be determined.

Calculations were done in number of individuals to account for the potential consequences of leaving non-commercial, small individuals at sea which are expected to grow and join the fishable stock once they attain minimum conservation reference size. Conceptually, what escapes from the codend are small individuals that will still be part of the population, and not kilograms of commercial catch. In any case, when calculated in weight instead, the equivalent reduction in days would be 5.6% of the total days for hake, and 11.1% of the total days for blue and red shrimp. It is worth mentioning that selectivity measures not only positively affect populations at the time of implementation, but also have an additive effect over time which has not been taken into account in these calculations, with the unfished small individuals increasing the abundance of larger size classes in the mid-term.

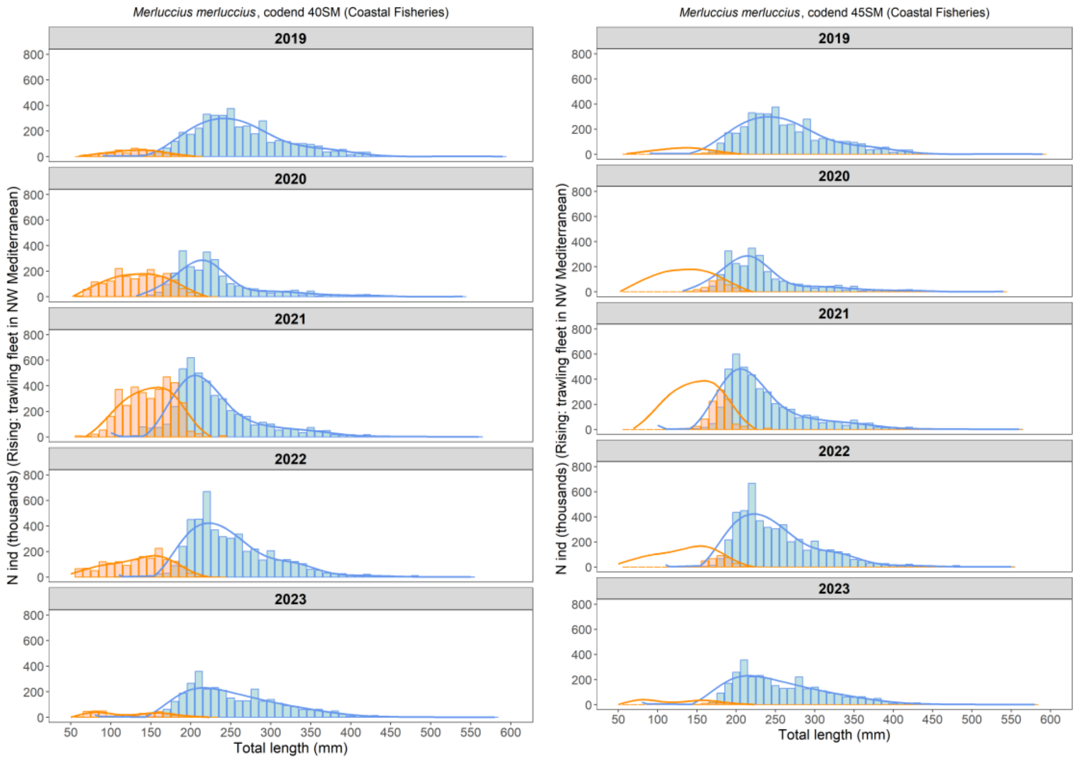

Figure 1. Left: Length frequency distribution of European hake for the years 2019 to 2023 in the northern GSA 6 with a commercial mesh size of 40 mm square codend. Right: Simulated length frequency distribution of European hake for the years 2019 to 2023 in the northern GSA 6 with a more selective mesh size of 45 mm square codend. Orange bars and line: discarded fraction of the catch. Blue bars and lines: commercial fraction of the catch. Data from ICATMAR monitoring program; selectivity vector from Bahamon et al. (2024).

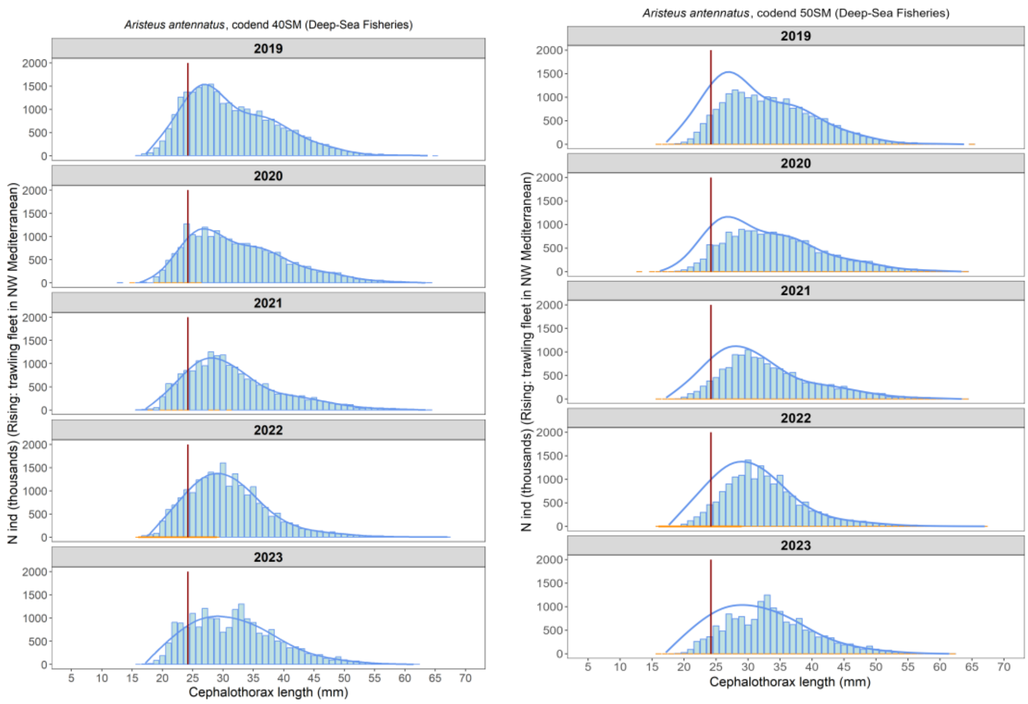

Figure 2. Left: Length frequency distribution of blue and red shrimp for the years 2019 to 2023 in the northern GSA 6 with a commercial mesh size of 40 mm square codend. Right: Simulated length frequency distribution of blue and red shrimp for the years 2019 to 2023 in the northern GSA 6 with a more selective mesh size of 50 mm square codend. Orange bars and line: discarded fraction of the catch. Blue bars and lines: commercial fraction of the catch. Data from ICATMAR monitoring program; selectivity vector from Bahamon et al. (2024) and ICATMAR 21-05.

2. Establishment of permanent fishing closures

Vessel Monitoring System (VMS) data were analyzed to map the spatial distribution of the N GSA6 bottom trawling fleet fishing effort (fishing hours/km^2) before and after the establishment of WWMAP closure areas. Since the protection of these areas, the yearly reduction in fishing time has reached an average of 2 793.53 hours over all closure areas, representing 3.8% in surface of the total fishable area (50-800 m), and 8.3% of the deeper shelf fishing grounds (100-250 m), where the abundance of European hake juveniles is highest (Figure 3). This is equivalent to 1.12% of total fishing time in the northern GSA 6, or 399 days, accounting for 7 hours effective fishing time per day in the N GSA6 (Figures 4 and 5). While there may be a degree of effort redistribution to adjacent areas which could also play a role in the life cycle of the species, the particular placement of these closures in well-known hake recruitment and nursery areas ensures the permanent protection of juvenile individuals in these areas year after year, while the work continues towards the permanent protection of 5% of the total fishable area. Furthermore, if accounting for spillover effect, this unfished pool of individuals is likely to act as a source for the stock and is an asset in the recovery of the population (Sala-Coromina et al. 2021).

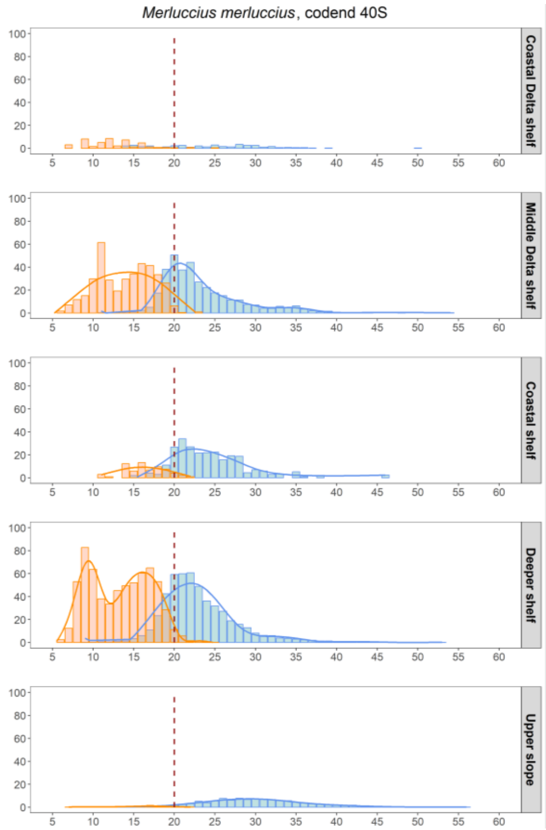

Figure 3. Size frequency distribution for the European hake by métier in the northern GSA 6 from ICATMAR monitoring data for years 2019 to 2023. Orange bars and line: discarded fraction of the catch. Blue bars and lines: commercial fraction of the catch. Note as the Deeper shelf is the area where higher abundance of hake recruits is caught. The permanent closure areas of N GSA6 were placed following this spatial hake recruit distributions (see Figure 6 for more details on closure areas in N GSA6).

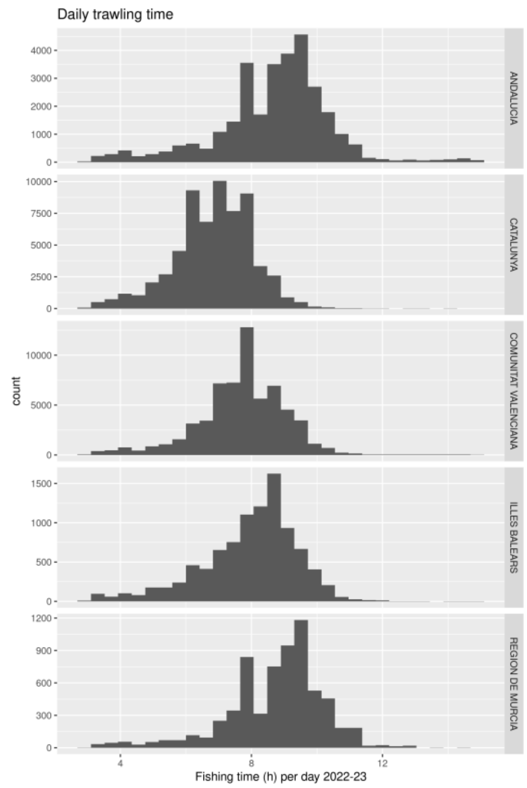

Figure 4. Effective daily fishing time (in hours) in different regions of the Spanish Mediterranean coast.

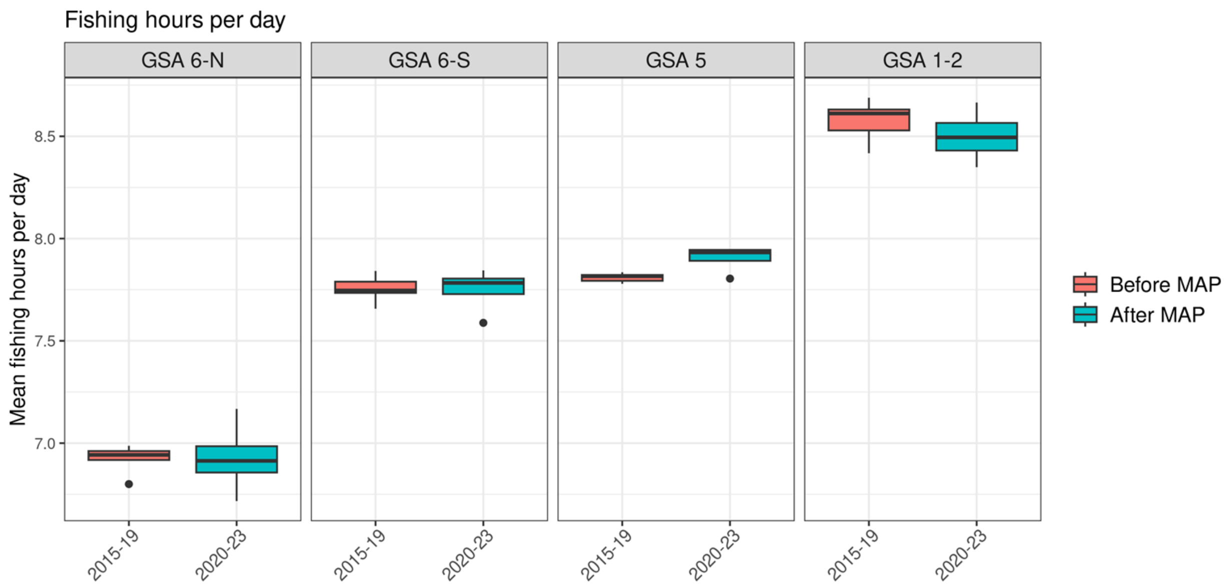

Figure 5. Effective fishing time (in hours) in N GSA6, southern GSA 6, GSA 5, and GSAs 1 and 2 combined. Red boxes: before WMMAP; blue boxes: after WMMAP.

In addition, a Generalized Additive spatial Model (spatial GAM formula: Number of individuals ~ s[longitude, latitude] + s[depth]) was fit using ICATMAR sampling data for European hake (Figure 6). According to these results, 7.3% of individuals are located within the existing closure areas, and remain protected from fishing. It is worth noting that abundance and biomass values inside closure areas can reportedly reach 2-3 times the values outside of the closures (Vigo et al. 2023, Tuset et al. 2021, Recasens et al. 2016), and so the model is likely to be underestimating the uncaught individuals.

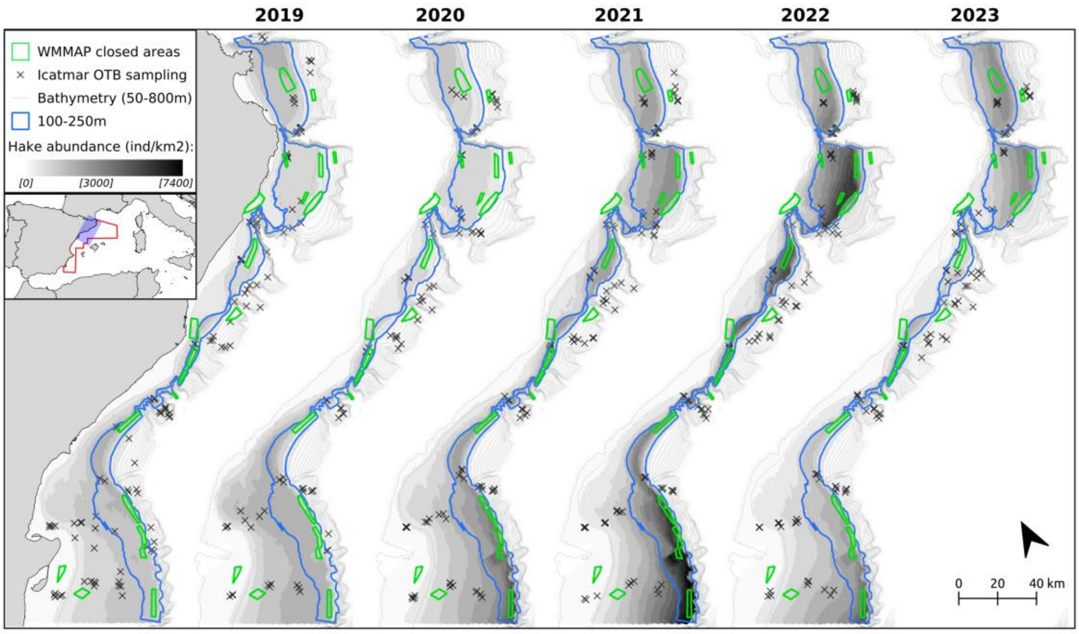

Figure 6. Generalized Additive Model for European hake distribution in the northern GSA 6 (individuals per km^2) for the years 2019 to 2023. Green polygons indicate location of current fishing closure areas.

3. Spatial closure for bottom trawling beyond 800 m depth

The ban on bottom trawling beyond 800 m depth in Mediterranean waters was implemented by Spain in May 2024 as a compensation mechanism (BOE 2024c). This measure, with a predominantly precautionary character, aims to ensure the protection of these grounds in the face of potential technological improvements that may render them more profitable and accessible in the future. The 800-1000 m area, now closed to bottom trawling activity, represents 10.3% of the total previous fishable area (50-1000 m), and 40.7% of previous blue and red shrimp fishing grounds (500-1000 m) (Figure 7). The blue and red shrimp caught in this depth range represents 2.9% in weight and 2.8% of the revenues of the total landings of the species in the N GSA6. The landings in kilograms within the 800-1000 m depth range were treated following the method described in Section 1 to determine the equivalence to 254 total fishing days, or 1.3 days per vessel. While the representation with reference to the total landings is limited, this measure is bound to have an effect in the long-term protection of these grounds.

Figure 7. Bathymetry lines along the northern GSA 6. Blue lines: 50 and 500 m for surface reference purposes; Red lines: 800 and 1000 m, bathymetric gradient banned to deep-sea fisheries.

4. Protection of hake spawners through temporary closures on small-scale fisheries

European hake spawners are the largest individuals of the stock, targeted exclusively by small-scale fisheries (LLS, GNS, and others), which represent a low percentage of the fleet in number of vessels, but are currently not affected by any restrictions linked to the life cycle of the species. The regulation of these gears during the reproductive peak of the species (from October to January; Recasens et al. 2008) would ensure the protection of a fraction of the stock that is key for its recovery.

Landings data per vessel for the years 2019 to 2023 in the N GSA6 were analyzed to detect vessels who caught over 20% in weight of European hake in any fishing trip during the months of the reproductive peak. An average of 20 vessels fulfilled this condition during the studied period. The proposal specifically includes a temporary closure that affects only these vessels during 2.5 months of this period, since it is unlikely that the entire fleet can be compensated for the totality of the duration of the reproductive peak. The enforcement of this measure would entail, in average, the reduction of 4002 kg of hake spawners per year, that is, 70.6% in weight of the small-scale fisheries hake catch in these 2.5 months, 7.1% of the annual hake catch of small-scale fisheries, or 0.6% of the total catch of hake in the northern GSA 6.

The quantification of this measure in terms of fishing effort reduction would then be 1000 total fishing days (2.5 months or 10 weeks with 5 working days a week, for 20 vessels), or 3.6 days per vessel (277 small-scale fisheries vessels in 2023).

Final remarks

The estimated impact on equivalent fishing days, catch, and fishable area reduction of the measures proposed in this report aims to address the specific needs of the WMMAP. This approach is based on the understanding that management focused solely on reducing fishing days does not necessarily lead to more sustainable practices, but instead prioritizes a general cutback in fishing activity.

Besides, fishing days do not account for the same amount of effective fishing hours throughout the GSA 6, and so management of days may lead to further inequalities in the time allocated to each region. The proposed measures are a key step towards protecting the exploited populations and the ecosystems they inhabit, while also maintaining job stability in the fishing sector.

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