

Deploying artificial nurseries in port areas: a complementary strategy to fisheries management for supporting coastal fish populations

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Supporting information

11

12 S1 Model description

13 S1.1. Population structure

14 In the model, the *D. sargus* population is divided into 15 age classes (C_0 to C_{14}), each one
 15 year apart except for C_0 and C_1 , in order to cover the different life stages of *D. sargus*
 16 (Belharet et al., 2020). The individuals in C_0 are between 1 and 6 months old. They are the
 17 young of the year (YOY) arriving in C_0 at *D. sargus*' cycle starting month: April (Lloret and
 18 Planes, 2003). Individuals in C_1 are between 7 months and one and a half years old, and
 19 those in C_{14} are 14 years old or older (Fig. 1). Each year, the transition from one age class to
 20 the next occurs in late September, aligning with the departure of juvenile nurseries from the

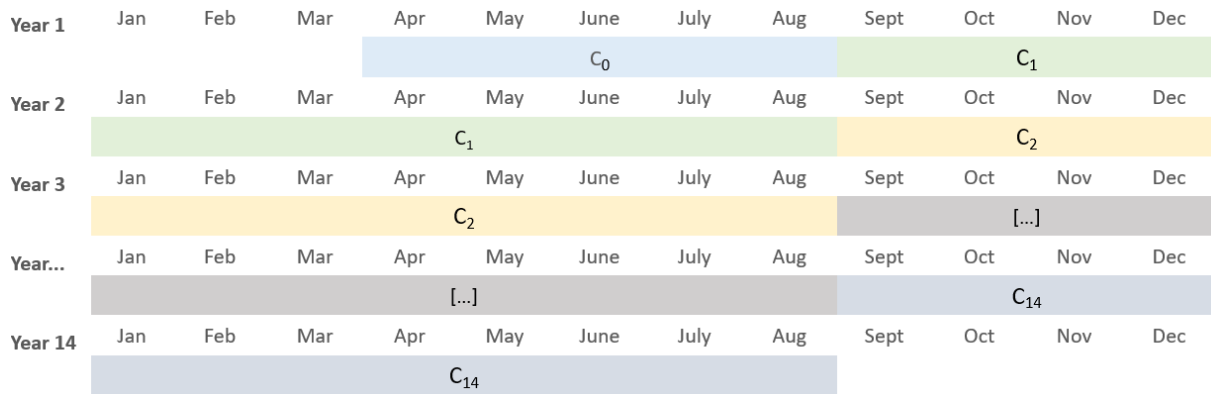


Figure 1: Age classes timetable in the model

21 study area. (Harmelin-Vivien et al., 1995; Planes and Romans, 2004).

22

23 S1.1.1. Growth

24 During the first year of *D. sargus*' development, the growth in length is considered linear
 25 (equation 1a, Planes et al., (1998). Older individuals' growth follows a Von Bertalanffy
 26 equation (equation 1b) (Belharet et al., 2020; Hussein et al., 2011):

$$L(a) = (a + m) * \frac{eq - 1}{eq} + 1 \quad (\text{eqn } 1a)$$

$$L(a) = l_{\infty} \left(1 - e^{-k \left(\frac{a+m}{12} - t_0 \right)} \right) \quad (\text{eqn } 1b)$$

27 with l_{∞} being *D. sargus* maximum length (cm), t_0 the hypothetical time at which the size of
 28 the individuals is zero, k the Brody's growth coefficient, a the age in months of the
 29 individuals, m the month in the cycle at which the calculation is performed and eq the
 30 succession point between the two equations (Table 1).

31

32 **S1.1.2. Weight and maturity rate**

33 The average weight $W(L)$ and maturity rate of individuals $M(L)$ are computed as a function of
34 their size (L) according to the following equations (equation 2) (Le Cren, 1951) and (equation
35 3) (Gonçalves and Erzini, 2000):

$$W(L) = a_w * L^{b_w} \quad (\text{eqn 2})$$

$$M(L) = \frac{1}{1 + e^{-m_{50}(L-c_m)}} \quad (\text{eqn 3})$$

36 With a_p and b_p being two coefficients, m_{50} the size of *D. sargus* for which the maturity rate is
37 50 % and c_m the slope of the maturity curve (Table 1).

38 **S1.1.3. Breeding and recruitment**

39 The reproduction of *D. sargus* in our study area occurs between February and April, and the
40 peak of juvenile settlement between April and June (Harmelin-Vivien et al., 1995; Lloret and
41 Planes, 2003; Planes et al., 1998; Vigliola et al., 1998). *D. sargus* is a non-binding
42 protandrous hermaphrodite fish. The proportion of females able to breed (s_r) in each class
43 size (L) is determined by the following equation (Mouine et al., 2007):

$$s_r = 1 - 2e^{-0.15L} \quad (\text{eqn 4})$$

44 The reproduction rate (r_r) corresponds to the number of eggs that can be laid by individuals
45 within each class according to their sex ratio (s_r), and their size L (equation 5). The
46 coefficients af and bf were estimated by Belharet et al. (2020):

$$r_r = s_r \cdot af \cdot L^{bf} \quad (\text{eqn 5})$$

47 The breeding algorithm scans all classes living in the areas defined as "breeding area" during
48 the breeding period (March). This algorithm takes in the reproductive rate r_r , maturity rate
49 $M(L)$ and number of individuals in each group Nb_{ind} and multiplies them (equation 6) by the
50 estimated egg and larval survival rate (l_{sr}) (Belharet et al., 2020). The breeding matrix is
51 browsed and filled with the number of eggs or future larvae within each zone, denoted N_L .

$$N_L = r_r * M(L) * Nb_{ind} * l_{sr} \quad (\text{eqn 6})$$

52 **S1.1.4. Recruitment**

53 Recruitment is limited by the nursery area capacity to host juveniles, which is different in
54 natural areas (R_{\max_nat}) and in port area (R_{\max_port}) (Planes et al., 1998). This capacity
55 represents the number of individuals able to settle in the recruitment area and to join C_0
56 equations 7a and 7b:

$$R_{max_nat} = L_n * d_m * S_w \text{ (eqn 7a)} \quad R_{max_port} = L_p * d_m * S_w \text{ (eqn 7b)}$$

57 Where L_n is the coastline length (meters) of the nursery area, d_m the maximum number of
 58 juveniles that can settle per meter of coastline, S_w the number of settlement waves and L_p
 59 the length of docks where *D. sargus* juveniles can settle (Table 1). Here, we have chosen to
 60 express nursery areas in terms of linear meters of coastline or structure (S_w). This choice is
 61 shared by several authors (Cheminée et al., 2017; Cuadros et al., 2018; Mercader et al.,
 62 2017; Vigliola et al., 1998) and allows us to compare the surface area of a nursery to that of
 63 a port infrastructure to that of an artificial nursery as settlers are often found against the
 64 docks or artificial structure rather than on the bottom. Finally, in ecological engineering,
 65 particularly in port areas, the linear dimension is often more directly related to the
 66 interventions required than surfaces. This unit directly resonates with port managers. The
 67 value of d_m is set to 10 ind.m⁻¹ to fit with (Cuadros et al., 2018). This value is a bit over the
 68 ones of Pastor et al., (2013) and Vigliola et al., (1998) because they report only the values of
 69 the pic abundance during settlement as a result some juveniles can settle and die before
 70 being counted and some other can arrive after the pic abundance. We however explored the
 71 values of d_m between 6 and 13 ind.m⁻¹ during the sensibility analysis (see S3) to consider
 72 this uncertainty.

73 The number of recruits N_r in each area (C_0 in nurseries and ports) is defined by a Beverton-
 74 Holt equation (equation 8) (Belharet et al., 2020):

$$N_r = N_L \left(\frac{R_{max}}{N_L + R_{max} * g} \right) \quad \text{(eqn 8)}$$

75 With N_L being the initial number of larvae arriving in the area and $R_{max} * g$ the intensity of
 76 the density dependency (Table 1).

77 **Determination of juvenile habitat coastal length**

78 The length of the “natural” and ports’ benthic settlement zones (L_n and L_p) were measured
 79 on the basis of a map overlay according to criteria defined by previous studies (Cheminée et
 80 al., 2021, 2011; García-Rubies and Macpherson, 1995; Harmelin-Vivien et al., 1995; Ventura
 81 et al., 2014)) such as the bathymetry of the studied area (© Shom-IGN, 2021), benthic
 82 biocenosis (Andromède Océanologie, 2021) and exposure to winds and currents (Ifremer,
 83 2021).

84 The coastal length of natural nurseries covers all sheltered areas within a depth of less than
 85 3m, a slope of less than 23% and a biocenosis corresponding to either infralittoral rocks or
 86 loose infralittoral bottoms such as gravel and sand (García-Rubies and Macpherson, 1995;

87 Harmelin-Vivien et al., 1995). This resulted in an estimation of 55,820 m of coastline (at a
 88 scale of 1:500). Using GIS we measured the linear length of port docks able to support the
 89 benthic settlement of juvenile fish from aerial photos (IGN and BRGM, 2022), resulting in an
 90 estimation of 24,751m (on a scale of 1:500). It corresponds to all the quays in the area with a
 91 depth of less than 2m. The total length of port docks was measured from aerial photos (IGN
 92 and BRGM, 2022) and estimated at 60,060m (comprising 24,751m of docks already
 93 welcoming juvenile fish and 35,309m welcoming none, on a scale of 1:500) (Table 1).

94 **S1.1.4. Natural mortality**

95 Nursery-dependent fish species such as *D. sargus* experience two major mortality phases
 96 during their first year of life. The first occurs during the pelagic planktonic larval phase
 97 (Cushing, 1990; Shepherd and Cushing, 1980) and the second during benthic settlement, i.e.
 98 when the larvae move from pelagic to benthic life in nursery areas (Di Franco et al., 2015;
 99 Macpherson et al., 1997; Planes et al., 1998). The survival of juvenile fish after benthic
 100 settlement in nurseries is mainly density dependent, and is affected by different biotic and
 101 abiotic factors such as food availability and predator abundance (Beck et al., 2001; Belharet
 102 et al., 2020; Cheminée et al., 2011; Ford et al., 2016; Ford and Swearer, 2013; Planes et al.,
 103 1998; Stewart and Jones, 2001). To represent these two mortality phases in our model, we
 104 assigned a "larval survival rate" of 0.8% to fish eggs and larvae before they entered C_0
 105 (pelagic mortality) (Belharet et al., 2020) and assigned a juvenile mortality rate of 80.8% to
 106 individuals in the C_0 class (Planes and Romans, 2004), i.e. during the first 4 months after
 107 benthic settlement (benthic mortality) for natural nurseries. In the port areas, the juvenile
 108 mortality rate during the first 4 months is very high due to the lack of refuge areas
 109 (Bouchoucha et al., 2016). In absence of data for this value, we set it to 99% (assumption not
 110 verified to date but on which most current nursery rehabilitation projects are based). We
 111 made the strong assumption that, for fish older than C_0 , there is no excess natural mortality
 112 of individuals having lived their first months in port areas compared to those from natural
 113 nurseries. For classes C_1 to C_{14} , the annual natural mortality rates were set to 26% (Belharet
 114 et al., 2020).

115 These mortality rates are first transformed into survival rates (t_s) with ($t_s = 1 - M_r$),
 116 expressed between 0 and 1, and then transformed in instantaneous mortalities (Table 2)
 117 according to the following equation (equation 9).

$$M_i = -\ln(t_s) \quad (\text{eqn 9})$$

118 *Table 1 : Summary table of the parameters governing the population dynamics sub-model in ISIS-Fish*

	Parameter	Value	Reference
Growth			

t_{∞}	Asymptotic body length (cm)	45 cm	(Froese and Pauly, 2022)
t_0	Age at length zero (yr)	- 0.99	(Belharet et al., 2020)
k	Brody growth coefficient (yr^{-1})	0.17	(Belharet et al., 2020)
eq	Continuity factor	11.93	
Weight			
a_w	Scale parameter ($g\text{ cm}^{-b}$)	0.016	(Belharet et al., 2020)
b_w	Exponent	3.05	(Belharet et al., 2020)
Maturity			
m_{50}	Length of 50% mature	20.06 cm	(Mouine et al., 2012)
c_m	Slope of the maturity curve	1.26	(Mouine et al., 2012)
Breeding			
af	Coefficient	0.084	(Belharet et al., 2020)
bf	Coefficient	4.51	(Belharet et al., 2020)
l_{sr}	Larval survival rate	0.008	(Belharet et al., 2020)
	Breeding month	March	(Lloret and Planes, 2003)
Recruitment			
L_n	Coastal length of nursery area (m)	55,820	Mesured on maps
L_p	Length of quay were juveniles fish settle (m)	24 751	Mesured on maps
d_m	Max number of settlers (ind.m^{-1})	10	(Cuadros et al., 2018)
S_w	Number of settlement waves	3	(Faillietaz et al., 2020)
	Recruitment month	April (4)	(Lloret and Planes, 2003)
Mortality			
$M_{i.cop}$	Natural of class C_0 in ports areas (see table 1)	11.11263	Expert estimation
$M_{i.con}$	Natural mortality of class C_0 in nursery areas (see table 1)	4.020845	(Planes and Romans, 2004)
$M_{i.f}$	Natural mortality of class C_1 to C_{14} (see table 1)	0.3011051	(Belharet et al., 2020)

119 Annual mortalities for each group were therefore computed according to (equation 9) to both
120 follow the literature data and fit our model (Table 2).

121 *Table 2: Mortality rates according to D. sargus life stages, calculation of natural mortality*
122 *rates for ISIS-Fish*

Class	Residence time	Survival	Formulae	Value in ISIS-Fish
C_0 port nursery	5 month	$t_{s.p} = 0,01$ $t_{s.f} = 0,74$	$t_{sa.cop} = \left(\sqrt[5]{t_{s.p} \times \sqrt[12]{t_{s.f}}} \right)^{12}$	$M_{i.cop} = 11.11263$
C_0 natural nursery	5 month	$t_{s.n} = 0,192$ $t_{s.f} = 0,74$	$t_{sa.con} = \left(\sqrt[5]{t_{s.n} \times \sqrt[12]{t_{s.f}}} \right)^{12}$	$M_{i.con} = 4.020845$
C_1 - C_{14}	12 month	$t_{s.f} = 0,74$	$t_{s.f}$	$M_{i.f} = 0.3011051$

123

124 **S1.1.5. Abundance at equilibrium**

125 The parameterisation of *D. sargus* population in ISIS-Fish is based on the parameter values
126 of mortality, carrying capacity, number of benthic settlement waves and the length of natural
127 nurseries (Table 2). Based on these parameters, ISIS-Fish was run to compute the

128 equilibrium abundance per age class of *D. sargus* population. In this work, the assessment of
 129 the effectiveness of management measures involving rehabilitation or conservation methods
 130 is based on this equilibrium abundance.

131 **S1.1.6 Accessibility**

132 The accessibility is a biological parameter accounting for biological behaviour (e.g. hidden
 133 behaviour) affecting *D. sargus* technical catch probability according to different fishing gear
 134 (usually called catchability, as in (Mahévas and Pelletier, 2004). Because of a lack of
 135 information in the literature, we calibrated this value with fishing parameters to reproduce the
 136 total annual catches.

137 **S1.2. Fishing activities**

138 **S1.2.1 Available data:**

139 The fishing activities *D. sargus* populations were parameterised on the basis of information
 140 provided by Ifremer's Service d'Information Halieutique (SIH), corresponding to declarative
 141 data from commercial fisheries in 2019 and 2020 (Système d'Information Halieutique, 2022).

142 The declarative data from professional fisheries indicate an average annual catches of *D.*
 143 *sargus* in the fishing district of Toulon of 17.3 tons, spread over five fishing gears (Table 3).
 144 Recreational fishing catches of *D. sargus* represent 5% of total recreational catches in
 145 France (BVA, 2009). Thus, recreational fishers catches are estimated at 12.5 tons, according
 146 to an extrapolation of the data from Cadiou et al. (2009).

147 In addition to the value of total catches by gear, observations made during field inspections
 148 by agents of the Blue Coast Marine Park MPA (Parc Marin de la Côte Bleue) west of
 149 Marseilles, report that 19% and 81% of *D. sargus* catches by professional and recreational
 150 fishing respectively were individuals smaller than 23 cm (Font and Lloret, 2014). However,

Table 3: Gear implemented in D. sargus fishing, associated with their catches.

Gear	Fishing activity	Mean annual catches 2019-2020 (kg.year⁻¹)	Fishing effort (hour.year⁻¹)
Long lining	Professional	14,280	757
Trap	Professional	25	4
Gillnet	Professional	780	494
Trammel net	Professional	1,920	1,060
Trawl	Professional	300	88
Boat or shore line	Recreational	6,000	1,216
Spearfishing	Recreational	6,400	1,216

151 current regulations prohibit the fishing of *D. sargus* individuals below this size.

152

153

154 **S1.2.2 Fishing parameters in ISIS-Fish:**

155 ISIS-Fish describes the fishing activity using gears characterized by a gear and a fleet (i.e.
156 group of vessels sharing same technical characteristics and gears). We divided fishing
157 activities into two categories based on available knowledge and data: (1) professional fishing,
158 composed with 5 gears (longline, gillnet, trammel net, trawl (named Gangui in the study area)
159 and trap) (2) recreational fishing, composed of 2 gears (angling and spearfishing).

160 Each gear is characterized by (i) a standardisation factor that allows to compare fishing time
161 between the different gears, and (ii) a selectivity curve of *D. sargus* depending on fish size
162 that allows, in this case study, to distinguish a probability of capture below and above the
163 minimum legal capture size of 23cm. As a result, in the model both recreational and
164 professional fishing target individuals from classes C1 to C14, differing mainly in gear
165 selectivity. Recreational fishing catches are 81% C1-C4 and 19% C5-C14, while professional
166 fishing catches are 20% C1-C4 and 80% C5-C14, based on field inspections (Blue Coast
167 Marine Park, Font and Lloret, (2014) and declarative data (Système d'Information
168 Halieutique, 2022).

169 The professional gears have been grouped into 3 fleets, "gillnetter" using gillnet and trammel
170 net, "trawlers" using trawl and "little metiers" using longline and traps, according to the
171 description of the local fishing fleet reported by (Ifremer. Système d'Informations
172 Halieutiques, 2022). To simplify and without additional data about it, the recreational gears
173 have been grouped into one fleet. For each fleet, the proportion of time dedicated to the
174 practise of a gear is set for each month (called strategy in ISIS-fish) using SIH data from
175 2019 and 2020. We defined the annual fishing effort per gear as a function of the fishing
176 profile and the average annual effort. The fishing profile per fleet was identical for every
177 month of the year. Annual fishing time was broken down into 8-hour fishing days, with the
178 number of days per month varying according to the season. Vessel activity increases
179 between winter and summer and then decreases between summer and winter. The number
180 of fishing days per year was defined such that the sum of the hours corresponded to the total
181 effort per trade reported by the SIH data.

182 **S1.2.3 Calibration of the fishing parameters**

183 The standardisation factor, the probability of selectivity for both professional and recreational
184 fishing activity and the accessibility coefficient were estimated using a calibration procedure
185 aiming at reproducing catches observations and expert knowledge described above (section
186 available data and Table 4).

187 Calibration consisted in setting initial values for 12 unknown parameters (standardisation of
 188 each gear, selectivity for professional and recreational fishing and accessibility), running
 189 ISIS-Fish, comparing simulated catches to observations, and changing the initial values of
 190 the unknown parameters to reduce the discrepancy between observations and simulated
 191 values. To identify a good combination of parameters values, we select randomly 5,000
 192 combinations using a random LHS (Latin Hypercube sampling).

193 The initial value of standardisation factor for the different gears was calculated by fitting a
 194 generalised linear lognormal model to the annual catches per unit of effort associated with
 195 fishing gear and by years (2019 and 2020) (Lehuta et al., 2010). The coefficients generated
 196 by the model and attributed for each gear were then exponentially transformed (Table 4). For
 197 recreational fishing, the coefficients were estimated in relation to the values calculated for
 198 professional fishing.

199 The calibration process was led following the ODDO method (Mahévas et al., 2019), (see
 200 table 5). The objective function (*OF*) used to select the best combinations of values
 201 minimising the difference between observed catches and simulated catches (Table 4). This
 202 function computes the sum of the comparisons between catches of *D. sargus* under 23cm
 203 from commercial and recreational fisheries from observations (D_{NMP_obs} & D_{NML_obs}) and
 204 simulations (D_{NMP_sim} & D_{NML_sim}) as well as total observed (D_{PMm_obs}) and simulated
 205 (D_{PMm_sim}) catch by métiers, taken one by one. The aim is to minimise *OF* to get closer to
 206 observations.

$$OF = |D_{NMP_sim} - D_{NMP_obs}| + |D_{NML_sim} - D_{NML_obs}| + \sum_m |D_{PMm_sim} - D_{PMm_obs}|$$

207 Three successive calibrations were carried out with a fishing parameter variation capacity of
 208 respectively $\pm 20\%$, $\pm 2\%$ and $\pm 1\%$ around the established value in order to get closer to an
 209 optimal combination of parameter values. The values of the fishing parameters in the
 210 simulation minimising *OF* at the end of the last calibration process were selected and kept
 211 fixed for the rest of the study (Table 4).

212

213 *Table 4: Initial and calibrated value of fishing parameters estimated in the model*

	Gear	Standardization factor		Selectivity		Accessibility	
		Initial value	Calibrated value	Initial value	Calibrated value	Initial value	Calibrated value
Recreational	Spearfishing	1.3	1.265361803	For Groups C₁ to C₄ :	For Groups C₁ to C₄ :	1x10 ⁻⁴	9.8336x10 ⁻⁵

fishing	Boat or Shore line	1,22	1.185281584	S = 0.8 For Groups C₅ to C₁₄ : S = 0.2	S = 0.770614002 For Groups C₅ to C₁₄ : S = 0.228198927		
Professional fishing	Long lining	10,7	10.54983412	For Groups C₁ to C₄ : S = 0.8 For Groups C₅ to C₁₄ : S = 0.2	For Groups C₁ to C₄ : S = 0.15697549 For Groups C₅ to C₁₄ : S = 0.824428461		
	Trap	1.0	0.998235716				
	Gillnet	0,86	0.879663216				
	Trammel net	0,74	0.756877503				
	Trawl	0,24	0.240777458				

Table 5 : ODDO filling with the ISIS-Fish model, fishing parameters calibration (see Mahévas et al., 2019)

Model	Performance	Time per run	45 sec
		Parallelisation	10 runs in parallel
	Development	Language	Java
		Implementation of the optimisation algorithm	Recoding of the algorithm in Java
Pre-processing	Problem formulation	Model	ISIS-fish model of <i>D. sargus</i> fisheries
		Question	Estimating fishing parameters for <i>D. sargus</i>
		Data	Two years catches in kg associated with gear and effort
		Parameters bounds	Continuous values around 20% from the initial value
		Uncertainty (process and data)	Declarative and projected data for professional fisheries, estimation for recreational fisheries
	Initial objective function	Absolute value of differences: $OF = D_{NMP_sim} - D_{NMP_obs} + D_{NML_sim} - D_{NML_obs} + \sum_m D_{PMM_sim} - D_{PMM_obs} $	
	Objective Function	Building	Other OF were tested: The standardised version: gives too much importance to the catches of gears that don't fish a lot of <i>D. sargus</i> and creates an imbalance. The squared version: Create an imbalance with large catches over-represented
		Final	Absolute value of differences: $OF = D_{NMP_sim} - D_{NMP_obs} + D_{NML_sim} - D_{NML_obs} + \sum_m D_{PMM_sim} - D_{PMM_obs} $
	Exploratory Analysis	data	No change
		reduction dimension	No
Algorithm	Family	Random LHS around the parameter values seed fixed	
	Description Justification	The aim is to explore parameter values within a broad spectrum, as the values established initially are uncertain.	
	Changes in the algorithm	No	

	Settings	<p>Test strategy: Number year of simulation = 15 Number of simulation = 5,000 Number of parameters tested 12 comprising 4 groups (2 of 2 parameters and 2 of 5 parameters)</p>
Post-processing	Convergence	<p>Visual examination of FO, extraction of catches and parameters of the best simulation (minimising FO). Visual comparison with catch targets. Progressive targeting of parameters in 3 rounds of simulations:</p> <p>First run : 20% around the parameter values -> select parameters of the best simulation Second run : 2% around the new parameter values -> select parameters of the best simulation Third run : 1% around the new parameter values -> select parameters of the best simulation, visual validation with observations and set of the values for the rest of the study</p>
	Optimum properties including identifiability	FO
	Residual analysis	No
	Multicriteria	No
Optimisation process	Number of simulation required	15,000
	Duration	21h
	Reached stopping criteria	Yes
Comments and failures	<p>Initially, the aim was to carry out a single analysis to select the simulation that minimised FO. However, the 20% variation around the values of the 13 (continuous) parameters was too large to find an ideal value for the parameters with this single design. 3 analyses were therefore carried out, progressively targeting the optimised values. This targeting concerns a single combination of parameters. It is very likely that there are other combinations of parameters that meet our objectives. Ideally, the simplex or bootstrap method should be applied to select the best of these combinations. However, given the uncertainty in our fishing data, the combination selected at the end of this calibration analysis is more than sufficient for our purposes.</p>	

S2: Management scenarios

Each scenario was established by modifying the value of specific parameters from the reference simulation in relation to the measure tested by the scenario. The values of these new parameters are described in Table 6.

		Parameter	New Value
Scenario 1	Recruitment	Coastal length of nursery area (m)	61,826
		Length of quay were juveniles fish settle (m)	22,276
Scenario 2	Recruitment	Coastal length of nursery area (m)	115,880
		Length of quay were juveniles fish settle (m)	0
Scenario 3	Accessibility	$C_0 - C_4$	0
		$C_5 - C_{14}$	9.8336×10^{-5}
Scenario 4	Recruitment	Coastal length of nursery area (m)	61,826
		Length of quay were juveniles fish settle (m)	22,276
	Accessibility	$C_0 - C_4$	0
		$C_5 - C_{14}$	9.8336E-5
Scenario 5	Recruitment	Coastal length of nursery area (m)	73,838
		Length of quay were juveniles fish settle (m)	17,325
	Accessibility	$C_0 - C_4$	0
		$C_5 - C_{14}$	9.8336E-5

Table 6 : New parameter values introduced to test measures for the various scenarios

S3: Uncertainty analysis

In the literature, there is no consensus on the values attributed to these parameters (Cuadros et al., 2018; Planes et al., 1998). To account for this uncertainty, 5000 simulations were carried out for each scenario in the model, using a random LHS (Latin Hypercube scaling) analysis. Each simulation therefore corresponds to a combination of values, sampled within the range of variation of the ecological parameter uncertain values mentioned above (Table 7). This gives 5 000 equilibrium numbers of *D. sargus* for each scenario. All these equilibria were considered to constitute the population associated with each scenario. When the simulations were launched, the random LHS seed was kept fixed and identical for both the initial population and the scenarios. That way, each simulation has its identifiable counterpart in terms of the combination of ecological parameter values in the other scenarios. The comparison of the scenarios with each other consists of comparing all the 5 000 simulations with their counterpart.

Table 7 : Interval of variation for the parameters identified as sensitive in the reference model, associated with their initial value and the range of variation applied during the sensitivity analysis.

	Parameters	Initial value	Variation range
ΘMortality	Class C_0 in nurseries (5 month)	80.80%	[64.06 ; 96.9]
	Class C_0 in harbours (5 month)	99%	[79.2 ; 99]

	Class C ₁ -C ₁₄ (1 year)	26%	[20.8 ; 31.2]
ΘRecruitment	linear nurseries (m)	55,820	[44,656 ; 66,984]
	Carrying capacity (individuals.m ⁻¹)	10	[6 ; 13]
	Number of settling waves	3	[1 ; 4]

S4: Additional Figures

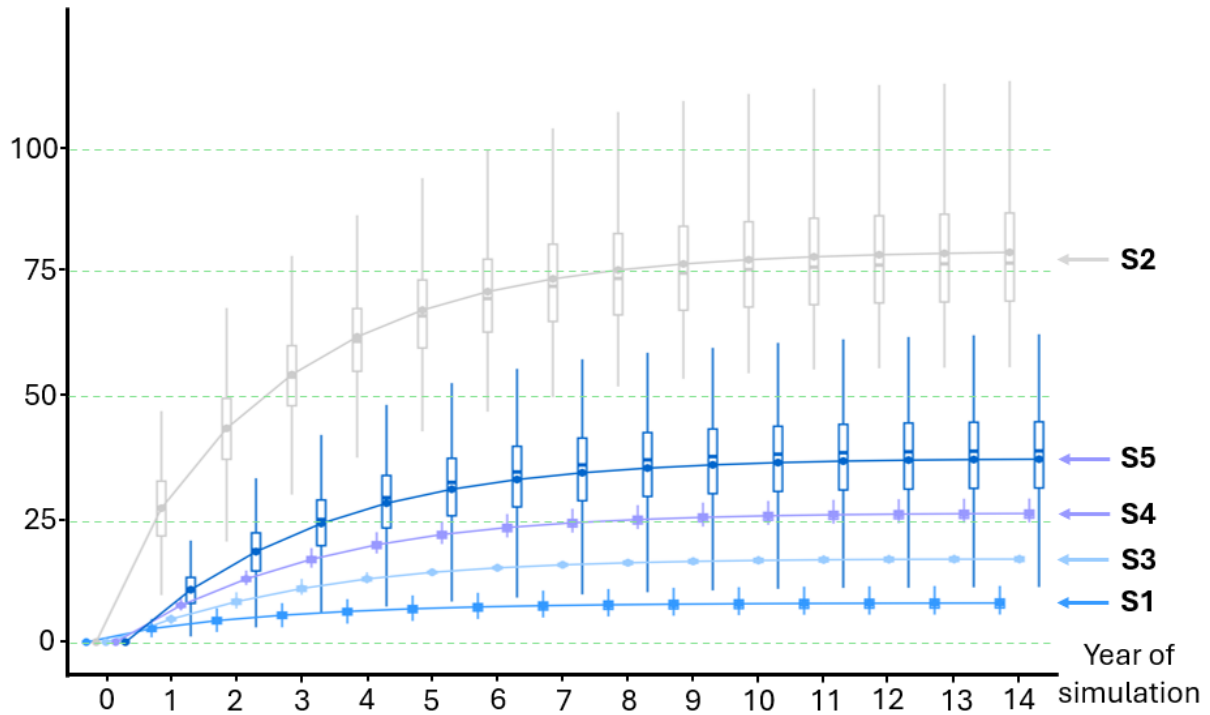


Figure 2 : Yearly gains in abundance (in %) of adult *D. sargus* individuals. Boxplots present the median at their centre surrounded by the first and third quartiles. The outliers are represented by black dots.

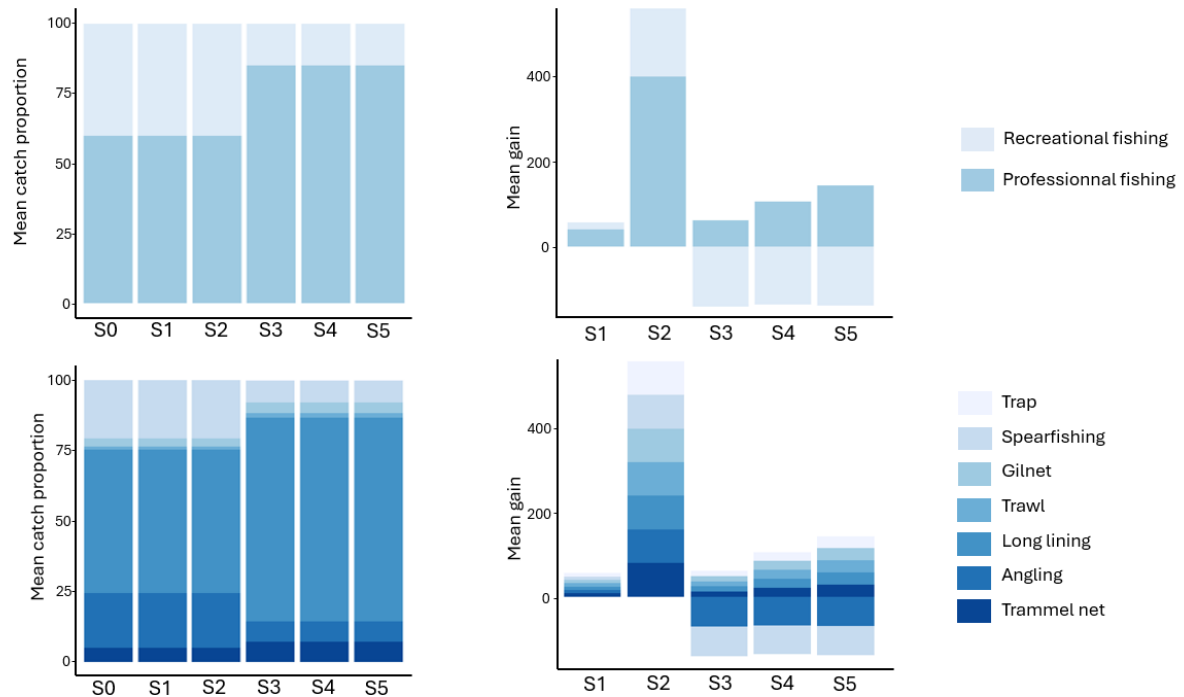


Figure 3 : Bar plot showing the proportion (in %) of catches by fishing gear in relation to total catches for each scenario and the mean gain per fishing type and per gear.

Differences in catches between gears can be explained by differences in catchability and effort:

$$C_s \approx q(s,g) \cdot E(g) \cdot N_s$$

$Q(s,g)$ is the product of the parameters in table 4. Scenarios S1 and S2 affect N_s while scenario S3 affects the parameter of selectivity of $q(s,g)$. This impact is different for the recreational and pro fleets but similar for the gears within each of these fleets. This assumption in the model is due to the fact that we did not have sufficient knowledge and data to parameterize differences. The only available data are catches (in weight) and the proportion of these catches under and over 23cm for professional and recreational fisheries. The consequences of this assumption are that the impacts of the scenarios on catches within each fleet do not differ between gears.

S5 - References

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