parameter	value
$r_F [d^{-1}]$	1
$r_M [d^{-1}]$	0.8
H_F, H_M $[\frac{\mu mol\, C}{m^3}]$	0.9
m $[d^{-1}]$	0.1

$$\frac{dN}{dt} = -\frac{r_F N}{N + H_F} P_F - \frac{r_M N}{N + H_M} P_M, \tag{5.1}$$

$$\frac{dP_F}{dt} = \frac{r_F N}{N + H_F} P_F - m P_F, \tag{5.2}$$

$$\frac{dP_M}{dt} = \frac{r_M N}{N + H_M} P_M - m P_M, \tag{5.3}$$

reached within the (Table 5.3; Figures 5.1, 5.2). The male strain reached the maximal cell concentration on day 8 (52×10^3 $[\frac{cells}{ml}]$ and 172.6×10^3 $[\frac{cells}{ml}]$ on RW1 and SH1), while the female strain on day 4 in both experiments (227×10^3 $[\frac{cells}{ml}]$ on RW1 and 529.5×10^3 $[\frac{cells}{ml}]$ on SH1). Therefore the exponential phase was significantly shorter in case of female strain. Simultaneously, the female growth rate (1.69 $[\frac{div}{d}]$ on RW1 and 1.99 on SH1) was higher than male growth rate under identical conditions (0.89 $[\frac{div}{d}]$ on RW1 and 0.79 on SH1). In all the cases, the exponential growth phase was followed by a short stationary phase followed by a rapid decline of vegetative cell concentration.

Growth dynamics and sexual reproduction of the co-cultures of the two parental strains on RW1 and SH1 The cell concentration patterns observed in the co-cultures of RW1 and SH1 experiments differed considerably (Figure 1, 2). In both experiments, a lag-phase was observed that, in the case of the SH, corresponded to a decrease in cell concentration. The exponential phase lasted till day 10 (1.27 $[\frac{div}{d}]$) and 14 (0.57 $[\frac{div}{d}]$) on RW1 and SH1, respectively. The maximum density of the vegetative cells was 558×10^3 $[\frac{cells}{ml}]$ on RW1 and 329.6×10^3 $[\frac{cells}{ml}]$ on SH1.

Sexual reproduction occurred on both RW1 and the SH1. In the SH, gametes and auxospores were found starting from the 2nd day, while initial cells were observed from day 3 until day 6. Large F1 generation cells were recorded on the 3rd day of the experiment and were growing exponentially till 7th day (with a maximum growth rate of 1.81 $[\frac{div}{d}]$). The time at which sexual reproduction started corresponds to the observed decrease of the total cell biomass observed in the first days in cross cultures (Fig. 5.2).

5.3.1.2 Experiment 2

Growth dynamics of the individual parental strains on RW2 and SH2 The growth dynamics of the parental strains in monocultures in SH2 and RW2 experiments varied considerably (Table 5.3; Figure 5.3, 5.4). The male strain reached the maximal cell concentration on day 6 ($108\times10^3\,[\frac{cells}{ml}]$) and day 3 ($81\times10^3\,[\frac{cells}{ml}]$) on RW2 and SH2, respectively, while the female strain on day 5 in both experiments ($84\times10^3\,[\frac{cells}{ml}]$ on RW2 and $182\times10^3\,[\frac{cells}{ml}]$ on SH2). Thus, the duration of exponential phase was comparable, though slightly shorter in case of male monoclonal culture in SH2 experiment. The female growth rate ($1.87[\frac{div}{d}]$ on RW2 and 1.45 on SH2) was higher than male growth rate ($1.1\,[\frac{div}{d}]$ on RW2 and 1.4 on SH2).

The concentration of silicate reached undetectable values on day 10 in both RW2 experiments, while on day 5 and 8 in case of female and male in SH2 experiment respectively (Figure 5.3, 5.4).

The maximal division rate of the male and female culture estimated with the SiO_2 consumption reached comparable values in the RW1 experiment (0.55 and 0.59 $[\frac{div}{d}]$ respectively). Conversely, considerable discrepancies were observed in the SH1 experiment as the division rates of the male strain ($0.82\,[\frac{div}{d}]$) was 27% lower than that of the female strain ($1.12\,[\frac{div}{d}]$; Table 5.3).

Growth dynamics and sexual reproduction of the co-cultures of the two parental strains on RW2 and SH2 The abundance patterns observed in the co-culture RW2 and SH2 experiments varied considerably in terms of growth rates but above cells concentrations (Figure 5.3, 5.4). In both experiments, a lag-phase was observed. The exponential phase lasted till day 11 (RW2 $0.53\,[\frac{div}{d}]$) and 12 ($0.82\,[\frac{div}{d}]$) on RW2 and SH2, respectively. The maximum density of the vegetative cells of both mating types was equal to $89\times10^3\,[\frac{cells}{ml}]$ on RW2 and $371\times10^3\,[\frac{cells}{ml}]$ on SH2. In the RW2 experiment gametes were observed from the 3rd day until 7th, and in SH2 from the 2nd day until 5th. Neither auxospores nor F1 generation cells were observed in these experiments.

Silicate concentration varied slightly till day 6 on SH2, and rapidly decreased afterwards reaching undetectable values within about 5 days (Figure 5.4). The depletion of silicate on the RW2 was observed at the end of experiment (Figure 5.3). The maximal division rate estimated with the silicate consumption of the co-culture on the rotating wheel reached $0.24\,[\frac{div}{d}]$ while on the shelf it was equal to $0.47\,[\frac{div}{d}]$ (Table 5.3).

	T_C	T_N	$Exp\ phase$	div_{cells}	div_{SiO_2}	C_{max} [$\times 10^3$]	SiO_{2lim}
Experiment 1 (RW/SH)							
female (-)	[0,2,4,...,12]	[0,6,12]	4 / 4	1.69 / 1.99	0.87 / 0.89	227 / 529	≤12
male (+)			8 / 8	1.01 / 0.79	0.87 / 0.87	526 / 172	≤12
cross	[0,1,2,...,12]	[0,1,2,...,12]	10 / >12	1.27 / 0.57 (F1) 1.44 / 1.81	0.60 / 0.39	544 / 258	11 />12
Experiment 2 (RW/SH)							
female (-)	[0,1,2,3,4,...	[0,1,2,3,4,...	5 / 5	1.87 / 1.45	0.59 / 1.12	84 / 182	10 / 5
male (+)	5,6,8,10]	5,6,8,10]	6 / 3	1.1 / 1.4	0.55 / 0.82	108 / 81	10 / 8
cross	[0,1,2,...,12]	[0,1,2,...,12]	11 / >12	0.53 / 0.82	0.24 / 0.47	89 / 371	>12 / 11
Experiment 3							
females (-)	[0,1,2,...,12]	[0,1,2,...,12]	4	2.36	1.97	1 440	4
males (+)			6	1.46	1.19	1 496	7
cross	[0,1,2,...,12]	[0,1,2,...,12]	5	1.47	1.29	615	5

Table 5.3: Sampling schedule and results of the laboratory experiments: sampling days for cell (T_C) and nutrients (T_N) concentration measurements, duration of the exponential phase in [days] ($Expphase$), maximal division rate based on cells concentration in [1/d] (div_{cells}), maximal division rate based on silicate consumption in [1/d] (div_{SiO_2}), maximal concentration reached in [cells/ml] (C_{max}), SiO_2 depletion day [day of the experiment] (SiO_{2lim}).

Regarding the specific EGC formulation, it merges two aspects:

1. a successful sexual reproduction starts at a species-specific concentration threshold C_{th} (Scalco et al. [2014]),

2. passing the threshold activates the EGC mechanism,

i.e., the growth rate decreases by R independently from the resources availability (Figure 6.1):

$$\mu(N, I, P) = \left(1 - 2 \cdot R \cdot \frac{P}{P + P_{th}}\right) \cdot \hat{\mu}(N, I), \tag{6.1}$$

where $\hat{\mu}(N, I)$ - species specific growth rate dependent on the resources (N - nutrients, I - light) availability, P - phytoplankton concentration, P_{th} - phytoplankton concentration threshold required for sexual reproduction and above which the growth rate decrease is observed, R - value of the growth rate decrease.

Marine diatoms span almost 6 orders of magnitude in cell volume, with the largest species reaching $\geq 10^6[\mu m^3]$ (Sarthou et al. [2005], but also Litchman and Klausmeier [2008]) and so does their carbon content per cell (Menden-Deuer and Lessard [2000]). Consequently, the 5000 [cells/ml] concentration threshold for *Pseudo-nitzschia multistriata* reported by Scalco et al (Scalco et al. [2014]) translated into carbon per m^3 would span from $1[\mu molC/m^3]$ to over 9 $[mmolC/m^3]$ if applied to all the diatom species. In particular it would be equal to 0.1 $[mmolC/m^3]$ for *Pseudo-nitzschia multistriata*.

considered. The maximal concentration of the cells is directly linked to the inoculum, thus to the strains survival rate. The model used for the simulations assumed a linear phytoplankton growth dependency on nutrients availability, thus strains were distinguished solely by their intrinsic growth rates. The model equations were:

$$\frac{dN}{dt} = -r_P N P_P - r_{F1} N P_{F1}, \tag{6.2}$$

$$\frac{dP_{F1}}{dt} = r_{F1} N P_{F1} - m P_{F1}, \tag{6.3}$$

$$\frac{dP_P}{dt} = r_P N P_P - m P_P, \tag{6.4}$$

where: N- nutrients concentration, P_{F1}, P_P - concentration of F1 and parental strains respectively, r_{F1},r_P - growth rate, respectively, for F1 and parental strains, m - mortality rate.

various initial concentrations of the F1 generation cells α (section 6.2.3). The growth rates ratio observed in the laboratory experiments were indicated by $r_{F1} : r_P = 3.2$ and $r_{F1} : r_P = 1.13$ in SH1 and RW1 experiments respectively (chapter 5), hence the F1 generation was considered competitively advantaged ($r_{F1} : r_P > 1$).

The numerical simulations revealed an increase of the F1 generation fitness corresponding to a decrease of the parental strains growth rate equivalent to the increase of the $r_{F1} : r_P$ ratio (Figure 6.19).

For instance, the fitness of the F1 generation cells increased by 6.5 folds when $r_{F1} : r_P$ increased from 1 to 3.2, and almost doubled when $r_{F1} : r_P = 1.13$ for $\alpha = 0.1$ (Figure 6.19). This corresponded to an increase from 10% to 65% of the biomass formed by F1 generation cells for $r_{F1} : r_P = 1$ and $r_{F1} : r_P = 3.2$ respectively before nutrients depletion (Figure 6.19). Notably, $\alpha = 0.1$ refers to the highest initial concentration of F1 generation cells observed during the experiments (Chapter 5 and Scalco et al. [2014]).