Supplement data of: Integrated Multi-Trophic Aquaculture systems: energy transfers and food web organization in coastal earthen ponds

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Aquaculture Environment Interactions

Model equations

Biomass and P:B ratios estimations of the produced species: meagre, white seabream, mullets and oysters.
Consumption / biomass ratios of meagre and white seabream
Macroalgae+periphyton estimates

Text S1. Biomass and P:B ratios estimations of the produced species: meagre, white seabream, mullets and oysters.

Daily individual meagre and seabream growth was estimated based on the individual weight (g) at age (days) during the experiment i.e., start (day 1), middle (day 97) and end (day 244) (Table S1). Daily biomass and average biomass were estimated from the growth equations given in Table S1 and the P:B ratio as the sum of the P:B daily ratio. For meagre the linear equation showed the best adjustment, with R^2=0.78 for FOM and FM treatments and R^2=0.54 for FM treatment. For white seabream (Table S1) the linear adjustments showed a R^2=0.90 for FOM, R^2=0.81 and R^2=0.88 for FO and FM respectively. In the case of grey mullets, a linear model was used since there were only data for two sampling occasions (start and end) (Table S2). Mortality was almost nil, varying between 0.3 to 0.5 % in meagre, 0.1 to 0.3 % in white seabream and 0.1 % in grey mullets. Although low, the observed mortality was integrated in the estimations of the number of meagre and seabream individuals over time (Table S1). For the grey mullets, an average number of individuals was considered (Table S2).

To estimate the daily individual oyster (*Crassostrea gigas*) growth, polynomial tendency lines were adjusted to average individual growth estimations (Table S1). For the daily density, negative exponential tendency lines were adjusted to the estimated survival rates. The daily biomass and production were then calculated, as well as the average biomass and P:B ratios (Table S1). The average biomass was estimated considering the complete experimental period (8 months) although oysters production occurred for only 6 and a half months.

Table S1. Estimations of meagre, white seabream and oysters individual weights, biomass and P:B ratios based on equations as functions of time (*t*) in days, for a total of 244 days. Pond area = 500 m^2; Days = 244.

	FOM	FO	FM
Meagre individual growth (W_t) (g)	$1.4801 * t + 204.51$	$1.5514 * t + 204.51$	$0.8923 * t + 204.51$
Bream individual growth (W_t) (g)	$0.5629 * t + 51.453$	$0.4586 * t + 51.453$	$0.5059 * t + 51.453$
Oysters individual growth (W_t) (g)	$-1.7 * 10^{-5} * t^3 + 0.004816 * t^2 - 0.007302 * t + 0.27697$	$0.001783 * t^2 - 0.008736 * t + 1.12978$	
Meagre number of individuals (N_t)	$-0.0184 * t + 1450$	$-0.0287 * t + 1450$	$-0.0164 * t + 1450$
Bream number of individuals (N_t)	$-0.0020 * t + 850$	$-0.0041 * t + 850$	$-0.0102 * t + 850$
Oysters number of individuals (N_t)	$18000 * e^{(-0.010545 * t)}$	$18000 * e^{(-0.011884 * t)}$	
Daily biomass (B_t) (g m^{-2})	$(N_t * W_t)/pond\ area$		
Biomass (mean biomass) (g m^{-2})	$(\sum B_t)/days$		
Daily production (P_t) (g m^{-2} day^{-1})	$B_t - B_{t-1}$		
Daily P:B ($P_t : B_t$)	$P_t/((B_{t-1} + B_t)/2)$		
P:B	$\sum(P_t : B_t)$		

Table S2. Average mullet biomass and P:B ratio estimations, based on a linear model. N (mean number of individuals) = 564; t*f* = final time (in days); t0 = initial time; W_{t0} = initial mean individual weight (g) = 118; pond area= 500 m^2; days=244.

	FOM	FO	FM
Final individual mean weight (W_{tf}) (g)	213.02	159.85	193.12
Daily growth rate (*gr*) (g day^{-1})	$(W_{tf} - W_{t0})/days$		
Individual mean biomass (B_i) (g)	$((gr * days)/2) + W_{t0}$		
Biomass (*B*) (g m^{-2})	$(N * B_i)/pond\ area$		
Total Production (*P*) (g m^{-2} 8 $month^{-1}$)	$((W_{tf} - W_{t0}) * N)/pond\ area$		
P:B	P / B		

Text S2. Consumption / biomass ratios of meagre and white seabream

A function of given food through time allowed to estimate the daily food given in each pond (Table S3). Since meagre and white seabream fed almost exclusively on formulated feed their C:B ratios were estimated from the amount of given ration. A 15% loss was included in C:B ratio estimations because, according to field observations and producer experience, there was a loss of 15 % of the ration. The mean meagre biomass varied between 84 and 85 % of the total feeding biomass in FOM and FO ponds. In the case of FM treatment, where meagre grew less, the final biomass was only 82 %. To estimate the C:B ratio, the daily artificial feed given (less 15 % of losses) was multiplied by the proportion of the biomass of meagre (Table S3). In FM treatment, a loss of 27.5 % instead of 15% was included. In this treatment, the amount of given food was similar to the other two treatments, but the average biomass of fish decreased by almost 17 %, which may imply that the food losses were higher. The same procedure was carried out regarding the white seabream. The average biomass of this species corresponded to 15 to 18 % of the total biomass of fish feeding on formulated feed.

Table S3. Equations for daily consumption (*Ct*) calculation for meagre and white seabream as a function of distributed daily feed (FF_t). Equations are functions of time (*t*) in days, for a total of 244 days. Estimation of C:B ratio. For daily biomass (B_t) see table S1.

	FOM	FO	FM
Meagre (*Ct*) (g m^{-2})	$(FF_t - FF_t * 0.15) * 0.84$	$(FF_t - FF_t * 0.15) * 0.85$	$(FF_t - FF_t * 0.275) * 0.82$
Bream (*Ct*) (g m^{-2})	$(FF_t - FF_t * 0.15) * 0.16$	$(FF_t - FF_t * 0.15) * 0.15$	$(FF_t - FF_t * 0.15) * 0.18$
Daily feed (FF_t) (g m^{-2})	$-5.940 * 10^{-12} * t^6 + 5.836 * 10^{-9} * t^5 - 1.979 * 10^{-6} * t^4 + 2.795 * 10^{-4} * t^3 - 0.0154967 * t^2 + 0.368511 * t + 7.111822$		
R^2	0.97		
Daily C:B	C_t/B_t		
C:B	$\sum(C_t/B_t)$		

Text S3. Macroalgae+periphyton estimates

Polynomial equations models were adjusted to the biomass of macroalgae+periphyton harvested during the experience, to estimate their average daily biomass (Table S4). According to field observations, around 20 % of the macroalgae remained in the ponds after harvesting. Likewise, all average estimated biomasses integrated in the models were increased by 20%.

Table S4. Equations for macroalgae+periphyton biomass estimation. Some equations are functions of time (*t*) in days, for a total of 244 days. Pond area= 500 m^2. Days= 244.

	FOM	FO	FM
Daily harvested biomass of macroalgae+periphyton (W_t) (Kg)	$3.0 * 10^{-5} * t^3 - 0.017 * t + 1.773 * t - 0.9718$	$-2.1 * 10^{-6} * t^4 + 6.9 * 10^{-4} * t^3 - 0.07633 * t^2 + 2.97533 * t - 2.63539$	$-0.00872 * t^2 + 1.250003 * t + 1.0$
R^2	0.91	0.58	0.93
Average harvested biomass of macroalgae+periphyton (*TW*) (g m^{-2})	$(\sum W_t / days * 1000)/pond\ area$		
Biomass (g m^{-2})	$1.2 * TW$		