NUTRIENTS SALT AND VOLUME FLUXES IN THE MAR MENOR COASTAL LAGOON IN THE SOUTH EAST SPAIN. LOICZ BUDGET.

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1. DESCRIPTION OF STUDY AREA

The Mar Menor lagoon is the largest coastal lagoon in the Western Mediterranean. The total area is 135.240 km^2 , the volume is 610.856 hm^3, the average depth is 4.5 m , and the maximum depth is around 6 m.. The Mar Menor is located in the South East of Iberian Peninsula in the Mediterranean Spanish coastal (37º38'-37º50'N 0º43'- 0º52'E). The Mar Menor is a hypersaline lagoon, with a salinity content of 43.89 PSU.

The lagoon is separated from the Mediterranean Sea by a 24 Km long sand strip with width varying between 100 and 1,200 m. There are several small channels that connect the lagoon with the Mediterranean. Inside the lagoon there are five islands of volcanic origin.

The Mar Menor lagoon receives the influence of the *Campo de Cartagena* river basin through several flows. The *Campo de Cartagena* or Mar Menor River Basin has approximately 1200 km^2 in surface area and it is drained by several riverbeds running into the Mar Menor lagoon. The mean annual temperature is 17.5 ºC and the mean annual rainfall is 313 mm.

The surface hidrology of *Campo de Cartagena* is reduced to some riverbeds whose natural flows are scarce and highly variable depending on big rainfall events. The main ephemeral channels (called *ramblas*) are *Rambla del Albujón* and *Rambla de Miranda*. However, although the usual functioning of the watercourses is conditioned by the sporadic and torrential rainfall regime, the significant increase in irrigation in the *Campo de Cartagena* by means of the Tagus-Segura water diversion has changed the water regime of some watercourses such as the *Rambla del Albujón*, which now maintains regular flows.

In relation to sub-surface hidrology, the hydro-geological unit of Campo de Cartagena consists of 5 aquifers of which the Andaluciense and Plioceno aquifers stand out.

The catchment is heavyly exploited for agriculture, more than 80% of total area of *Campo de Cartagena* is used for agriculture. Dryland is the traditional agricultural landscape, with almond trees and cereals as the main crops. There was some small irrigated lands around artesian wells. During the past century the area occupied by irrigated lands for horticultural and tree crops increased due to the Tagus-Segura water diversion.

The LOICZ approach has been applied to this system to carry out a first balance on volume fluxes, salt and nutrients making use of the data presented in the table 1. These data have allowed the estimation of the annual budgets of salt, nutrients and water volume for year 2003. This has been computed under the simplest LOICZ model, the one box-one layer (Annex 1), following the steady-state hypothesis (Gordon *et al.* 1996).

Table 1. Data used in budget calculation for the Mar Menor lagoon.

Type of data	Spatial resolution	Frequency of sampling	Sources
$Area_{sys}$, $Depth_{sys}$, V_{sys}	lagoon	-	Mas, 1996
Sal_{sys}	lagoon	Monthly	IEO*
DIN_{sys}, DIP_{sys}	6 stations in the lagoon	From September 2002 to November 2003. Five sampling data.	Velasco et al. 2004
Sal_{sea}, DIN_{sea}, DIP_{sea}	4 stations	One for season	IEO Network
V_P	8 stations in the river basin	Daily	SIAM
DIN_P, DIP_P	-	-	Gómez, 1995
V_E	3 stations in the river basin	Daily	SIAM**
V_G	-	-	Rodriguez Estrella, 2003
Sal_G, DIP_G, DIN_G	9 piezometers	One a year	CHS***
V_Q, Sal_Q, DIP_Q, DIN_Q	3 station in the main inflowing water courses	From September 2002 to November 2003. Nine sampling dates.	Velasco et al. 2004
V_O, DIP_O, DIN_O	River basin	Daily	Simulation results watershed model Mar Menor site. DITTY Project.
Sal_O	-	-	Bernal, 2004
C:N:P	3 stations in the lagoon	One for season 1987-88	Terrados, 1991

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2. WATER AND SALT BUDGET.

The water and salt balance are illustrate in figure 1.

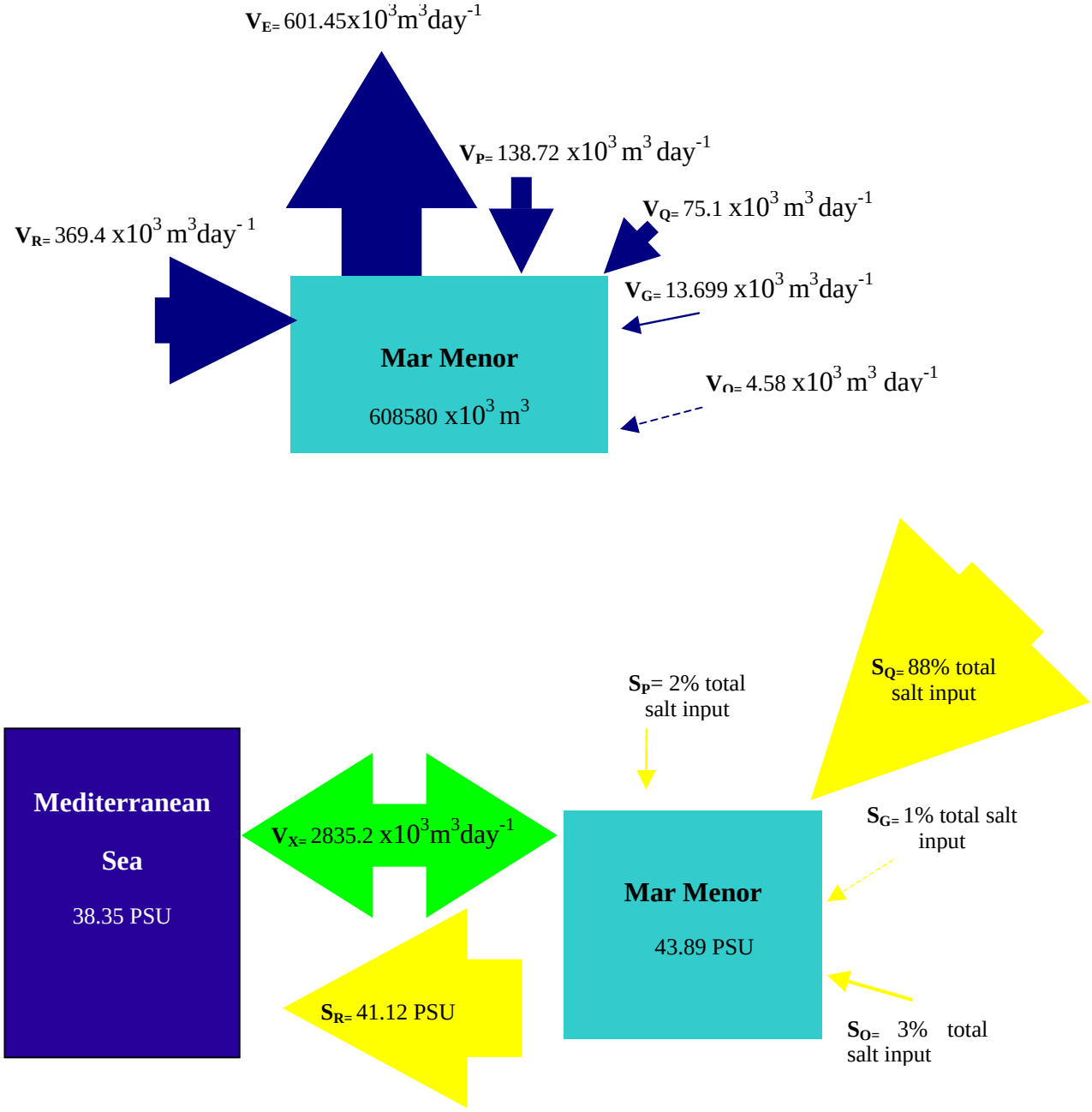

Figure 1. Water and salt balance for Mar Menor lagoon.

The most important inputs are the atmospheric precipitation (V_p) and the river discharges (V_Q). The *Rambla del Albujón*, the main ephemeral channel in the watershed, and two *drainage channel*, accounted for the 32% of all freshwater inputs in 2003, a year in which three floods events took place (15th January, 21st October and 20th November). Precipitation accounts for the 60% of freshwater inputs and ground water (V_G) only accounted for about 6%. The discharges from sewage treatment plants (V_o)

accounted for about 2%. The evaporation volume (V_E) was 250% higher than total inputs. As a result of this water balance, in the Mar Menor there is a residual flow from the Mediterranean into the lagoon (V_R), whose value is 369.3 $x10^3$ m^3 day^{-1}.

Regarding salt budget, the most important input was accounted from the river discharges (V_QS_Q), which reaches 88 % of total salt inputs. The precipitation (V_QS_Q) only accounts for about 1%. Although precipitation is the most important volume input, the salt concentration in the rain is only 0.04 PSU, whereas the salt concentration in the water of *Rambla del Albujón* and drainage channels is around 6.35 PSU .

The exchange flow between Mediterranean sea and Mar Menor lagoon (V_X), computed on the salinity values of the salinity of the system and the sea and on the residual flow, was 2835.2 $x10^3$ m^3 day^{-1}. The corresponding estimated turnover time (τ) is 190 days.

The data and results of the water and salt budget for year 2003 are summarised in the tables 2a and 2b.

Table 2a. Data used in the water and salt budget in Mar Menor lagoon.

	Sys	**Sea**	**P**	**E**	**G**	**Q**	**O**
Volume 10^3 m^3 day^{-1}	608580.00	-	138.72	601.45	13.699	75.1	4.58
Salt PSU	43.90	38.35	0.04	-	2.800	6.35	4.28

Table 2b. Summary of salt and water budget for 1-box 1-layer model.

Parameters	**V_R 10^3 m^3 day^{-1}**	**V_X 10^3 m^3 day^{-1}**	**S_R PSU**	**τ day**
Results	369.4	2835.2	41.12	190

3. NUTRIENTS BUDGET AND STOICHIOMETRIC CALCULATIONS.

The DIP and DIN budgets are illustrated in figures 2 and 3.

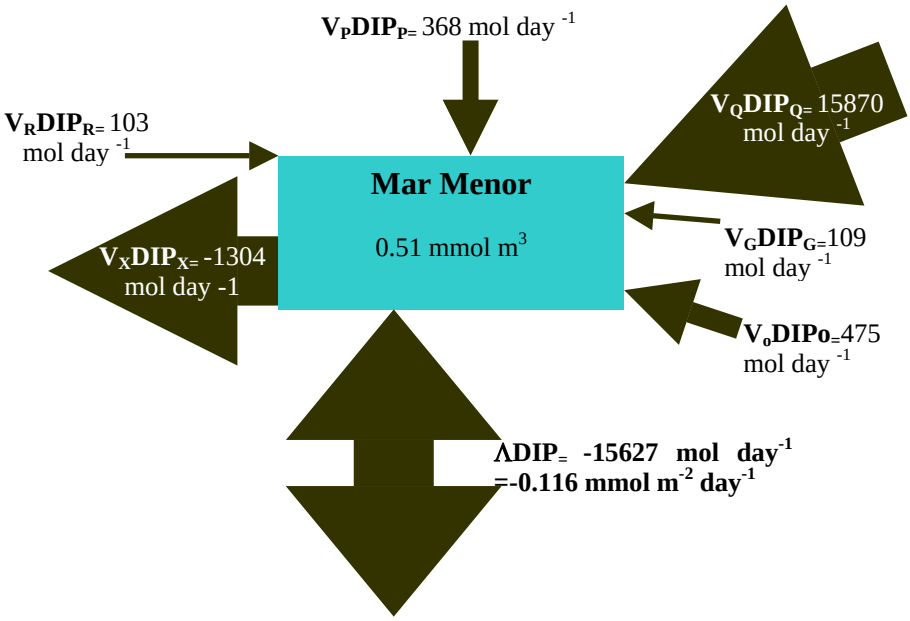

Figure 2. DIP balance budget for Mar Menor lagoon.

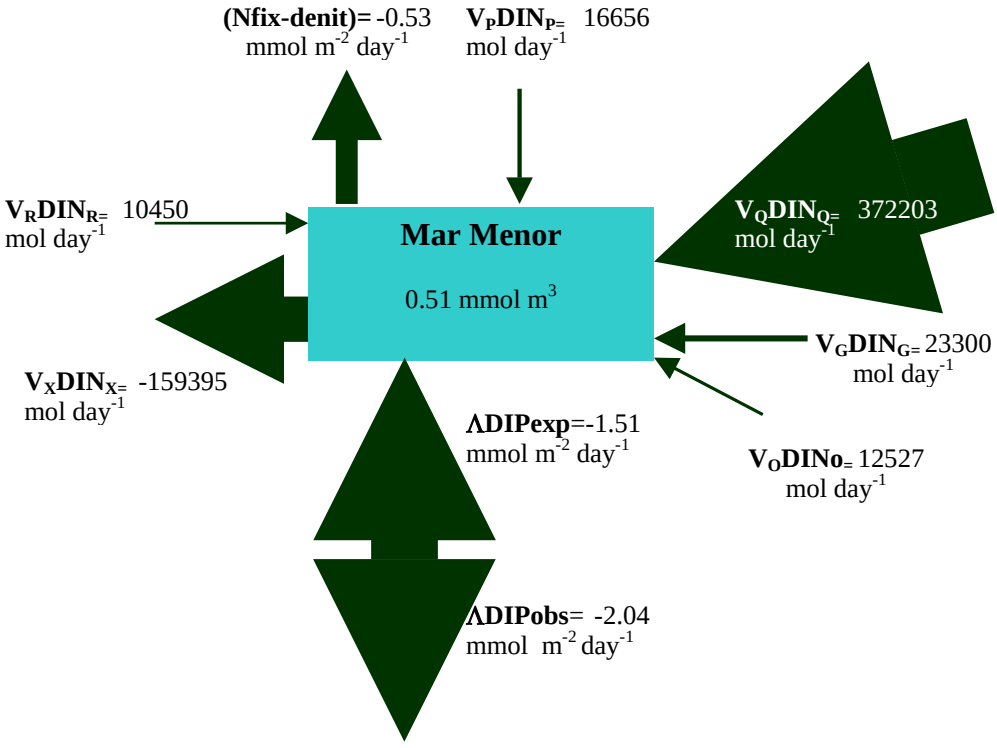

Figure 3. DIN balance budget for Mar Menor lagoon.

In year 2003 the Mar Menor lagoon receive important inputs of N (2170 Tn $year^{-1}$) and P (196 Tn $year^{-1}$). Mainly, the source of N and P was the discharges from the watershed runoff, which accounts for about 94% of P and 88% of N that arrive to the lagoon .

The data and results of the budget calculation for DIP and DIN for year 2003 are presented in tables 3a and 3b. The balance between inputs and outputs of DIP and DIN in the lagoon took up 15,621 mol day^{-1} (182,453 kg $year^{-1}$) of DIP and 275,741 mol day^{-1} of DIN (1,409,037 kg $year^{-1}$). The net values of the observed net internal source or sink for N and P are both negative. Therefore, the Mar Menor is functioning as a sink for N and P.

The main primary producers in Mar Menor are two macrophytes: *Cymodocea nodosa* and *Caulerpa prolifera*. For these species, the overall C:N:P molar ratio is 393:13:1. This ratio has been calculated using the empirical C:N:P data obtained by Terrados (1991) on the assemblages of macrophytes in Mar Menor.

Regarding the results of the stoichiometric calculations, the net difference between primary production and respiration (NEM) is 45.6 mmol m^{-2} day^{-1}, so the system is globally autotrophic. The value of (*nfix-denit)*, which represents the balance between the fixation and denitrification processes, is -0.53 mmol m^{-2} day^{-1}, hence, denitrification prevail over fixation. The net value of the expected value of net internal source of sink for N is also negative. The comparison between the observed and expected values of net internal source of N, making use of the specific C:N:P ratio for the Mar Menor, shows very similar values.

Table 3a. Data used in the DIP and DIN budgets in the Mar Menor lagoon.

	Sys	**Sea**	**P**	**G**	**Q**	**O**
DIP mmol m^{-3}	0.51	0.05	2.656	7.91	211.406	103.77
DIN mmol m^{-3}	56.40	0.18	120.071	1700.86	4958.214	2737.90

Table 3b. Summary of DIP and DIN budgets and stoichiometric calculations for 1-box 1-layer model.

Parameters	**DIZ_R** mol m^{-3}	**$V_R DIZ_R$** mol m^{-3}	**$V_X DIZ_X$** mol m^{-3}	**ΔDIZ** mmol m^{-2} day^{-1}		**Nfix-denit** mmol m^{-2} day^{-1}	**NEM** mmol m^{-2} day^{-1}
				obs	**exp**		
P	0.28	103	-1304	-0.116	-	-	-
N	28.29	10450	-159395	-2.0	-1.51	-0.53	45.6

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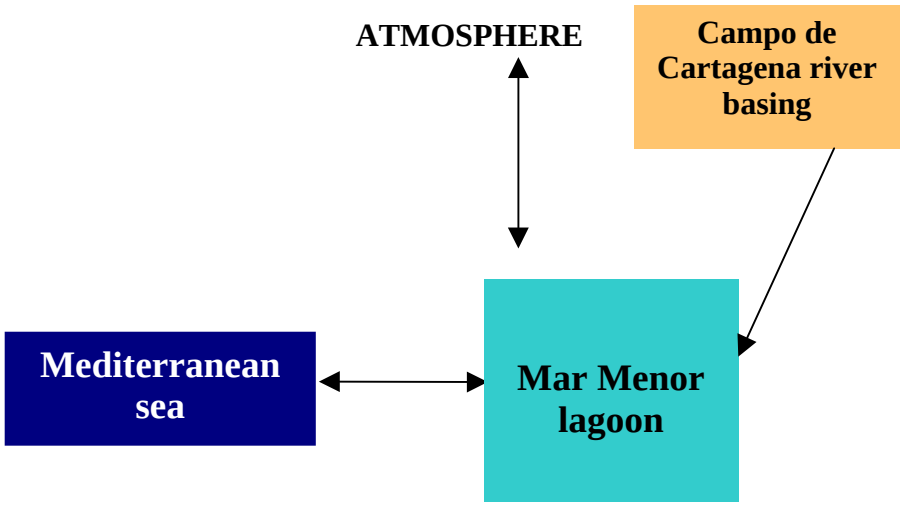
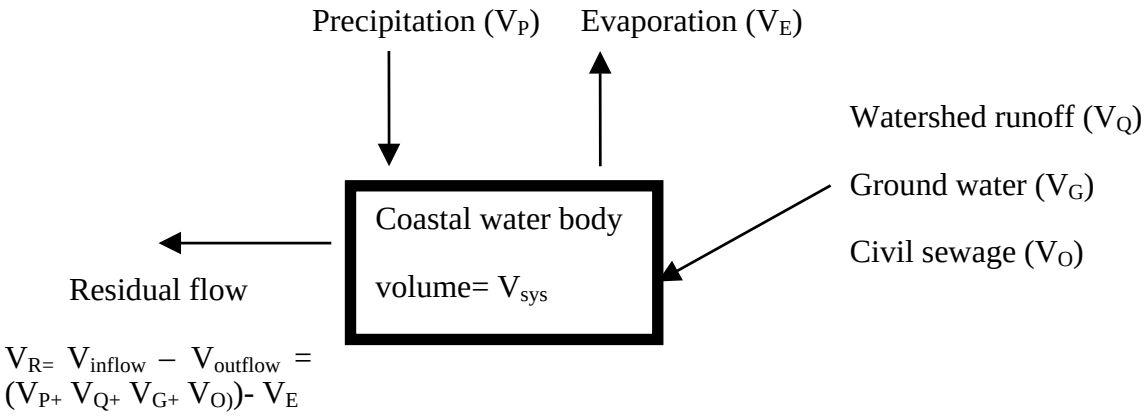
ANNEX

SYSTEM 1 BOX 1 LAYER

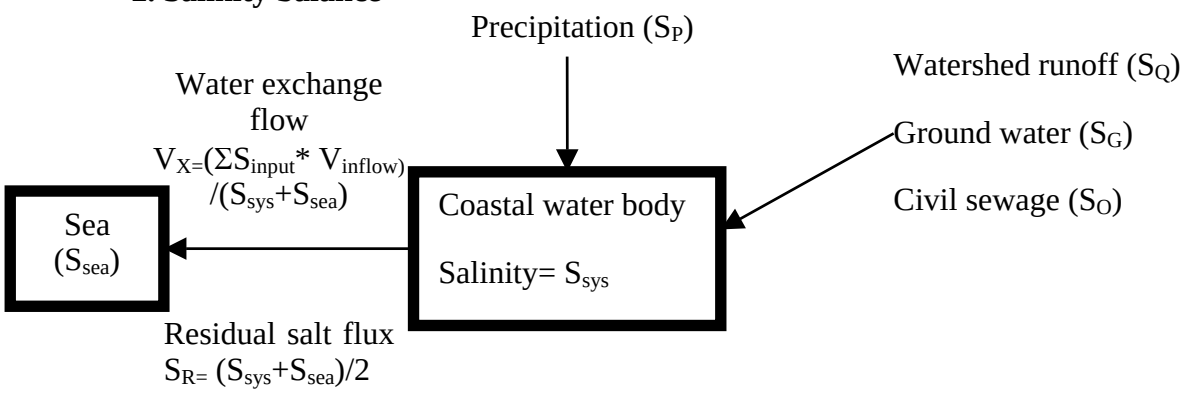


EQUATIONS USED FOR THE BALANCES

1. Water balance



2. Salinity balance



3. DIP and DIN balances