Biomass and species composition of macrophytes in Arcachon Bay and Prévost lagoon, with a compilation of data on primary production in Arcachon Bay

Isabelle Auby, Guy Bachelet and Pierre-Jean Labourg

Laboratoire d'Océanographie biologique, Centre d'Océanographie et de Biologie marine, Université de Bordeaux I, 2 rue du Professeur Jolyet, 33120 Arcachon, France

Introduction

In coastal lagoons macrophytes include algae (which belong to the Thallophytes) and phanerogams (which belong to the other group within the vegetable kingdom, the Cormophytes). Within the framework of the CLEAN Project, primary production and respiration by macrophytes are measured by the Italian group. The objective of this paper is to provide the participants in the Project with seasonal figures on species composition and biomass of macrophytes in the six CLEAN stations. In addition, available data on plant biomass and primary production in Arcachon Bay were compiled from literature and are presented below.

Biomass and species composition of macrophytes

Materials and Methods

Sampling was performed on 8-16 March, 1-7 June, and 30 August - 9 September 1993. Sample collection differed according to the station characteristics and the apparent abundance of plants:

- in intertidal (stns A and B in Arcachon Bay, and stn X in the Prévost lagoon) and shallow subtidal (stn C1 in Certes) stations, plants were collected using a small spade inside a 20 x 20-cm metal frame dug into the sediment to 10-15 cm; sampling was done at low tide in Arcachon Bay;
- in station C2 (Certes, subtidal) samples were taken with a 225-cm^2 Ekman grab which penetrated about 10 cm into the substratum;
- in station 11 (Prévost lagoon) plants were harvested by hand within a 50 x 50 x 100-cm aluminium enclosure whose sides were covered by a plastic net.

Four to five replicates were randomly taken at each station.

All samples were transported in plastic bags to the laboratory where they were stored in a cool place, in the dark. The processing of samples took place within 24 hrs. Samples were first grossly washed through a 0.5-mm mesh sieve to remove the smallest particles. Material retained on the sieve was then laid out in a dish, and with forceps all plant material was separated from the remaining particulate matter and the fauna that

might have been collected as well. Plants were sorted and identified to the species level. For each species, biomass was determined as fresh (= wet) weight, dry weight (DW, after desiccation at 80°C for 48 hrs), and ash-free dry weight (AFDW, after ignition at 550°C for 2 hrs); biomass was expressed as g m^{-2}. Above- (leaves) and below-ground (roots and rhizomes) biomass of the seagrass *Zostera noltii* were determined separately.

Results and discussion

During the course of the CLEAN Project, the following species were collected:

. Algae
. Chlorophytes (green algae)
. Ulvacea
Enteromorpha flexuosa (Wulfen ex. Roth) J. Agardh
Enteromorpha intestinalis (Linnaeus) Link
Monostroma obscurum (Kützing) J. Agardh
(= *Ulvaria obscura* (Kützing) Gayral)
Ulva sp.
. Rhodophytes (red algae)
Gracilaria verrucosa (Hudson) Papenfuss
. Spermaphytes
. Phanerogams
. Ruppiacea
Ruppia cirrhosa (Petagna) Grande
. Zosteracea
Zostera noltii Hornemann.

Species composition and biomass of macrophytes are presented as raw data in Table 1. The seasonal evolution of the biomass of living, above-ground parts of plants is shown in Fig. 1; the below-ground biomass is also shown in Fig. 2.

Stn A was located in a seagrass bed (*Zostera noltii*) on a sandy mudflat in the eastern part of Ile aux Oiseaux. Total living biomass (leaves + roots + rhizomes) of seagrass amounted to 141-167 g AFDW m^{-2} (= 173-211 g DW m^{-2}), which is close to the values found by Auby [1] in Arcachon Bay (140-260 g DW m^{-2}). The above-ground biomass did not show any clear seasonal trend (29-34 g AFDW m^{-2}).

In stn B living biomass was dominated by the green alga *Monostroma obscurum*. It declined from March to September (29-13 g AFDW m^{-2}, or 43-15 g DW m^{-2}) and never reached the high values found for other Ulvacea in the Prévost lagoon (see below). This biomass was also considerably lower than that occurring in the accumulating areas of the Eyre delta, in the SE corner of the Bay (350-667 g DW m^{-2}; PJL, unpubl. data). A high biomass of below-ground debris of *Zostera* was measured (92-186 g AFDW m^{-2}). The occurrence of some oak leaves shows the proximity of fresh waters.

In stn C2 only *Ruppia* debris were collected.

The shallow lagoons of Certes (stn C1) were colonized by *Ruppia cirrhosa*. Biomass was measured for the whole plant because leaves were too much difficult to separate from roots. There was a clear seasonal trend with the highest biomass (63 g AFDW m^{-2}) occurring in June. Numerous epiphytes on *Ruppia* leaves were observed in September; however, they were not weighed separately due to the occurrence of high numbers of tubes constructed by invertebrates. Some *Monostroma* were also collected in September.

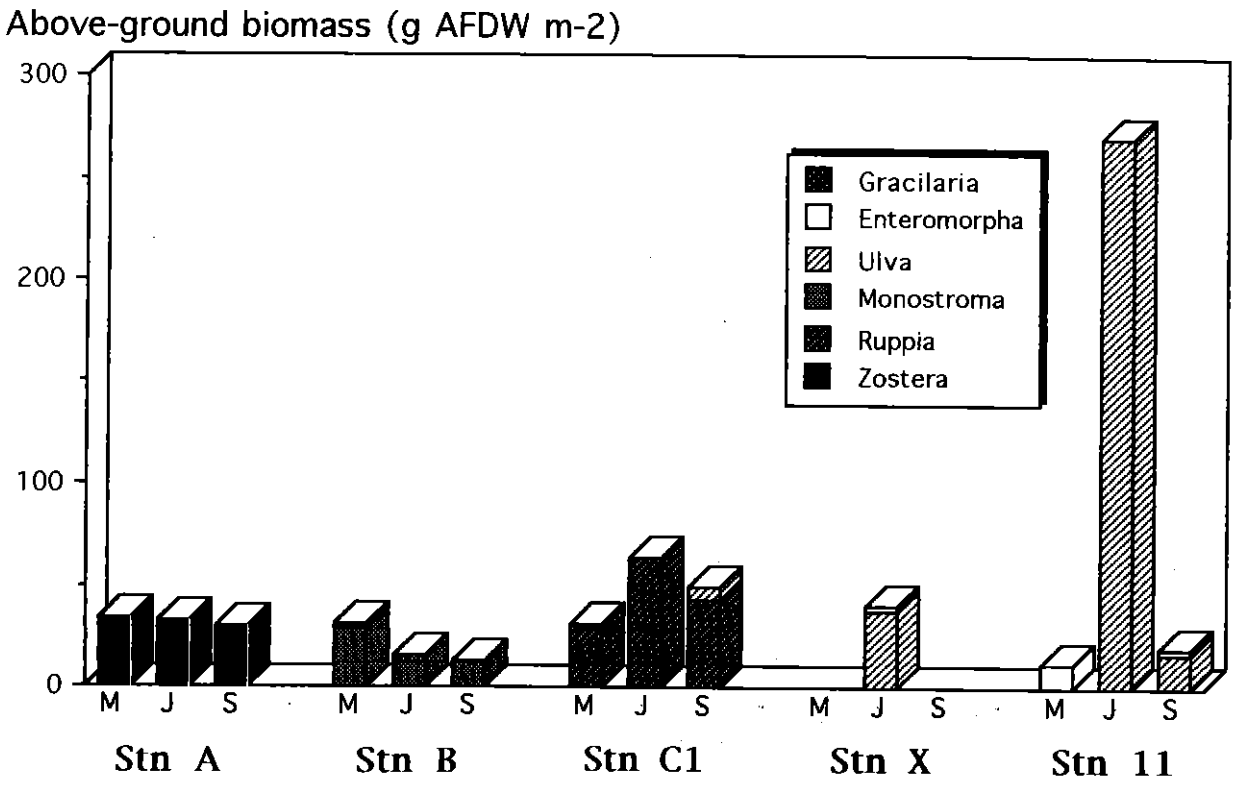

Fig. 1. Biomass of living, above-ground parts of macrophytes at the CLEAN stations in March, June, and September 1993.

In stn 11 (Prévost lagoon) the March samples contained a small amount of *Enteromorpha flexuosa* and *E. intestinalis* (12 g AFDW m^{-2}). These algae disappeared in June when they were replaced by proliferating *Ulva sp.* (270 g AFDW m^{-2}) which filled the whole water layer and probably induced anoxia for the benthos. In September algal biomass (*Enteromorpha* + *Ulva*) decreased to a low value (19 g AFDW m^{-2}).

No algae were collected in March and September at stn X. Only the June samples contained some *Enteromorpha* and *Ulva* flowing from the inner parts of the lagoon.

To summarize, macrophytes did not show any seasonal trend in biomass in Arcachon Bay; some sign of eutrophication was visible in Certes lagoons; the most obvious changes in macrophyte biomass occurred in the Prévost lagoon, especially at the inner station, with a huge development of green algae in June, followed by their almost complete disappearance in September.

Table 1

Biomass (mean ± 1 SD) and species composition of macrophytes at the six CLEAN stations in March, June, and September 1993.

Station	Sampling date	Species		Biomass		
				Fresh weight g m^{-2}	Dry weight g m^{-2}	Ash-free dry weight g m^{-2}
A	March	*Zostera noltii*	leaves	307.87 (100.82)	35.84 (14.08)	33.89 (13.84)
			roots + rhizomes	1343.12 (886.16)	136.98 (86.28)	107.26 (64.52)
		Monostroma obscurum		3.19 (6.38)	0.44 (0.87)	0.30 (0.60)
	June	*Zostera noltii*	leaves	330.25 (126.55)	43.71 (16.20)	32.36 (18.29)
			roots + rhizomes	1303.54 (552.30)	167.47 (69.05)	134.77 (53.10)
	Septemb.	*Zostera noltii*	leaves	263.98 (104.79)	31.52 (11.71)	29.48 (10.69)
			roots + rhizomes	1221.01 (216.16)	150.49 (31.82)	124.30 (25.20)
B	March	*Monostroma obscurum*		389.37 (117.05)	42.53 (29.10)	29.10 (10.74)
		Zostera debris		2059.37 (744.51)	221.70 (63.40)	154.13 (52.53)
		Oak leaves		5.34 (4.84)	2.03 (3.05)	1.71 (2.66)
		Gracilaria verrucosa		10.30 (20.59)	1.79 (3.58)	1.52 (3.03)
	June	*Monostroma obscurum*		135.00 (119.36)	19.19 (21.40)	16.23 (18.26)
		Zostera debris		747.95 (178.16)	123.07 (28.22)	92.22 (20.02)
	Septemb.	*Monostroma obscurum*		83.45 (10.33)	14.93 (2.41)	12.50 (1.87)
		Zostera debris		1367.10 (388.62)	215.03 (60.40)	185.58 (141.90)
C2*	March	*Ruppia* debris		1005.22 (309.57)	146.90 (45.66)	104.67 (39.66)
C1	March	*Ruppia cirrhosa*		425.62 (539.60)	41.92 (57.18)	31.67 (43.42)
	June	*Ruppia cirrhosa*		599.54 (485.99)	69.01 (64.46)	63.26 (58.77)
	Septemb.	*Ruppia cirrhosa*		398.94 (227.76)	44.44 (26.99)	43.05 (26.63)

(to be continued)

Table 1 (continuation)

X	March	no plant			
	June	*Ulva sp.*	386.30 (285.25)	47.24 (42.74)	38.23 (35.08)
		Enteromorpha spp.	27.32 (54.64)	1.91 (3.82)	1.49 (2.98)
	Septemb.	no plant			
11	March	*Enteromorpha spp.*	268.00 (226.27)	15.52 (14.02)	12.16 (10.67)
	June	*Ulva sp.*	2647.80 (869.60)	370.42 (117.91)	270.15 (74.31)
	Septemb.	*Ulva sp.*	136.17 (54.06)	18.97 (7.77)	16.89 (6.93)
		Enteromorpha spp.	23.05 (20.12)	3.20 (1.24)	2.09 (1.53)

* Samples of June and September at station C2 have still to be analysed.

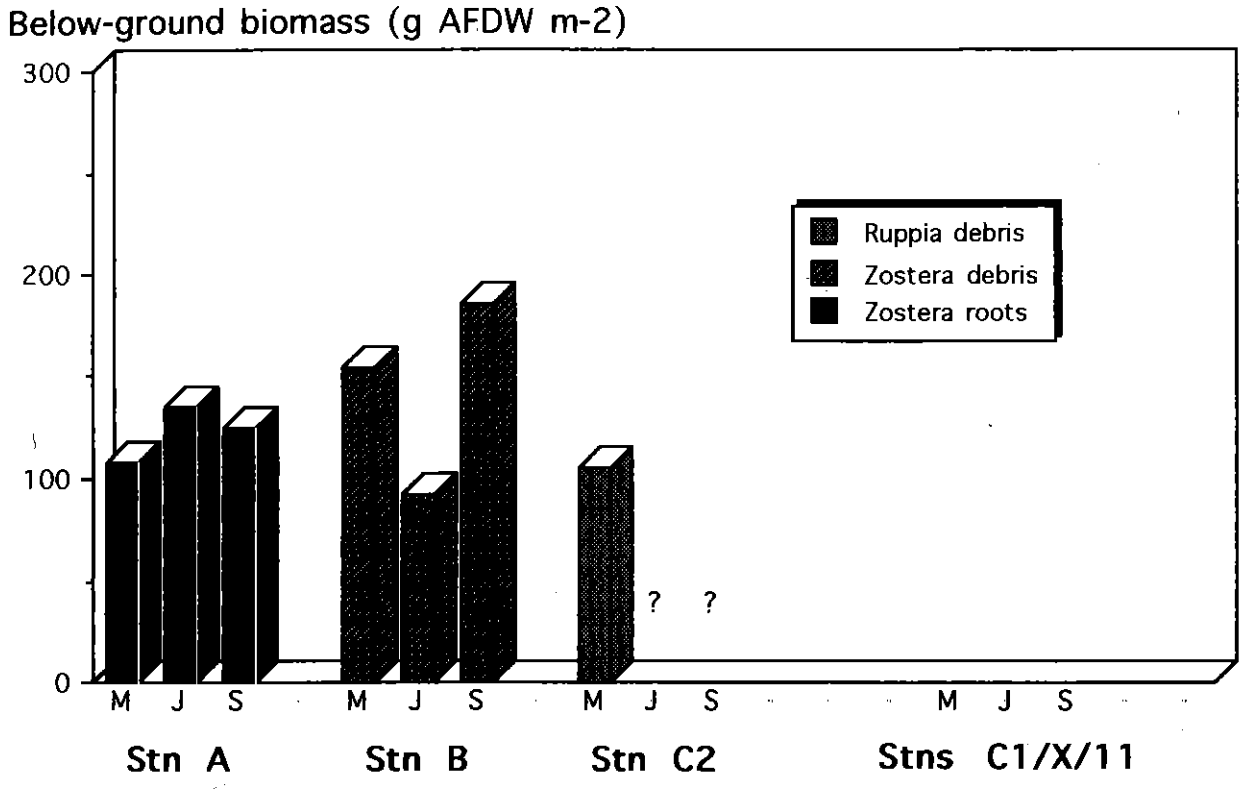

Fig. 2. Biomass of below-ground parts (dead, or living) of macrophytes at the CLEAN stations in March, June, and September 1993.

Literature survey on primary production in Arcachon Bay

Zostera noltii

In Arcachon Bay, the widgeon grass covers 61 % of the intertidal area (115 km^2). With 70.14 km^2, these *Z. noltii* beds are the largest ones in Europe. Mean annual biomass is 70-100 g DW m^{-2} for the leaves and 70-160 g DW m^{-2} for the roots and rhizomes [1].

The annual net production of *Z. noltii* was calculated by Auby [1] at 7 intertidal stations. It amounted to 224-336 g DW m^{-2} yr^{-1} for above-ground organs and 215-287 g DW m^{-2} yr^{-1} for below-ground parts, i.e. a total of 439-623 g DW m^{-2} yr^{-1} or 127-181 g C m^{-2} yr^{-1}; these values are within the range found in other seagrass beds [2]. By extrapolating, this gave for the whole bay an estimate of 30791-43697 t DW yr^{-1}. Based on the elemental composition of plants, the total production for the bay amounted to 9275-13300 t C yr^{-1}, 660-960 t N yr^{-1}, and 70-100 t P yr^{-1}.

In situ decomposition experiments showed that half the biomass of plant material disappeared within 1 month [3]. During a 2-months laboratory experiment, Durin [3] also found that, in anaerobic conditions, decomposition of 1 g DW of *Z. noltii* leaves released 16,9 mg N-NH_4 and 1.8 mg P-PO_4 in the light, and 33.2 mg N-NH_4 and 5.1 mg P-PO_4 in the dark.

This low decomposition rate may account for the high amount (annual mean: 218.0-290.0 g DW m^{-2}) of *Zostera* debris within seagrass beds; other environments contain much less *Zostera* debris: 0.5-3.7 g DW m^{-2} in bare sands, and 25.5-49.7 g DW m^{-2} in oyster beds [4].

Zostera marina

The subtidal eelgrass occupies 4.26 km^2 in the channels. Based on values found for *Z. noltii*, Auby [1] estimated the total production of *Z. marina* for the bay as 6213 t DW yr^{-1}, partitioned in 2003 t C yr^{-1}, 157 t N yr^{-1}, and 14.7 t P yr^{-1}.

The production of epiphytes was estimated as 390 t C yr^{-1} [1].

Halophytic phanerogams of salt marshes

The salt marshes occupy 7.67 km^2 in the bay, 7.14 km^2 of which are covered by halophytic plants [5]. Soriano-Sierra [5] calculated the net primary production (above-ground material) of 3 dominant species at Arcachon: *Spartina stricta* (586-945 g DW m^{-2} yr^{-1}), *Halimione portulacoides* (487-652 g DW m^{-2} yr^{-1}), and *Sarcocornia fruticosa* (393-407 g DW m^{-2} yr^{-1}). For the whole bay, this production has been estimated as 7612-9098 t DW yr^{-1}[5], or 3045-3639 t C yr^{-1}, 537-686 t N yr^{-1}, and 73-93 t P yr^{-1} (IA, unpubl. data).

In field experiments, Soriano-Sierra [5] showed that half the plant material was decomposed within 5-6 months.

Phytoplankton

Biomass and production of phytoplankton were measured in 1985/86 at six stations by Guillocheau [6]. The mean daily production amounted to 21 mg C m^{-3} d^{-1}, with extreme values in January (about 4 mg C m^{-3} d^{-1}) and in May (about 67 mg C m^{-3} d^{-1}). From these data, Auby [1] calculated, for the whole bay, a mean annual production of 30.8 g C m^{-2} yr^{-1} and total annual productions of 3540 t C yr^{-1}, 625 t N yr^{-1}, and 85 t P yr^{-1}.

Microphytobenthos

The production of microbenthic algae was estimated by Auby [1] from data on chlorophyll *a* and phaeopigment contents in the sediment [7, 8]:

- semi-exposed sandy beaches: 19.5-45.5 g C m^{-2} yr^{-1},
- oyster parks: 74-135 g C m^{-2} yr^{-1},
- *Zostera noltii* beds: 46-135 g C m^{-2} yr^{-1},
- bare sands: 10-20 g C m^{-2} yr^{-1},
- channels: 10 g C m^{-2} yr^{-1}.

Knowing the area of each biotope, Auby [1] calculated an average production of 32-79.7 g C m^{-2} yr^{-1}, and, for the whole bay, a total production of 4926-12268 t C yr^{-1}, 860-2140 t N yr^{-1}, and 120-290 t P yr^{-1}.

Macroalgae

A study in progress is devoted to *Ulvaria* (= *Monostroma*) *obscura*. Preliminary measurements on this summer-proliferating alga indicate a total biomass of 2100-2500 t DW in June and a total annual production of approximately 10000 t DW yr^{-1},

composed of 3435 t C yr^{-1}, 416 t N yr^{-1}, and 42 t P yr^{-1} [IFREMER-Arcachon, pers. comm.].

In field decomposition experiments, half the biomass of *Ulvaria* disappeared in 8 days (summer) [9] or 30 days (winter) [IA, unpubl. data]. Bourguès [9] also found that, in a 2-months laboratory experiment, 1 g DW of *Ulvaria* released 6.3 mg $N\text{-}NH_4$ and 0.3 mg $P\text{-}PO_4$ in the light; in the dark these values were 15.8 and 0.5, respectively.

Other proliferating macroalgae, i.e. *Enteromorpha cf. clathrata* and *Centroceras clavulatum*, have not been studied so far.

Acknowledgements

Our thanks go to Marylène Durin who processed most of the samples; Xavier de Montaudouin also helped us in the field collection.

References

1 Auby, I. (1991) Contribution à l'étude des herbiers de *Zostera noltii* dans le Bassin d'Arcachon: dynamique, production et dégradation, macrofaune associée, 162 + 72 pp. PhD thesis, Univ. Bordeaux I, France.

2 Mann, K.H. (1972) Macrophyte production and detritus food chains in coastal waters. Mem. Inst. Ital. Idrobiol. 29, Suppl., 353-383.

3 Durin, M. (1992) Etude de la dégradation de *Zostera noltii* (Hornem.) dans les sédiments du Bassin d'Arcachon; rôle des bactéries sulfato-réductrices et fermentatives, 38 pp. DEA memoir, Univ. Bordeaux I, France.

4 Castel, J., P.J. Labourg, V. Escaravage, I. Auby and M.E. Garcia (1989) Influence of seagrass beds and oyster parks on the abundance and biomass patterns of meio- and macrobenthos in tidal flats. Estuar. Cstl Shelf Sci. 28, 71-85.

5 Soriano-Sierra, E.J. (1992) Etude écologique des marais salés du Bassin d'Arcachon: structure et évolution des schorres, production et dégradation de leur végétation et échanges de matières particulaires entre les schorres et le Bassin, 257 pp. PhD thesis, Univ. Bordeaux I, France.

6 Guillocheau, N. (1988) Répartition spatio-temporelle du phytoplancton du Bassin d'Arcachon, 156 pp. PhD thesis, Univ. Aix-Marseille II, France.

7 Escaravage, V. (1989) Implication et contrôle du méiobenthos dans des écosystèmes littoraux exploités (Bassin d'Arcachon), 149 pp. PhD thesis, Univ. Bordeaux I, France.

8 Escaravage, V., M.E. Garcia and J. Castel (1989) The distribution of meiofauna and its contribution to detritic pathways in tidal flats (Arcachon Bay, France). Scient. Mar. 53, 551-559.

9 Bourguès, S. (1992) Contribution à l'étude de la dégradation de l'algue verte *Ulvaria obscura* (Kutzing). Rôle des bactéries anaérobies hétérotrophes (bactéries sulfato-réductrices et fermentatives), 30 pp. DEA memoir, Univ. Bordeaux I, France.