TRANSPORT AND BUDGET OF NUTRIENTS IN KASTELA BAY (ADRIATIC SEA)

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Abstract

Kastela Bay is a semi-enclosed coastal bay in the middle Adriatic which acts as a dilution basin due to the fresh water, industrial and urban inflows. Nutrient content and basic hydrographic parameters were studied and discussed, as well as the effects of some other biological and geochemical processes on their concentrations. The following phenomena were studied: fresh water, waste water, and atmospheric input, water mass exchange between the Kastela Bay and the adjacent sea, and loss of nutrients through the sedimentation of organic matter. On the basis of the results obtained, Kastela Bay may be categorized as a very eutrophic area with its eastern part (Vranjic basin) suffering from an extremely high degree of eutrophication. During the last few years the Bay has shifted into the highest category of productivity (> 500 mg C m^2 a^{-1}) of sea water.

Key-words: nutrients, eutrophication, Adriatic Sea

Introduction

Calculation of the nutrient balance provides a basis for quantitative studies of the biogeochemical mechanisms in a particular aquatic environment.The nutrient balance for Kastela Bay was obtained from long-term studies carried out in this area by the Institute of Oceanography and Fisheries, (IOF) Split, and data from the literature. Balance calculations took into account a series of input and loss mechanisms of which some are particular for nutrients. Fresh water, waste water and atmospheric input, water mass exchange by transport between Kastela Bay and the adjacent sea, and loss of organic matter by sedimentation were studied.

The annual mean rate of nutrient recycling linked to biological processes (*e.g.* phytoplankton assimilation, regeneration through excretion of heterotrophic microorganisms and macrozooplankton) and sediment release were also estimated. A simplified conceptual model of nutrient cycling in the enclosed bays is outlined in Figure 1.

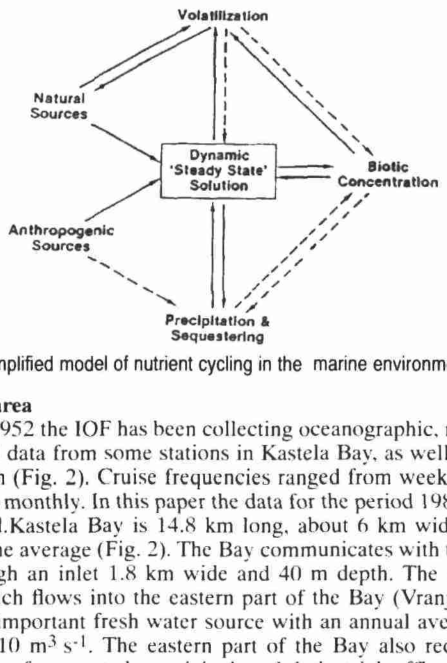

Fig. 1. A simplified model of nutrient cycling in the marine environment.

Study area

Since 1952 the IOF has been collecting oceanographic, nutrient and biological data from some stations in Kastela Bay, as well as an open sea station (Fig. 2). Cruise frequencies ranged from weekly (summer period) to monthly. In this paper the data for the period 1982-1995 has been used.Kastela Bay is 14.8 km long, about 6 km wide and 23 m deep on the average (Fig. 2). The Bay communicates with the adjacent sea through an inlet 1.8 km wide and 40 m depth. The small Jadro River which flows into the eastern part of the Bay (Vranjic basin) is the most important fresh water source with an annual average inflow of about 10 m^3 s^{-1}. The eastern part of the Bay also receives large quantities of untreated municipal and industrial effluents (104 x 10^6 m^3 a^{-1}). The Bay has a total area of 61 x 10^6 m^2 with a water volume of 1.4 x 10^9 m^3. Water exchange and changes in the current field are mostly induced by local winds related to the passing of mid-latitude cyclones over the area (2). The annual average precipitation of 1 m and the total rate of water over the Bay surface exceeds 61 x 10^6 m^3 a^{-1}. The local coastal drainage basin is approximately twice the area of the Bay (*i.e.* 122 x 10^6 m^2). Precipitation is also doubled there, *i.e.* 122 x 10^6 m^3 a^{-1}. The Bay is particularly threatened by organic matter and nutrient input which cause an extreme phytoplankton bloom each summer (3, 4). Anoxia in the bottom layer develops as the most frequent consequence. Furthermore, microbial pollution jeopardizes the Bay's eastern part and northern coast (5).

Results

For the nutrient balance calculations, water quantity and chemical component contents in the Bay were considered to be in a "steady state" that is, the supply of chemical substances and their removal through different physical and chemical processes were assumed to be equal. Water balance was calculated by a simple salinity balance calculation (6) : **Si * (Q+x) = So * x**

where S_i is the mean value of water salinity, which was 36.80 in Kastela Bay. S_o is the mean salinity value (38.40) at the offshore station (I.Vis). Q is the annual mean input of fresh water into the Bay (Q= 474 x 10^6 m^3 a^{-1}). This value is the sum of rainfall, river discharge and losses by evaporation. The x value is the annual input of seawater from the open sea (x = 10902 x 10^6 m^3 a^{-1}) Residence time of sea water in the Bay was calculated to be as 0.12 years or 44 days. This is in good agreement with values obtained from current flushing time (30 days) (7). This calculation shows Kastela Bay to be a dilution area for the adjacent sea where the outgoing water mass exceeds the water input, (Q + x) = 11376 x 10^6 m^3 a^{-1}). Nutrient balance calculations for the Bay require knowledge of nutrient levels in the Bay and open sea water as well as in all the waters which enter the Bay from the mainland (Table 1 and 2). As shown in Table 1, nutrient concentrations decrease with distance from the source of nutrient input.

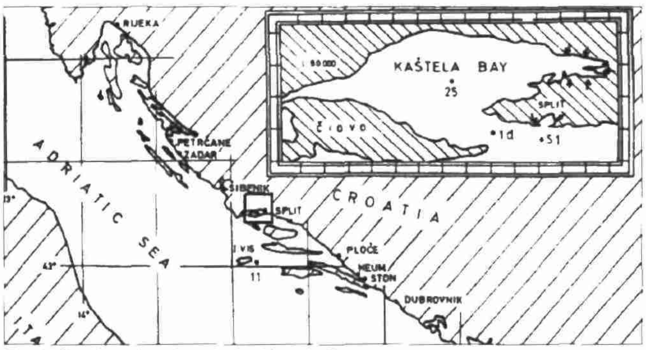

Fig. 2. Position of stations in the Kastela Bay.

So, the highest values were recorded in the Bay, slightly lower values at the mouth of the Bay. The lowest values were recorded in front of the town port (S-1), even though this station is strongly affected by urban effluents carrying large quantities of nutrients, particularly phosphates (PO_4-P). Higher concentrations of NH_4-N at the open

Table 1. Ranges (R), mean nutrient concentrations (x), standard deviation (s) and data number (n) in Kastela Bay and offshore waters.

Stations		NH_4-N mmol m^{-3}	NO_2-N mmol m^{-3}	NO_3-N mmol m^{-3}	PO_4-P mmol m^{-3}	SiO_2-Si mmol m^{-3}
25	R	0.16-3.02	0.04-0.75	0.22-10.1	0.042-0.250	0.42-
	x	0.81	0.136	1.32	0.079	6.20 1.88
	s	0.43	0.05	0.34	0.014	0.48
	n	840	840	840	840	840
1d	R	0.24-1.48	0.03-0.35	0.29-13.6	0.042-0.115	0.36-5.70
	x	0.74	0.99	1.63	0.076	1.98
	s	0.39	0.03	0.45	0.024	0.23
	n	740	740	740	740	740
S-1	R	0.28-1.82	0.03-0.30	0.24-12.1	0.042-0.17	0.13-5.40
	x	0.68	0.09	1.00	0.103	1.81
	s	0.32	0.03	0.46	0.03	0.91
	n	388	388	388	388	388
11 I.Vis	R	0.36-1.98	0.04-0.12	0.60-0.91	0.04-0.20	0.53-7.53
	x	1.08	0.08	0.81	0.09	1.78
	s	0.39	0.02	0.34	0.01	0.21
	n	960	960	960	960	960