TWO DIFFERENTS NORTHERN ADRIATIC WINTER OCEANOGRAPHIC TYPES

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Abstract
It has been observed that two types (A and B) of winter oceanographic conditions can occur in the northern Adriatic. The difference between the eastern and western parts bottom layer density distinguishes the two winter types. We intend to present a precise definition of the two types and introduce a third winter type (C). A and B types differ in hydrographic (temperature and salinity), dynamic (geostrophic currents distributions), chemical (total inorganic nitrogen and phosphorous) and biological (phytoplankton) parameters.
Keywords: Adriatic Sea, Circulation, Nutrients, Phytoplankton, Po Delta

Introduction
The northern part of the Adriatic is under the influence of the Po River, one of the largest Mediterranean rivers. Spreading of the Po River waters highly influences oceanographic processes in this region. Depending on circulation patterns, Po River waters are drawn into the northern Adriatic region or are diverted southwards (Figure 1). According to Supic and Vilibic [1], who described winter hydrographic conditions in the northern Adriatic for the 1966-2000 period, two basic hydrographic February conditions (A and B) can occur in the region. The A type occurs when bottom density is higher in the eastern part than in the western one of the northern Adriatic and the B type is when it is just the opposite. A detailed analysis of the two types was needed.

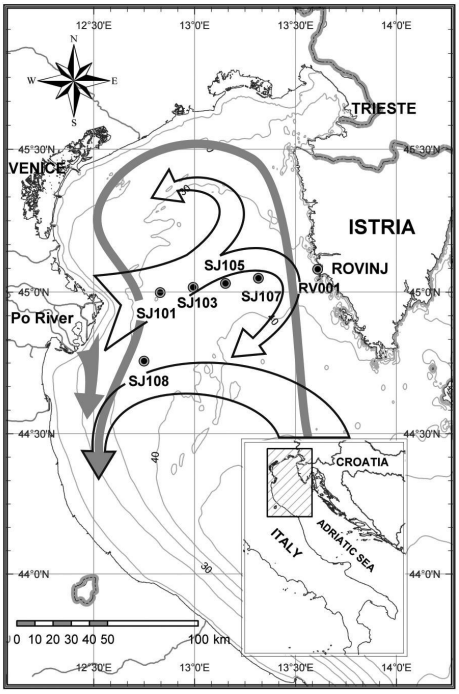

Fig. 1. Northern Adriatic map and schematics of two circulation types in its surface layer. The "open" circulation pattern (solid arrows) favors the inflow of southern Adriatic waters, and the "closed" circulation pattern (open arrows) spreads the Po River waters towards the east.

Methods
Sampling strategy, parameters determination and calculation

Hydrographic (temperature, salinity and density), dynamic (geostrophic currents relative to 30 m depth between each two neighboring stations), chemical (total inorganic nitrogen and phosphorous) and biological (microphytoplankton) samples were collected in February at six stations between the Po River delta (Italy) and Rovinj (Croatia) (Figure 1) in the 1981-2007 period. The parameters were determined by standard oceanographic methods.

Type determination

The A or B type occurs when average 30 m sigma-t value at western stations SJ108 and SJ101 (Table 1) is at least 0.1 lower or higher than at eastern SJ107, respectively. The special C type occurs when the difference is less than 0.1.

Results
In type A winters temperature, nutrient concentrations and phytoplankton abundance at the entire Po River delta - Rovinj transect were generally higher than in type B winters, while salinity and density were lower (Table 1). The difference in phytoplankton abundances between A and B types for the eastern part of the transect was especially pronounced (Table 1).

Tab. 1. Bottom density of the western (W) and eastern (E) northern Adriatic (bottom ρ), the corresponding winter type, surface geostrophic currents relative to 30 m between SJ105 and SJ107 (v; + means flow towards north, and - means flow towards south), intensity of the Po River flow during January and February compared to long-term means (Po flow) and water column averages for temperature (T), salinity (S), density (ρ), orthophosphate (P), total inorganic nitrogen (N; nitrite, nitrate and ammonium) and phytoplankton (phyto; 20-200μm)

Year	Bottom ρ (-1)		Winter type	v (cm s^{-1})	Po flow	Water column averages											
						T (°C)		S (-1)		ρ (-1)		P (μmol L^{-1})		N (μmol L^{-1})		Phyto (cells L^{-1})	
	West	East				W	E	W	E	W	E	W	E	W	E	W	E
1993	29.0	29.2	A	-3	L	8,3	9,3	36,7	37,6	28,6	29,1	0,06	0,03	5,7	2,0	2.488.435	1.618.318
2001	28.7	29.0	A	-1	H	11,3	12,0	37,5	38,0	28,6	29,0	0,16	0,03	5,3	2,7	552.410	208.707
2004	29.6	29.7	A	-10	L	8,8	8,4	36,7	36,8	28,5	28,6	0,05	0,06	6,5	5,4	891.176	1.832.672
2007	29.0	29.1	A	0	L	11,5	11,8	37,8	38,1	28,8	29,1	0,06	0,02	2,9	1,7	112.079	7.030
AVG	**29.1**	**29.3**	**A**	**-4**	**-**	**10,0**	**10,4**	**37,2**	**37,6**	**28,6**	**29,0**	**0,08**	**0,04**	**5,1**	**3,0**	**1.011.025**	**916.182**
1987	29.8	29.5	B	1	L	7,8	8,7	38,0	37,9	29,6	29,5	0,17	0,01	1,5	1,8	-	-
1990	29.6	29.2	B	3	L	9,9	10,4	38,3	38,1	29,5	29,3	0,08	0,01	1,7	1,1	15.417	4.533
1991	29.9	29.8	B	0	L	7,8	8,7	37,3	38,3	29,2	29,7	0,03	0,00	3,9	2,1	2.555.621	5.858
1994	29.5	29.2	B	2	H	9,1	10,2	37,8	37,9	29,3	29,2	0,06	0,00	2,9	1,3	2.780	33.252
1999	29.8	29.6	B	3	L	8,5	8,9	38,2	38,2	29,7	29,8	0,08	0,03	1,4	1,1	202.822	9.898
2000	29.9	29.6	B	1	L	8,4	9,1	38,0	38,2	29,8	29,7	0,05	0,01	2,4	1,0	1.201.020	19.519
2003	29.7	29.6	B	0	H	8,2	8,8	38,2	38,1	29,7	29,8	0,07	0,04	1,8	2,1	4.024	5.010
2005	29.9	29.6	B	4	L	-	-	-	-	-	-	0,05	0,04	2,9	2,8	10.684	589.760
2006	29.9	29.7	B	3	L	7,9	8,5	38,2	38,3	29,8	29,8	0,08	0,04	2,3	2,2	262.762	40.738
AVG	**29.8**	**29.5**	**B**	**2**	**-**	**8,5**	**9,2**	**38,0**	**38,1**	**29,6**	**29,6**	**0,07**	**0,02**	**2,3**	**1,7**	**531.891**	**88.449**
1981	29.8	29.8	C	0	L	8,4	8,6	38,3	38,3	29,8	29,8	0,04	0,02	1,0	0,9	-	-
1982	29.4	29.4	C	3	L	9,0	9,2	37,4	37,6	29,0	29,1	-	-	-	-	5.966.959	853.775
1995	29.2	29.2	C	0	H/L	9,4	10,1	37,6	37,9	29,1	29,2	0,11	0,05	2,2	1,8	578803	2523
1998	29.1	29.1	C	-6	L	9,8	10,0	36,9	37,1	28,5	28,6	0,08	0,01	2,4	1,6	450.596	349.989
AVG	**29.4**	**29.4**	**C**	**-1**	**-**	**9,2**	**9,8**	**37,6**	**37,7**	**29,1**	**29,2**	**0,08**	**0,03**	**1,9**	**1,4**	**2.332.120**	**402.096**

In winters of A type (except in 2007, when currents were very weak) there was a geostrophic flow towards south between stations SJ105 and SJ107, indicating the presence of a large anticyclonic gyre off the Po River delta and spreading of Po waters towards east (Table 1, Figure 1). On the contrary, in winters of B type a geostrophic flow towards north between stations SJ105 and SJ107 was observed. Results of an analysis of winter circulation fields (in preparation) show that the distribution of surface geostrophic currents in winter strongly depends on bottom density distribution. Winter types occur independently of the Po River input (Table 1). Values obtained for all parameters during C type winters are generally between values characteristic for A and B type ones.

Conclusion
Results strongly indicate that in A type winters Po River waters spread over the northern Adriatic, distributing fresh nutrient rich waters towards east and favoring phytoplankton blooms over a large area. In winters of B type, these waters are restricted to the western area. C type winters are more vague and cannot be described as precisely as A and B type winters.

References
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