How to use biological time series in Mediterranean ecosystem studies: can hydromedusae be indicator species ?

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INTRODUCTION

When looking into rational explanations for disturbances in an ecosystem we regularly try to get as many data as possible from historical databases, and, more often than not, we face the problem of incomplete data sets characterized by gaps in the information base.

One approach to identify patterns, regularities and irregularities is to focus on regions possessing extensive long-term research, documented in large number of published scientific papers. This is the case of the Adriatic Sea – especially its northern part – the focus of this paper.

The research of various aspects of the North Adriatic Ecosystem goes back to early modern oceanographic and marine biological investigations. Plankton research was very fashionable in the 19th and 20th centuries (Fonda-Umani and Specchi, 1979; Ghirardelli, 1983). Contributions from marine research expeditions such as R/V *R. Virchov* in 1909, 1911 (Neppi, 1912), R/V *Najade* in 1912-1914 (Neppi, 1922), R/V *Hvar* in 1948-1949 (Vucetic, 1963) were notable. In addition, a number of other research cruises took place in the Adriatic sea, although a large number of samples and biological material was were not examined and therefore potentially valuable information was lost (Mikus *et al.*, 1996).

TIME SERIES OF HYDROMEDUSAE

The first account of hydromedusae of the Adriatic Sea came from the Gulf of Trieste (Will, 1844). Further results originated mostly from the shallow north Adriatic, with a few investigations conducted also in deep waters of the middle and south Adriatic.

Claus (1877, 1880) has described medusan fauna with special reference to Aequoridae; Graeffe (1884) described medusan fauna and its development in the Gulf of Trieste; Stossich, (1885) gave a comprehensive account of coelenterata; Neppi (1912) published results from coastal and open waters of the entire Adriatic Sea; Neppi and Stiasny (1913) provided an excellent review of hydromedusan fauna of the Gulf of Trieste; Babic (1913) published results from the coastal waters of Kvarner region; Grobben (1915) and Neppi (1922) elaborated on medusae from open Adriatic waters; Pell (1938) elaborated on medusae from Hungarian expedition of R/V *Najade*; Babnik (1948) published results on the middle and south Adriatic. Since 1965 Benovic and collaborators have published a number of papers on systematics, distribution, abundances and vertical migration. The most comprehensive bibliography is given in papers of Benovic and

Bender (1987), Benovic and Lucic (1996) and Purcell *et al.* (1999). The most recent work of Benovic *et al.* (in preparation) will describe medusae in the middle and south Adriatic open waters.

DISCUSSION AND CONCLUSIONS

By quoting the entire list of published resources on hydromedusae in the Adriatic Sea we can clearly see that intensive research took place only during certain time periods, especially when large expeditions were organized. The historical record is therefore characterized by periodic publication of data collected for different aims, using different methods. The resulting record is so variable that the only consistent data that can be extracted through time are species names.

A comparative examination of records (Table 1) suggests that some inferences can be made about patterns of hydromedusan distributions. In the entire Adriatic Sea we recognize 66 species. There are differences between northern, middle and southern Adriatic populations. The indicator species are those that are present consistently through the time in a specific area and depths. Thus, their appearance in other regions probably indicates shift of water masses (Vucetic, 1969; Krcinic and Grbec, 2002). However, since the rare species appear very infrequently, it can be assumed that we missed them because of time gaps in research (Seguera-Puertas, 1992). An additional limitation of the intermittent hydromedusan record is that little or no evidence may be available around “bloom” events of various medusae.

Benovic *et al.* (1987) analyzed the hydromedusan fauna and environmental factors in the North Adriatic Sea. Based on comparisons of species composition from almost 100 years of research with recent data, they suggested that changes in environmental factors resulting from the discharge of terrigenous material by the northern Adriatic rivers probably caused changes in hydromedusan fauna and depletion of many species. In addition, they predicted that in the future environmental changes would take place on a large scale in the north Adriatic. Further papers (Degobbis *et al.*, 1995) dealing with blooms of plankton, mucilages and other disturbances in the North Adriatic that were published after 1987, confirmed those predictions.

Can a hydromedusa be an indicator species? Analyzing the list of species and trying to understand populations in different regions of the sea, Benovic and Lucic (1996) speculated about possible repopulations of the North Adriatic by species shifted from southern regions. Though some species appeared, they were in very small numbers, thus not having the potential to repopulate altered environment of the North Adriatic. These species can be considered as indicator species of some regions (Benovic *et al.*, in preparation), but they cannot serve as indicators of the entire environment.

In conclusion, studies of hydromedusae may be useful tools in Mediterranean ecosystem studies. However, only knowledge of entire populations can enable us to make predictions, even if weak and approximate.

Historical observations and knowledge about Hydromedusae of the Mediterranean Sea, as one of the oldest known marine ecosystems (Gili *et al.*, 1998), will contribute greatly to our current knowledge of hydromedusae, and their use as indicators. In all aquatic ecosystems, hydromedusae represent one of the oldest and most primitive of metazoan animal taxa (Buecher and Gibbons, 1999) : in their long time existence, they have developed populations that fit very specific niches in the vertical and horizontal sea horizons.

Table 1. Findings of hydromedusae of the Northern and Southern Adriatic Sea. Compilation of data from: **A**: Neppi, 1912; **B**: Neppi and Staisny, 1913; **C**: Neppi, 1922; **D**: Pell, 1938; **E**: Benovic, 1973; **F**: Benovic, 1976; **G**: Benovic and Bender, 1986; **H**: Benovic and Bender, 1987; **I**: Benovic and Lucic, 1995; **J & K**: Benovic and Lucic, 1996; **L**: middle and south Adriatic 2002 (see text).
(**+** indicates northern Adriatic and ***** indicates southern Adriatic).

SPECIES DATA	A	B	C	D	E	F	G	H	I	J	K	L
ANTHOMEDUSAE												
1. Dicodonium adriaticum		+			+							*
2. Dipurena halterata	+	+		*	+							
3. Sarsia gemmifera		+	*	*	+		+ *	+ *	+	+		
4. Stauridiosarsia producta		+			+							
5. Ectopleura dumortieri		+			+		+	+ *				
6. Eucodonium brownie	+	+	*		+							
7. Euphysa aurata	+*				+	*	+ *	+ *			*	
8. Rhabdoon singulare	+					*	+ *	+ *			*	*
9. Corymorpha nutans	+	+	*	*	+		+ *	+ *	+			*
10. Zanclea costata	+	+	*	*	+	*	+ *	+ *				*
11. Cladonema radiatum		+										
12. Eleutheria dichotoma		+										
13. Cytaeis tetrastyla	+		*	*	+							
14. Oceania armata			*	*			*	*				*
15. Turitopsis nutricula		+										
16. Podocoryne carnea		+	*		+							*
17. Podocoryne areolata		+						*				
18. Podocoryne minima					+		+ *	+ *	+	+		
19. Podocoryne minuta	+	+	*		+	*	+ *	+ *	+	+		*
20. Rhatkea octopunctata		+	*	*								
21. Bougainvillia ramosa	+*	+	*	*	+		*	+ *	+			
22. Koellikerina fasciculata			*	*								
23. Lizzia octostyla		+										
24. Lizzia blondina	+*	+			+			+				
25. Thamnostoma dibalia		+		*	+	*			+	+		
26. Amphinema dinema	+	+						+ *				*
27. Leuckartiara octona				*			*	+ *			*	*
28. Merga tergestina	+	+	*		+							
29. Neoturris pileata	*	+		*	+		+	+*				
30. Pandea sp.		+										
31. Protiara tetranema				*								
32. Bythotiara murrayi			*			*	*	*				

(Table 1: Cont.) **SPECIES** **DATA**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**
LEPTOMEDUSAE												
33. Orchistomella graeffei		+										
34. Krampella dubia							*	+ *				
35. Laodicea ocelata							*	*				
36. Laodicea undulata	+*	+	*			*	*	*			*	*
37. Melicertissa adriatica			*									
38. Mitrocoma annae			*									
39. Octogonade mediterranea				*								
40. Obelia spp.	+*	+	*	*	+	*	+ *	+ *	+	+	*	*
41. Clytia hemisphaerica	+*	+	*	*	+	*	+ *	+ *	+	+	*	*
42. Eucope picta		+		*								
43. Eucheilota maasi		+		*								
44. Octophialucium funerarium						*	*					*
45. Eirene viridula	*	+				*	*	*	+	+	*	
46. Helgicirrha schultzei		+	*		+		+ *	+ *	+			*
47. Eutima gegenbauri	+	+	*		+		+ *	+ *				
48. Eutima gracilis	+	*	*				+ *	+			*	
49. Eutonina scintillans		+										
50. Tima luculana	+											
51. Aequorea aequorea		+		*					+			
52. Proboscidactyla ornata	+*	+	*									
TRACHYMEDUSAE												
53. Haliscera bigelowi												*
54. Geryonia proboscidalis		+	*									*
55. Liriope tetraphylla	+*	+	*	*	+	*	+ *	+ *	+	+	*	*
56. Aglaura hemistoma	+*	+	*	*	+	*	+ *	+ *			*	*
57. Arctapodema australis				*			*	*				*
58. Homoeonema platygonon			*	*								
59. Persa incolorata					+	*	+ *	+ *			*	*
60. Rhopalonema funerarium				*			*	*			*	*
61. Rhopalonema velatum	+*	+	*		+	*	*	+ *			*	*
62. Sminthea eurygaster			*	*		*	*	*			*	*
NARCOMEDUSAE												
63. Solmundella bitentaculata	*		*			*	+ *	+ *			*	*
64. Solmaris spp.	+*	+	*		+	*	+ *	+ *	+	+	*	*
65. Cunina globosa			*									*
66. Solmissus albescens			*	*		*	*	*				*
TOTAL SPECIES	**25**	**41**	**31**	**27**	**27**	**18**	**31**	**35**	**14**	**9**	**15**	**28**