MONITORING AND ASSESSMENT OF THE ENVIRONMENTAL QUALITY OF TRANSITIONAL WATERS IN SICILY (ITALY)

Giancarlo Bellissimo, Francesca Galfo, Paolo Balistreri, Benedetto Sirchia

Abstract: Transitional waters represent high valuable wetlands characterized by extremely dynamic processes and irregular temporal trends. These coastal areas are vulnerable interface systems sensitive to natural and human pressures that cause a continuous environmental degradation and a consequential unbalance of the natural ecosystem. Monitoring plays a key role in the management of these ecosystems in order to prevent further deterioration and enhance the status of environmental quality. This paper aims to evaluate the ecological and chemical status of five Sicilian transitional waters systems (Oliveri-Tindari, Cape Peloro, Vendicari, Longarini-Cuba and Marsala) over a 3-year monitoring cycle according to the Water Framework Directive (WFD, 2000/60/EC). The water quality exhibited negative evidences since no water body monitored achieved the overall good environmental status assessed by different biological and chemical elements.

Keywords: WFD, transitional waters, environmental status, water quality, Sicily

Giancarlo Bellissimo, ARPA, Agenzia Regionale per la Protezione dell'Ambiente della Sicilia, Italy, gbellissimo@arpa.sicilia.it, 0000-0001-5287-6686
Francesca Galfo, ARPA Sicilia, Italy, fgalfo@arpa.sicilia.it
Paolo Balistreri, ARPA Sicilia, Italy, pbalistreri@arpa.sicilia.it
Benedetto Sirchia, ARPA, Agenzia Regionale per la Protezione dell'Ambiente della Sicilia, Italy, bsirchia@arpa.sicilia.it

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Introduction

Transitional waters, hereafter TWs, include all types of water bodies (WBs) which are brackish or hyperhaline at the boundary between terrestrial/freshwater and marine/coastal systems [4]. TWs are recognized as very complex systems characterized by weak hydrodynamics, shallow depth, limited size and high potential biodiversity around which numerous human activities revolve. Almost all of these ecosystems are subject to protection by several international conventions (e.g., Ramsar Convention) and directives (e.g., EU Birds Directive 2009/147/EC) and they are encoded as priority habitat type for conservation (1150 *Coastal lagoons*) under the EU Habitats Directive (92/43/EEC) because of their notable naturalistic value and ecological importance.

The European Water Framework Directive (WFD, 2000/60/EC) legally defines TWs the "bodies of surface water in the vicinity of river mouths which are partly saline in character as a result of their proximity to coastal waters but which are substantially influenced by freshwater flows" [10]. In the context of the WFD only five typologies of TWs are reported: delta, estuaries, lagoons, brackish lakes and coastal ponds. The WFD requires monitoring and assessment of the Ecological Status (ES) and Chemical Status (CS) in order to evaluate the Environmental Quality (EQ) of TWs. In accordance with the WFD, the ES is an expression of the quality of the structure and functioning of aquatic ecosystems associated with surface waters. In Italy, the ES is assessed using four Biological Quality Elements (BQEs, phytoplankton, macrophytes, benthic macroinvertebrates and fish faunal) and related indices that are adopted by the national law (MD 260/2010 and subsequent modifications and integration) in agreement with the WFD requirements. In particular, MPI (Multiparametric Phytoplankton Index), MAQI (Macrophyte Quality Index), M-AMBI (Multivariate-Azti Marine Biotic Index) and HFBI (Habitat Fish Bioindicator) are being regularly applying as monitoring tools for the Regional Agencies to assess the ecological quality of TWs [12]. Parallel, the WFD establishes the use of Supporting Quality Elements (SQEs) identified as chemical, physical-chemical and hydro-morphological quality elements that contribute to the ES classification, confirming or not the classification provided by the BQEs. The classification of a WB is based on the "one out-all out" principle, proposed by the WFD [9], meaning that the worst quality of any of the BQEs used in the assessment is sufficient to downgrade all of them. The ES provides a composite assessment in five quality classes, from High to Bad, based on the conditions of several BQEs and their deviation from a referenced WB.

The CS is determined via the monitoring of the priority substances in two matrices (water and sediment) established in the Environmental Quality Standards (EQSs) Directive 2008/105/EC (as amended by the Priority Substances Directive 2013/39/EU), transposed into the Italian legal system by LD 172/2015 (Table 1A and Table 2A). EQSs are limits on the concentration, expressed as maximum allowable concentration (MAC) and annual average (AA) of a chemical pollutant that must never be exceeded. The CS is represented by two quality classes (Good and Not Good) based on compliance with EQSs. The good CS is achieved when no concentrations of one or more priority substances exceed agreed standards. Finally,

the environmental quality (EQ) is determined combining the ES with the CS: the worst class quality of either one regulates the overall status. In particular, the good EQ is reached when the CS is good, and the ES is in at least a good status.

In Italy, TWs are divided according to MD 131/2008 into typologies identified on the basis of their geomorphology (coastal lagoons or river mouths), tidal range (>50 cm or <50 cm), total surface of the WB (>2.5 km^2 or between 0.5 km^2 and 2.5 km^2) and, finally, salinity (oligohaline <5 PSU; mesohaline between 5 PSU and 20 PSU; polyhaline between 20 PSU and 30 PSU; euhaline between 30 PSU and 40 PSU; hyperhaline >40 PSU). For the purposes of the classification under the WFD, three macrotypes of TWs have been defined according to the tidal and salinity (divided into two types: less than 30 PSU; greater than 30 PSU) range variation: two macrotypes for tidal systems and one macrotype for non-tidal systems (MD 260/2010 - Table 4.4/a).

In Sicily, TWs include brackish lakes, coastal ponds, lagoon-like coastal basins, mires, swamps and saltworks but only a few areas fall within the WFD-compliant monitoring requirements. Accordingly, in 2016 the last Management Plan of the Hydrographic District of Sicily selected five significant TWs systems (including thirteen WBs) in the framework of the institutional activities for the implementation of the Italian national legislation (LD 152/06) that acknowledges the WFD [3]. Here, we present the results of a 3-year monitoring cycle (2020-2022) in order to provide an update of the data and obtain the current evaluation of EQ of five Sicilian TWs systems.

Materials and Methods

All TWs systems monitored in this study (Fig. 1) fall into different protection regimes (e.g., Natural Oriented Reserves, Sites of Community Importance, Special Protection Zones, Important Bird Areas and International Important Wet Zones). They include non-tidal ecosystems of different typology from a geomorphological point of view and salinity (Table 1). In particular, two TWs systems fall within the WFD typologies (Oliveri-Tindari and Cape Peloro), while three are listed under typologies not included in the WFD. Specifically, the four WBs of Oliveri-Tindari (Marinello, Mergolo della Tonnara, hereafter Mergolo, Porto Vecchio and Verde) and the two WBs of Cape Peloro (Ganzirri and Faro) can be classified as coastal ponds and brackish lakes, respectively. The three WBs of Vendicari area (Piccolo, Grande and Roveto) can be classified as mires while the Longarini-Cuba wetland-complex ones (Cuba, Longarini 1 and Longarini 2) as swamp lakes. Stagnone di Marsala, hereafter Stagnone, represents the largest lagoon of Sicily characterized by hydrodynamic exchange with the adjacent open sea and it can be defined as a lagoon-like coastal basin. Their detailed description in terms of ecological and environmental features is given by [5, 11, 13]. However, according to the last Sicilian Management Plan, all thirteen WBs within the five transitional systems belong to the only typology "coastal lagoon", defined macrotype M-AT-1 *sensu* MD 260/2010, with a dimension lower than 2.5 km^2 with the exception of the Stagnone (about 20 km^2). A variable number of stations (1 or 2) for each WB was sampled in accordance with [12]. Due to the larger spatial extension of the Stagnone, six stations in three areas (northern, central and southern) were selected. At all

stations, surface water samples were collected monthly in each year and analysed for determination of priority substances (LD 172/2015 - Table 1/A). Physical-chemical parameters such as pH, temperature, salinity and dissolved oxygen were also obtained monthly by a multiparameter probe (Aquaread AM-200). Additional water samples were collected quarterly in each year for quantifying non-priority chemical substances (LD 172/2015 - Table 1B), phytoplankton, chlorophyll-*a* (Chl-*a*) and dissolved nutrients. The latters, including nitrogen as ammonium ($N\text{-}NH_3$), nitrites ($N\text{-}NO_2$) and nitrates ($N\text{-}NO_3$), summed and reported as dissolved inorganic nitrogen (DIN) and reactive phosphorus as orthophosphates ($P\text{-}PO_4$) were considered as representatives of the physical-chemical quality elements to support BQEs classification. According to MD 260/2010, thresholds for DIN are defined for two different salinity typologies: <30 PSU, including oligohaline, mesohaline and polyhaline WBs (threshold = 30 µM); >30 PSU, including euhaline and hyperhaline WBs (threshold = 18 µM). Currently, the threshold for $P\text{-}PO_4$ is set only for WBs with salinity >30 (threshold = 0.48 µM). The frequency of macrophyte and benthic macroinvertebrates monitoring was two seasonal samples (spring and autumn) in only one year over the studied period. Fish faunal was collected but it was not taken into account in the ES evaluation. A sediment sample was collected and analysed for quantifying priority and non-priority chemical substances (LD 172/2015 - Table 2/A and Table 3/B) from each WB in only one year over the studied period. Field and laboratory activities were performed according to the national protocol [12].

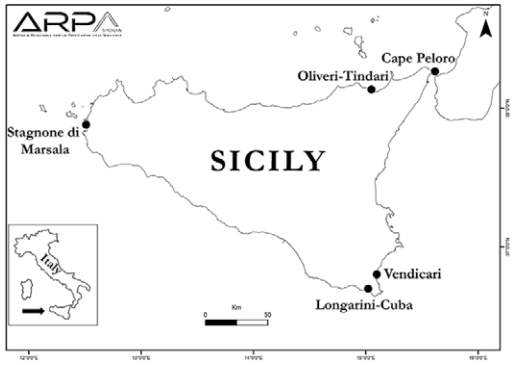

Figure 1 – The five Sicilian TWs systems monitored in this study.

Results

The monitored TWs systems cover all salinity classes, with a prevalence of eu-hyperhaline WBs (eight out the thirteen) and oligo-mesohaline (four out the thirteen), while only one WB was polyhaline (Table 1). The annual mean physical-chemical parameters of the water column are reported in Table 2. Among the supporting physical-chemical elements required for confirming the ES classification (Table 3), DIN concentrations exceeded the good/moderate threshold (i.e., in moderate status) set in MD 260/2010 (Table 4.4.2/a) in six out the thirteen WBs (Marinello, Ganzirri,

Piccolo, Grande, Longarini 1, and Cuba); the remaining seven WBs resulted below the good/moderate threshold (i.e., in good status). In particular, the NO_3 ions were predominant within the dissolved inorganic N (DIN=NH_4+NO_2+NO_3) pool of all the examined WBs. The annual mean concentrations of DIN (range 0.47÷113.26 μM) resulted beyond the threshold in Cuba, Longarini 1, Piccolo and Grande (the latter with values up to 6 times higher than the threshold). Marinello and Ganzirri showed the highest DIN concentrations in Oliveri-Tindari and in Cape Peloro, respectively. Differently, Stagnone was a nutrient-poor area referring to the lowest values of DIN detected in all three areas. The annual mean concentrations of P-PO_4 (range 0.02÷0.28 μM) resulted below the threshold in all WBs with the highest values in Longarini 2. The Chl-*a* mean concentration in all WBs showed a trophic gradient varying from oligotrophic (0.23±0.16 μgl^{-1} in southern Stagnone) to hypertrophic (55.67±106.74 μgl^{-1} in Ganzirri). Peak values of 47.87 and 311.87 μgl^{-1} were recorded in summer months in Roveto and in Ganzirri, respectively. Within the supporting chemical elements, non-priority substances analysed in all WBs resulted under the settled thresholds of MD 260/2010 (Table 4.5/a).

Four priority substances were found to be exceed the EQSs in eight WBs (Mergolo, Porto Vecchio, Faro, Grande, Longarini 1, Longarini 2, Cuba, and Stagnone). Particularly, mercury was detected only in water in seven out the thirteen WBs with values about 4 times higher than MAC-EQS in Mergolo and Longarini 1 (Table 4). In addition, lead occurred only in sediment in all three WBs of the Longarini-Cuba complex with values 4.5 times higher than AA-EQS in Longarini 2. DDE [2.4+4.4] was found in sediment in Longarini 2 and Cuba with values 2.5 and 2 times higher than AA-EQS, respectively. Lastly, tributyltin was found in sediment only in Stagnone with values up to 2.5 times higher than AA-EQS (Table 4). Hence, eight out the thirteen WBs were classified as "Not Good" (Mergolo, Porto Vecchio, Faro, Grande, Longarini 1, Longarini 2, Cuba and Stagnone) (Table 5).

Regarding the ES, nine out the thirteen WBs were classified as "Bad" and "Poor" (Marinello, Mergolo, Porto Vecchio, Verde, Grande, Roveto, and all WBs of the Longarini-Cuba complex), three as "Moderate" (Piccolo, Faro and Ganzirri) and one as "Good" (Stagnone). Finally, the overall EQ is resulted "Not Good" in all WBs (Table 5).

Discussion

No WB of the Sicilian TWs achieved the good environmental quality. The target set by the WFD, that all TWs should be in at least a good status by 2021 in its second management cycle, was therefore missed by a wide margin. Among the thirteen WBs monitored, the failure of the WFD goal is related to the CS and ES classification in eight and in five WBs, respectively. Specifically, the missing target was determined in seven WBs by both the ES and CS, in five WBs exclusively by the ES and in only one WB by the CS. These results state that the assessment of water quality was particularly critical because Sicilian TWs systems support both extreme fluctuations in environmental variables (e.g., salinity, temperature, dissolved oxygen, exchanges with the sea, and meteorological conditions) and anthropic activities that influence

directly and indirectly the biological communities, making these ecosystems high spatially and temporally heterogenous. Organic matter, depth, and salinity have been reported to be among the environmental variables that significantly affect spatial distribution of BQEs [7]. Moreover, the latters can be either sensitive to natural stressors and at the same time to increasing concentrations of nutrients or chemical substances making it difficult to distinguish a naturally stressed habitat from an anthropogenically stressed one. The cases of Oliveri-Tindari and Vendicari are emblematic. In spite of the pristine character of the areas, which are far from urban centres and are characterized by very low anthropogenic impact, the resulting ES is mainly driven by the low M-AMBI index values. This outcome can be explained by the fact that these areas are easily subject to dystrophic crises until reaching complete anoxia with the production of hydrogen sulfide and widespread deaths of species in all habitats present. Generally, this happens as a synergistic effect of a set of conditions, which occur during the summer season and in basins with shallow depths, such as high temperatures and water stagnation due to poor water exchange. Particularly, in some WBs it was not possible to apply the M-AMBI index since no benthic macroinvertebrates were detected. For instance, in Grande the community is likely to not have established over the monitored period, as this WB has a water supply linked to meteoric contributions and infiltrations of seawaters via a ducting system, up to dry up in the summer period. In Piccolo, the number of species detected was not suitable for the application of the index. The only species found was the gastropod *Pirenella conica* (Blainville, 1829) reported in the literature in a salinity range from 15-90 to 280 PSU [14]. Due to its wide tolerability range, it could be the only species to be present in the periods in which the two samplings were carried out in this WB which it is fed by a spring of freshwater and by the contribution of atmospheric precipitations. Similarly, low M-AMBI index values were recorded in the Longarini-Cuba complex. This transitional system is subject to natural stresses comparable to those of Oliveri-Tindari and Vendicari; however, this area is also influenced by pollution from diffuse sources (e.g. intensive agriculture, contaminated or abandoned industrial sites) as highlighted by the analysis of pressures and impacts of the last Sicilian Managment Plan. The presence of large quantities of toxic agricultural chemicals and artificial fertilisers together with illegal garbage dumps are likely to explain both DDE [2.4+4.4] and lead concentrations beyond the AA-EQS. In addition, the presence of these two chemical contaminants could have a direct impact on benthic communities. Macroinvertebrates are sensitive to an enrichment of organic substance and chemical pollution in water and sediment deriving from activities mainly linked to intensive and widespread agriculture [15]. The latter togheter with surface runoff of urban areas can determine nutrient enrichment altering the water quality and, therefore, an increase in the frequency and intensity of algal blooms, especially in the summer months. This fact was likely to cause the low MPI index values in Grande and Ganzirri where significant blooms of phytoplankton, validated by higher chlorophyll-*a* and DIN concentrations, were recorded. On the contrary, all WBs resulted above the MaQI moderate status with the exception of Mergolo where no sensitive macroalgal species, *sensu* MAQI, was detected, indicating a negligible probability of alteration of the functioning or the structure of the ecosystem due to nutrient enrichment [6]. The good or high

macrophyte ecological status was related to both the presence and high cover values of the seagrass *Cymodocea nodosa* (Ucria) Ascherson, in Porto Vecchio, Ganzirri and Stagnone, while the aquatic angiosperm *Ruppia maritima* Linnaeus contributed on its own to the good or high MaQI status in some WBs of Vendicari and Longarini-Cuba complex. Stagnone was the only WB exhibiting a good/high class of all biotic indeces confirming the previous ecological quality evaluation [3, 8]. However, according to "one out-all out" approach, this WB resulted in not good environmental status, because of the exceeding of AA-EQS for tributyltin (TBT), a class of organotin compounds widely used as a biocide in anti-fouling paints [2]. A similar outcome was recorded in seven WBs showing concentrations beyond the MAC-EQS for mercury that it is considered as one of the most serious contaminants entering the marine environment through a variety of sources, including atmospheric deposition, runoff from land, and industrial discharges [1]. TBT and mercury are among priority hazardous substances identified in the Priority Substances Directive as uPBT (ubiquitous, persistent, bioaccumulative and toxic).

Conclusions

According to the WFD, for those TW systems that did not achieve the good status, it is necessary to develop specific programs of measures to ensure the achievement of good status by the deadline extension to 2027 at the latest. Altough all WBs monitored in our study did not reach the WFD goal, being classified as "not good", it would be important to take into consideration the intrinsic features of each WB when considering these results. Moreover, caution is needed when the environmental quality is assessed by the "one out-all out" principle. One or more BQEs can appear to have a low or a moderate correlation with various stressors, thus leading to a misclassification of the overall status. Finally, a revision of analysis of pressures and a long-term monitoring are required in the management plans aimed at protecting or reclaiming these extremely important environments from both a naturalistic and productive point of view.

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Table 1 – Sicilian TW(s) systems with indications of each Water Body (WB) and its code, identified by the Management Plan of the Hydrographic District of Sicily, typology, geographical references and salinity typology.

TW(s) systems	WB	WB code	Typology	Geographical references (Latitude – Longitude)		WB type* (Salinity)
Oliveri-Tindari	Marinello	IT19TW011313	Coastal ponds	38°08'11"N	15°03'15"E	Euhaline
	Mergolo	IT19TW011315	Coastal ponds	38°08'22"N	15°03'08"E	Polyhaline
	Porto Vecchio	IT19TW011299	Coastal ponds	38°08'30"N	15°03'11"E	Euhaline
	Verde	IT19TW011314	Coastal ponds	38°08'36"N	15°02'53"E	Euhaline
Cape Peloro	Faro	IT19TW001297	Coastal lakes	38°16'06"N	15°38'12"E	Euhaline
	Ganzirri	IT19TW102296	Coastal lakes	38°15'38"N	15°36'59"E	Euhaline
Vendicari	Piccolo	IT19TW085306	Mires	36°48'43"N	15°06'15"E	Hyperhaline
	Grande	IT19TW085305	Mires	36°48'22"N	15°05'54"E	Euhaline
	Roveto	IT19TW085269	Mires	36°47'18"N	15°05'23"E	Mesohaline
Longarini-Cuba	Longarini 1	IT19TW084268	Swamp lake	36°42'33"N	15°00'01"E	Mesohaline
	Longarini 2	IT19TW084267	Swamp lake	36°42'45"N	15°00'30"E	Mesohaline
	Cuba	IT19TW084266	Swamp lake	36°42'24"N	15°01'39"E	Mesohaline
Marsala	Stagnone	IT19TW052302	Coastal lagoon	37°52'22"N	12°27'51"E	Hyperhaline

*Salinity types resulted over the 3-year monitoring period.

Table 2 – Physical-chemical parameters (pH; water temperature, T; salinity, S; dissolved oxygen, DO) expressed as 3-years mean values and range variation (minimum-maximum) in each Water Body (WB); ±s.d. = standard deviation; I.D.L. = Instrument Detection Limit (70 PSU).

WB	Mean pH	Min. pH	Max. pH	Mean T (°C)	Min. T (°C)	Max. T (°C)	Mean S (PSU)	Min. S (PSU)	Max. S (PSU)	Mean DO (%)	Min. DO (%)	Max. DO (%)
Marinello	8.23± 0.05	8.02	8.65	22.6± 0.5	10.3	34.0	31.21± 0.43	15.68	36.85	126.6± 12.3	94.5	184.4
Mergolo	8.04± 0.05	7.82	8.26	21.5± 0.3	9.5	33.4	28.06	22.68	32.52	113.2± 0.4	101.9	125.8
Porto Vecchio	8.11± 0.01	7.86	8.33	22.9± 0.4	10.8	35.4	35.66	32.59	38.78	120.0± 0.7	104.4	142.6
Verde	8.29± 0.08	7.33	8.64	22.1± 0.3	8.8	34.0	33.65	22.73	36.55	128.1± 8.7	97.8	204.2
Faro	8.10± 0.03	7.74	8.53	21.7± 0.2	12.3	30.6	35.85± 0.24	34.29	37.45	117.2± 2.7	91.6	154.9
Ganzirri	8.24± 0.04	7.85	8.96	21.2± 0.2	9.3	31.5	31.98± 0.60	29.35	35.34	117.6± 1.1	38.0	197.3
Piccolo	8.22	7.87	8.62	21.7	12.6	31.3	41.76	18.71	>I.D.L.	109.7	91.6	144.1
Grande	8.39	8.11	8.86	22.2	11.9	33.1	34.66	11.29	64.26	132.9	102.2	203.2
Roveto	8.53	8.22	9.26	21.5	11.4	32.2	18.63	4.18	>I.D.L.	126.3	105.0	171.8
Longarini 1	9.11± 0.23	8.55	10.11	21.4± 0.1	12.8	32.7	10.21± 0.45	3.62	21.25	145.2± 2.7	113.2	188.2
Longarini 2	8.48± 0.27	8.03	8.98	21.1± 0.5	13.1	30.5	20.11± 1.77	7.87	66.84	114.0± 12.9	84.0	144.9
Cuba	8.69± 0.01	8.22	9.33	19.9± 0.4	11.4	28.3	10.34± 0.66	5.09	31.41	114.7± 1.9	100.4	134.2
northern Stagnone	8.32± 0.01	7.92	8.65	21.8± 0.6	10.4	32.1	38.72± 0.65	36.61	44.24	114.3± 10.6	94.0	187.0
central Stagnone	8.37± 0.05	7.99	8.80	21.2± 0.3	10.0	32.1	41.38± 0.30	36.55	48.61	114.3± 1.3	96.7	143.9
southern Stagnone	8.33± 0.06	7.84	8.86	20.8± 0.1	9.9	30.5	40.23± 1.32	35.63	47.85	111.9± 2.8	101.5	126.6

Table 3 – Trophic parameters (DIN, P-PO_4, Chl-*a*) expressed as 3-years mean values and range variation (minimum-maximum) in each Water Body (WB); ±s.d. = standard deviation. *Mean values of two samplings during the year: the swamps were dry in August and in November.

WB	Mean DIN (µM)	Min. DIN (µM)	Max. DIN (µM)	Mean P-PO_4 (µM)	Min. P-PO_4 (µM)	Max. P-PO_4 (µM)	Mean Chl-*a* (μgl^{-1})	Min. Chl-*a* (μgl^{-1})	Max. Chl-*a* (μgl^{-1})
Marinello	32.33± 61.09	3.81	181.54	0.02	0.02	0.02	1.62± 0.99	0.03	3.00
Mergolo	19.45± 15.58	6.95	43.69	0.02	0.02	0.02	1.29± 0.59	0.55	2.08
Porto Vecchio	13.13± 11.97	0.53	36.54	0.03± 0.03	0.02	0.10	0.69± 0.55	0.20	1.44
Verde	13.59± 12.83	1.53	37.16	0.03± 0.03	0.01	0.09	2.83± 2.16	0.52	6.26
Faro	16.47± 13.04	3.44	40.11	0.22± 0.28	0.01	0.88	1.45± 0.99	0.39	3.06
Ganzirri	24.05± 32.39	1.13	93.14	0.09± 0.12	0.02	0.34	55.67± 106.74	1.25	311.87
Piccolo	77.7± 85.20	13.59	202.20	0.11± 0.09	0.02	0.23	7.25± 4.93	0.79	12.39
Grande	106.87± 94.01	7.72	211.90	0.06± 0.06	0.02	0.14	9.23± 12.13	1.70	27.35
Roveto	22.82± 26.29	5.54	61.78	0.06± 0.04	0.02	0.09	24.59± 26.36	0.72	47.87
Longarini 1	113.26± 163.89	0.60	348.38	0.13± 0.16	0.02	0.36	0.84± 1.49*	0.35	1.49
Longarini 2	25.25± 34.67	2.06	88.52	0.28± 0.26	0.02	0.63	8.17± 13.84*	1.72	13.84
Cuba	39.73± 31.05	2.14	76.95	0.06± 0.05	0.02	0.12	2.39± 3.14*	0.60	7.97
northern Stagnone	7.09± 7.24	1.19	22.83	0.03± 0.02	0.02	0.06	0.30± 0.27	0.02	0.84
central Stagnone	12.55± 16.31	1.29	48.57	0.03± 0.02	0.02	0.06	0.28± 0.13	0.09	0.47
southern Stagnone	4.32± 4.32	0.47	11.92	0.04± 0.03	0.02	0.08	0.23± 0.16	0.03	0.49

Table 4 – Concentration values of priority substances that exceeded the maximum allowable concentration (MAC) and the annual average (AA) of the Environmental Quality Standard (EQS) in water and sediment in each Water Body (WB), respectively.

WB	Matrix	Priority substance [conc.]	Value	MAC- EQS	AA- EQS
Mergolo	water	Mercury [µg/l]	0.20	0.07	
Mergolo			0.26		
Porto Vecchio			0.16		
Faro			0.19		
Grande			0.21		
Longarini 1			0.16		
			0.19		
			0.08		
			0.28		
Cuba			0.14		
			0.13		
			0.12		
Stagnone			0.15		
Longarini 1	sediment	Lead [mg/kg]	37		30
Longarini 2		Lead [mg/kg]	137		30
Longarini 2		DDE [2.4+4.4] [µg/kg]	4.6		1.8
Cuba		Lead [mg/kg]	123		30
Cuba		DDE [2.4+4.4] [µg/kg]	3.5		1.8
Stagnone		Tributyltin [µg/kg]	11.5		5.0
			10.8		
			12.6		
			11.4		

Table 5 – Ecological Status (ES), Chemical Status (CS) and Environmental Quality (EQ) of the Sicilian transitional Water Bodies (WBs).

WB	EQB/Index			ES	CS	EQ
	Macroinvertebrates/ (M-AMBI)	Phytoplankton/ (MPI)	Macrophyte/ (MaQI)			
Marinello	Bad	High	Moderate	Bad	Good	Not Good
Mergolo	Moderate	Good	Poor	Poor	Not Good	Not Good
Porto Vecchio	Bad	High	Good	Bad	Not Good	Not Good
Verde	Poor	Good	Moderate	Poor	Good	Not Good
Faro	Good	Good	Moderate	Moderate	Not Good	Not Good
Ganzirri	Moderate	Moderate	Good	Moderate	Good	Not Good
Piccolo	*[a]	Moderate***	Moderate	Moderate	Good	Not Good
Grande	*[b]	Poor	Moderate	Poor	Not Good	Not Good
Roveto	Bad	Poor	Good	Bad	Good	Not Good
Longarini 1	Poor	Moderate**	High	Poor	Not Good	Not Good
Longarini 2	Bad	Poor**	Moderate	Bad	Not Good	Not Good
Cuba	Bad	Poor**	High	Bad	Not Good	Not Good
Stagnone	Good	High	High	Good	Not Good	Not Good

*Judgment not available: a) the number of species found is not suitable for the application of M-AMBI index, b) absence of evaluable *taxa*.
**Indicative judgment: the MPI index was calculated only three times during the year and not four, the swamps were dried up.
***Indicative judgment: the MPI index was calculated but it is not applicable for the purposes of classification, the mire is hyperhaline.

Table 6 – List of taxa of each Biological Quality Element (macroinvertebrates, phtytoplankton, macrophytes) from the Sicilian transitional Water Bodies.

Taxa	Marinello	Mergolo	Porto Vecchio	Verde	Faro	Ganzirri	Piccolo	Grande	Roveto	Longarini 1	Longarini 2	Cuba	Stagnone
Macroinvertebrates													
Annelida													
Abyssoninoe sp.		+											
Amphitrite cirrata													+
Aphelochaeta marioni													+
Aricidea fragilis mediterranea													+
Aricidea mediterranea													+
Aricidea wassi													+
Capitella capitata					+	+							
Capitella giardi													+
Caulleriella bioculata													+
Ceratonereis costae						+							
Chaetozone gibber													+
Cirratulidae					+								
Cirriformia tentaculata					+	+							
Cirrophorus furcatus													+
Diopatra neapolitana													+
Dorvillea sp.													+
Eunereis longissima					+								+
Euclymene oerstedii					+								+
Glycera alba					+	+							
Glycera sp.						+							
Glyceridae					+								
Hediste diversicolor									+	+	+		
Heteromastus filiformis	+				+	+							
Hydroides elegans					+								
Lanice conchilega						+							+
Leodice antennata					+								
Linopherus canariensis					+								
Lumbrineris coccinea		+			+								+
Lumbrineris latreilli		+	+		+								+
Lumbrineris sp.													+
Lysidice ninetta													+
Maldane glebifex													+
Maldane sarsi													+
Maldanidae													+
Maldanidae indet.													+
Melinna monoceroides													+
Melinna palmata													+
Naineris laevigata	+	+	+	+	+	+							
Naineris sp.	+	+	+	+	+	+							+
Neoamphitrite sp.					+								
Nephtys hombergii													+

Taxa	Marinello	Mergolo	Porto Vecchio	Verde	Faro	Ganzirri	Piccolo	Grande	Roveto	Longarini 1	Longarini 2	Cuba	Stagnone
Nereiphylla rubiginosa		+											
Notomastus latericeus					+								+
Oligochaeta	+			+									
Orbinidae		+	+	+									
Orbinidae indet.	+	+	+		+	+							
Paradoneis lyra		+	+	+	+	+							
Parapionosyllis sp.						+							
Phylo foetida					+	+							+
Phylo ligustica					+	+							
Phylo norvegica						+							+
Phylo sp.													+
Pista cretacea						+							+
Platynereis dumerilii					+	+							+
Polychaeta indet.			+		+	+							
Polycirrus haematoides		+											
Prionospio cirrifera					+	+							
Pseudopolydora antennata					+								
Pseudopotamilla reniformis					+								
Scoloplos armige						+							
Scoloplos sp.													+
Streblosoma sp.					+								
Syllidae													+
Syllis prolifera		+	+	+		+							
Syllis sp.		+		+									+
Arthropoda													
Ammothella longipes													+
Ampelisca sp.													+
Aoridae			+		+	+							+
Apseudopsis latreillii													+
Brachynothus sexdentatus						+							
Caprellidae													+
Chironomidae										+			
Chondrochelia savignyi					+								
Apocorophium acutum					+								+
Monocorophium insidiosum				+		+							
Corophium sp.	+	+		+	+	+							
Cyathura carinata					+								+
Cymodoce truncata					+								+
Elasmopus rapax					+	+							
Elasmopus sp.						+							+
Erichtonius punctatu					+								
Ericthonius sp.		+											+
Gammarella fucicola					+	+							
Gammarus equicauda										+	+		
Gammarus insensibilis						+				+	+	+	
Gilvossius tyrrhenus													+

Taxa	Marinello	Mergolo	Porto Vecchio	Verde	Faro	Ganzirri	Piccolo	Grande	Roveto	Longarini 1	Longarini 2	Cuba	Stagnone
Grandidiriella japonica						+							
Hippomedon massiliensis													+
Idotea balthica						+							
Lysianassina longicornis													+
Microdeutopus gryllotalpa						+							
Microdeutopus sp.						+							
Paguristes eremita													+
Paguristes sp.													+
Paguristes syrtensis													+
Paracerceis sculpta					+								
Perioculodes aequimanus													+
Sphaeroma serratum				+									
Cnidaria													
Actiniaria					+	+							+
Echinodermata													
Amphipholis squamata		+			+	+							+
Asterina gibbosa													+
Mollusca													
Abra segmentum	+	+		+									+
Abra sp.													+
Alvania sp.													+
Cerastoderma glaucum	+		+	+		+						+	
Cerastoderma sp.	+												
Cerithium sp.		+	+		+								+
Cerithium vulgatum			+		+								+
Columbella rustica													+
Conus ventricosus													+
Ecrobia ventrosa				+		+			+	+	+	+	
Euspira intricata													+
Gastrana fragilis			+		+	+							
Gibberula miliaria					+								
Steromphala adansonii					+	+							
Gibbula sp.													+
Glans trapezia			+	+									
Hamionea hydatis						+							
Hexaplex trunculus		+			+	+							+
Loripes orbiculatus		+	+		+	+							+
Mytilaster marioni		+											
Natica stercusmuscarum													+
Odostomia sp.													+
Papillicardium papillosum					+								
Parvicardium exiguum		+	+										+
Pirenella conica							+						
Polititapes aureus			+		+	+							+
Retusa truncatula													+
Rissoa sp.													+

Taxa	Marinello	Mergolo	Porto Vecchio	Verde	Faro	Ganzirri	Piccolo	Grande	Roveto	Longarini 1	Longarini 2	Cuba	Stagnone
Ruditapes decussatus			+	+	+	+							+
Tricolia sp.													+
Tritia coriculum						+							
Tritia cuvierii					+								+
Tritia mutabilis													+
Tritia neritea	+	+		+		+							
Tritia tinei					+	+							
Turbonilla sp.													+
Veneridae				+									
Vexillum sp.													+
Nematoda													
Nematoda	+			+									
Phytoplankton													
Bacillariophyta													
Achnanthes cf. *longipes*	+			+									
Achnanthes longipes									+				+
Achnanthes sp.					+	+							
Amphora sp.p.	+	+	+	+	+	+	+	+					+
Bacillaria paxillifera													+
Undetermined Bacillariales					+	+							+
Undetermined Bacillariophyceae	+	+	+					+	+	+	+		+
Undetermined Bacillariophyta					+	+							+
Bacteriastrum sp.			+										+
Caloneis sp.					+	+							+
Cerataulina pelagica					+	+							+
cf. *Pseudo-nitzschia*		+	+										
Chaetoceros danicus					+								
Chaetoceros decipiens					+								
Chaetoceros simplex					+	+							
Chaetoceros socialis						+							
Chaetoceros sp.p.		+	+	+	+	+	+	+	+			+	+
Chaetoceros tenuissimus					+	+							
Chaetoceros throndsenii						+							
Climacosphenia moniligera	+		+	+	+	+							+
Cocconeis scutellum		+	+	+	+	+	+	+	+			+	+
Cocconeis sp.p.										+	+		+
Coscinodiscus sp.p.		+			+	+							
Cyclotella sp.						+							
Cylindrotheca closterium	+	+	+	+	+	+	+	+	+	+	+	+	+
Cymbella sp.					+								+
Dactyliosolen blavyanus					+								+
Dactyliosolen fragilissimus					+	+							
Diploneis sp.p.	+		+	+	+	+				+	+		+
Ditylum brightwellii					+								
Entomoneis alata													+

Taxa	Marinello	Mergolo	Porto Vecchio	Verde	Faro	Ganzirri	Piccolo	Grande	Roveto	Longarini 1	Longarini 2	Cuba	Stagnone
Entomoneis sp.p.	+	+				+	+	+	+		+	+	+
Fragilaria sp.													+
Grammatophora marina													+
Grammatophora sp.													+
Guinardia flaccida													+
Guinardia striata	+												+
Gyrosigma sp.													+
Haslea sp.		+			+								
Hemidiscus cuneiformis									+			+	
Leptocylindrus danicus					+								+
Leptocylindrus minimus			+										
Leptocylindrus sp.p.		+	+		+								
Licmophora flabellata	+		+										+
Licmophora gracilis													+
Licmophora sp.p.	+		+	+	+	+							+
Navicula sp.p.	+	+	+	+	+	+	+	+	+	+	+	+	+
Undetermined Naviculaceae	+	+				+	+	+		+	+	+	+
Nitzschia longissima					+							+	+
Nitzschia sigma	+	+	+				+	+					+
Nitzschia sp.p.	+	+	+	+	+	+	+	+	+	+	+	+	+
Nitzschiella sp.						+							
Paralia sulcata	+												
Pleurosigma sp.p.	+	+	+	+	+	+	+	+	+	+	+	+	+
Podosira sp.		+			+								
Proboscia alata			+										
Pseudo-nitzschia galaxiae					+								
Pseudo-nitzschia multistriata					+								
Pseudo-nitzschia sp.p.	+	+	+	+	+		+	+	+	+	+	+	+
Pseudo-nitzschia sp.p. of the *Nitzschia delicatissima* complex	+	+	+		+	+							+
Rhizosolenia minima						+							
Skeletonema sp.p.					+								
Striatella unipunctata					+	+							+
Surirella sp.												+	
Synedra sp.p.	+	+	+	+	+	+					+	+	+
Tabellaria fenestrata													+
Tenuicylindrus belgicus					+								
Thalassionema frauenfeldii		+											+
Thalassionema nitzschioides					+	+							
Thalassiophysa hyalina					+	+							+
Thalassiosira sp.p.		+											
Toxarium undulatum	+		+	+									+
Charophyta													
Staurastrum sp.					+								
Chlorophyta													
Cymbomonas sp.					+								

Taxa	Marinello	Mergolo	Porto Vecchio	Verde	Faro	Ganzirri	Piccolo	Grande	Roveto	Longarini 1	Longarini 2	Cuba	Stagnone
Pachysphaera sp.						+							
Undetermined Pyramimonadophyceae	+	+	+	+	+	+		+			+		+
Ciliophora													
Mesodinium rubrum	+		+		+	+							+
Cryptophyta													
Undetermined Cryptophyceae	+	+	+	+	+	+	+	+	+	+	+	+	+
Euglenozoa													
Euglena sp.p.			+	+		+							+
Undetermined Euglenida	+	+	+		+								+
Eutreptia sp.p.		+											+
Eutreptiella sp.p.			+		+	+							+
Katablepharidophyta													
Leucocryptos marina	+	+	+	+	+	+							+
Miozoa													
Akashiwo sanguinea	+	+	+	+	+								+
Alexandrium sp.p.			+	+	+								+
Amphidinium carterae		+											
Amphidinium sp.p.		+			+	+							+
Amphidoma sp.					+								
Cochlodinium sp.p.	+	+	+	+	+								+
Cucumeridinium coeruleum	+				+								
Undetermined Dinophyceae	+	+	+	+	+	+	+	+	+	+	+	+	+
Diplopsalis sp.p.	+	+		+		+							+
Gonyaulax sp.p.		+	+	+	+	+							+
Undetermined Gymnodiniales	+	+	+	+	+	+	+	+	+		+	+	+
Gymnodinium sp.p.	+	+	+	+	+	+	+	+					+
Gyrodinium fusiforme		+	+		+	+							
Gyrodinium sp.p.	+	+	+	+	+	+							+
Heterocapsa sp.p.					+	+							+
Karenia papilionacea					+								
Karlodinium veneficum	+			+									
Kofoidinium velleloides													+
Lebouridinium glaucum	+				+	+							
Oxyrrhis marina						+						+	
Oxytoxum sceptrum													+
Oxytoxum sp.					+								+
Undetermined Peridiniales	+	+	+	+	+	+	+	+	+		+	+	+
Peridinium quadridentatum					+	+							
Phalacroma oxytoxoides					+								
Polykrikos kofoidii						+							
Polykrikos sp.	+		+										+
Pronoctiluca pelagica													+
Prorocentrum cordatum						+							
Prorocentrum gracile	+					+							+
Prorocentrum lima													+

Taxa	Marinello	Mergolo	Porto Vecchio	Verde	Faro	Ganzirri	Piccolo	Grande	Roveto	Longarini 1	Longarini 2	Cuba	Stagnone
Prorocentrum mexicanum					+								
Prorocentrum micans	+	+	+			+							+
Prorocentrum scutellum	+	+	+	+	+	+							+
Prorocentrum sp.p.	+	+	+	+	+	+							+
Prorocentrum triestinum					+	+							+
Protoceratium sp.													+
Protoperidinium cf. *elegans*													+
Protoperidinium divergens	+												
Protoperidinium sp.p.	+	+	+		+	+							+
Protoperidinium tuba					+								
Pyrophacus sp.						+							
Pyrophacus steinii						+							
Scrippsiella acuminata	+	+		+	+	+	+	+					+
Scrippsiella sp.p.													+
Torodinium robustum	+												
Tripos extensus		+											
Ochrophyta													
Dinobryon sp.					+	+							
Undetermined Raphidophyceae	+	+	+	+	+	+	+	+	+	+	+	+	+
Other undetermined phytoplankton	+	+	+	+	+	+	+	+	+	+	+	+	+
Macrophytes													
Chlorophyta													
Aegagropila linnaei													+
Anadyomene stellata													+
Caulerpa cylindracea	+		+										
Caulerpa prolifera													+
Chaetomorpha linum	+	+	+	+	+	+							+
Cladophora albida													+
Cladophora fracta		+											
Cladophora lehmanniana	+												
Cladophora vadorum													+
Cladophora vagabunda	+	+		+		+							
Halimeda tuna													+
Leptosiphonia brodiei													+
Lychaete echinus													+
Ulva laetevirens					+								
Ulva paradoxa	+					+							
Valonia utricularis													+
Ochrophyta													
Cystoseira compressa													+
Cystoseira foeniculacea f. *tenuiramosa*													+
Cystoseira schiffneri													+
Dictyota implexa													+

Taxa	Marinello	Mergolo	Porto Vecchio	Verde	Faro	Ganzirri	Piccolo	Grande	Roveto	Longarini 1	Longarini 2	Cuba	Stagnone
Dictyota mediterranea													+
Gongolaria barbata													+
Hincksia mitchelliae					+								+
Sphacelaria fusca													+
Rhodophyta													
Anotrichium tenue													+
Carradoriella denudata					+								
Ceramium diaphanum													+
Ceramium siliquosum v. *elegans*					+	+							
Chondria capillaris	+												
Chroodactylon ornatum	+												+
Colaconema leptonema													+
Corallina officinalis					+								
Gayliella flaccida	+												
Gelidium crinale					+								
Gymnogongrus griffithsiae					+								
Hydrolithon farinosum													+
Hypnea cornuta					+	+							
Lophosiphonia obscura													+
Palisada patentiramea													+
Peyssonnelia squamaria													+
Polysiphonia breviarticulata	+												+
Polysiphonia scopulorum													+
Rytiphlaea tinctoria													+
Spongites fruticulosus													+
Spyridia filamentosa					+								+
Tracheophyta													
Cymodocea nodosa			+	+	+	+							+
Posidonia oceanica													+
Ruppia maritima	+		+										