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HYDROCHEMICAL CHARACTERIZATION AND TYPIFICATION OF PONDS IN A SEMI-ARID REGION OF SOUTHEASTERN SPAIN (MURCIA)

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ABSTRACT

A catalogue of aquatic ecosystems has been made for Murcia, a region located in semi-arid southeastern Spain, where those systems show a high degree of variability in their chemical, physical and biological characteristics. One of the most variable of these aquatic ecosystems was the ponds. To classify the ponds and develop better management strategies, a survey was undertaken of physico-chemical and biological characteristics of 25 ponds. The results showed the ponds could be divided into 4 groups on the basis of ionic composition. Nutrient (NO_3^- and PO_4^{3-}) and chlorophyll a concentrations also allowed classification of the ponds on the basis of trophic status. The combination of these different patterns along with the geographic location of the source of incoming water explained the hydrochemical composition of the ponds.

INTRODUCTION

At present, wetlands are a subject of much interest particularly with respect to their management and conservation (Maltby 1986; Mitsch and Gosselink 1986; Hook et al. 1988a, 1988b; McComb and Lake 1988). However, very little is known about structure, function, evolution and succession of those ecosystems, possibly because of their environmental complexity (Gonzalez-Bernaldez 1988). As a first step toward assessing and managing wetlands in Spain, 74 wetlands in the Murcia Region of southeastern Spain were studied in 1989 and classified into 11 types based upon abiotic and biotic factors and uses (Ramirez-Diaz 1989). In general, these wetlands are small systems, characterized by extreme and fluctuating conditions.

One of these wetland types is the ponds, which are so environmentally diverse as to warrant further study and classification. Although there is a tendency to consider that size confers importance to a water body, in semi-arid and arid regions small wetlands (ponds, coastal lagoons, etc.) are valuable resources because they provide a temporary or permanent water supply. The ponds also play an important role in the development and support of agriculture and cattle raising (Probert 1989) and more are being created in order to favour, for example, the conservation of amphibian populations (Maltby 1986).

In this paper, some aspects concerning ionic composition and nutrients in the ponds of Murcia Region are analyzed and discussed.

STUDY AREA

The 25 study ponds are located in the Murcia Region, of southeastern Spain (Figure 1 and Table 1): five are on the coast and the rest are inland. The climate is typically mediterranean. For the inland ponds, average annual rainfall is less than 300 mm, average annual temperature is about 17°C, and evapotranspiration exceeds precipitation for 8 or 9 months each year. The coastal ponds are directly influenced by the Mediterranean Sea, with average annual rainfall about 300 mm, average annual temperature greater than 17°C, and average minimal annual temperature between 11 and 12°C.

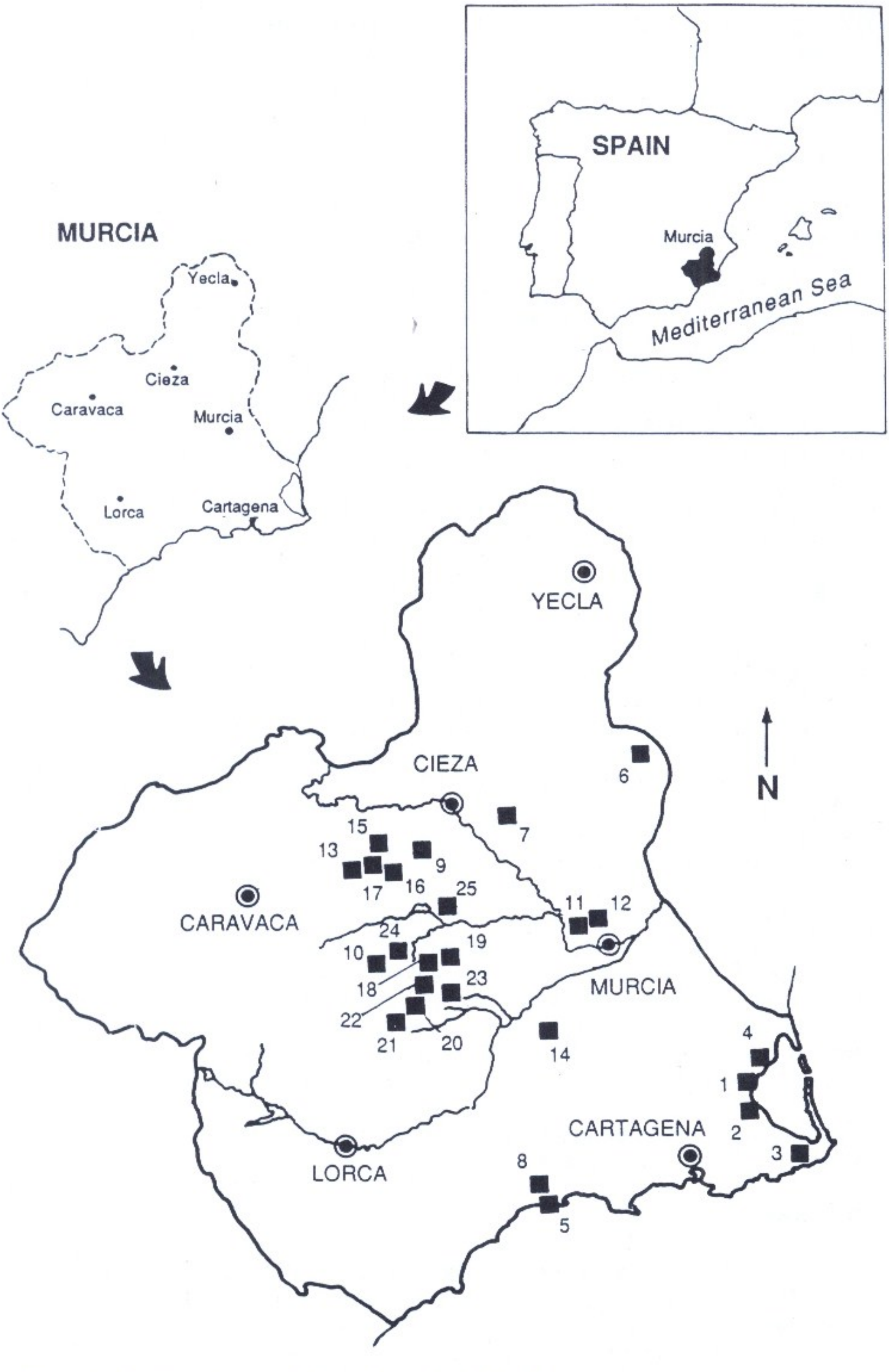

Figure 1. Location of the ponds. The numbers refer to Table 1.

Table 1. Physical characteristics and use of 25 ponds in the Murcia Region, Spain.

Name	Area m^2	Depth cm	Altitude m	Permanence	Description	Origin	Substrate	Impacts
1 Carmoli	350	50	0	Permanent	Coastal pond	S.N	1	Non-impacted
2 Lo Pollo	2500	40	0	Temporal	Coastal pond	S.N	1	Non-impacted
3 Calblanque	30	30	0	Permanent	Coastal pond	M-m	1	Non-impacted
4 Punta Galera	100	20	0	Permanent	Coastal pond	S.N	1	Non-impacted
5 Rambla Moreras	30000	200	0	Permanent	Coastal pond	N	1	Receives sewage from campground
6 Saladar Chicamo	3	50	140	Temporal	Inland pond	N	1	Non-impacted
7 Venta Punales	400	20	200	Temporal	Inland pond	M-m	1	Sewage from household
8 Gravel-pit Moreras	40000	75	30	Permanent	Gravel-pit	M-m	1	Receives sewage from treatment plant
9 La Bermeja	7	50	450	Temporal	Inland pond	S.N	1	Waste
10 Casa Bulleros I	60	10	460	Temporal	Inland pond	S.N	2	Livestock drinking water
11 Los Conejos I	7	50	120	Permanent	Inland pond	M-m	1	Non-impacted
12 Los Conejos II	28	30	120	Temporal	Inland pond	S.N	5	Livestock drinking water
13 Carpinteros	200	50	370	Temporal	Inland pond	N	3	Livestock drinking water
14 Carrascoy	30	50	1000	Permanent	Inland pond	M-m	1	Livestock drinking water
15 Casa del Ramel	300	100	350	Temporal	Inland pond	S.N	2	Livestock drinking water
16 Casa la Parra	2000	100	380	Temporal	Inland pond	S.N	2	Livestock drinking water
17 Casa Hita	80	30	470	Temporal	Inland pond	S.N	4	Livestock drinking water
18 Lacuas I	2000	100	440	Permanent	Inland pond	S.N	3	Non-impacted
19 Lacuas II	200	100	440	Temporal	Inland pond	S.N	2	Non-impacted
20 Los Chorrillos	100	50	640	Temporal	Inland pond	S.N	2	Livestock drinking water
21 Malvariche	100	50	540	Temporal	Inland pond	M-m	2	Livestock drinking water
22 El Barbo	300	15	460	Temporal	Inland pond	M-m	2	Non-impacted
23 Finca Barbol	400	100	840	Permanent	Inland pond	M-m	2	Non-impacted
24 Casa Bulleros II	90	75	460	Temporal	Inland pond	M-m	2	Livestock drinking water
25 Yechar	300	70	280	Permanent	Inland pond	S.N	3	Livestock drinking water

Origin - N: Natural; M-m: Man-made; S.N: Natural but area/depth increased by dredging.

Substrate - 1: sand, gravel, stones. alluvial, and clay; 2: clay; 3: marly clay; 4: marl; 5: gypsum marl.

All the ponds types are small (surface area < 2500 m^2), except ponds 5 and 8, which have surface areas of 30000 and 40000 m^2, respectively. Maximum depth does not exceed 2 m (Table 1).

The inland ponds are underlain by limestone and impermeable marl and are not normally connected with groundwater flow. As a result, they tend to be temporary water systems (Table 1). The coastal ponds lie on sedimentary material; some of them isolated by a barrier of sand. These ponds are permanent and are influenced by groundwater flow.

MATERIAL AND METHODS

Water samples were collected at midday from the water surface of each pond once in the winter and once summer of 1989 (dates are indicated in Table 2). However, due to the small size of the ponds and their temporary nature, it was difficult to collect water samples during both seasons for each pond. Thus, summer and winter data are only available for 11 ponds.

A total of 15 physico-chemical parameters and 1 biological parameter were measured. pH, water temperature and salinity were measured *in situ* using a pH-meter (CRISON 2001), thermometer (Mortimer 1953), and conductivity meter-Spectronic-20, respectively. Dissolved oxygen concentrations were determined following the Winkler method (Carpenter 1966). Alkalinity, calcium, and magnesium were analyzed following the methods of Golterman et al. (1987). Hardness was determined following the method described by APHA (1985). Chloride, sulphate, sodium, potassium, nitrate, and phosphate were analyzed by ion chromatography. Chlorophyll a was analyzed following the method described by Talling and Driver (1963). All the samples were diluted when concentrations exceeded the upper limit of the method.

RESULTS

Salinity and ionic concentration

Salinity levels in the ponds ranged from 0 to 34 $g.L^{-1}$ (Table 2). Following the classification system Montes and Martino (1987) adapted from the Venice System of Classification for brackish waters (Anonymous 1958) and Hammer's (1986) classification of saline waters, the ponds were divided into four salinity classes (Table 2):

- Mixo-haline coastal ponds (0.5-30 $g.L^{-1}$ salinity): the 5 coastal ponds.
- Hyposaline continental ponds (3-20 $g.L^{-1}$ salinity): ponds 6 and 7.
- Subsaline continental ponds (0.5-3 $g.L^{-1}$ salinity): ponds 8 to 13.
- Fresh continental ponds (< 0.5 $g.L^{-1}$ salinity): ponds 14 to 25.

Figure 2 shows the position of the ponds on a triangular diagram (Eugster and Hardie 1978) according to relative anionic and cationic composition. Anionic composition showed four patterns: (1) Group A: ponds dominated by chloride ($Cl^- > SO_4^{2-} > HCO_3^-$), (2) Group B: inland ponds dominated by SO_4^{2-}($SO_4^{2-} > Cl^- > HCO_3^-$), (3) Group C: inland ponds dominated by bicarbonate ($HCO_3^- > SO_4^{2-} > Cl^-$) although summer sulphate concentration may exceed bicarbonate concentrations and (4) Group D: inland ponds in which anionic concentrations are approximately equal. With respect to cationic composition, the general pattern was $Na^+ > Ca^{2+} >$ or $< K^+ > Mg^{2+}$, with sodium dominant in all ponds except Pond 16 where potassium concentrations were highest.

Table 2. Physico-chemical parameters measured in the ponds (inap = inappreciable).

	Date	Salinity g.L^{-1}	Cl^- mg.L^{-1}	$SO_4^=$ mg.L^{-1}	Alk mg.L^{-1}	Na^+ mg.L^{-1}	Ca^{++} mg.L^{-1}	K^+ mg.L^{-1}	Mg^{++} mg.L^{-1}	S.S. mg.L^{-1}	O_2 mg.L^{-1}	NO_3^- mg.L^{-1}	PO_4^{3-} mg.L^{-1}	Chl a mg.L^{-1}
1 Carmoli	25-2-89	26.0	7766	3880	151	8621	40.8	87.2	86.0	114	20.0	1.45	inap	0.09
1 Carmoli	3-8-89	34.0	7228	3614	140	7968	107.2	195.5	24.7	171	8.3	6.64	inap	0.02
2 La Pollo	25-2-89	27.0	836	3839	139	6515	189.6	192.0	61.7	91	17.0	2.27	inap	0.03
3 Calblanque	2-8-89	18.0	10914	2573	199	6960	98.0	256.0	24.3	106	7.3	2.37	inap	0.06
4 Punta Galera	25-2-89	12.0	8512	4124	146	5911	163.2	47.4	31.1	51	8.0	1.40	inap	0.06
4 Punta Galera	13-7-89	18.0	5452	4987	6	6001	98.0	25.3	30.3	1379	3.8	0.11	inap	0.09
5 Rambla Moreras	1-2-89	3.5	1810	2624	203	1126	27.2	52.9	41.3	8	6.4	3.30	0.24	0.01
6 Saladar Chicamo	12-7-89	13.0	2980	7092	9	4179	92.8	29.5	37.1	84	13.7	0.17	inap	0.07
7 Venta Punales	28-7-89	10.0	8134	15864	77	4005	86.4	168.5	33.0	78	6.0	0.51	0.12	0.01
8 Gravel-pit Moreras	1-2-89	3.0	815	555	175	551	21.6	27.2	17.0	582	3.5	0.28	1.34	0.25
8 Gravel-pit Moreras	7-8-89	2.5	940	400	177	633	9.6	46.4	17.2	368	27.5	0.16	0.69	4.50
9 La Bermeja	23-2-89	1.0	282	468	141	218	6.8	6.6	11.9	49	7.0	0.34	inap	0.01
10 Casa Buleros I	2-8-89	1.0	302	410	43	210	12.4	16.6	3.1	68	12.9	0.05	0.03	0.32
11 Los Conejos I	25-2-89	1.0	187	435	86	96	13.2	5.1	8.0	10	12.0	0.37	inap	0.01
11 Los Conejos I	21-7-89	0.5	201	405	8	86	9.6	3.4	5.8	1	10.6	0.24	0.06	0.01
12 Los Conejos II	28-2-89	0.5	39	88	117	34	0.0	8.0	0.0	7	8.0	0.02	inap	0.01
13 Carpinteros	3-3-89	0.5	25	34	78	22	3.6	7.5	2.6	16	10.0	0.02	0.03	0.01
13 Carpinteros	20-7-89	0.0	125	80	21	53	8.0	10.8	3.6	228	9.6	0.01	inap	0.03
14 Carrascoy	1-3-89	0.0	19	24	28	13	3.2	3.0	1.9	37	9.0	0.01	inap	0.04
14 Carrascoy	20-7-89	0.0	13	17	10	15	5.2	5.1	1.7	78	5.4	0.01	0.20	0.09
15 Casa del Ramel	2-8-89	0.0	11	18	105	12	3.6	9.1	2.1	41	7.1	0.01	inap	0.52
16 Casa la Parra	2-8-89	0.0	9	10	97	6	3.6	9.6	2.4	98	7.5	0.01	0.02	0.01
17 Casa Hita	2-8-89	0.0	4	14	119	19	4.4	10.9	3.1	371	12.9	inap	inap	0.91
18 Lacuas I	1-3-89	0.0	10	21	53	9	6.4	1.0	0.9	44	15.5	inap	inap	0.09
19 Lacuas II	2-8-89	0.0	121	29	54	50	3.6	5.5	2.9	20	11.2	0.01	inap	0.15
20 Los Chorrillos	1-3-89	0.0	15	22	47	15	3.6	2.4	1.9	128	12.0	0.06	0.02	0.01
20 Los Chorrillos	20-7-89	0.0	31	63	9	29	6.0	3.3	2.4	41	19.9	0.01	0.05	0.02
21 Malvariche	1-3-89	0.0	10	18	77	9	5.2	4.3	2.1	30	7.0	0.01	inap	0.01
22 El Barbo	1-3-89	0.0	11	16	108	11	3.6	1.4	0.9	607	15.0	0.06	inap	0.01
22 El Barbo	20-7-89	0.0	14	26	19	11	7.6	5.0	0.2	211	10.0	0.01	0.05	0.38
23 Finca Barbol	20-7-89	0.0	13	23	9	14	7.2	0.8	1.7	0	12.6	inap	inap	0.01
24 Casa Bulleros II	2-8-89	0.0	61	93	29	50	4.8	3.7	2.6	71	13.3	0.01	inap	0.03
25 Yechar	23-2-89	0.0	9	18	51	10	6.0	4.2	1.2	29	10.0	0.02	inap	0.01
25 Yechar	20-7-89	0.0	14	19	4	18	3.2	12.4	2.9	328	9.6	inap	inap	0.07

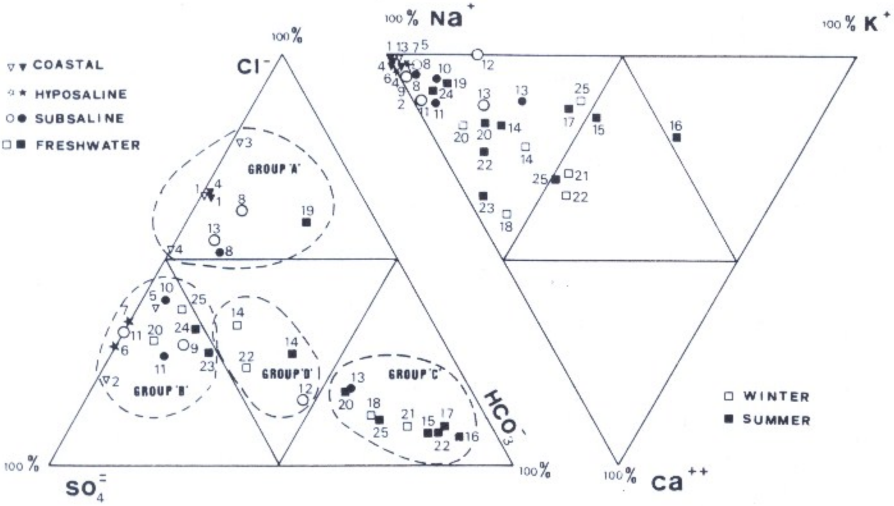

Figure 2 Relative anionic and cationic composition of the ponds shown on a triangular diagram.

Nutrients, dissolved oxygen, suspended solid and chlorophyll a.

The concentrations of nutrients, oxygen and suspended solids varied considerably between ponds (Table 2). Nitrate concentrations varied from not detectable (0) to 6.64 $mg.L^{-1}$, and were higher during winter. Phosphate concentrations ranged from not detectable to 1.34 $mg.L^{-1}$, although in 67% of the ponds the phosphate value was not detectable. Oxygen concentrations ranged between 3.5 and 27.5 $mg.L^{-1}$. In general the dissolved oxygen concentrations were higher during the summer, exceeding 10 $mg.L^{-1}$ in many ponds. Pond 8 has the highest oxygen values in summer and lowest oxygen values in winter, which is consistent with the fact that it receives inputs of urban and agricultural sewage. Suspended solids concentration varied between 0 and 1379 $mg.L^{-1}$. This high value was recorded for Pond 4 (a coastal pond) where wind and seawater movements disturb the pond bottom.

Chlorophyll a ranged from 0.01 to 4.5 $mg.L^{-1}$. In general the coastal ponds had low chlorophyll "a" values, between 0.02 and 0.09 $mg.L^{-1}$. The inland ponds, with low nutrient concentrations (numbers: 10, 15, 17, 19 and 22) had chlorophyll a values ranging from 0.01 to 0.09 $mg.L^{-1}$, whereas Ponds 11, 12, 13, 20, 21, 23, and 25, had concentrations of about 0.01 $mg.L^{-1}$.

DISCUSSION

The relative ionic composition of the pond water is determined by the origin of the water, its temporal dynamics, and the bedrock. For the coastal ponds the ionic composition depends upon the mix of sea and fresh-water (Lopez and Tomas 1989). The ponds with regular inflows of seawater have anionic patterns similar to seawater (Ponds 1, 3, 4). However, Pond 5, located at the mouth of an ephemeral stream, receives sporadic inputs of stream water so that the ionic composition is dominated by sulphate concentration (Figure 2). Pond 2, although it has a marine littoral origin, is now isolated from the sea and its water regime depends on the groundwater flow system, rainfall, and runoff from surrounding cultivated land. It is a temporary pond and the sulphate concentration (85%) is higher than chloride (15%) (Figure 2). In these ponds the pattern of dominance for cations is $Na^{+}>K^{+}>Ca^{2+}><Mg^{2+}$, which is different from that of seawater.

The hyposaline inland ponds (6 and 7) (Figure 2) have a high salinity due to the salt inputs from the soil. These ponds are components of the sebkha complex defined by Gonzalez-Bernaldez (1988). Their anionic composition is typical of saline water with continental origin (Montes and Martino 1987): high sulphate concentrations (65-75%), less chloride (25-30%) and a little bicarbonate. The cationic proportions are similar to those of the coastal ponds, with a high concentration of sodium (95%).

Subsaline inland ponds show all three patterns of anionic composition (Figure 2). Pond 8 is a gravel-pit pond which receives agricultural and domestic waste. This effluent contains high concentrations of chlorine used for water disinfection, which is probably the origin of the high chloride concentrations. In Pond 13, high concentrations of sulphate are found in summer due to evaporation. Many of the ponds with high sulphate concentrations are also located on marls with gypsum. Their cation concentrations are similar to the other ponds.

Fresh-water inland ponds have high concentrations of bicarbonate, although during summer, it precipitates out of the water column and the relative proportions of sulphate or chloride increase. These ponds are located on limestone and detritic marls which provide carbonate and bicarbonate to runoff water. The pattern of cation dominance is different from that of the other ponds ($Na^{+}>Ca^{2+}>K^{+}>Mg^{2+}$).

The high number of freshwater ponds (12) with 0 $g.L^{-1}$ of salinity (Table 2) contrasts with the high salinities reported for other aquatic systems on the Murcia Region (Vidal-Abarca 1985). Many authors report that there is a tendency for salinization to increase with the aridity of the territory because of evaporation processes. The saline waters of Australia, for example, are located in the more arid regions (McComb and Lake 1988). In our case, the degree of water permanence can not explain this situation since permanent water ponds have higher salinities than temporary water ponds (Table 1). However, the level of human activity correlates with levels of salinity: coastal ponds and hyposaline inland ponds have no human uses, and have higher salinities whereas subsaline and fresh inland ponds have lower salinities and support a variety of human activities (Table 1). One of these activities focuses on maintaining high water quality by draining the pond bottom during summer before autumn rains. This activity reduces salt precipitation on the pond bottom and its subsequent resuspension into solution.

In relation to the cations, calcium usually predominates in the freshwater ponds and sodium in the coastal ponds. Williams (1980) reported that sodium is dominant in standing water bodies in Australia, and Montes and Martino (1987) indicated that sodium and magnesium are the dominant cations in saline waters in Spain. According to Vidal-Abarca (1985), most natural lotic and lentic bodies of water in Murcia Region have high calcium concentrations because of the limestone bedrock. The high proportion of sodium is likely a result of evaporation processes: evaporation increases alkalinity causing $CaCO_3$ precipitation at alkalinities about 2.5 $meq.L^{-1}$ (=77 $mg.L^{-1}$) (Table 2), thereby increasing the proportion of sodium (Kilham 1990). For our 12 fresh and subsaline ponds this relationship between Ca and alkalinity was highly significant ($r=0.64$; $p < 0.01$).

On the basis of NO_3^{-}, PO_4^{3-} and chlorophyll <u>a</u> concentrations, the ponds can be classified into three groups (Figure 3):

Group 1	Ponds with PO_4^{3-} values greater than 0.1 $mg.L^{-1}$, variable nitrate concentrations (0-3 $mg.L^{-1}$), and intermediate values of chlorophyll <u>a</u> (0.01-0.09 $mg.L^{-1}$). This group includes one coastal and two inland ponds. All receive nutrients inputs of urban and agricultural sewage.

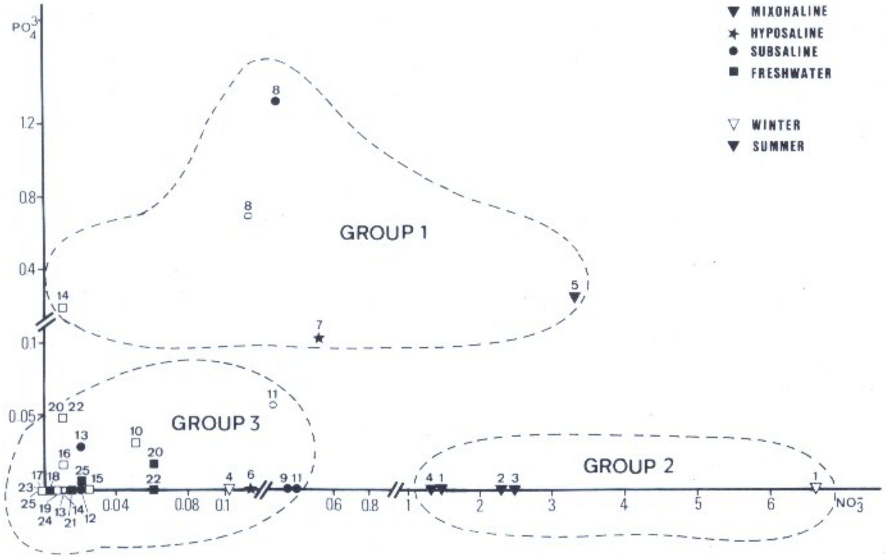

Figure 3. Relationship between the concentrations of NO_3^- and PO_4^{3-} in the ponds.

Group 2 Ponds with PO_4^{3-} concentrations less than 0.1 mg.L^{-1} and nitrate values greater than 1 mg.L^{-1}. This group includes four coastal ponds. All receive runoff from surrounding cultivated land.

Group 3 Ponds with PO_4^{3-} concentrations lower than 0.06 mg.L^{-1} and nitrate values <1 mg.L^{-1}. This group includes seven subsaline and 11 fresh inland ponds.

Figure 4 shows a summary of the chemical composition of the ponds based upon a combination of salinity, anionic patterns and nutrient concentrations. Five different groups can be defined:

Group A: the coastal ponds with euryhaline water, an anionic pattern dominated by the chloride and PO_4^{3-} concentrations lower than 0.1 mg.L^{-1} and nitrate values higher than 0.01 mg.L^{-1}.

Group B: the hyposaline inland ponds, with anionic composition dominated by SO_4^{2-}. The nutrient concentrations depend on metabolic processes.

Groups C, D, and E: subsaline and fresh inland ponds with low nutrient concentrations (PO_4^{3-} < 0.1 mg.L^{-1} and NO_3^- < 0.4 mg.L^{-1}). Ponds in group C have an equilibrate anionic balance; group D ponds are dominated by bicarbonate; group E ponds have sulphate as the dominant anion.

In summary, the chemical heterogeneity found in the 25 ponds is mainly due to the origin and temporal dynamics of the water in relation to climate (rainfall, evaporation processes, etc.) and edaphic processes typical of semi-arid regions. Human activity plays an important role in determining chemical composition as it can affect loading as well as *in situ* mineralization and metabolic processes.

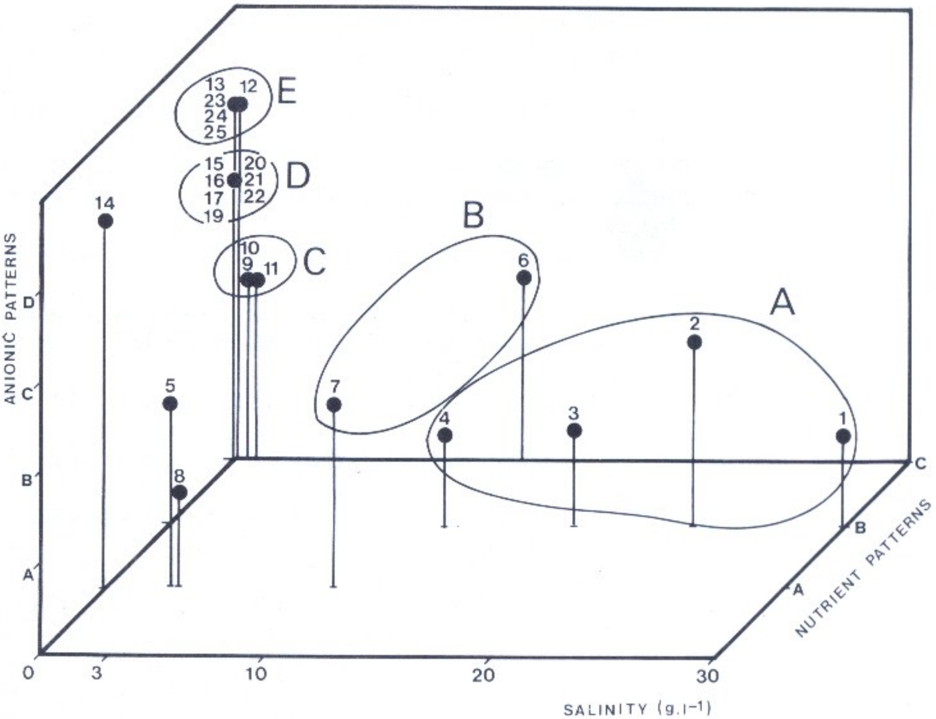

Figure 4. Ordination of the ponds according to salinity, anionic patterns and nutrient concentrations.

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REFERENCES

ANONYMOUS. 1958. The Venice System for the classification of marine waters according to salinity. Oikos. 9:311-312.

AMERICAN PUBLIC HEALTH ASSOCIATION. 1975. Standard methods for the examination of water and wastewater. 14th ed. Washington, D. C. 1193 p.

CARPENTER, J. M. 1966. The accuracy of the Winkler method for dissolved oxygen analysis. Limnol. Oceanogr. 10:135-140.

EUGSTER, H. P. and L. A. HARDIER. 1978. Saline lake. p. 237-293. *In*: A. Lerman [ed.] Lake chemistry, geology, physic. Springer-Verlag. New York.

GOLTERMAN, H. L., R. S. CLYMO, and M. A. M. OHNSTAD. 1978. Methods for chemical analysis of freshwater. IBP Handbook no. 8. Blackwell, Oxford.

GONZALEZ-BERNALDEZ, F. 1988. Typology of wetlands of the resources they present. International Symposium on Hydrology Wetlands in semi-arid and arid regions: 7-39

HAMMER, U. T. 1986. Saline lake ecosystems of the world. Junk Publ. 616 p.

HOOK, D. D. and OTHERS [eds.]. 1988a. The ecology and management of wetlands. Volume 1: Ecology of wetlands. Croom Helm London & Sydney. 592 p.

HOOK, D. D. and OTHERS [eds.]. 1988b. The ecology and management of wetlands. Volume 2: Management, use, and value of wetlands. Croom Helm. London & Sydney. 394 p.

KILHAM, P. 1990. Mechanisms controlling the chemical composition of lakes and rivers: Data from Africa. Limnol. Oceanogr. 35:80-83.

LOPEZ, P. and X. TOMAS. 1989. Chemical composition of the small coastal lagoons of the Mediterranean Spanish littoral. p. 591-599. *In*: J. D. Ros [ed.] Topics in marine biology. Scient. Mar. 53(2-3).

MALTBY, E. 1986. Waterlogged wealth. Why waste the world's wet places? Earthscan. London, U. K. 200 p.

McCOMB, A. J. and P. S. LAKE. 1988. The conservation of Australian wetlands. Surrey Beatty & Sons Pty Limited and World Wildlife Fund Australia. Chipping Norton. Australia. 196 p.

MITSCH, W. J. and J. G. GOSSELINK. 1986. Wetlands. Van Nostrand Reinhold. New York. 539 p.

MONTES, C. and P. MARTINO. 1987. Las aguas salinas espanolas. p. 95-145. *In*: Seminario sobre Bases Cientificas para la proteccion de los Humedales en Espana. Real Academia de Ciencias Exactas, Fisicas y Naturales. Madrid.

MORTIMER, C. H. 1953. A review of temperature measurement in limnology. Mitt. Int. Verein. Limnol. 1:1-25.

PROBERT, C. 1989. Pearls in the landscape. The conservation and management of ponds. Farming Press. Ipswich, U. K. 226 p.

RAMIREZ-DIAZ, L. (Dir). 1989. Inventario abierto de los humedales de la Region de Murcia. Agencia Regional para el Medio Ambiente y la Naturaleza. Comunidad Autonoma de la Region de Murcia. (inedito).

TALLING, J. F. and D. DRIVER. 1963. Some problems in the estimation of chlorophyll a in phytoplankton. Proc. Conf. Primary Productivity Measurement, Marine and Freshwater. Hawaii (1961). U. S. Atomic Energy Comm. TLD-7633:142-146.

VIDAL-ABARCA, M. R. 1985. Las aguas superficiales de la Cuenca del Rio Segura (S.E. de Espana). Caracterizacion fisico-quimica en relacion al medio fisico y humano. Ph. D. thesis. Univ. Murcia. 789 p.

WILLIAMS, W. D. [ed.]. 1980. An ecological basis for water resource management. Australian National University Press. Canberra. Australia.