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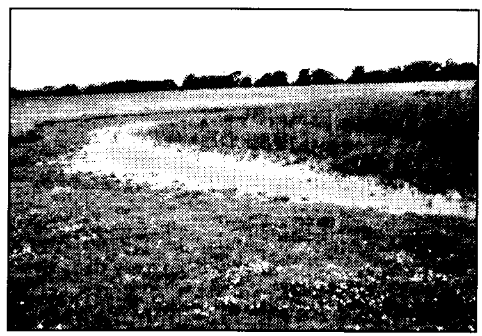

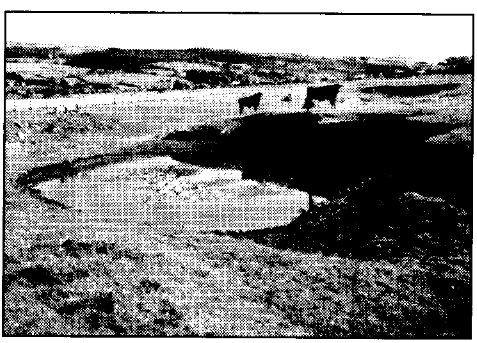

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Karstic ponds and pools: history, biodiversity and conservation

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Abstract

The study area is the dry karstic plateau near Trieste (NE Italy - SW Slovenia). Except for rock pools and some temporary water bodies, ponds were created by man and used as a supply of drinking water for humans and animals, as reservoirs for agriculture and for the production of ice during winter. Biodiversity of these ponds consists of at least 300 species of vertebrates, invertebrates, plants and algae. The lack of management led to the loss of 70% of ponds in the last 30 years. Non-native species were introduced, leading to the local extinction of many native populations. To prevent the disappearance of karstic pond, the Trieste Natural History Museum since 1969 started an ecological survey and developed a management plan consisting in: 1) creation of a pond database and publication of a cadastre, an atlas and several papers on history and biodiversity; 2) restoration of disappeared and disappearing ponds and pools; 3) removal of allochthonous fish using rotenone; 4) construction of new ponds; 5) reintroduction of autochthonous amphibian species; 6) development of educational programs addressed to schools and citizens; 7) long-term monitoring of ecological successions.

Introduction

The Karst of Trieste is a well delimited geographic unit, administratively divided between NE Italy and SW Slovenia. It consists of a karstic plateau (approximately 600 km^2), with an average altitude of 300 m above the sea level (D'Ambrosi, 1976) and a quite homogeneous sub-mediterranean climate (Polli, 1985) and vegetation. The fissured limestone of the karstic plateau caused the almost complete disappearance of surface running water. Nevertheless, in this dry landscape, hundreds of old (at least one thousand years) man-made ponds were present and used as reservoirs of rainy water for agricultural and zootechnical activities.

Considering the interest of these "oases" in the landscape as biodiversity spots and sites of reproduction for amphibians, the Natural History Museum in Trieste has undertaken an ecological survey of the karstic ponds since 1969, the date of publication of the first pond cadastre. Unfortunately, the lack of pond management (consequent upon the decline of the traditional economic activities and the construction of new aqueducts) led to a high rate of ponds loss in the last 30 years. For this reason, attention has been focussed upon the development of a plan of pond protection, restoration and management, as well as on the use of ponds and their amphibians as educational tools.

The present paper deals with the principal lines of research and intervention as follows:

1) creation of a pond database including data on history and biodiversity;
2) restoration of impounded or destroyed basins;
3) removal of non-native species;
4) construction of new habitats;
5) reintroduction of native amphibian species;
6) educational activities about pond conservation and management;
7) long-term monitoring of ecological successions and environmental evolution.

Pond history and typology

The ponds and pools located in the karstic plateau surrounding Trieste represented for centuries the only surface water resource for human activities (Polli & Alberti, 1969; Pagnini Alberti, 1972). The more natural surface water basins in the karstic landscape are ephemeral puddles and rock-pools (Ranzoli et al., 1979). The rock-pools developed on limestone banks as a result of the dissolution of the rock due to the action of rainfall. In the Province of Trieste there are probably more than one hundred rock-pools larger than 0.5 m diameter (Marini, pers. comm.); unfortunately most of them have a diameter smaller than 1.5 m and retain water only during rainy seasons (autumn and spring); only a dozen of rock-pools are known to be perennial.

The other ponds and pools were artificially created by man who had to face with the natural scarcity of surface waters in a karstic land (Fig.1). The problems of water supply were solved by relying on rainfall, snow and ice collection; the rainy water was conveyed from roofs into water tanks after filtration. These water reservoirs often belonged to several families of the same village, and were used as a supply of drinking water for humans and animals. Furthermore, every village had at least one reservoir for field irrigation: water was conveyed into these reservoirs through underground channels, in order not to damage the crops. Pasture ponds were dug taking advantage of natural depressions usually sited close to the village; these basins were rendered water-proof by pressing a clay layer and, in some cases, covering the bottom with squared limestone blocks. The upkeep of the ponds was performed at regular intervals, usually every year, to keep the basins free of vegetation and remove the layer of decaying leaves which accumulated on the bottom. This work prevented eutrophication.

Although most of these man-made ponds were created to supply drinking water or to support agricultural activities, it is noteworthy that the purpose of these veryy shallow ponds was the production of ice. During Winter, when water froze, karstic ponds yielded ice sheets of variable thickness. These blocks of ice were subsequently stored in suitable and thermally isolated "ice-cisterns" and sold in the neighbouring town during Summer, representing a considerable profit to the poor Karst farmer (Pagnini Alberti, 1972). Up to the second half of the past century, ice came mainly from ice-caves of the national forests of Tarnova and Nanos

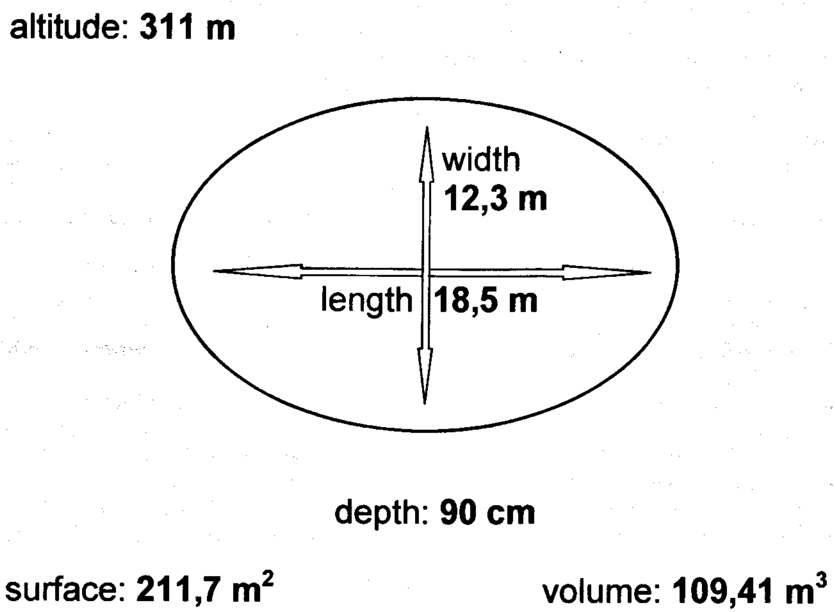

Figure 1: Average dimensions of a pond in the Karst of Trieste.

(Julian Pre-Alps, today in Slovenia). Competition by cheaper ice from ponds in the karstic area of Trieste slowed down to a halt this trade. The ice-tanks used for ice-keeping were built in the same manner as the water-tanks of the villages, and were protected with a roof, similarly to stables. Trieste and its harbour represented the chief outlet to this activity and in that period ice blocks from the Karst were also exported - as far as Egypt; this trade developed till 1930. Today rainy water fills the bottom of abandoned ice-tanks, wherever they are not collapsed, buried by mud or degraded to garbage heaps.

Unfortunately, the economic activities connected with karstic water bodies stopped after World War II, and the consequent lack of management lead to a drastic infilling of the basins and to a subsequent disappearance of many ponds. Some additional drinking troughs were constructed during the last 20 years in the game-reserves using concrete, but they are usually very small (less then 4 m diameter) compared to the older ponds (Polli & Polli, 1987, 1989).

Biodiversity

Karstic ponds and pools are not reminders of the wetland drainage activities, as usual in alluvial territories. For this reason there is no long history of community succession and there are no relicts among the components of biodiversity. The colonisation processes of karstic ponds probably belong to the following categories:

1) active colonisation (mainly amphibians, reptiles, flying insects)
2) passive colonisation (passive transport of individuals, eggs, resistant stages, cysts, seeds etc. carried by wind, cattle, birds)
3) introduction by humans (fishes, turtles, water plants and some species collected in other ponds).

Surveys

More than 60 karstic ponds and pools in the Province of Trieste were intensively sampled during the last 20 years to assess regional and local biodiversity and to study colonisation, succession and distributional ecology of species assemblages. Surveys yielded a total of 293 species identified. These included: algae (112 species: Poldini & Rizzi Longo, 1975); mosses (6 species: Poldini & Rizzi Longo, 1975); higher plants (35 species considering water plants: Poldini & Rizzi Longo, 1975; Mezzena & Polli, 1982); microcrustaceans (29 species: Stoch, 1985 and unpubl. data); water beetles (38 species: Alberti, 1983, 1985; Stoch, unpubl. data); water bugs (12 species: Stoch, unpubl. data); dragonflies (40 species: Bognolo & Pecile, 1995); mayflies (1 species: Stoch, unpubl. data); molluscs (8 species: Dolce & Stoch, unpubl. data); amphibians (10 species: Dolce, 1976; Bressi & Dolce, 1992); and reptiles (2 species: Dolce, 1976, 1983).

Some other groups, widespread in the area (microturbellarians, oligochaetes, dipteran larvae, water wheelers) are under study and their identification probably will at least double the total number of species, without taking into account protozoan, some neglected algae groups and the non-native, introduced species.

The value of local (alpha) diversity of invertebrates is usually low, if compared with non-karstic ponds located close to the Karst border (Stoch, 1995), or with karstic lakes in the province of Gorizia and in Slovenia (Stoch, unpubl. data). The lower number of species found in karstic ponds and pools is probably related to environmental harshness, to the low total number of water bodies in the karstic area and to the isolation of the basins. The role of biotic interactions is being investigated; it seems probable that competition and predation play an important role to set an upper limit to local species richness in karstic water bodies, but regional species richness is probably better explained by habitat selection and environmental variability (Stoch, in prep.).

Moreover, the invertebrate species turnover for the whole karstic area was very low during the last 20 years (and probably during the last century as well), showing the important role of environmental structure in the selection of the regional species pool. On the contrary, at a local scale the species turnover is very important during the later stages of ecological succession, when a perennial pond becomes temporary, showing the important contribution of small and very small water bodies to overall biodiversity. In this case, the species pool includes only organisms which developed strategies to survive the summer dry phase and the winter ice phase (production of resting stages, resistant eggs and recolonisation by adults: see Wiggins et al., 1980). The assemblages have a lower species number than in perennial ponds. On the contrary, larger ponds often possess even poorer species assemblages, due to the introduction of predatory fishes (Fig.2). The causal relationship between fish presence and low species number of invertebrates was demonstrated by fish removal experiments using rotenone. The results show that after fish removal, the number of microcrustacean species increased dramatically (Fig.3); the number of water bugs and water beetles increased as well. For the reasons cited above, the higher invertebrate diversity was observed in perennial ponds devoid of fishes, which are nowadays very scarce in the Karst of Trieste.

Vertebrate biodiversity is quite high considering the extension of the study area and the average small dimension of the karstic ponds. Some vertebrate species endangered in many parts of Europe (*Triturus carnifex*, *Bombina variegata variegata*, *Hyla arborea arborea*, *Rana dalmatina*) are still present in the karst of Trieste and even locally very abundant in some small biotopes. The Karst of Trieste is also a very important bio-geographical threshold between Italian and Western European species (*Rana latastei*, *Hyla intermedia*) and Eastern-Central European or Balkanic species (*Rana (Pelophylax) ridibunda*, *Hyla arborea arborea*) which in the karst of Trieste reach the limit of their Mediterranean distribution and sometime coexist.

Pond conservation, restoration and management

In the Province of Trieste from 1969 to 1985, 122 ponds and rock-pools were registered in a cadastre (Polli & Alberti, 1969; Alberti et al., 1981; Polli & Polli, 1985). The same authors reported that at least other 26 ponds disappeared before the publication of the first contribution. Details of the number of water-bodies are given in Table 1. Over 70% of the small water bodies of the Karst near Trieste disappeared in the last 10 years (approximate rate of ponds/pools loss = 4.4 units/year). The main causes of pond loss are, in order of importance:

Table 1: Loss of waterbodies, Trieste region, 1979-1998

	1979	1998	% loss
Ponds	96	33	66 %
Pools	51	11	78 %

Note: Karstic ponds have a surface area > 20 m^2; pools have a surface area of between 2 and 20 m^2, filled with water at least 4 months/year.

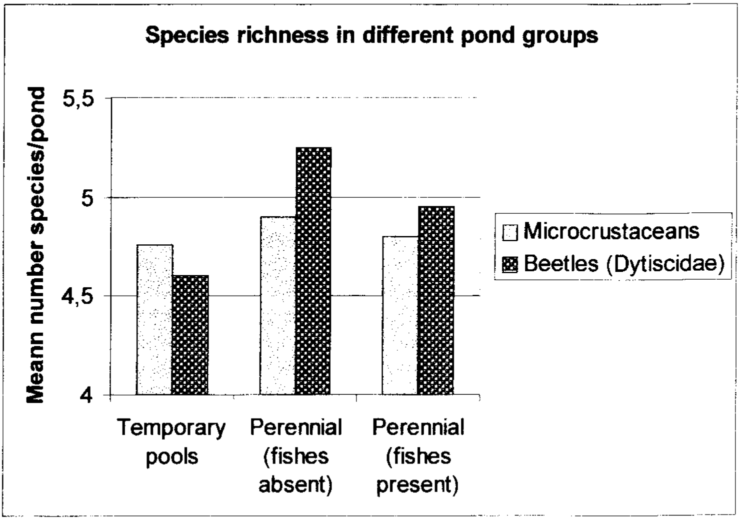

Figure 2 : Invertebrate richness in different pond groups.

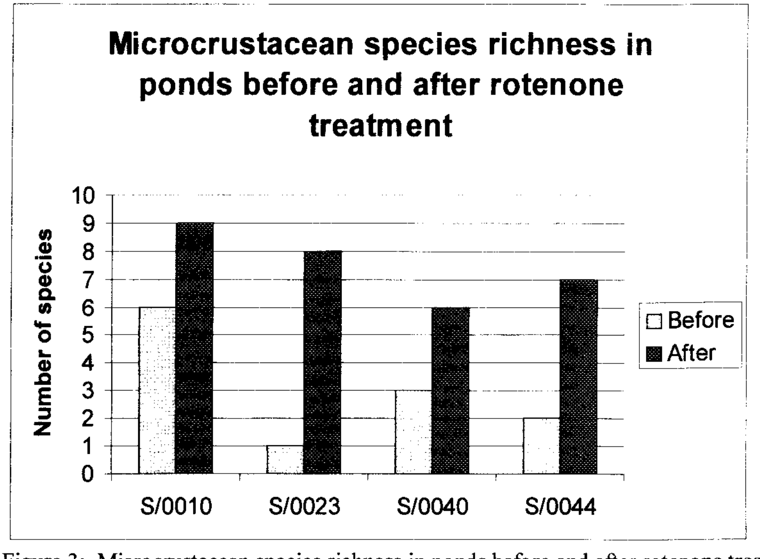

Figure 3: Microcrustacean species richness in ponds before and after rotenone treatment.

a) the lack of management due to the construction of the new aqueducts and the decline of agricultural and zootechnical activities, as well as of ice production, during the second half of this century, and a consequent natural ecological succession towards a terrestrial environment
b) human activity (construction of buildings, reclamation)
c) use of the ponds as dumps.

Only 19 ponds are perennial; several species of fishes were introduced in 15 of these basins (Specchi & Dolce, 1982; Dolce & Dramis, 1977, 1981; Bressi & Cassola, 1989). The most common species is *Carassius auratus* (crucian carp or gold-fish), which was found in 9 ponds; *Lepomis gibbosus, Gambusia holbrooki* and *Ictalurus* sp. were found in other ponds. In one of these ponds a small colony of domestic ducks was also introduced (*Anas platyrhinchos*).

In the ponds where fish are present, biodiversity is lower both for invertebrates than amphibians. Only some species well adapted to survive together with fish become predominant *(Bufo bufo spinosus, Rana (Pelophylax) esculenta* complex) while more endangered and selective species disappear in a few years (*Triturus carnifex, Bombina variegata variegata, Hyla arborea arborea*) (Bressi & Dolce, 1992).

<u>Remedial work</u>

Removing fish

Considering the threat for invertebrate and amphibian populations, fish were experimentally removed from 8 different ponds using 11 PW Rotenone (InterAgro AB) 25% solution for 1000 m^3 of pond water (1 ppms). This product acts at the level of branchial receptors of oxygen, and is not toxic for most invertebrates and for the other vertebrates (fishes killed using rotenone were eaten by 2 adults of *Natrix natrix* and 2 adults of *Trachemys scripta*, without any consequence). The results, already discussed for invertebrates which developed rich populations within one month after fish removal, show no consequence at all for adult amphibians. All adult amphibians abandoned the water for 12-48 hours after the treatment, some tadpoles still present in the ponds died. After 3-10 days, amphibians came back to the water, colonising and/or recolonising successfully the pound. In the following years amphibian populations and biodiversity grow up very briefly.

Habitat restoration and reconstruction

Another management activity carried on by the Museum of Trieste was habitat restoration and the construction of new ponds. The major problem encountered in the karstic area was the need to water-proof the bottom.; experimentation was made using different materials: clay, concrete (amalgamated with latex), plastic resins, PVC sheets, and bentonite. The best performance (after the natural clay, not always usable) was obtained using concrete (very resistant, long lasting and easy to clean from vegetation); the use of the bentonite is the least successful material in drought conditions.

The restoration of several basins was performed to a large extent by private associations, by the Province and Municipality of Trieste and the Municipality of Sgonico (Bressi, 1996). The restoration of pre-existing damp zones has involved the extension and the deepening of the basins. The restoration was performed in September and January, when the smaller number of amphibians was present in the pond. Amphibians eventually captured in the pond before restoration were kept in aquaria, together with samples of plants and invertebrates, and re-introduced at the end of the restoration works.

In several of the new-restored ponds, biodiversity in few years resembled that of the original ones. Unfortunately, in some restored ponds fish and plants were observed a few days after the conclusion of the work (Bressi, 1996); this kind of problems may be prevented with an appropriate educational activity.

Ponds and amphibians as educational tools

Educational activity is an essential point to allow local people to have a correct approach toward the pond environment and its management (i.e. to avoid the introduction of fishes and other species). Particular attention is given to schools; in the period 1992-96 the programmes of environmental education on the safeguard of amphibians and their habitat were followed by over 3500 pupils and teachers from 170 classes. They were organised in 3 courses for teachers, 4 exhibitions with aquaria, drawings, photos, videos, 1 popular book, 8 trips and over a dozen lectures.

A major part of our educational activity may be compared to the job of an ecological guard or a forester. As already mentioned above, fishes and introduced plants were observed in some ponds few days after the restoration (Bressi, 1996). For this reason, we supposed that environmental education is the only way to limit such events which, in a few days, can frustrate years of studies and efforts, and that the better method to prevent damages to pond ecosystems was to entrust pond management and amphibian monitoring to a school. In this way the students became personally responsible of a pond or pool, learning how to protect it and to respect the organisms living there (Bressi et al., 1995), with encouraging results.

Moreover, the naturalists of the Natural History Museum in Trieste use amphibians and reptiles as educational tools in several ways. The methods, developed according to the age of the students and different educational aims, generally consist of experiences such as watching animals in the field and touching them both in nature than in the Museum. Children are involved by games and little "adventures"; adults are faced mainly with real and, above all, economic problems owed to the loss of biodiversity. A typical program of educational training consists of:

1. A brief lesson at the classroom or at the Museum (with few words and many slides and videotapes) on amphibians, reptiles and pond ecosystems. These lessons are only an introduction: people have to become interested and discover problems by themselves.

2. A field-trip to a pond where pupils, teachers or common people can watch, catch (generally by dip-netting) and handle local amphibians and reptiles, and several species of

freshwater invertebrates (younger children are more free of prejudices and seem to enjoy the new experience).

3. A field trip to a pond where fishes and ducks were introduced; in this kind of site amphibians, reptiles and invertebrates are rare or extinct, and people cannot hear frogs call or see dragonflies flying around. Children who expect to repeat the previous nice experience remain very disappointed; thus everyone feels immediately the loss of biodiversity.

4. A concluding session at the Museum where all the field observations are correctly correlated with new data obtained by exhaustive lessons or teaching games such as "Identifrog". (In this game, pupils, using specimens kept at the Museum, have to understand the life and habitat features of an animal paying attention only to shapes and colours; otherwise students have to build an imaginary, well-adapted species, knowing only its way of life).

After 10 years, the educational program brought significant results in nature conservation. The concept that a pond is an important part of the natural environment is now quite widespread. Goldfish and ducks are still preferred to amphibians and reptiles by many people, but many people nowadays know and respect these cold-blooded animals as well. In concrete terms of nature conservation, this means that many restored or newly created ponds are not immediately polluted or damaged by the introduction of fishes. For instance, two ponds (one located very close to a village, another sited in a suburban park of Trieste) were restored 4 years ago and they are still devoid of fish and inhabited by amphibians and reptiles which were introduced into the ponds after restoration or actively colonised them. Such a long time without pollution would have not been even conceivable just ten years ago.

The educational training carried on in the schools conveys a new ecological awareness, free of prejudices, to the new generations. An important goal was to involve teachers in this training, since they are the first responsible of the diffusion of methods and principles. The use of amphibians and reptiles as educational tools, easily-handled and visible in nature during the different stages of their life cycles, was a winning card.

The educational program started exactly from some of the most feared and mistreated animals, and turned them, in the eye of the students, from victims bound to extinction to respectable creatures. Amphibians, namely frogs, were used to teach anatomy and physiology to thousands of students during more than two centuries; nowadays we use the same frogs to teach how to respect nature and, as a consequence, to take care of our own life.

References

Alberti G. (1983) Contributo alla conoscenza dei coleotteri degli stagni del Carso triestino (Italia nordorientale). I. Dytiscidae. *Atti Mus. Civ. Stor. Nat. Trieste*, 35: 329-358.

Alberti G. (1985a) Contributo alla conoscenza dei coleotteri degli stagni del Carso triestino (Italia nordorientale). II. Haliplidae, Hygrobiidae, Gyrinidae. *Atti Mus. Civ. Stor. Nat. Trieste*, 37(2): 207-216.

Alberti G. (1985b) Notizie su alcuni stagni poco noti della provincia di Trieste (Italia nordorientale). *Atti Mus. Civ. Stor. Nat., Trieste.* 37 (2): 189-205.

Alberti G., Dolce S. & Polli S. (1981) Gli stagni della provincia di Trieste. Secondo contributo. *Atti Mus. Civ. Stor. Nat., Trieste.* 32 (2): 135-174.

Beebee T.J.C. (1996). Ecology and Conservation of Amphibians. Chapman & Hall, London.

Bognolo E., Pecile I. (1995) La fauna odonatologica del Carso triestino, del Carso goriziano e di alcune località limitrofe. *Atti Mus. Civ. Stor. Nat. Trieste*. 46: 145-171.

Bressi N. (1995) Catalogo della Collezione Erpetologica del Museo civico di Storia Naturale di Trieste. I - Amphibia. *Cataloghi I, Mus. Civ. Stor. Nat., Trieste.* 1-64.

Bressi N. (1996) Nuovi specchi d'acqua: esperienze di realizzazione, ripristino e gestione di piccoli stagni e dei loro ecosistemi in Comune di Trieste. *Gr. Spel. "S. Giusto" / Com. Di Trieste-Sett. 18°*, Trieste: 1-40.

Bressi N. & Cassola C. (1989) Stagno carsico o vasca ornametale?. *Boll. WWF – Friuli-Venezia Giulia*. Udine. 38: 7.

Bressi N. & Dolce S. (1992) Primi dati sulla situazione e la salvaguardia degli anfibi in provincia di Trieste. *Quad. Civ. Staz. Idrobiol., Milano.* 19: 93-100.

Bressi N., Calligaris R., Dini A., Di Pinto N. & Radacich M. (1995) Lo Stagno di Contovello. *Com. Reg. Dif. Fen. Cars.*, Trieste. 1-32.

Bruno S., Dolce S., Sauli G. & Veber M. (1973) Introduzione a uno studio sugli Anfibi e Rettili del Carso triestino. *Atti Mus. Civ. Stor. Nat., Trieste.* 28 (2): 485-576.

Calligaris R. (1985) Gli stagni della provincia di Trieste - Atlante. *Atti Mus. Civ. Stor. Nat., Trieste.* 36 (Suppl): 1-128.

Dolce S. (1976) Distribuzione degli Anfibi e biologia del Rospo comune (*Bufo b. spinosus* Daud., 1803) sul Carso triestino. *Atti Mus. Civ. Stor. Nat., Trieste.* 29 (3): 175-212.

Dolce S. (1983) Osservazioni eco-etologiche su *Natrix natrix* (L.) negli stagni del Carso triestino. *Atti Mus. Civ. Stor. Nat., Trieste.* 35 : 313-328.

Dolce S. & Dramis G. (1977) Problemi di conservazione degli stagni carsici e ripristino dello stagno di Colludrozza (Sgonico, TS). *Pro Natura Carsica*, Trieste: 1-24.

Dolce S., Dramis G. (1981) Nota introduttiva sui Pesci degli stagni del Carso triestino. Atti *I Conv. Ecologia dei Territori Carsici*, Sagrado d'Isonzo: 189-200.

Dolce S. & Specchi M. (1982) Contributo alla conoscenza dell'ittiofauna di alcuni stagni del Carso triestino. *Quad. ETP*, Udine. 3: 1-9.

Dolce S. & Stoch F. (1984) Osservazioni sull'alimentazione degli Anfibi: I. *Triturus vulgaris meridionalis* (Boul.) Negli stagni del Carso triestino (Italia nordorientale). (Amphibia Caudata Salamandridae). *Atti Mus. Civ. Stor. Nat., Trieste.* 36 (1): 31-45.

Dolce S. & Stoch F. (1985) Distribuzione e stazioni di riproduzione di *Salamandra salamandra* (L., 1758) nella provincia di Trieste (Italia nordorientale). *Atti Mus. Civ. Stor. Nat., Trieste.* 37 (2): 183-188.

Dolce S., Stoch F. & Palma M. (1991) Stagni carsici: storia - flora - fauna. Ed. LINT, Trieste.

Mezzena R. & Polli E. (1982) Gli stagni della provincia di Trieste: Contributo alla conoscenza della flora e vegetazione. *Atti Mus. Civ. Stor. Nat., Trieste.* 33: 1-216.

Pagnini-Alberti M.P. (1972) Sistemi di raccolta d'acqua del Carso triestino. *Atti Mus. Civ. Stor. Nat., Trieste.* 28 (1): 13-66.

Poldini L. & Rizzi-Longo L. (1975) Studi preliminari sulla flora e sulla vegetazione degli stagni del Carso triestino. *Atti Ist. Bot. E Lab. Critt. Univ.*, Pavia. 6 (10): 187-240.

Polli S, & Alberti G. (1969) Gli stagni della Provincia di Trieste. *Atti Mus. Civ. Stor. Nat. Trieste*, 26(4): 81-127.

Polli S. & Polli E. (1985) Gli stagni della provincia di Trieste. Terzo contributo. *Atti Mus. Civ. Stor. Nat., Trieste.* 37 (1): 1-101.

Polli S. & Polli E. (1987) Stagni e vasche d'acqua nella zona di Trebiciano-Fernetti (Carso di Trieste). *Alpi Giulie*, Trieste. 81(2): 93-113.

Polli S. & Polli E. (1989) Stagni e vasche d'acqua nella zona di Gabrovizza-Bristie (Carso di Trieste). *Alpi Giulie*, Trieste. 83(1): 27-40.

Polli S. (1985) Ambiente climatico degli stagni della provincia di Trieste. *Atti Mus. Civ. Stor. Nat., Trieste.* 37 (2): 217-233.

Ranzoli F., Rottini-Sandrini L., Stolfa D. (1979) Caratteristiche idrogeochimiche e popolamenti di copepodi e cladoceri in tre vaschette di corrosione del Carso triestino. *Atti Accad. Sci. Ist. Bologna, Cl. Sci. Fis., Rendiconti ser.* 13, 6: 1-22.

Stoch F. & Dolce S. (1985) Osservazioni sull'alimentazione degli Anfibi. *Triturus cristatus carnifex* (Laur., 1768) negli stagni del Carso triestino (Italia nordorientale). *Atti Mus. Civ. Stor. Nat., Trieste.* 37 (2): 153-159.

Stoch F. (1983) Cladocera, Copepoda, Ostracoda delle acque epigee del Carso Triestino. Nota faunistica. *Atti Mus. Civ. Stor. Nat., Trieste.* 34 (3): 161-182.

Stoch F. (1985) Contributo alla conoscenza dei popolamenti ad entomostraci delle acque epigee del Carso Triestino (Italia nordorientale). *Atti Mus. Civ. Stor. Nat., Trieste.* 37 (2): 153-159.

Wiggins G.B., MacKay R.J. & Smith I.M. (1980) Evolutionary and ecological strategies of animals in annual temporary pools. *Arch. Hydrobiol. (suppl.)*, 58: 97-206.