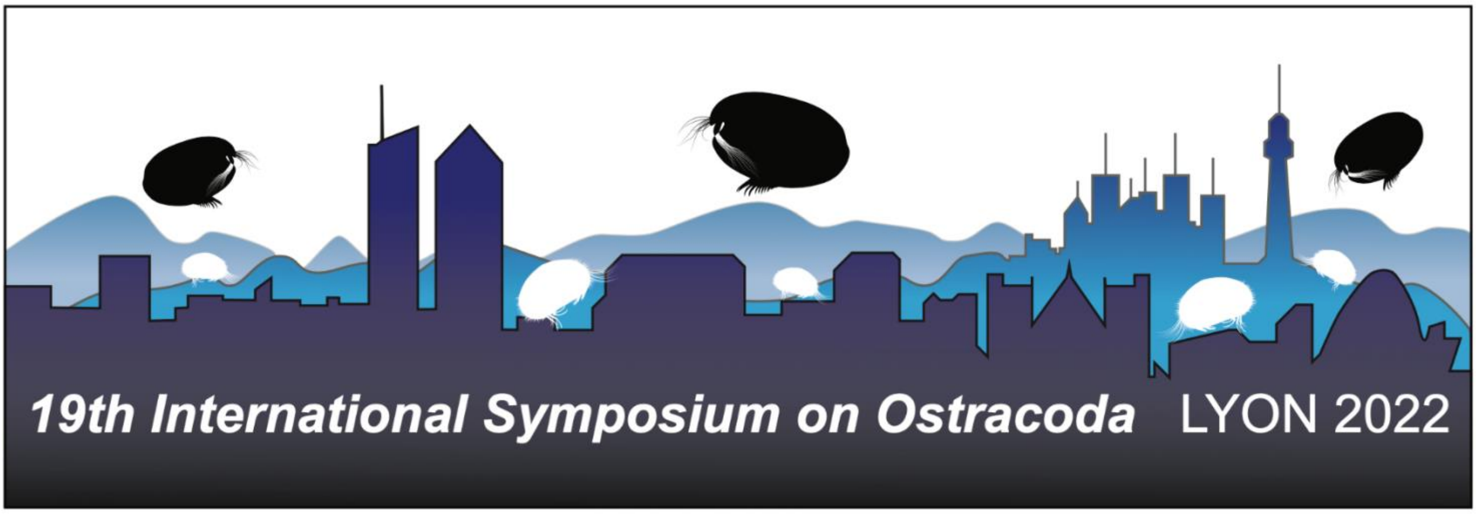

Post-Symposium Fieldtrip

Ostracods from the South-East of France: the Rhône and Camargue areas

23rd-25th July 2022

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Day 1: From Lyon to Arles

Stops 1 and 2: The lônes of the Rhône River

Stop 3: The fossiliferous site of Saint Restitut

Day 2: The protected area of the Tour du Valat (Camargue)

Day 3: Rice field at the Mas du Sonnailler (Camargue)

Biosecurity protocol

To minimize the risk of introducing new and potentially invasive species into Camargue waterbodies, we request that all participants intending to collect samples should ensure that their equipment (e.g., nets, waders) is thoroughly cleaned to remove any mud or organic debris (that might potentially contain resting eggs) and dried, in advance of the field trip.

23rd of July, 2022: OSTRACODOLOGISTS FROM LYON TO ARLES

STOPS 1, 2. The Lônes of the Rhône River

A *lône* is an arm of a river which remains set back from the main bed. It is supplied with water by infiltration from the alluvial aquifer or directly by the river during floods. Its layout and its morphology can then strongly evolve under the influence of eddies and quantity of displaced sediments.

"Lône" is a local term used only on the Saône, Rhône and Isère rivers that derives from the Franco-Provençal word *lona*, from the Germanic *lûhno*. It was originally only used for the Rhône but was later extended to other rivers.

There are more than 250 *lônes* of various size along the Rhône, often referred to by a surname such as the *Lône des Pêcheurs* (lône of the fishermen), *Lône des Chèvres* (lône of the goats), *Lône de la Grange Écrasée* (lône of the crushed barn).

The *lônes*, with their stagnant waters, are rich ecosystems that consist of habitats particularly favourable to biodiversity: alluvial forests, shrubby willow beds, eutrophic stagnant freshwater, hydrophyte beds and reedbeds. They have often been the subject of preservation initiatives and many are thus protected by a biotope preservation order or, at the very least, a European Natura 2000 classification. The *lônes* of the Rhône are home to many species, including some emblematic protected species of mammals (European beaver, European otter), birds (e.g., kingfisher), bats, insects.

Formerly filled in or drained, the *lônes* have been victims of hydraulic dam developments since the end of the 19th century. On many sections of the Rhône, the construction of dams and navigation canals has diverted most of the water and reduced its flow gradient (compensated by locks). Restoration actions have been implemented on certain sections: reconnection of the *lônes* to the main course of the river, remodelling aimed at complexifying and diversifying their morphology as well as revegetation in water (reedbeds) and on banks (willow beds, alluvial forests), with elimination of invasive species such as Japanese knotweed, water primrose or ragweed.

Ostracods from *lônes* have so far mainly been reported from areas east of Lyon (**Fig. 1**; e.g., Meisch *et al.*, 1989):

- *Lône du Grand Gravier* (Rhône): *Candona candida*, *Cypria ophtalmica*, *Cyclocypris ovum*, *Herpetocypris reptans*, *Cypridopsis vidua*, *Potamocypris variegata*
- *Lône des Pêcheurs* (Rhône): *Cryptocandona kieferi*
- *Lône de Puits-Novet* (Ain): *Cryptocandona kieferi*

The mid-symposium excursion included visiting and collecting from the *Lône du Content*, northeast of Lyon (**Fig. 1**). On our way to Arles, heading south, we will collect samples from *lônes* that have never been investigated for ostracods. They are along the same river but associated with different fauna and flora.

On our way, the traffic jams may be problematic so that we will be guided by the progresses we make.

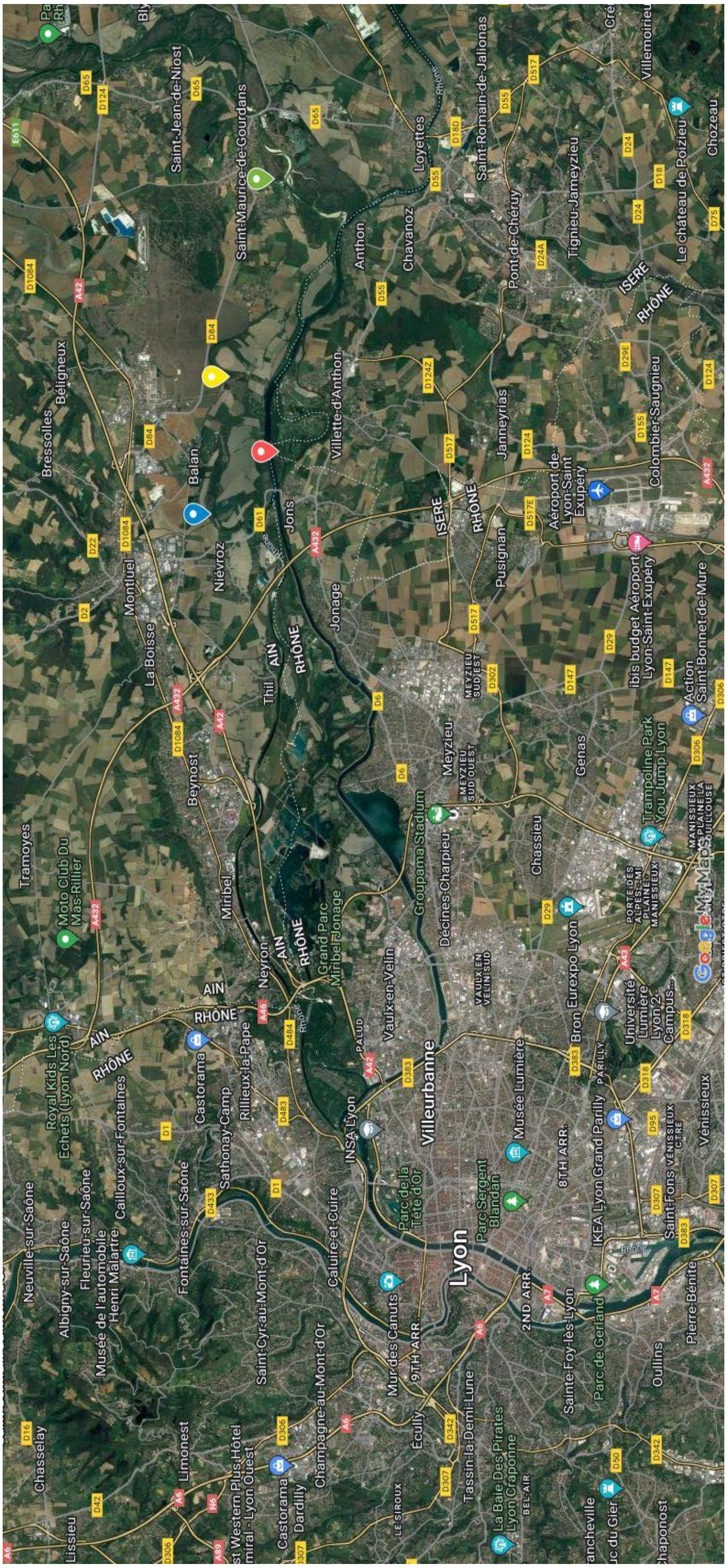

Figure 1. Examples of lônes where ostracods have been documented. In yellow: *Lône du Grand Gravier* (Rhône River), in red: *Lône des Pêcheurs* (Rhône River), in green: *Lône de Puits-Novet* (Ain River). In blue, *Lône du Content*, visited during the mid-symposium excursion.

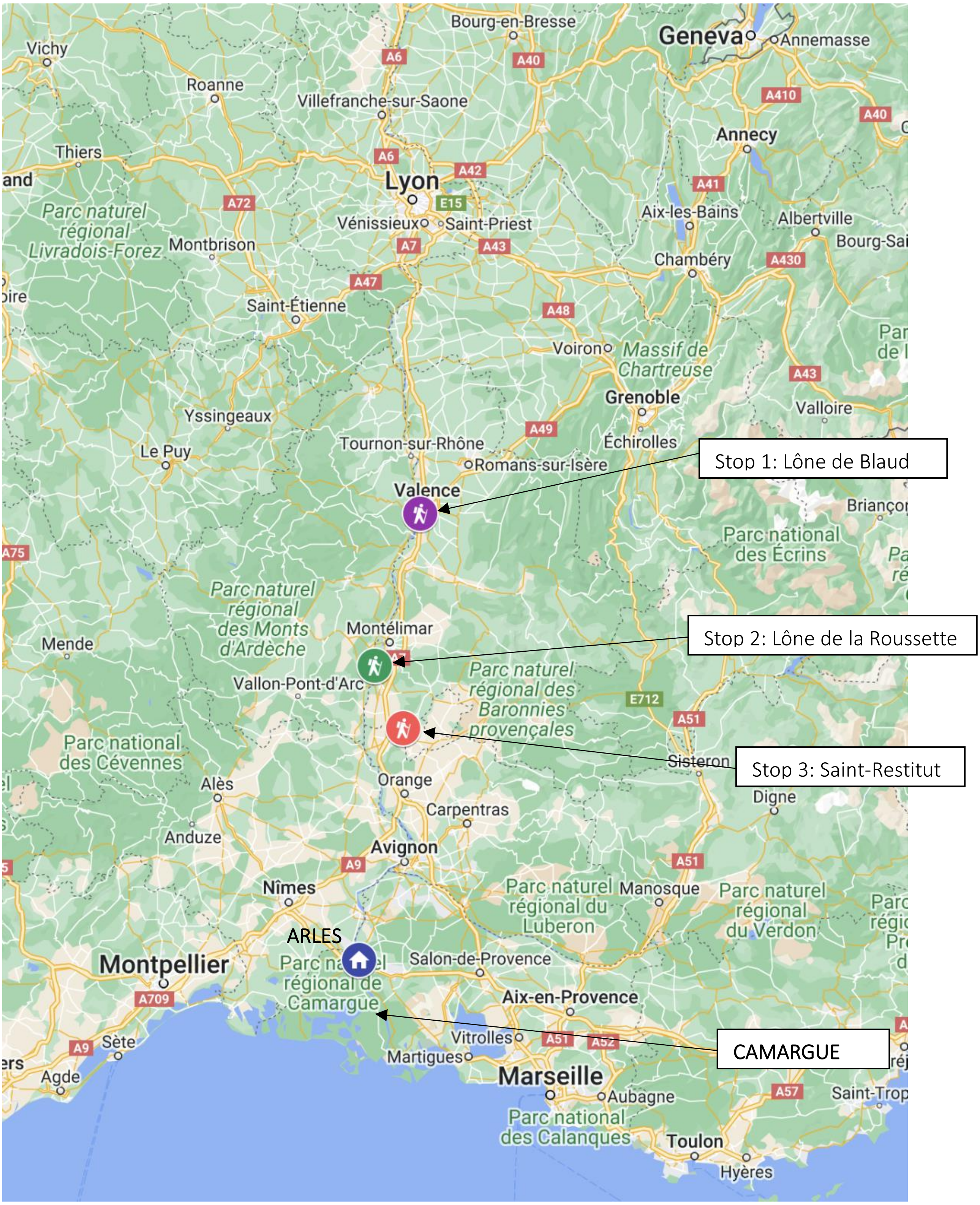

Figure 2. Planned stops of the first day. For a more detailed map of Camargue, see Fig. 6.

STOP 1. Lône de Blaud

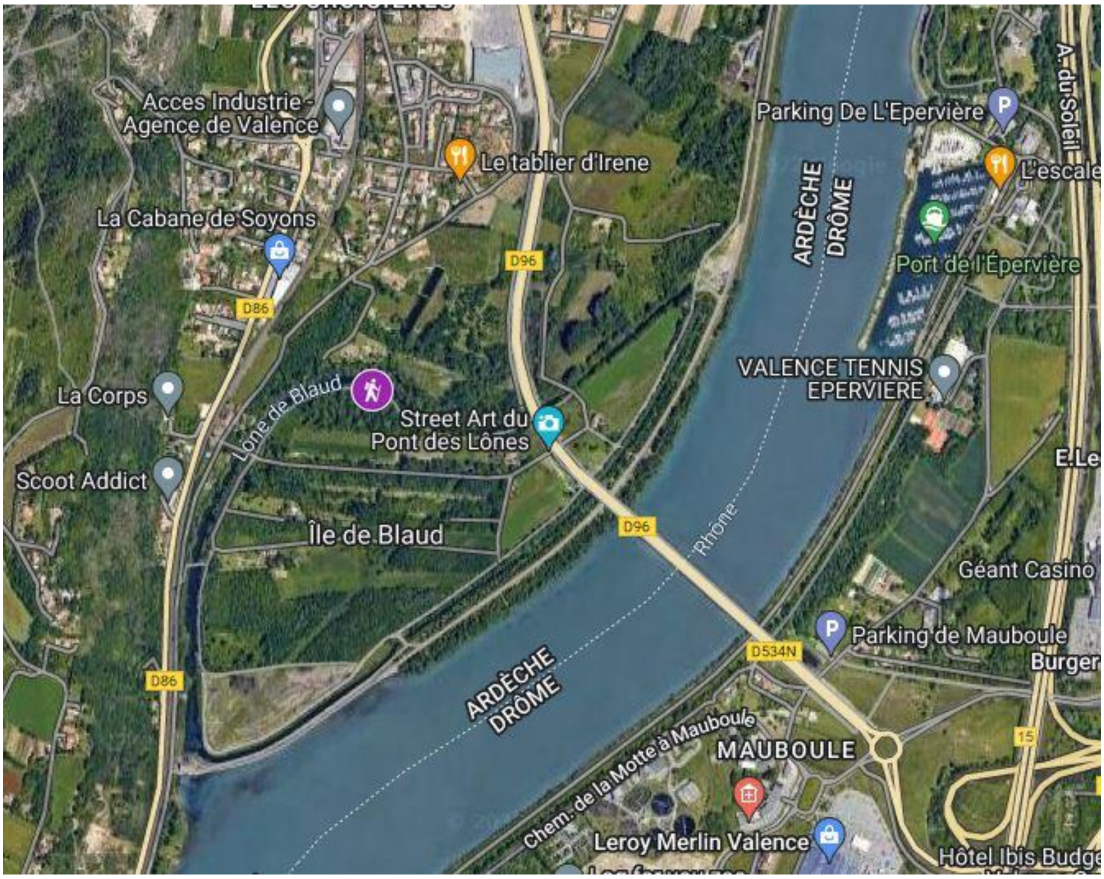

Figure 3. *Lône de Blaud*, Soyons municipality, Ardèche.

The *Lône de Blaud* is located in the municipality of Soyons, in the middle Rhône valley, south of Valence (right bank of the river; **Figs 2, 3**). The *Lône de Blaud* and the entire Blaud Island (*Ile de Blaud*) is a famous area among the inhabitants of the city of Valence for walks and bicycle trips. It serves as a "natural trap" for flood waters from the Rhône.

This *lône* is composed of a mosaic of natural habitats allowing the development of many plant and animal species. The gallery forests surrounding the *lône* are favorable to nesting birds such as the Hobby. Open and stagnant water are likely to host the Great Naiad (butterfly *Geometra papilionaria*) and the Emerged Bur-reed (plant *Sparganium emersum*), that are regionally protected. The site also presents a wealth in terms of dragonflies with rare species, some of which are protected: Aeschne paisible (*Boyeria irene*), Cordulégastre annelé (*Cordulegaster boltonii*), Agrion de Mercure (*Coenagrion mercurial*)… The European Pond Turtle was observed on this site, it uses the fallen trees to rest and the sandy embankments to lay eggs. A small population of European Beaver is regularly observed and the well-exposed environments near the *lône* are used by reptiles such as the wall lizard and the green lizard. Bird species are also diversified with, for instance, the Martin-pêcheur d'Europe (Common Kingfisher, *Alcedo atthis*), Aigrette garzette (Little Egret, *Egretta garzetta*), Chardonneret élégant (*Carduelis carduelis*).

STOP 2. Lône de la Roussette

Figure 4. *Lône de la Roussette*, Viviers municipality, Ardèche.

Located in the municipality of Viviers in the department of Ardèche, the *lône de la Roussette* has an area of 30 hectares and is fed by groundwater and downstream (Figs 2, 4). The purpose of this site is to preserve the biological balance of the environments and the conservation of the biotopes necessary for the feeding, reproduction, rest and survival of multiple animal and plant species.

Since 2000, it is protected by a Prefectural biotope protection order, which nevertheless does not preclude sampling. So far, 27 species of trees, 25 species of shrubs, 22 species of aquatic plants, 43 herbaceous species, 80 species of birds, 17 fish, 17 mammals, five amphibians, six reptiles have been documented around the *Lône de la Roussette*. Of them, butterflies (e.g., *Aeshna cyanea, Coenagrion puella*), orchids (*Himantoglossum robertianum*), thistle (*Eryngium bourgatii*). Five species of amphibians including the Spotted Salamander have been identified on the site. Beavers and European Otters are very present in the Rhône valley, particularly in the area of the *Lône de la Roussette*.

STOP 3. The fossiliferous site of Saint Restitut

Depending on traffic, we will reach St Restitut around lunch time (and have lunch there) or in the early afternoon (and thus have lunch on the way).

Composed of fossiliferous sandstones, marls and limestones of Burdigalian age (early Miocene, 16-20Ma), this level corresponds to a marine transgression in the Rhône valley (**Figs 2, 5**).

From the Paleocene to the Oligocene (from 65 to 23Ma) was a period of profound geological upheavals marked by the formation of the Alps under the thrust of the African continent. The Rhône valley was hollowed out by collapses, and lakes accumulated the alluvium coming from the various surrounding reliefs. During the early Miocene, the sea ascended the Rhône valley up to Valence (Burdigalian transgression) and initiated a new phase of marine sedimentation while eroding the soils in place.

From 15 to 150 m thick, depending on the irregularities of the previous topography, the Burdigalian is represented by quite varied facies which range from sandstone (or sand) more or less calcareous, to marl and limestone. The fossils, often broken by the agitation of the depositional environment, comprise bryozoans, bivalves (*Chlamys praescabriusculus, C. latissimus, Pecten subbenedictus, P. paulensis, Ostrea* sp.), echinoderms (*Cidaris, Echinolampas, Psammechinus dubius*), barnacles, and numerous ray and shark teeth. The ostracod fauna of the Burdigalian of Saint Restitut has been studied by Carbonnel (1969) and comprises *Aurila cicatricosa lauzea*, *A. haueri*, *A. ventroinflata*, *Cytheridea fourniei*.

Figure 5. Geological map of the Saint Restitut hill and examples of ray and shark teeth found at the locality.

24th of July, 2022: OSTRACODOLOGISTS IN CAMARGUE

The localities visited for collecting during the fieldtrip will be determined by their conditions (many ponds are likely to be partially or completely dry in July) and by our guide.

The Camargue wetland

Camargue is a natural region located south of Arles, between the Mediterranean Sea and the two arms of the Rhône delta (**Figs 2, 6**). Administratively, it lies within the department of Bouches-du-Rhône (Mouths of the Rhône), and covers parts of the territory of the communes of Arles, Saintes-Maries-de-la-Mer, and Port-Saint-Louis-du-Rhône. A further expanse of marshy plain, the Petite Camargue (little Camargue), just to the west of the Petit Rhône, lies in the department of Gard.

The first wetland in France by surface area, the Camargue is the second largest delta in the Mediterranean after that of the Nile. An emblematic site in France and in Europe, the Camargue has been shaped over the centuries by nature and man and has developed a strong cultural identity and a unique natural heritage. The Camargue extends over nearly 150,000 hectares, between the Gulf of Aigues-Mortes and that of Fos, in the form of a triangular delta whose base is the Mediterranean Sea on 80 km of sandy shore. Its central artery, the Rhône, divides into two branches at Arles: the Grand Rhône, which drains 85% of the water, and the Petit Rhône, draining 15%. These two arms delimit the island of Camargue, bordered by the Gard Camargue to the west of the Petit Rhône, and the Plan du Bourg area to the east of the Grand Rhône, itself bordered by the steppe plain of the Crau, former bed of the Durance.

Figure 6. Map of Camargue.

The first traces of human presence date back to antiquity. The Ligurians, indigenous people living on the shores of the Mediterranean, lived from fishing in the pond of Vaccarès. Then the Romans began the cultivation of the Rhône delta and settled the first salt marshes in the territory of Aigues-Mortes. Other peoples also settled in the Camargue such as the Vikings, who spent the winter of 859 in the Saintes-Maries-de-la-Mer, or the Saracens during the 10th century. However, very few traces of their passage remain. During the Middle Ages, the monks dried out the marshes and developed agriculture, the forests were also exploited to provide wood for the navy. In 1240, Louis IX (known as Saint-Louis) bought the lands of Aigues-Mortes to build a fortified port and thus benefit from direct access to the Mediterranean Sea. From the 17th to the 19th century, the extension of salt pans and villages contributed to the advance of agriculture in the delta. During the 20th century, the intensification of rice growing and market gardening accentuated the industrialization and urbanization of the Camargue and consequently led to the regression of wetlands in the delta. From the 1970s, protective measures were put in place to prevent the loss of these fragile natural areas.

The Camargue is home to many animal and plant species. Vertebrates are represented by 75 species of fish, 15 of amphibians, six of reptiles, 32 of mammals and 412 of birds including 111 regular breeding species. Of the 4,700 species of flowering plants recorded in France, more than 1,500 are present in the Camargue.

For a century and a half, and in particular since the total containment of the Rhône in 1869, the hydraulic functioning of the delta has been profoundly modified by human activity, in particular for the needs of agriculture (rice growing and salt farming). This resulted in significant changes in the natural functioning of Camargue ecosystems.

The Camargue plays a major role for certain species of birds for which it is home to most of the national breeding population (Greater Flamingo, Collared Pratincole, Hairy Crab-eating Heron, Glossy Ibis, Bittern…), wintering (Mallard, Gadwall, Red-crested Pochard, Green-winged Teal, Bewick's Swan, Greater Spotted Eagle…) or migratory (Avocet, Ring-necked Plover, Curlew Sandpiper, Black Tern…).

You can even adopt a Flamingo here: https://monflamant.com/en/

Geological and hydrological setting

The Camargue basin contains up to 4000 m of syn-rift sediments which overly a substratum of carbonates from Lower Cretaceous (130 Ma; **Fig. 7**).

The Grande Camargue (≈750 km^2; **Fig. 6**) has been formed by ancient channels of the Rhône River and by offshore bars, which constitute elongated topographic highs. The plain of the Rhône delta was mainly formed during the Quaternary period, by a progradation of sedimentary bodies influenced by fluvial sedimentary flows. Two morphological units are recognized in the Grande Camargue, according to geology:

- the fluvio-lagoonal Camargue unit (from Arles to the offshore bar in south of the Vaccarès lagoon), composed of a fluvial covering, with riverbanks deposited over lagoonal salt formations;
- the lagoonal-marine Camargue unit (south of the offshore bar), consisting of marine and lagoonal deposits covered by a limited fluvial layer.

The Middle Plain is a mixed environment with fluvial deposits forming elongate sand bodies (ancient riverbanks of the Rhone River) with meander patterns isolating freshwater to brackish water ponds. Riverbanks of the Rhône channel present a good permeability, while marsh areas are quasi-impermeable ponds where water is retained. Therefore, the water table is limited by the extension of silty-sandy deposits of ancient distributaries of the Rhône. The hydraulic head of the superficial aquifer is close to the ground surface.

Vertically, the Camargue is composed of two aquifers: a gravel deep aquifer and an unconsolidated superficial aquifer (consisting mainly of sand and clay). These aquifers are separated by a layer of silt with peat levels, which represents an impermeable level (aquitard). The impermeable level corresponds to the substratum of the local superficial aquifer.

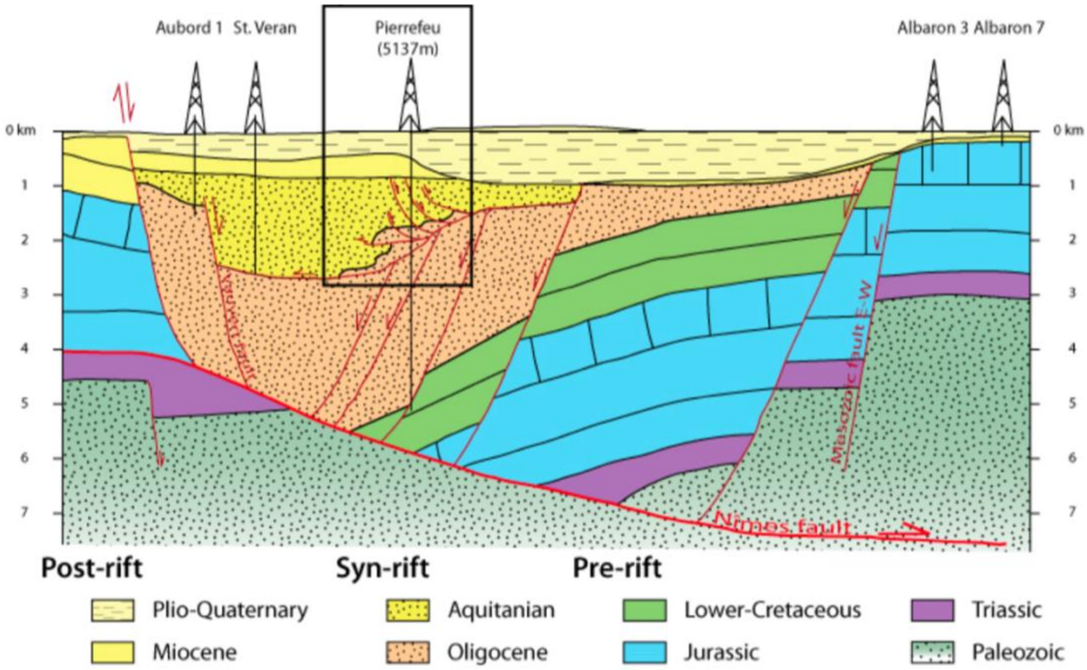

Figure 7. Geological cross-section (NW-SE) across the Camargue Basin. The site of brine exploitation is delimited by the black rectangle (from Valette & Benedicto, 1995).

The Tour du Valat

The Tour du Valat is a research institute for the conservation of Mediterranean wetlands that carries out numerous activities with partners in the North and South of the Mediterranean basin. The Tour du Valat employs around 80 people, who operate throughout the Mediterranean. Its scientific team develops research programs on the functioning of wetlands and tests management methods adapted to the challenges and particularities of Mediterranean wetlands.

Its domain, which includes all the natural habitats representative of the fluvio-lacustrine Camargue, extends over 2649 hectares, 1845 of which are classified as Regional Nature Reserve. It is a privileged site for conducting research, testing and developing agricultural or hunting activities. The Tour du Valat is also a unique documentary resource centre in the Mediterranean, specializing in the ecology of wetlands.

The domain

The Tour du Valat area covers a total area of 2,649 ha divided into two distinct geographical entities, located:

- The Tour du Valat estate itself (**Fig. 8**), near the village of Sambuc (municipality of Arles, Bouches-du-Rhône), with a total surface area of 2,548 ha, including 1,845 ha classified as a Regional Nature Reserve;

- The domain of Petit Saint-Jean with an area of 101 ha, located about thirty kilometers further west.

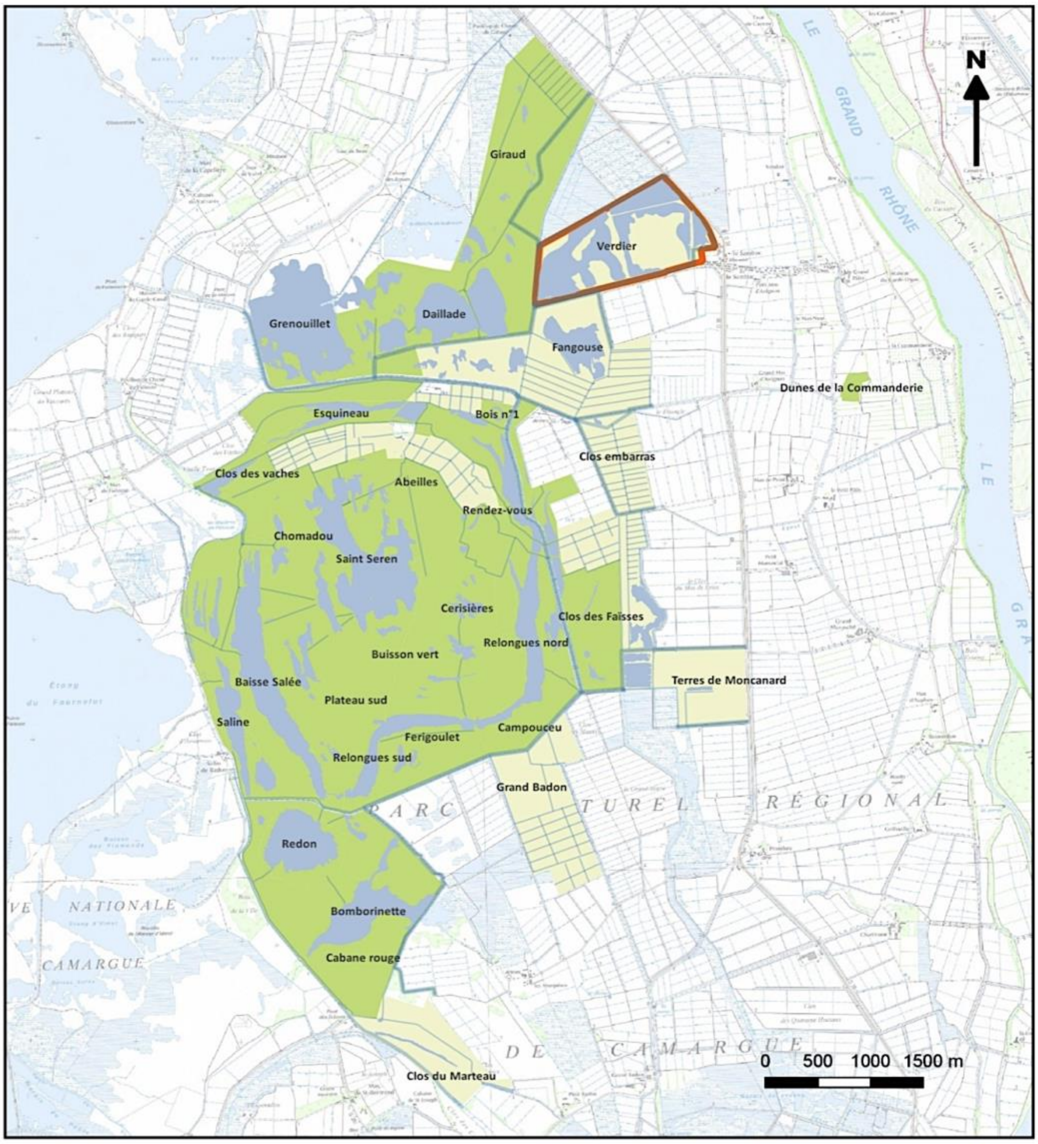

Figure 8. The Tour du Valat estate. In green: Regional Nature Reserve, in beige: area non-classified as Regional Nature Reserve, in red: Verdier marshes.

Our excursion will lead us to the heart of the Tour du Valat estate with natural habitats characteristic of the Camargue, in particular rare and threatened environments such as temporary marshes and *montilles* (small dunes), but also large areas of *sansouires* (salt meadows).

The fauna and flora adapted to these particular environments are remarkable: among other things, 590 species of plants (including about twenty with protected status), more than 300 species of birds (out of a total of approximately 450 species in Metropolitan France), and more than 1,600 species of invertebrates.

The principles of domain management consist of:

- Preservation of this exceptionally rich natural heritage, through monitoring and inventories of the natural heritage such as mapping of vegetation, floristic surveys, counting of water birds, mammals...
- Promotion of the implementation of research programs,
- Maintaining traditional activities (breeding, hunting) compatible with conservation issues.

Ostracods from Camargue

As a whole, in fresh and brackish waterbodies in Camargue, the following ostracod species have been reported (e.g., Hartmann 1953; Schachter 1950, 1960; Petit & Schachter 1954; Marazanof 1965; Steger 1979; Bodergat 1983; Bodergat *et al*. 1991; Meisch *et al*. 1989; taxonomic names have been updated where possible):

Superfamily Cypridoidea Baird, 1845
Family Candonidae Kaufmann, 1900
- Subfamily Candoninae Kaufmann, 1900
  - *Candona* sp.
  - *Candona candida* (O.F. Müller, 1776)
  - *Neglecandona neglecta* (Sars, 1887) *sensu lato*
  - *Pseudocandona albicans* (Brady, 1864)
  - *Pseudocandona lobipes* (Hartwig, 1900)
  - *Pseudocandona marchica* (Hartwig, 1899)
- Subfamily Cyclocypridinae Kaufmann, 1900
  - *Cypria ophtalmica* (Jurine, 1820)
  - *Cyclocypris ovum* (Jurine, 1820)

Family Cyprididae Baird, 1845
- Subfamily Cypricercinae McKenzie, 1971
  - *Bradleystrandesia reticulata* (Zaddach, 1844)
  - *Bradleycypris vittata* (Sars, 1903)
  - *Strandesia reticulata* (Daday, 1898)
- Subfamily Cypridinae Baird, 1845
  - *Cypris bispinosa* Lucas, 1849
- Subfamily Cypridopsinae Kaufmann, 1900
  - *Cypridopsis hartwigi* G.W. Müller, 1900
  - *Cypridopsis vidua* (O.F. Müller, 1776)
  - *Potamocypris mastigophora* (Methuen, 1910)
  - *Potamocypris variegata* (Brady & Norman, 1889)
  - *Sarscypridopsis aculeata* (Costa, 1847)
- Subfamily Cyprinotinae Bronshtein, 1947
  - *Heterocypris salina* (Brady, 1868)
- Subfamily Dolerocypridinae Triebel, 1961
  - *Dolerocypris sinensis* Sars, 1903
- Subfamily Eucypridinae Bronshtein, 1947
  - *Eucypris virens* (Jurine, 1820)
- Subfamily Herpetocypridinae Kaufmann, 1900
  - *Herpetocypris chevreuxi* (Sars, 1896)

Family Ilyocyprididae Kaufmann, 1900
- Subfamily Ilyocypridinae Kaufmann, 1900
  - *Ilyocypris gibba* (Ramdohr, 1808)
  - *Ilyocypris bradyi* Sars, 1890

Family Notodromadidae Kaufmann, 1900
- Subfamily Notodromadinae Kaufmann, 1900
  - *Notodromas persica* Gurney, 1921

Family Limnocytheridae Klie, 1938
- Subfamily Limnocytherinae Klie, 1938
  - *Paralimnocythere psammophila* (Flössner, 1965)
  - *Limnocythere sanctipatricii* Brady & Robertson, 1869
- Subfamily Timiriaseviinae Mandelstam, 1960

Metacypris cordata Brady & Robertson, 1870
Superfamily Cytheroidea Baird, 1850
Family Cytherideidae Sars, 1925
Cyprideis torosa (Jones, 1850)
Family Leptocytheridae Sars, 1925
Leptocythere petiti Hartmann, 1953
Leptocythere sp.
Family Loxoconchidae Sars, 1925
Loxoconcha elliptica Brady, 1868
Loxoconcha rhomboidea (Fischer, 1855)
Family Paradoxostomatidae Brady & Norman, 1889
Cytherois fischeri (Sars, 1866)
Lanceostoma cf. *intermedium* (G.W. Müller, 1894)
Family Xestoleberididae Müller, 1894
Xestoleberis aurantia (Baird, 1838)
Superfamily Pontocypridoidea Müller, 1894
Family Pontocyprididae Müller, 1894
Pontocypris dispar G.W. Müller, 1894

In the Haute Camargue, North of Vaccarès (**Figs 9, 12**), Bodergat (1983) reported only continental species of fresh or brackish water from the Marsh of Cabassole (locality 1 in **Fig. 9**): *Ilyocypris biplicata* (= *I. gibba*), *Cypridopsis vidua, Potamocypris variegata* and *Notodromas persica.*

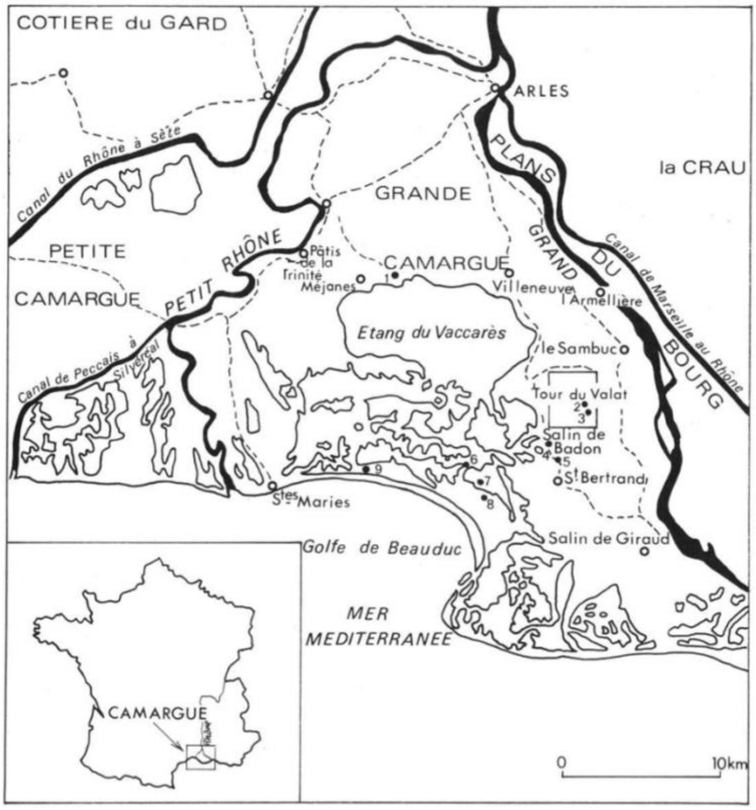

Figure 9. Stations studied in Camargue (Bouches-du-Rhône) by Bodergat (1983).
1: Marsh of Cabassole; 2: Salt pond; 3: *Emprunt* of the Petite Cerisière; 4: Salines of the Tour du Valat; 5: Ditch of the Tour du Valat salines; 6: Martyrs of La Gacholle; 7: Pond of the Lady; 8: Galabert pond; 9: Batayolles pond. In bold, stations within the Tour du Valat, a close-up is given in Figure 10.

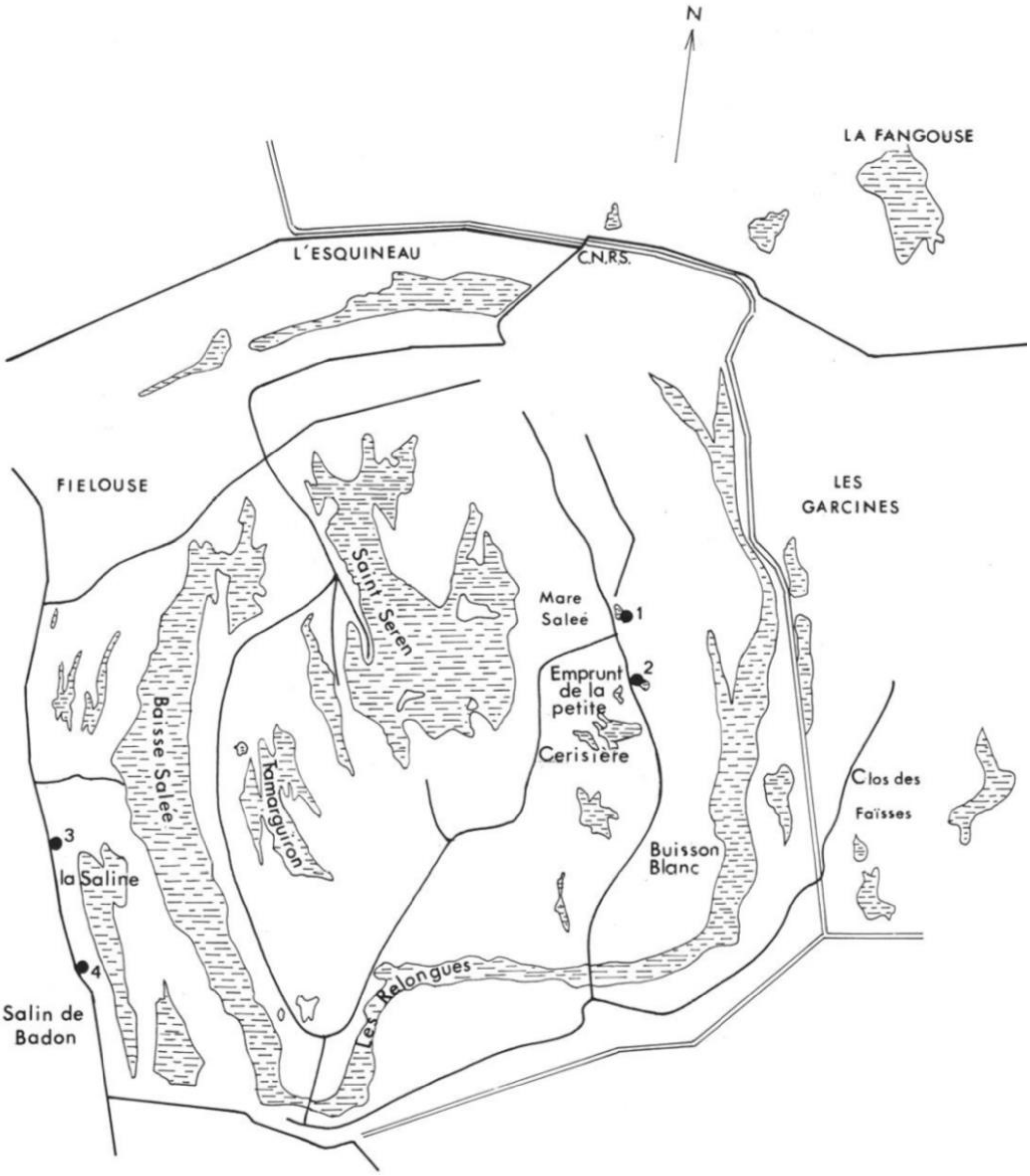

Figure 10. Stations studied in Tour du Valat, Moyenne Camargue (Bouches-du-Rhône) by Bodergat (1983). 1: Salt pond; 2: *Emprunt* of the Petite Cerisière; 3: Salines of the Tour du Valat; 4: Ditch of the Tour du Valat salines.

In the Moyenne Camargue, Domain of the Tour du Valat, in temporary ponds with bottoms lined with Characeae (la Mare Salée, l'Emprunt de la Petite Cerisière and les Salines de la Tour du Valat near l'Oratoire; localities 1, 2, 3 in **Fig. 10;** see also **Fig. 12**), Bodergat (1983) found: *Eucypris virens* var. *media, Potamocypris variegata, Ilyocypris biplicata* (= *I. gibba*) and *Pseudocandona albicans.* In a ditch near l'Oratoire (locality 4 in **Fig. 10**; see also **Fig. 12**) these species were accompanied by *Cyprideis torosa* and *Loxoconcha elliptica*. Their presence may be related to the rise of the salty water table contributing to a higher salinity compared to the neighbouring waterbodies. *Sarscypridopsis aculeata* was found in a temporary pond close to Point 4 and is considered, in Camargue, as an oligobrackish species that disappears when salinity exceeds 5g/L.

In Moyenne Camargue, the presence of *C. torosa* and *L. elliptica* is linked to an increase in salinity, while the exclusive presence of *C. torosa* corresponds to an absence of vegetation. *Xestoleberis aurantia* and *Lanceostoma* cf. *intermedium* have also been observed; the presence of the former in the Beauduc pond close to the Gulf of Beaduc (**Fig. 11**) seems related to the constant influx of marine waters in the ponds allowed by companies to maintain the saline systems.

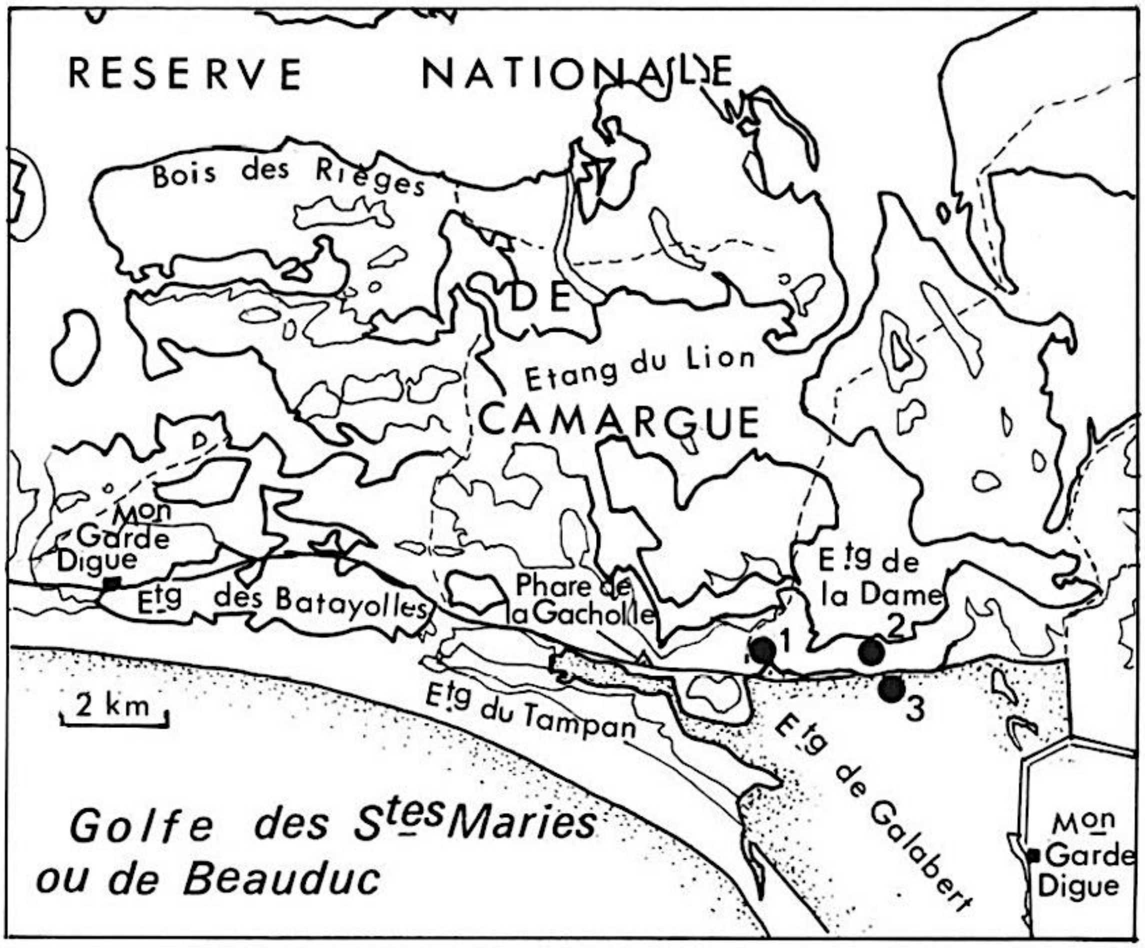

Figure 11. Stations studied in Basse Camargue (Bouches-du-Rhône) by Bodergat (1983).
1: Martyrs de la Gacholle (perennial pond with fixed vegetation); 2: Etang de la Dame (temporary pond devoid of vegetation); 3: Etang de Galabert (temporary pond devoid of vegetation).

Areas sampled by Bodergat (1983) in the Basse Camargue are shown in **Figs 11** and **12**. In ponds devoid of vegetation (Etang de la Dame and Etang de Galabert, localities 2 and 3 in **Fig. 11**), monospecific populations of *Cyprideis torosa* were found. A point for discussion during the field trip is that Bodergat (1983) listed these two ponds as "temporary", but a truly temporary pond seems an unlikely habitat for *Cyprideis torosa*, which has brood care and lacks resting eggs. These ponds are certainly likely to vary seasonally in their lateral extent and depth; probably her sampling was done in the temporary margins of the large perennial ponds.

General conclusions can be proposed:

- In Haute Camargue, the waterbodies rest on weakly haline soil; the oligohaline nature of the water allows the installation of fixed vegetation (mainly reeds and Characeae). In these stations, the ostracod fauna is represented by species reputed to be continental, frequent in brackish water and neither *Cyprideis torosa* nor *Loxoconcha elliptica* have been found.
- In Moyenne Camargue, the associations of ostracods are identical to those of the Haute Camargue in the waterbodies occupied by fixed vegetation. The appearance of *C. torosa* and *L. elliptica* corresponds to an increase in water salinity and the exclusive presence of *C. torosa* corresponds to the absence of vegetation.
- In Basse Camargue, the observations confirm this last remark.

Figure 12. Ostracod localities from Bodergat (1983).

Additional ostracod records (**Fig. 13**) were reported by Bodergat *et al*. (1991). In L'Étang de Scamandre they found C*yprideis torosa* and *Loxoconcha elliptica,* and in two connected ponds (L'Étang de la Dame and l'Étang des Martyrs de la Gacholle) they found the same two species with the addition of *Leptocythere* sp. and *Cypridopsis vidua*.

Figure 13. Ostracod localities from Bodergat *et al*. (1991).

Marazanof (1965) recorded ostracods from four localities (**Fig. 14**) as listed below (taxonomic names updated where possible).

Pont du St Gilles (a levy in an irrigation canal): *Dolerocypris sinensis, Notodromas persica.*
La Baisse Salée de la Tour du Valat: *Sarscypridopsis aculeata*, *Eucypris virens.*
Mare temporaire près des Salines de la Tour du Valat: *Sarscypridopsis aculeata.*
Marais de l'Esquineau de la Tour du Valat: *Cypris bispinosa, Herpetocypris chevreuxi, Eucypris virens, Notodromas persica.*

Figure 14. Ostracod localities from Marazanof (1965)

Steger (1972) listed 14 localities (**Figs 15a** and **15b**); details are given below (taxonomic names updated where possible).

Station 1. Salicam: *Cyprideis torosa, Eucypris* sp.

Station 2. Faraman: *Cyprideis torosa, Cytherois fischeri*

Station 3. La Gacholle: no ostracods recorded

Station 4. Les Frignants**:** *Sarscypridopsis aculeata, Eucypris virens, Ilyocypris gibba, Potamocypris mastigophora*

Station 5. Mas Michel: *Cyprideis torosa, Sarscypridopsis aculeata, Ilyocypris gibba*

Station 6. Mas d'Agon: *Bradleystrandesia reticulata, Cypris bispinosa, Eucypris virens, Herpetocypris chevreuxi, Sarscypridopsis aculeata*

Station 7. Saint Michel: *Cyclocypris ovum, Bradleystrandesia reticulata, Cypridopsis hartwigi, Cypridopsis vidua. Cypris bispinosa, Eucypris* sp., *Notodromas persica, Strandesia vittata* (= *Bradleycypris vittata*)

Station 8. Les Tuiles: *Pseudocandona albicans, Neglecandona neglecta, Sarscypridopsis aculeata, Cypridopsis hartwigi, Cypridopsis vidua, Cypris bispinosa, Eucypris virens*

Station 9. Les Salines (connected with the Baisse Salée. Stations 9 and 13 appear to have been transposed on the map in Steger's thesis): *Cyprideis torosa, Ilyocypris gibba, Limnocythere sanctipatricii*

Station 10. L'Esquineau: *Pseudocandona albicans, Pseudocandona marchica, Cyclocypris ovum, Bradleystrandesia reticulata, Cypridopsis vidua, Cypris bispinosa, Eucypris virens, Herpetocypris chevreuxi, Notodromas persica, Bradleycypris vittata*

Station 11. Clos des Faisses: *Eucypris virens, Paralimnocythere psammophila*

Station 12a (12 in original). Grande Cerisière: *Pseudocandona albicans, Pseudocandona marchica, Neglecandona neglecta, Eucypris virens, Cypridopsis hartwigi*

Station 12b (12' in original). Moyenne Cerisière: *Pseudocandona albicans, Pseudocandona marchica, Neglecandona neglecta, Eucypris virens, Cypridopsis hartwigi*

Station 13. Salin de Badon (connected to l'Etang du Fournelet in winter; Stations 9 and 13 appear to have been transposed on the map in Steger's thesis): *Pseudocandona albicans, Eucypris virens, Sarscypridopsis aculeata*

Also of interest are the findings of Brochet *et al*. (2010) who found live ostracods, including *Potamocypris* cf. *mastigophora* (as *P.* cf. *producta*) and *Paralimnocythere* cf. *psammophila*, in and on the plumage of Teal (*Anas crecca*) wintering in the Camargue, demonstrating that these birds may be important vectors of ostracod dispersal both within the Camargue and along their migratory flyways.

Figure 15a. Ostracod localities from Steger (1972).

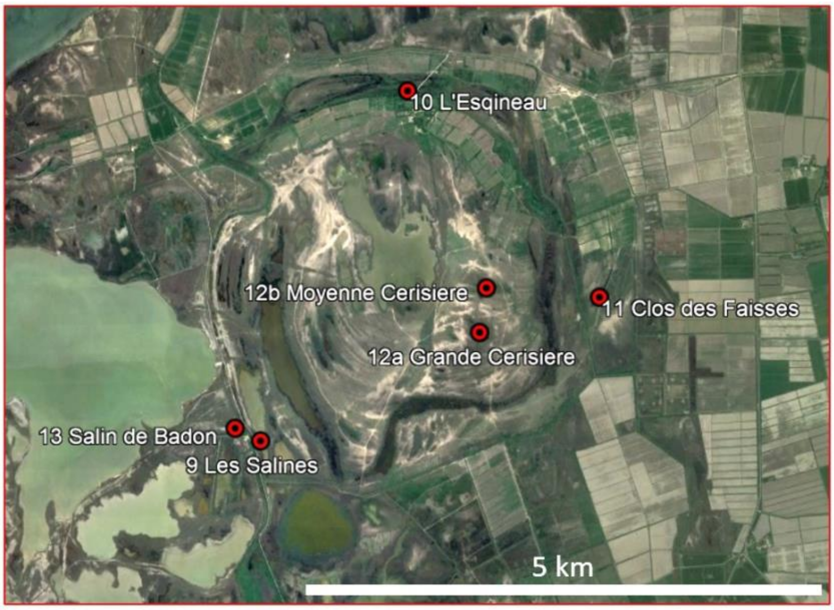

Figure 15b. Ostracod localities from Steger (1972).

25th of July, 2022: OSTRACODOLOGISTS IN RICE-FIELDS OF CAMARGUE

Figure 16. Camargue rice field blooming in July.

The rice fields habitat (based on Smith *et al*. 2018)

Rice fields cover 163 million hectares, accounting for 11.7% of the world's arable land. They are found in 116 countries worldwide, but production is concentrated in relatively few countries. There are several different types of rice growing environments, including, rain-fed lowland, deep water, upland, tidal wetlands environments, but the majority of rice is grown in irrigated paddy fields (**Fig. 16**).

Rice includes about ten species belonging to the genus *Oryza*, among which *Oryza sativa*, the main one, originating from Asia and *Oryza glaberrima* originating and only cultivated in West Africa. Molecular evidence indicates that farming for Asiatic rice originated from a single domestication event c. 8,200-13,500 years ago in the Yangtze Valley of China and spread to different regions over the following thousands of years. Although rice fields represent relatively young habitat, they have been colonized by diverse flora and fauna. The invertebrate fauna includes mainly: ostracods, copepods, cladocerans, aquatic insects, insect larvae, rotifers, molluscs, oligochaetes and nematodes.

Rice fields are harsh environments for aquatic faunas. Temperature fluctuations, especially in rice fields of temperate regions, can be over 20°C in a 24-hour period, and maximum temperatures can reach 40°C. The growth of algae and aquatic plants cause marked diurnal changes in pH and oxygen levels: during times of algal blooms, diurnal changes in pH from neutral to 9.5 are not uncommon, reaching as high as 11, and the standing water in rice fields can become oversaturated in oxygen. Methane emissions from rice fields also show diurnal changes, positively correlated to soil temperatures. The most extreme diurnal variations in water chemistry and temperature tend to occur during the beginning of the crop cycle after the fields have been fertilized (thus causing algal blooms), and later decrease when the water is shaded by the canopy of the rice plants. Ultra violet radiation is high, especially in the early part of the growing season before the rice plants produce a shading canopy. The application of pesticides and herbicides can have a negative effect on their aquatic inhabitants, and ploughing, planting, weeding, and harvesting of rice fields are high impact activities that can dramatically disturb the rice field ecosystem. The growing rice changes the physical and chemical characters of the rice field, thus the ecosystem dramatically changes through the rice-growing cycle. The duration of the aquatic phase of rice fields varies considerably depending on the region, and also year by year, and the physical nature of the water varies through the rice cycle, from flowing, stagnation, and finally a drying out phase.

If a species can tolerate the harsh and variable conditions of rice fields, there are considerable benefits. For microfauna, these environments are usually rich in food resources, such as algae and organic detritus, and they tend to lack larger predators, such as fish, although in some parts of the world, rice fields are used as fish nurseries. They are also a very large habitat to exploit, and the movement of people, machinery and rice seedlings between fields are useful dispersal mechanisms.

Rice fields in Camargue: The French Rice Center

In 1593, Henri IV, advised by his minister Sully, ordered the cultivation of sugar cane, madder and rice in the Camargue. Untimely flooding of the Rhône, epidemics of malaria, and the preponderance of wheat in customary uses, jeopardized this project. In the 19th century, following the damming up of the Rhône, a revival took place, the enormous quantities of water introduced into the rice fields being seen as favourable means of desalinating the land. But the effects were small.

Figure 17. *Echinochloa crus galli* from Camargue. www.centrefrancaisduriz.fr

The food shortages of the Second World War having shown the interest of rice, the National Institute for Agronomic Research (*INRA*) began the selection in 1947. Rice cultivation then developed regularly until 1965, a time of major works: land cleared, levelled, networks of irrigation canals and modernized pumping stations, construction of large silos and processing plants. During the following decades, climatic hazards, low yields, Italian competition due to the common market induced a new gradual decline. In 1981, a recovery plan, boosted by the public authorities, the Camargue rice farmers and the resumption in 1986 of a research program, enabled the Camargue to produce third of the 240,000 tons of rice consumed today in France. It was the time when rice growing found its way and, having become the mainstay of Camargue agriculture, its economic impact became well established. In 1995, the selection program was expanded and since then, around thirty varieties of rice have been registered.

In Camargue, 178 species grow in the rice-growing environments (including the rice fields but also the exposed areas close to the rice fields: http://plantes-rizieres-camargue.cirad.fr/accueil). Among these, about 40 species can be considered as crop weeds, and some have a major impact on the crop: weed rice, *Echinochloa* (**Fig. 17**), sedges.

The French Rice Centre's mission is to give rice farmers the means to produce quality rice, at a competitive cost, within the framework of an harmonious relationship with the environment. The French Rice Centre experiments with cultivation techniques, implements a varietal selection program and also provides constant technical support to rice growers. Today in Camargue, there are 230 rice farmers.

We will be guided through rice fields at the Mas du Sonnailler, within the French Rice Centre's boundaries (**Fig. 18**).

Figure 18. The French Rice Center, a few kilometers west from Arles.

Ostracods in rice fields: a short summary (based on Smith *et al*. 2018)

Ostracods are often the dominant group in the rice field environments. Many rice field ostracods have desiccation-resistant eggs, their carapaces help to retain moisture during periods of drought and protect them from UV radiation, they have a short life cycle, and consume organic detritus, algae and cyanobacteria, all prolific in rice fields.

Ostracods live on and in the surface-oxidized soil layer of rice fields, and nektobenthic species additionally use the floodwater. The family Notodromadidae contains species that spend considerable amounts of time as neuston, hanging upside down from the water surface, typically in small shallow habitats, including rice fields. The oxidized soil layer is a photic aerobic environment with a positive redox potential and is microbiologically very active. Carbon dioxide, nitric oxide, ferric oxide and sulphate levels are stable, and algae and aerobic bacteria predominate. The depth of the oxidized layer is typically between 2 and 20 mm, and is dependent, not only on the concentration of dissolved oxygen in the water and reducing capacity of the soil, but also on the activities of benthic and interstitial faunas, which include ostracods. The activities of benthic invertebrates directly affect nutrient recycling through excretion, and indirectly by physically disturbing the soil and releasing minerals. The extent to which ostracods contribute to nutrient recycling in rice fields is unknown, but is likely to be significant considering their high densities and near ubiquitous presence. The surface-oxidized soil layer is in continuous exchange with the water above and the two can be seen as a continuous environment; nektobenthic ostracod species mirror this continuum by constantly moving from the soil layer to the floodwater.

The consumption of cyanobacteria by ostracods is the most researched aspect of ostracod ecology in rice fields. Of the grazers that have the biggest impact on the photosynthetic biomass of rice fields, ostracods and gastropods have been reported to be particularly important in limiting the growth of nitrogen-fixing cyanobacteria. This grazing of cyanobacteria by ostracods (and other invertebrates) can therefore have a deleterious effect on the growing rice.

Ostracods can be targeted by pesticide application due to their deleterious effect on nitrogen-fixing cyanobacteria, or be affected by applications that target other taxa. Pesticides developed and used in rice fields in the 1950s and 60s were generally more potent and environmentally damaging than their recent counterparts and, for instance, the widespread use of pesticides during the 1960s onwards in Italian rice fields may have been the cause of the decline of ostracod diversity over a thirty-year period. Ostracods have been reported to be highly sensitive to some pesticides and resilient to others, with generally a lower tolerance than other taxa to imidacloprid, a pesticide widely used in rice fields. Rice fields in which imidacloprid was used have significantly reduced ostracod populations and turbidity of the water is lower compared to rice fields with abundant ostracods. This is because ostracods and other meiofauna continuously disturb the soil layer searching for food, increasing turbidity.

A total of 192 named species and subspecies of ostracods from 26 countries and sovereign states have been reported from rice fields in the published scientific literature. Seventy eight percent of these ostracod species belong to the family Cyprididae. The next most diverse family found in rice fields is the Candonidae, followed by Ilyocyprididae.

Ostracods in Camargue rice fields

So far, in the Camargue rice fields, 11 ostracod species have been documented (Pont 1977; Meisch *et al*. 1989; Smith *et al*. 2018; taxonomic names updated where possible):

Family Cyprididae Baird, 1845
Subfamily Cypricercinae McKenzie, 1971
Strandesia bicuspis bicuspis (Claus, 1892) : Brazil, France
Strandesia reticulata (Daday, 1898): France, Italy
Subfamily Cypridopsinae Kaufmann, 1900
Cypridopsis parva G.W. Müller, 1900 (a possible junior synonym of *Cypridopsis vidua*)
Cypridopsis vidua (O.F. Müller, 1776): Brazil, Bulgaria, France, India, Iran, Italy, Japan, Russia, Spain, Turkey
Potamocypris mastigophora (Methuen, 1910): France, Macedonia
Subfamily Cyprinotinae Bronshtein, 1947
Heterocypris barbara (Gauthier & Brehm, 1928): France, Japan
Heterocypris capensis (G.W. Müller, 1908)
Subfamily Dolerocypridinae Triebel, 1961
Dolerocypris sinensis Sars, 1903: China (mainland), France, Iran, Italy, Japan, Macedonia, Romania, Spain, Tadzhikistan, Uzbekistan
Subfamily Herpetocypridinae Kaufmann, 1900
Stenocypris major (Baird, 1859): Brazil, China (mainland), France, India, Indonesia, Italy, Japan, Malaysia, Philippines, Romania, Sri Lanka, Thailand, Uzbekistan
Family Ilyocyprididae Kaufmann, 1900
Subfamily Ilyocypridinae Kaufmann, 1900
Ilyocypris bradyi Sars, 1890: France, India, Iran, Italy
Family Notodromadidae Kaufmann, 1900
Subfamily Notodromadinae Kaufmann, 1900
Notodromas persica Gurney, 1921: France, Italy

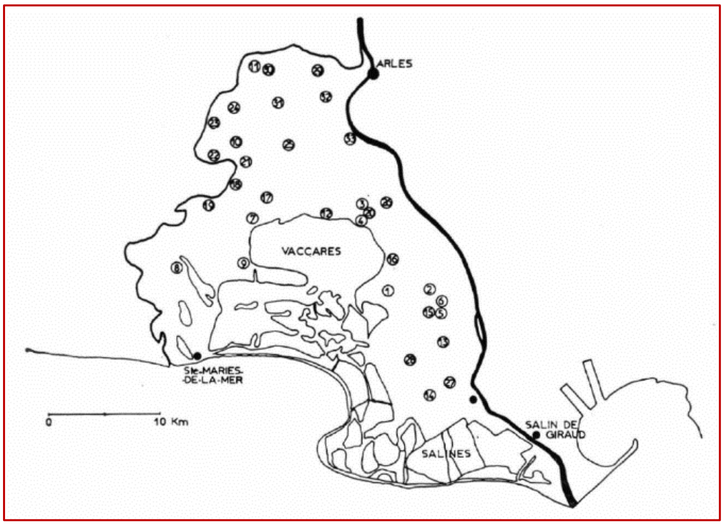

Figure 19. Camargue rice fields sampled by Pont (1977).

Pont (1977) carried out seasonal sampling of 33 rice fields in Camargue in 1975 and 1976, recording 41 species of Copepoda, Cladocera and Ostracoda. Unfortunately, no detailed localities information was given, although the approximate locations are shown on a small-scale map (reproduced here as **Fig. 19**). The seven ostracod species recovered were (taxonomic names updated): *Strandesia bicuspis bicuspis*, *Strandesia reticulata*, *Cypridopsis parva*, *Cyprinotus capensis*, *Dolerocypris sinensis*, *Stenocypris major* and *Ilyocypris bradyi*.

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Arles through history

Arles is a commune, of about 50.000 habitants, situated in the south of France in the Provence-Alpes-Côte d'Azur region. Thanks to the inclusion of most of the Camargue Region, the city of Arles is the largest municipality in metropolitan France with about 760km^2.

The origins of Arles are shrouded in mystery. The Greeks were the first to build a settlement on this spot, named *Théliné.* Then, the Celts founded *Arelate* on the site of the Greek establishment. But it was only with the arrival of the Romans that the city really bloomed.

The architectural heritage of Arles is part of its history, from antiquity to contemporary times. The city owes its importance, through the centuries, to its geographical position, on a rocky hill on the banks of the Rhône. Close to the sea, in the middle of the marshes, it has, since Roman times, an immense territory. At its level, the Rhône, facing up against a hill, describes a wide and majestic curve favourable to the establishment of a bridge and the creation of the port connected with the Mediterranean.

Its position at a crossroads of an Italy-Spain land route and a waterway penetrating into the heart of Gaul, has been the foundation of Arles' prosperity in the Antiquity. The city was then enriched with superb monuments: forum, temples, theatre, amphitheatre, circus, thermal baths... Under the reign of Constantine, it experienced vigorous urban growth on both banks of the Rhône. The prosperity of Arles society was expressed, then, by the rhythm of imports of sumptuous marble sarcophagi. From the 3rd century, the church of Arles was founded. The Christian necropolis of Alyscamps, where Saint-Genest, Arles' martyr, is buried, takes on an exceptional size. The primitive cathedral found place close to the city walls and was later (5th century) transferred near the Forum, and took the name of Saint-Etienne.

During the medieval period, its religious importance grew and the influence of the Archdiocese of Arles knew its apogee in the 12th century. It is on the site of the Saint-Étienne church that the Saint-Trophime primatial church and the canonical buildings were built, around a cloister. Nearby are many churches and convents, the most famous being that of Saint-Césaire. Booming economically and geographically, Arles welcomed pilgrims heading for Santiago de Compostela. After a period of recession at the end of the Middle Ages, the city experienced a new period of prosperity during the Renaissance (middle of the 16th century). One of the finest jewels of the city is the Clock Tower, which was built from 1543 to 1553 on the model of the Roman mausoleum of Saint-Rémy.

The reconstruction period of the 17th and 18th centuries gave Arles its current landscape: the Town Hall, most of the mansions, houses and churches surrounding the streets of the protected area, date from this period. The volutes, foliage and lambrequins of the facades, in particular of the Hôtel de Mandon, recall the decorations of the banners which were hung there on holidays. At the start of the 19th century, the aristocracy and the bourgeoisie affirmed their taste for the neoclassical style by erecting vast residences such as the Hôtel de Chartrouse. The Institute of Research on Ancient Provence built by H. Ciriani, will be the mark of the 20th century.

From left to right: St-Trophime Cloister – Roman Amphitheatre - arena


Avignon (D570)
Les Baux-de-Provence (D17)
St Rémy-de-Provence
Musées / Monuments / Sites
Edifices publics / publics buildings / edifici pubblici
Entrée du public / public entrance / ingresso del pubblico
Parkings payants / paying carparks / parcheggi a pagamento
Parkings gratuits / free car park / parcheggi gratuiti
Gare de bus / bus station / stazione degli autobus
Accessible aux personnes à mobilité réduite / Accessible for disabled / Accesso per portatori di handicap
Borne de recharge pour véhicules électriques
Electric vehicle (EV) charging station
Colonnina di ricarica per auto elettriche
Voie ferrée / railway / strada ferrata
Pistes cyclables / cycling path / pista ciclabile
ViaRhôna
Chemin d'Arles – St Jacques de Compostelle
pilgrimage route to Santiago de Compostela
il cammino di Arles – San Giacomo di Compostela
Vi'Arelate
Vi'Arelate (Circuit du samedi)
Bornes d'accès / limited acces, boundary marker / paletto-zona a traffico limitato
Points de vue / viewpoint / panorama
Quais du Rhône / the banks of the Rhône / lungofiume del Rodano
100 mètres
100 metri
100 yards
Le Grand Rhône
Hotêl Atrium
Offices de Tourisme de France
Sortie N°5 Centre Ville
Jardin d'été
Cimetière Arles Ville
Espace Mistral
Boulevard Georges Clémenceau
Boulevard des Lices
Boulevard Emile Combes
Pont de Trinquetaille
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Monuments / museums / sites
Monumenti / musei / sites
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The Amphitheater (arena) - E3
L'Anfiteatro (L'arena) - E3
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The Roman Theater - E4
Il Teatro antico - E4
03 Les Thermes de Constantin - D3
The baths of Constantine - D3
Le Terme di Costantino - D3
04 Les Cryptoportiques (le forum souterrain) - D3-D4
The Cryptoportico (underground Forum) - D3-D4
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Gli Alyscamps (necropoli antica e cimitero medievale) - F5
06 Le Cloître Saint –Trophime - E4
Saint Trophime's cloister - E4
Il Chiostro Saint Trophime - E4
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The Réattu museum, muséum of Fine Arts - E3
Il Museo Réattu, museo delle belle arti. - E3
08 Le musée départemental Arles Antique - A5
The Arles Archaeological Museum - A5
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(en dehors du centre d'Arles).
The Camargue museum (outside the Arles city center).
Il Museo della Camarga (fuori città).
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Le museon Arlaten, museum of Provence - D4
Le museon Arlaten, museo della Provenza - D4
11 L'église Saint-Trophime - E4
Saint Trophime's church - E4
La Chiesa Sant Trofimo - E4
12 Tour des Mourgues - F4
Tower « des Mourgues » - F4
Torre « des Mourgues »- F4
13 Remparts - F2-F4
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Le mura - F2-F4
14 Conservatoire du santon provençal - E3
Conservatory of the Provençal santon - E3
Museo del santon provenzale - E3
15 La fondation Vincent van Gogh Arles - D3
Hors Pass.
The Arles Vincent van Gogh Foundation - D3
Not included in the Pass.
La Fondazione Vincent van Gogh Arles - D3
Non inclusa nel Pass
16 Luma Arles – Parc des Ateliers - G5
Luma Arles – Parc des Ateliers - G5
Luma Arles – Parc des Ateliers - G5
17 Fondation Lee Ufan - E3
Lee Ufan Foundation - E3
La Fondazione Lee Ufan - E3
18 Abbaye de Montmajour : R-S12
(en dehors du centre d'Arles).
Montmajour Abbey : R-S12 (outside the Arles city center).
Abbazia di Montmajour : R-S12 (fuori dal centro d'Arles).