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Checklist

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The Checklist of Canterno lake. Update to December 2020 (Southern Latium)

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Abstract

This study was carried out in the Canterno lake (Lat 41° 45′ 10,9′′ N - Long 13° 15′ 1,5′′ E) in the 2018 – 2020 period. 133 species (72 Non-Passerines - 54,5% - and 61 Passerines 46,2%) were recorded. 124 species are in the Red List of Italian breeding birds, 31 species are listed in Annex I of the Directive 2009/147/EC on the conservation of wild birds. The data shows the presences of *Ciconia nigra*, *Coracias garrulus*, *Clamator glandarius*, *Accipiter gentilis*, *Tadorna tadorna*, *Tadorna ferruginea* and the regular migration of *Pandion haliaetus*, *Hieraaetus pennatus*, *Falco vespertinus* and *Ficedula albicollis*. 41 species have a status of resident and breeding; 19 species are summer breeding visitors; 26 are migrant species; 16 species are wintering. The data integrate the last published checklist (Roma & Rossetti 1998) making a review of the water-birds list. The list adopts the systematic classification and the italian common name of the recently check-list of birds of Latium (Brunelli et al., 2019).

Keywords: Checklist, birds, Canterno lake, Latium, Central Italy.

Riassunto

Nel periodo 2018 – 2020 si è svolta una ricerca con obiettivo la redazione di una check-list del lago di Canterno (Lazio, Italia). Mediante rilevamento da 9 punti fissi, posizionati in modo da coprire l'intero bacino, sono state censite 133 specie: 72 (54,1%) Non Passeriformi e 61 Passeriformi. 116 specie risultano inserite nella Lista Rossa degli Uccelli nidificanti italiani (Gustin et al., 2019) e 31 specie sono elencate nell'Allegato I della Direttiva 2009/147 / CE "Direttiva Uccelli". Risultano presenti 43 specie sedentarie nidificanti; 19 specie nidificanti estive; 34 specie migratrici (M reg, M irr); 4 specie svernanti (W reg, W irr). Data la posizione geografica del bacino lacustre, e nonostante sia di piccole dimensioni, isolato, minacciato dalla pesca sportiva, da una fruizione non regolamentata e dall'inquinamento delle acque, il lago di Canterno si connota come importante area di transito e sosta per numerose specie migratrici e svernanti. Si ritengono interessanti e importanti le osservazioni di *Ciconia nigra*, *Coracias garrulus*, *Clamator glandarius*, *Accipiter gentilis*, *Tadorna tadorna*, *Tadorna ferruginea* e i flussi migratori regolari di *Pandion haliaetus*, *Hieraaetus pennatus*, *Falco vespertinus* e *Ficedula albicollis*. Con la presente ricerca si vuole integrare l'ultima checklist pubblicata (Roma & Rossetti 1998) con conoscenze maggiormente approfondite dell'avifauna lacustre. L'elenco delle specie censite utilizza la classificazione sistematica e il nome comune italiano adottati della check-list degli uccelli del Lazio (Brunelli et al., 2019).

Parole chiave: Checklist, uccelli, Lago di Canterno, Lazio, Italia centrale.

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Introduction

Wetlands play a primary role in the phenological phases of numerous bird species (Fraissinet 2017) and are among the most threatened natural environments in the world (http://ramsar.org). Canterno lake has never been at the center of systematic ornithological studies even if, recently, the avifauna has been studied (Roma & Rossetti 1998) as happened for other lakes in the Frosinone province such as San Giovanni Incarico (Roma & Rossetti 1995) and Posta Fibreno (Puzzanghera 1986). Some ornithological researches involving Canterno lake have been carried out in the context of broader provincial-based researches (Roma & Rossetti 1989, 1990a, 1991, 1992a; Corsetti & D'Orsi 2007) or about studies concerning specific taxa (Roma & Rossetti 1990b, 1992b). The lake has recently been the subject of ornithological researches conducted in Latium (Zapparoli 2011): IWRB censuses, nesting and wintering birds, monitoring of herons, diurnal birds of prey (Boano et al., 1995; Brunelli et al., 2004; Brunelli et al., 2006; De Giacomo & Tinelli 2006; Brunelli et al., 2009; Brunelli et al., 2011; Aradis et al., 2012; Biancolini et al., 2017) and monitoring of *Aquila chrysaetos*, *Falco biarmicus*, *Falco peregrinus* (Borlenghi et al., 2016). This work proposes the update of the check-list of Canterno lake integrating the latest published checklist (Roma & Rossetti 1998) through an exhaustive revision of the list of waterbirds. This work represents to the first results of scientific studies on the Riserva Naturale "Lago di

Canterno", part of the field studies of the "Sylvatica – Associazione Naturalistica". General objective is to provide a contribution to the knowledge of the avifauna of the Ernici Mountains.

Materials and Methods

Study area

Canterno lake (Fig. 1) is the only lake basin of the Ernici Mountains, located in the western hilly belt of the mountain group (latitude: 41 ° 45 '10,9 '' N; longitude: 13 ° 15 '1,5 '' E); is 11 km from Sacco river (to SW) (Fig. 1).

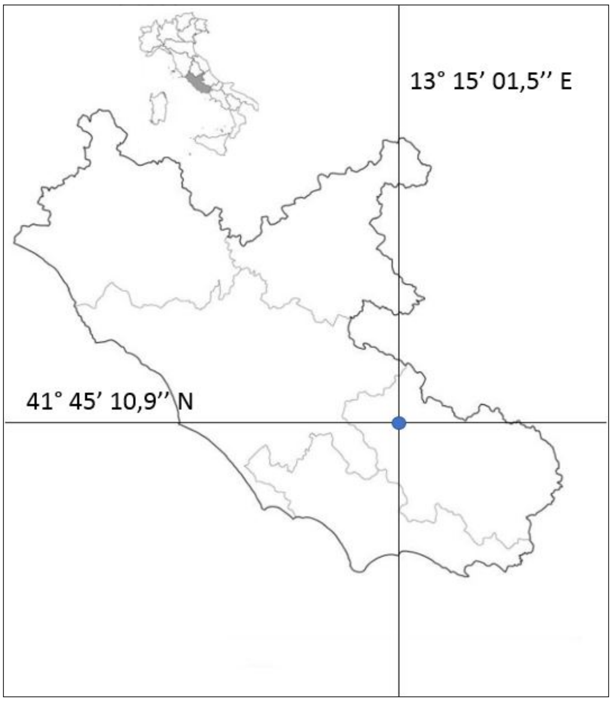

Figure 1: Canterno lake in Latium region.

It is located in the large central flat sector of the Riserva Naturale "Lago di Canterno" (Fig. 2), managed by the Parco Naturale Monti Ausoni and Lago di Fondi and is part of the municipalities of Ferentino (Porciano), Trivigliano and Fumone, in the Frosinone province (Fig. 2).

The main feature of Canterno lake was, for a long time, its periodicity, linked to the filling of the primitive karst basin and its recurrent emptying through the Pertuso sinkhole. This phenomenon was linked to obstruction and unblocking cycles linked to the progressive accumulation of river debris and sediments at the mouth of the karst cavity. Its definitive formation is due to the obstruction of the sinkhole, which took place in 1821. The lake became perennial with the construction of a power plant begun in 1942 by the Società Romana Elettrica (S. R. E.) and completed in 1945; currently the water is controlled by means of an intake tower (Fig. 3).

The basin is located at an altitude of 547 masl, has an area of about 0.6 km^2, an average depth of 15 m and a perimeter of about 5 km. The area belongs to the region with a temperate climate, upper hilly thermotype (submontane), lower hyperhumid ombrotype (Blasi 1994).

The average annual temperature is 12,5° C, is a polimittic lake and is considered hypertrophic for the α chlorophyll values, annually estimated at about 29 μg/l. The phytoplankton community is mainly characterized by Cyanobacteria (genera *Mycrocistis* and *Aphanizomenon*), Chlorophyta (e.g.: *Scenedesmus quadricauda*, *S. obtusus*, *Sphaerocystis schroeteri* and *S. planktonica*) and Cryptophyta (*Cryptomonas erosa* and genus *Rhodomonas*). The planktonic Bacyllariophyta *Cyclostephanos dubius* is present. In the waters or on the banks there are also very interesting botanical entities: *Persicaria amphibia* (L.) Delarbre (*Polygonaceae*), *Herniaria incana* Lam. (*Caryophyllaceae*), *Rorippa palustris* (L.) Besser, *Potentilla supina* L. (*Rosaceae*) and *Ranunculus neapolitanus* Ten.

Figure 2: Canterno Lake, overview; photo by Davide Petrucci.

(*Ranunculaceae*) (Petriglia 2015). The riparian tree cover is fragmented and forming groves in the flooded areas of the Fosso del Diluvio, the only torrential tributary of the lake (Fig. 4).

The tree species are: *Salix alba*, *S. fragilis*, *Populus alba* and *P. nigra*. At a greater distance, the tree cover is composed of deciduous woods dominated by *Quercus cerris*, *Quercus pubescens, Castanea sativa*, *Ostrya carpinifolia*, *Carpinus betulus*, *Fraxinus ornus*, *Acer campestre*, whose shrub expanses consist of *Crataegus monogyna* and *Rubus fruticosus* (Petriglia 2015).

The surrounding plain is used for arable land, with areas regularly mowed or used for grazing. There are 1 autochthonous fish species (*Scardinius erythrophtalmus*) and 1 allochthonous species (*Cyprinus carpio*). For sport fishing the following species were introduced: *Alburnus alborella*, *A. albidus* and *Micropterus salmoides* (Bruno 1983; Roma & Rossetti 1998); *Carassius carassius*, *Ctenopharyngodon idella*, *Tinca tinca* and *Perca fluviatilis* (Culicelli 2017). *Silurus glanis* was introduced in 2018 (https://www.facebook.com/BioBlitzItalia). Other invasive species are reported: *Anodonta cygnea* (Bivalvia: *Unionidae*), *Procambarus clarkii* (Malacostraca: *Cambaridae*), *Trachemys scripta* (Reptilia: *Emydidae*).

Elaboration of checklist

The checklist originates from the need to update the knowledge about the waterbirds

Figure 3: Intake tower; photo by Ermanno De Pisi.

of Canterno lake starting from data of the only published checklist (Roma & Rossetti 1998). This study drafted one checklist relating to the entire area of the Riserva Naturale "Lago di Canterno" (18,2 km²) on the basis of weekly observations over a period of twenty years.

The research was carried out from January 2018 to December 2020. Due to travel restrictions imposed by the SARS-CoV-2 epidemic, activities during the first half of 2020 took over sporadic character. The study was carried out using 9 observation points places along the coast. The census took place through direct observation and through the identification of the songs of the bird species. For species very close to the lake, from the same observation points the census also extended to a coastal strip no wider than 150 meters towards the hinterland.

Every single point was visited at least once a month. 10x binoculars and 20-60x spotting scopes were used. Days with rain, strong wind and fog were avoided to avoid underestimation in the counts (Bibby et al., 2000).

For systematics and nomenclature, the one used in the most recent checklist of the Birds of Latium (Brunelli et al., 2019) has been adopted, which refers to the CISO-COI List (Baccetti et al., 2019).

In order to evaluate the conservation status of breeding species species present in checklist was used and adapted the algorithm of Ornithological Value Index (I.V.O.), elaborated by Massa et al. (2004). Algorithm is the following:

$$\begin{aligned} \mathrm{I.V.O.} = S_{Tot}\Big[\big(S_{Spec1} * 1\big) + \big(S_{Spec2} * 0{,}75\big) + \big(S_{Spec3} * 0{,}5\big) \\ + \big(S_{Non\ SpecE} * 0{,}25\big) + (S_{EN} * 0{,}75) + (S_{VU} * 0{,}5) \\ + (S_{NT} * 0{,}25) + S_6\Big] * 100^{-1} \end{aligned}$$

Where: S_{Tot} is the number of total breeding species; S_{Spec1}, S_{Spec2}, S_{Spec3}, $S_{Non\ SpecE}$ is the number of breeding species categorized as SPEC (BirdLife International 2017). Following the most recent IUCN guidelines (IUCN, 2012) was used: S_{EN}, S_{VU}, and S_{NT} are the numbers of breeding species categorized in the Italian Red List of Birds (Gustin et al., 2019); S_6 is the number of breeding species reported in Annex I in Directive on the conservation of wild birds (2009/147/EC).

Status assessment

The attribution of status categories of the species was assessed on the basis of the data collected in the present research and on the checklist of birds of Latium (Brunelli et al., 2019). The following categories were used:

SB – Sedentary breeding,
B – Summer breeding,
M – Migrant,
W – Wintering,
E – Summer visitor: continuous presence of no resident birds outside the breeding territories;
reg – regular,
irr – irregular,
? – uncertain status,
A – Vagrant: observed only once, with no more than 1 individual (Fasola & Brichetti 1984; Brunelli et al., 2019).

The symbol "S", not flanked by the symbol "B" indicates the species present but nesting outside the study area.

Figure 4: Environmental context of Canterno lake; photo by Ermanno De Pisi.

Results and Discussion

133 species were recorded (Tab. 1).

These are divided between 72 Non-Passerines (NP), 54,1% of the total, and 61 Passerines (P); ratio NP / P = 1,18. Compared to the previous checklist of the "Lago di Canterno" Nature Reserve (Roma & Rossetti 1998), which also includes the avifauna of the lake basin, 29 species were not observed during the research and, of these, 14 are in relation with the lake environment.

62 breeding birds were registered (19 summer breeding), including 23 Non-Passerines, 37,1% of the total, and 39 Passerines; ratio NP / P = 0.58. *Anas platyrhynchos*, *Fulica atra*, *Podiceps cristatus* and *Ardea cinerea* are the only nesting lake environment species.

The conservation status in Europe of breeding species is evaluated by SPEC categories (BirdLife International, 2017), as follows: 1 species is in SPEC 1 category; 9 in SPEC 2; 10 in SPEC 3; 42 in NON SPEC^{E}. 61 breeding species are included in the Italian Red List (Gustin et al., 2019). These species are divided into the categories: "Endangered - EN" (S: 2), "Vulnerable - VU" (S: 2); "Nearly Threatened - NT" (S: 5), "A Minor Concern - LC" (S: 51), "Insufficient Data - DD" (S: 1) (Table 1). *Phasianus colchicus* is not evaluated in the Italian Red List. 6 species are included in Annex I of Directive 2009/147 / EC "Birds Directive". The Ornithological Value Index (IVO) is equal to 20,46.

37 migratory species (M reg, M irr) were detected; 4 wintering species (W, W irr) were detected: *Rallus aquaticus*, *Periparus ater*, *Melanocorypha calandra* and *Fringilla montifringilla*.

Here are some summary notes of the taxa relating to the lake basin.

Charadriiformes (*Scolopacidae*, *Charadriidae*, *Recurvirostridae*, *Laridae*).

13 migratory species were detected (2018-2020, n.: 46). The presences are sporadic and less numerous compared to the Latium coasts (Spina & Volponi 2008; Brunelli et al., 2009).

The small number of individuals observed is probably due to edaphic factors that characterize the lake. The basin has banks mainly characterized by cinerites (volcanism of the "Latina Valley", Sacco river valley), calcarenites, calcilutites and the presence of eluvial soils and marsh sediments is limited (Alberti et al., 1975).

The correlation between shorebirds presence and the abundance of their prey (e.g.: *Annelida*) is well known however the presence of vegetated silty banks and associated biotic communities, such as to provide rest and food, in the Canterno lake is limited to a few areas of the lake basin.

Actitis hypoleucos, *Tringa ochropus*, *Tringa erythropus*, *Tringa glareola* and *Tringa nebularia* were the most frequent. These species are able to frequent inland wetlands with various banks' types (Brichetti & Fracasso 2004). *Calidris pugnax*, *Calidris ferruginea*, *Calidris alba*, *Calidris minuta* and *Tringa totanus* showed a sporadic presence but are species that only along the coastal areas shows a more regular and conspicuous migratory flow. In inland wetlands with muddy / sandy shores, are very rare and less frequent (Brichetti & Fracasso 2004; Spina & Volponi 2008). Muddy / sandy shores are not present in the Canterno lake.

Larus michahellis is the only *Charadriiformes* present all year round also thanks to a purely trophic "commuting" (groups of 25 - 50 birds) from the "Valle Latina" (Sacco river valley), more evident in winter (January) and at the end of summer (September).

Anseriformes (*Anatidae*).

In the 2018-2020 period, 12 species were detected (1 nesting and 5 wintering) equal to 44,5% of the no accidental *Anatidae* surveyed for Latium (Brunelli et al., 2019). 6 species showed regular presence: *A. platyrhynchos*, *Anas crecca*, *Mareca penelope*, *Spatula clypeata*, *Aythya ferina* and *Aythya nyroca*.

A. platyrhynchos was detected in each census session and was resulted the most abundant (max: 205; 11 December 2018) and the only nesting *Anatidae*; regular migrant. The other abundant species were: *M. penelope* (max: 142; 17 December 2019. Observed in over 15 census sessions) and *A. crecca* (max: 138; 5 January 2018. In 16 sessions). Species less abundant and frequent: *S. clypeata* (max: 57; 5 January 2018. In 23 sessions), *A. ferina* (max: 40; 5 January 2018. In 6 sessions) and *A. nyroca* (max: 19; 18 March 2019. In 4 sessions).

The characteristics of the Canterno lake strongly influence the presence of the lake birds. The lithology of the seabed, the chemical-physical nature of the sediments, the lake water quality and turbidity do not allow diversified lake flora to take up.

These aspects are probably to the base of low abundance ad frequency of "diving ducks" (Brichetti & Fracasso 2004). *Aythya ferina* was the only frequent species (M reg, W reg); the others species (*Aythya nyroca* and *Aythya fuligula*) were much more sporadic.

The eutrophication and water level fluctuations restrict aquatic macrophytes (e.g. *Polygonum amphibium*) to the tributary and its surrounding areas (Lucchese, 2017) and influence presences and distributions of "dabbling ducks" (Brichetti & Fracasso 2001): *M. penelope*, *A. crecca* and *S. clypeata* were regularly detected, during the wintering and the migrations, in areas where is present lake vegetation.

Podicipediformes (*Podicipedidae*).

Podiceps cristatus is the only *Podicipedidae*, present all year round but slightly more abundant during migratory flows and wintering. Mating rituals are already observed in January; adults with eggs and chicks in the period from April to August. *Tachybaptus ruficollis* was observed less frequently. *Podiceps nigricollis* is accidental.

Pelecaniformes (*Ardeidae*).

This taxon consisting of 8 species. *A. cinerea* is the most frequent species, present all year round with relatively numerous groups (20 - 25 indd.). It is the only breeding *Ardeidae*: the small heronry near the lake, present at least since 2012, in 2016 consisted of 7 nests, 6 of which are active (Biancolini et al., 2016). *Nycticorax nycticorax* has been observed only with very few individuals: 2 juv (August 2018), 1 juv (September 2018) and 1 juv (November 2019); however, this species, together with *Egretta garzetta*, is known to be present in the area during the period reproductive (Biancolini et al., 2016). *Ardeola ralloides* is to be considered occasional.

Suliformes (*Phalacrocoracidae*).

Phalacrocorax carbo is the only species present. It's observed throughout the year with variable numbers seasonally and with individuals of various age groups (adults, adults in reproductive dress, immature, young).

Gruiformes (*Rallidae*).

F. atra is the most abundant and frequent species: observed all year round with relatively high quantities. There is a significant increase during the winter season. It is the only breeding *Rallidae* (April – June period). *Gallinula chloropus* is less frequent, with significant contingents only in January 2019 (n.: 51). *R. aquaticus* is a wintering species.

Accipitriformes (*Pandionidae*), *Falconiformes* (*Falconidae*).

The only species closely related to Canterno lake are strictly migratory and observed mainly in April: *Pandion haliaetus*, *Pernis apivorus* and *Circus aeruginosus*, *Circus pygargus* with single individuals; *Falco vespertinus*, even in relatively numerous groups (n.: 10-20). Other species exploit the lake for trophic purposes: *Milvus migrans*, *Accipiter nisus*, *Buteo buteo*, *F. peregrinus*. *Accipiter gentilis* is to be considered an accidental species.

The current management of the protected area tends to re-naturalize the entire natural environment with the aim of making coexistence with human activities possible (Copiz 2017). Despite the great naturalistic value and, in perspective, the economic importance for local populations, the basin is oppressed by a vast series of threats, not duly monitored except by local environmental associations and individual citizens. The greatest risks lie in the pollution of the water mainly due to the urban wastewater that flows into the basin through the riverbed of the Fosso del Diluvio: in the last decades, and also recently (2017, 2020), several "crises" have occurred which have also led to the flowering of toxic microalgae with a strong impact on fish fauna. To these factors have to be added the presence of various materials, illegal fishing and construction near the banks. There are no acts of poaching but there are attempts to allocate the protected area to recreational and recreational activities (rowing school, sailing school, etc.). Low-altitude helicopter flights are planned for military exercises carried out by the armed forces (“Esercito Italiano”) and by institutional agencies (“Vigili del Fuoco”). Private aircraft are also observed. All this makes it important to initiate more effective protection and safeguard measures, also aimed at promoting a better naturalistic use of the territory and a greater awareness of the naturalistic importance of the lake by local populations.

Table 1: Checklist of birds of Canterno lake updated to 31st December 2020.

	Scientific name	English common name	Italian common name	Fenology	Dir. 2009/147 /EC Annex I	Status in Europe (SPEC categories)	Italian Red List categories
	GALLIFORMES						
	Phasianidae						
1	*Coturnix coturnix*	Common Quail	Quaglia	M reg, B		3	DD
2	*Phasianus colchicus*	Common Pheasant	Fagiano	SB			
	ANSERIFORMES						
	Anatidae						
3	*Anser anser*	Greylag Goose	Oca selvatica	M irr			LC
4	*Tadorna tadorna*	Common Shelduck	Volpoca	A			VU
5	*Tadorna ferruginea*	Ruddy Shelduck	Casarca	A	X	3	
6	*Aythya ferina*	Common Pochard	Moriglione	M reg, W reg		1	VU
7	*Aythya nyroca*	Ferruginous Duck	Moretta tabaccata	M reg, W irr	X	1	EN
8	*Aythya fuligula*	Tufted Duck	Moretta	M irr		3	VU
9	*Spatula querquedula*	Garganey	Marzaiola	M reg		3	VU
10	*Spatula clypeata*	Norhern Shoveler	Mestolone	M reg, W reg			VU
11	*Mareca strepera*	Gadwall	Canapiglia	M irr			NT
12	*Mareca penelope*	Wigeon	Fischione	M reg, W irr			
13	*Anas platyrhynchos*	Mallard	Germano reale	SB, M reg, W reg			LC
14	*Anas crecca*	Teal	Alzavola	M reg, W reg			EN
	PODICIPEDIFORMES						
	Podicipedidae						

15	*Tachybaptus ruficollis*	Little Grebe	Tuffetto	M reg, E irr, W irr			LC
16	*Podiceps cristatus*	Graet Crested Grebe	Svasso maggiore	SB, M reg, W reg			LC
17	*Podiceps nigricollis*	Black-necked Grebe	Svasso piccolo	A			
	PHOENICOPTERIFORMES						
	Phoenicopteridae						
18	*Phoenicopterus roseus*	Graeater Flamingo	Fenicottero	A			LC
	COLUMBIFORMES						
	Columbidae						
19	*Columba palumbus*	Common Wood Pidgeon	Colombaccio	SB, M reg, W reg			LC
20	*Streptopelia decaocto*	Eurasian Collared Dove	Tortora dal collare	SB			LC
21	*Streptopelia turtur*	European Turtle Dove	Tortora selvatica	B, M reg		1	LC
	CAPRIMULGIFORMES						
	Caprimulgidae						
22	*Caprimulgus europaeus*	European Nightjar	Succiacapre	M reg, B	X	3	LC
	Apodidae						
23	*Apus apus*	Common Swift	Rondone comune	M reg, B		3	LC
	CUCULIFORMES						
	Cuculidae						
24	*Clamator glandarius*	Great Spotted Cuckoo	Cuculo dal ciuffo	A			EN
25	*Cuculus canorus*	Common Cuckoo	Cuculo	M reg, B			LC
	GRUIFORMES						
	Rallidae						
26	*Rallus aquaticus*	Water Rail	Porciglione	W reg			LC
27	*Gallinula chloropus*	Common Moorhen	Gallinella d'acqua	SB, M reg, W reg			LC
28	*Fulica atra*	Eurasian Coot	Folaga	M reg, W reg		3	LC

	Gruidae						
29	*Grus grus*	Common Crane	Gru	M reg	X		RE
	CICONIIFORMES						
	Ciconiidae						
30	*Ciconia nigra*	Black Stork	Cicogna nera	A?	X		EN
	Ardeidae						
31	*Ixobrychus minutus*	Little Bittern	Tarabusino	M irr	X	3	VU
32	*Nycticorax nycticorax*	Black-crowned Night Heron	Nitticora	E?, M reg?	X	3	LC
33	*Ardeola ralloides*	Squacco Heron	Sgarza ciuffetto	M reg, E irr, W irr	X	3	NT
34	*Bubulcus ibis*	Western Cattle Heron	Airone guardabuoi	A			LC
35	*Ardea cinerea*	Grey Heron	Airone cenerino	SB, M reg, E, W reg			LC
36	*Ardea purpurea*	Purple Heron	Airone rosso	M irr	X	3	LC
37	*Ardea alba*	Great Egret	Airone bianco maggiore	M reg, E, W	X		NT
38	*Egretta garzetta*	Little Egret	Garzetta	M reg, E, W	X		LC
	SULIFORMES						
	Phalacrocoracidae						
39	*Phalacrocorax carbo*	Great Cormorant	Cormorano	S			CR
	CHARADRIIFORMES						
	Recurvirostridae						
40	*Himantopus himantopus*	Black -winged Stilt	Cavaliere d'Italia	M reg	X		LC
	Charadriidae						
41	*Vanellus vanellus*	Northern Lapwing	Pavoncella	M reg		1	LC
	Scolopacidae						
42	*Calidris pugnax*	Ruff	Combattente	M reg	X	2	
43	*Calidris ferruginea*	Curlew Sandpiper	Piovanello comune	M irr		1	
44	*Calidris alba*	Sanderling	Piovanello tridattilo	M irr			

45	*Calidris minuta*	Little Stint	Gambecchio comune	M reg			
46	*Actitis hypoleucos*	Common Sandpiper	Piro piro piccolo	M reg		3	NT
47	*Tringa ochropus*	Green Sandpiper	Piro piro culbianco	M reg			
48	*Tringa erythropus*	Spotted Redshank	Totano moro	M reg		3	
49	*Tringa nebularia*	Common Greenshank	Pantana	M reg			
50	*Tringa glareola*	Wood Sandpiper	Piro piro boschereccio	M reg	X	3	
	Laridae						
51	*Larus michahellis*	Yellow-legged Gull	Gabbiano reale	S			LC
52	*Chlidonias niger*	Black Tern	Mignattino comune	M reg	X	3	CR
	STRIGIFORMES						
	Strigidae						
53	*Athene noctua*	Little Owl	Civetta	SB		3	LC
	ACCIPITRIFORMES						
	Pandionidae						
54	*Pandion haliaetus*	Western Osprey	Falco pescatore	M reg	X		
	Accipitridae						
55	*Pernis apivorus*	European Honey Buzzard	Falco pecchiaiolo	B, M reg	X		LC
56	*Hieraaetus pennatus*	Booted Eagle	Aquila minore	M reg	X		
57	*Circus aeruginosus*	Western Marsh Harrier	Falco di palude	M reg	X		VU
58	*Circus pygargus*	Montagu's Harrier	Albanella minore	M irr	X		VU
59	*Accipiter nisus*	Eurasian Sparrowhawk	Sparviere	SB, M reg, W irr			LC
60	*Accipiter gentilis*	Northern Goshawk	Astore	A?	X		LC
61	*Milvus migrans*	Black Kite	Nibbio bruno	M reg, B	X	3	LC
62	*Buteo buteo*	Common Buzzard	Poiana	SB, M reg, W reg			LC
	BUCEROTIFORMES						
	Upupidae						

63	*Upupa epops*	Eurasian Hoopoe	Upupa	M reg, B			LC
	CORACIIFORMES						
	Meropidae						
64	*Merops apiaster*	European Bee-eater	Gruccione	M reg			LC
	Coraciidae						
65	*Coracias garrulus*	European Roller	Ghiandaia marina	A?	X	2	LC
	Alcedinidae						
66	*Alcedo atthis*	Common Kingfisher	Martin pescatore	M reg, W irr	X	3	LC
	PICIFORMES						
	Picidae						
67	*Picus viridis*	European Green Woodpecker	Picchio verde	SB			LC
68	*Dendrocopos major*	Great Spotted Woodpecker	Picchio rosso maggiore	SB			LC
	FALCONIFORMES						
	Falconidae						
69	*Falco tinnunculus*	Common Kestrel	Gheppio	SB, M reg, W reg		3	LC
70	*Falco vespertinus*	Red-footed Falcon	Falco cuculo	M reg	X	1	VU
71	*Falco subbuteo*	Eurasian Hobby	Lodolaio	M reg, B			LC
72	*Falco peregrinus*	Peregrine Falcon	Pellegrino	SB	X		LC
	PASSERIFORMES						
	Laniidae						
73	*Lanius collurio*	Red-backed Shrike	Averla piccola	M reg, B	X	2	VU
74	*Lanius senator*	Woodchat Shrike	Averla capirossa	M reg, B		2	EN
	Corvidae						
75	*Garrulus glandarius*	Eurasian Jay	Ghiandaia	SB			LC
76	*Pica pica*	Eurasian Magpie	Gazza	SB			LC
77	*Corvus monedula*	Western Jackdaw	Taccola	S			LC

78	*Corvus coronae*	Hooded Crow	Cornacchia	SB			LC
	Paridae						
79	*Periparus ater*	Coal Tit	Cincia mora	W reg			LC
80	*Cyanistes caeruleus*	Eurasian Blue Tit	Cinciarella	SB			LC
81	*Parus major*	Great Tit	Cinciallegra	SB			LC
	Alaudidae						
82	*Melanocorypha calandra*	Calandra Lark	Calandra	W irr	X	3	VU
83	*Lullula arborea*	Woodlark	Tottavilla	M reg	X	2	LC
84	*Alauda arvensis*	Eurasian Skylark	Allodola	SB, M irr		3	NT
	Cisticolidae						
85	*Cisticola juncidis*	Zitting Cisticola	Beccamoschino	SB, M irr			LC
	Acrocephalidae						
86	*Hippolais polyglotta*	Melodious Warbler	Canapino comune	M reg, B			LC
	Hirundinidae						
87	*Delichon urbicum*	Common House Martin	Balestruccio	M reg, B		2	NT
88	*Hirundo rustica*	Barn Swallow	Rondine	M reg, B		3	NT
89	*Riparia riparia*	Sand Martin	Topino	M reg		3	VU
	Phylloscopidae						
90	*Phylloscopus collybita*	Common Chiffchaff	Luì piccolo	M reg, B			LC
	Scotocercidae						
91	*Cettia cetti*	Cetti's Warbler	Usignolo di fiume	SB, W reg			LC
	Aegithalidae						
92	*Aegithalos caudatus*	Long-tailed Tit	Codibugnolo	SB, W reg			LC
	Sylviidae						
93	*Sylvia atricapilla*	Eurasian Blackcap	Capinera	SB, M reg, W reg			LC

94	*Sylvia borin*	Garden Warbler	Beccafico	M reg			VU
95	*Sylvia melanocephala*	Sardinian Warbler	Occhiocotto	SB, M reg, W reg			LC
96	*Sylvia cantillans*	Eastern Subalpine Warbler	Sterpazzolina comune	M reg, B			LC
	Certhiidae						
97	*Certhia bachydactyla*	Short-toed Treecreeper	Rampichino comune	SB			LC
	Troglodytidae						
98	*Troglodytes troglodytes*	Eurasian Wren	Scricciolo	SB, M reg, W reg			LC
	Sturnidae						
99	*Sturnus vulgaris*	Common Starling	Storno	SB, M reg		3	LC
	Turdidae						
100	*Turdus viscivorus*	Mistle Thrush	Tordela	SB, M reg, W reg			LC
101	*Turdus philomelos*	Song Thrush	Tordo bottaccio	M reg			LC
102	*Turdus merula*	Common Blackbird	Merlo	SB, M reg, W reg			LC
	Muscapidae						
103	*Muscicapa striata*	Spotted Flycatcher	Pigliamosche	M reg, B		2	LC
104	*Erithacus rubecula*	European Robin	Pettirosso	SB, M reg, W reg			LC
105	*Luscinia megarhynchos*	Common Nightingale	Usignolo	M reg, B			LC
106	*Ficedula albicollis*	Collared Flycatcher	Balia dal collare	M reg	X		LC
107	*Phoenicurus ochruros*	Black Redstart	Codirosso spazzacamino	SB, M reg, W reg			LC
108	*Saxicola rubetra*	Whinchat	Stiaccino	M reg		2	VU
109	*Saxicola torquatus*	European Stonechat	Saltimpalo	SB, M reg, W reg			EN
110	*Oenanthe oenanthe*	Northern Wheatear	Culbianco	M reg		3	LC
111	*Oenanthe hispanica*	Western Black-eared Wheatear	Monachella	A			DD
	Prunellidae						
112	*Prunella modularis*	Dunnock	Passera scopaiola	M reg, W reg			NT

	Passeridae						
113	*Passer italiae*	Italian Sparrow	Passera d'Italia	SB		2	NT
114	*Passer montanus*	Eurasian Tree Sparrow	Passera mattugia	SB, M reg, W reg		3	LC
	Motacillidae						
115	*Anthus pratensis*	Meadow Pipit	Pispola	M reg, W reg		1	
116	*Anthus spinoletta*	Water Pipit	Spioncello	M reg, W reg			LC
117	*Anthus campestris*	Tawny Pipit	Calandro	M reg		3	VU
118	*Motacilla flava*	Western Yellow Wagtail	Cutrettola	M reg		3	LC
119	*Motacilla cinerea*	Grey Wagtail	Ballerina gialla	M reg, W reg			LC
120	*Motacilla alba*	White Wagtail	Ballerina bianca	SB, M reg			LC
	Fringillidae						
121	*Fringilla coelebs*	Common Chaffinch	Fringuello	SB, M reg, W reg			LC
122	*Fringilla montifringilla*	Brambling	Peppola	W irr		3	
123	*Coccothraustes coccothraustes*	Hawfinch	Frosone	M reg, W reg			LC
124	*Chloris chloris*	European Greenfinch	Verdone	SB, M reg, W reg			NT
125	*Linaria cannabina*	Common Linnet	Fanello	SB, M reg, W reg		2	LC
126	*Carduelis carduelis*	European Goldfinch	Cardellino	SB, M reg, W reg			LC
127	*Serinus serinus*	European Serin	Verzellino	SB, M reg, W reg		2	LC
128	*Spinus spinus*	Eurasian Siskin	Lucherino	M irr, W irr			LC
	Emberizidae						
129	*Emberiza calandra*	Corn Bunting	Strillozzo	SB		2	LC
130	*Emberiza cia*	Rock Bunting	Zigolo muciatto	M reg, W reg			LC
131	*Emberiza hortulana*	Ortolan Bunting	Ortolano	M reg, B	X	2	VU
132	*Emberiza cirlus*	Cirl Bunting	Zigolo nero	SB			LC
133	*Emberiza citrinella*	Yellowhammer	Zigolo giallo	M irr?		2	VU

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Some considerations on the Pleistocenic Elephants of the Mediterranean islands

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Abstract

During the Pleistocene some Mediterranean islands were repeatedly colonized by species of elephants that evolved into endemic dwarf forms. The reason for such dwarfism is to be found among multifacet ecological adaptations. The key to understand the size reduction of the insular Pleistocenic elephants is to consider a plurality of evolutionary *patterns*, including island area, the limited natural resources, absence of genetic flow, the interaction with the other elements of the insular fauna, the type of habitat (niches) and the different geological periods in which the fossils were found.

Keywords: Elephants; islands; Mediterranean; Pleistocene; evolution; isolation; endemism; patterns

Riassunto

Durante il Pleistocene, nelle isole del Mediterraneo, gli elefanti che vi sono giunti attraverso corridoi naturali durante le glaciazioni, sono stati interessati da processi evolutivi endemici, un adattamento morfologico-funzionale alle particolari condizioni ambientali, con riduzione di taglia fino a forme estreme di nanismo. La chiave di lettura per comprendere la riduzione e la diversità di taglia degli elefanti insulari pleistocenici è multifattoriale e quindi occorre considerare una pluralità di *pattern* evolutivi quali: anzitutto la grandezza dell'isola, le conseguenti limitate risorse naturali, l'accoppiamento fra un numero limitato di individui, l'interazione con i predatori presenti, il tipo di habitat (nicchie) e infine i diversi periodi geologici in cui ricadono i resti fossili ritrovati con la loro ricostruzione biocronostratigrafica.

Parole chiave: Elefanti; isole; Mediterraneo; Pleistocene; evoluzione; isolamento; endemismo; *patterns*

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Introduction

The geographical isolation involves "forced" pairing among a narrow group of individuals and the lack of sexual mixing among the different genetic pools of the separate populations, or rather the absence of genetic flow and therefore of variability: under the push of the environmental pressure some individuals are selected endowed with larger adaptive value. The insular endemic faunas present opposite evolutionary phenomena: the dwarfism (reduction size in comparison to the continental ancestor) that manifests in the larger mammals and the gigantism (the increase in comparison to the continental form of origin) of small mammals and of birds and reptiles. The causes of the insular dwarfism, of which we have numerous examples in Pleistocene, are to be found in the fact that the smaller dimensions allow the mammalian colonizers (who succeed in migrating through the narrow natural corridors) to survive in environments with limited resources (such as the islands), while the insular gigantism (the other form of adaptation) of micromammals and of birds and reptiles is primarily due to the absence of predators, or, however, to an altered food chain: very well known cases are the Moa of the New Zealand and the Monitor Lizard of Komodo. For the assessed insular gigantism in some islands of the Mediterranean represented, for instance, by the giant dormouse *Leithia melitensis* that lived in the middle Pleistocene in Sicily, as well as in Malta, the matter is more complex because there was no complete lack of predators in these environments: in Sicily lived, for instance, *Mustelercta arzilla* a mustelid similar to the pine marten, a well known formidable predator of dormice, which, in theory, could have prevented the appearance of the gigantism. *Mustelercta arzilla* (De Gregorio 1886), shows a lot of affinities with its close relative *Pannonicitis kormos* and *Enhydrictis major,* that lived from the superior Pliocene to the inferior Pleistocene (Burgio & Fiore 1997). In the Mediterranean islands the discovered fossils of the Mustelidae such as *Mustelercta arzilla* or of Felidae such as *Felis silvestris*, natural predator of the dormice and other rodents, are quite rare: probably this is due not as to their absence in nature, as to the brittleness of their bones that can be more easily lost and breakable, in comparison to those stronger of elephants, hippos and endemic bucks. It is also necessary to say that in Sicily *Leithia melitensis* is found in partnership with the rests of *Leithia cartei* of the same genus but of similar size as the actual dormouse: the geographic ranges were clearly separate however occupying two different ecological niches (Petronio 1970). Probably an immigration of the continental progenitor of *Leithia cartei* occurred when on the island *Leithia melitensis* was already present and differentiated with a process of endemic speciation. A more recent hypothesis to explain the size increase of small mammals on the islands, implies an adaptive modification to render them less vulnerable by the birds of prey: the latter however are also present on the continent even in larger measure, but we don't find cases of gigantism. I believe that the answer has to be found elsewhere. Made this premise, we turn our attention to the insular endemic pleistocene elephants.

A plurality of evolutionary patterns

During the periods of sea level lowering, in correspondence of the glaciations, the islands were colonized many times by elephants coming from the continent, belonging to the kind *Palaeoloxodon antiquus* (5 ms of height at the withers), which, adapting themselves to the insular environmental conditions, reduced size in the time, giving origin to different kinds (or subspecies) of different bodily dimensions, up to extreme forms of dwarfism, as in the case of *Palaeoloxodon falconeri* (90 cm at the withers). Fossils of dwarf elephants have also been discovered in Cyprus, Malta, Crete, Sardinia, Cyclades and Dodecanesian islands. Of course the insular dwarfism in the Mediterranean islands has interested a lot of other kinds of mammalia such as the hippo and the wild boar (Raia & Meiri, 2006). It needs to be said that the procedures of colonization and the migratory routes of the continental faunas can not be referred to one episode: every island in fact exhibits a peculiar geological evolution with specific characteristics. Tectonic activity in concomitance with oscillations of the sea level during the glaciations created some bridges through which the continental fauna could reach the islands with subsequent colonization; small kinds as reptiles and rodents could also have reached the islands on trunks and planking, without considering the flight for the birds and the bugs (Caloi et al., 1996). But how to explain the presence of nearby fossils of elephants of different size on different islands of the Mediterranean besides, if not in different geological layers, the dwarf forms? In Sicily and Malta we find in fact fossils of elephants of average size (*Palaeoloxodon mnaidriensis*, tall around 2 ms at the withers), as long as in Crete we have *Palaeoloxodon creutzburgi*, and other intermediate sizes have been found in Cyprus, in some Dodecanesian islands and in the Cyclades. The size of the elephant of Delos and of Rhodes had dimensions comparable to those of *P. mnaidriensis* (Van der Geer et al., 2004), while on the island of Tilos we find both elephants of dwarf and medium size (*P. tilensis*), but the two groups refer to sexual dimorphism (Theodorou 1983-1988). Also the Sardinian elephant

(*Mammuthus lamarmorae*) shows a middle form descending from the gigantic *Mammuthus meridionalis*.

An advanced hypothesis on the presence of elephants of different size on some islands of the Mediterranean brings back the possible explanation of the different migratory flows of representatives of *P. antiquus* from the continent: the evolutionary attempt of reduction would have occurred a first time (in the medium Pleistocene) to a form of extremely reduced size (*P. falconeri*), while a second time (close to the superior Pleistocene) it would have arrested toward a medium form. One can wonder indeed what is the cause that brings the evolutionary way of reduction toward two forms of different sizes.

To my advise the fossil remains of elephants of reduced size could be explained by a form more or less accented of dwarfism, an adaptation to the different present ecological niches on islands of a certain magnitude and in a determined geological period that the continental elephants in migration occurred to occupy: a first niche is represented by the forest, a habitat in which elephants of small size were able better to hide from the predators (es. dwarf elephant of Borneo) and to find a precious source of nourishment; the second niche corresponds to an environment of more open clearings for an elephant of medium size that, thanks to the most greater massive structure and the fact of living in small groups, was able of a better self defence from the predators chasing in flock, such as wild dogs of

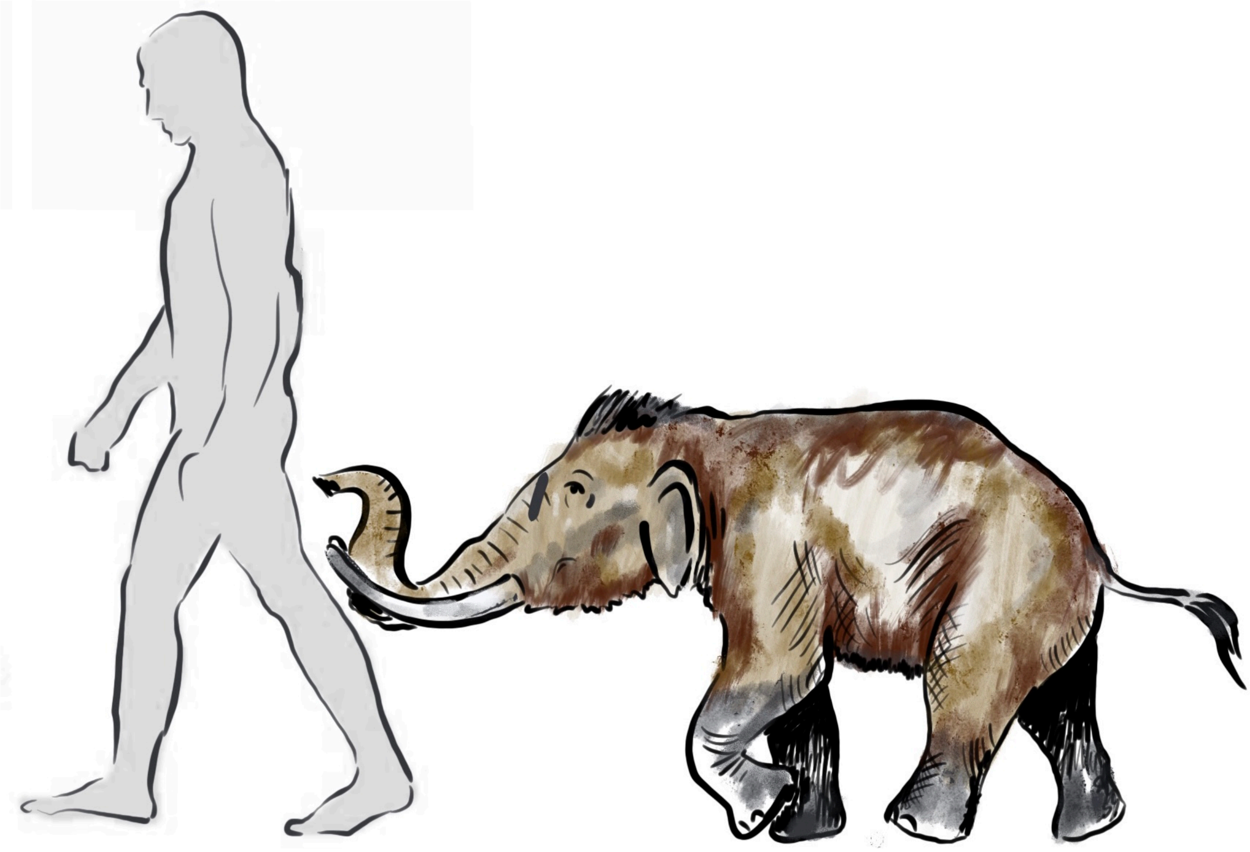

Illustration created by Domenico Fulgione limited size. it is not a case the lack of fossils of elephants of medium size in the small islands because the proper environmental conditions to allow their survival did not subsist there: the only available niche was that for elephants of small size (but also for deer and dwarf hippos, of which we have found trace).

In all the islands of the Mediterranean, where we find in the larger mammals endemic forms of insular dwarfism, we necessarily have to hypothesize the presence of some wild dogs of small and medium sizes similar to the *Cynotherium sardous* or to the *Cynotherium malatestai* (whose fossils have been found in Sardinia and in Corsica): otherwise, in the lack of predators, the populations of elephants, bucks and endemic wild boars would have been exceedingly increased so impoverishing the insular resources at the limit and jeopardising their survival: it is an incontrovertible ethological datum. *Cynotherium sardous*, a wild dog of the fox size, lived during the Pleistocene, perhaps descending from *Xenocyon lycanoides*, *Canis arnensis* or *Cuon arnesi* (Abbazzi et al., 2005); it fed on small preys having a low sagittale crest and a slender jaw but the hypercarnivorous teeth allow to hypothesize that he could also chase large mammals such as the *Megaloceros*, a large Pleistocene deer. The other wild dog, *Cynotherium malatestai*, represents a transitional form between *Xenocyonly lycanoides* and *Cynotherium sardous*, being larger than the last and having a stronger jaw (Madurell et al., 2015). It can be hypothesized that *Cynotherium malatestai* occupied a different trophic niche, represented by the elephants and dwarf wild boars, which could be chased from the wild dogs in flock, thanks to the more robust jaws and skulls and of course of the size. One may however object: why so rarely on the Mediterranean islands have been found the remains of fossils dogs as the *Cynotherium malatestai*? The answer has perhaps to be searched in the same brittleness of the bones of these small mammals (as for mustelids and wild cats) as they can be shattered and lost more easily, while the strong bones of the insular endemic mammals such as those of the elephant and of the dwarf hippo are better preserved.

Conclusions

The key of point to understand the reduction and the difference of size of the insular elephants is multifactorial and therefore it is necessary to consider several complex interdependent factors, i.e. the limited natural resources, the size of the insular environment, the type of habitat (niches) and the geological period pertinent to the remains, and finally, the interaction with the predators present at that time.

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Breeding sites of the Italian Green Toad, *Bufotes balearicus* (Boettger, 1880) in Naples (Italy)

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Abstract

Here we report the results of a longitudinal field study (2002 -2018) aimed at monitoring the presence and the breeding activity of the Italian Green Toad, *Bufotes balearicus,* within the area of the administrative boundaries of Naples. We identified breeding sites in five sub-areas (Bagnoli – ex sito industriale, Mostra d'Oltremare, Parco del Poggio, Scalo Ferroviario-zona orientale, Parco Massimo Troisi), one of which (Parco M. Troisi) since 2018. Only in two subareas (Mostra d'Oltremare and Parco del Poggio) the reproductive activity took place regularly, almost every year, although the development of tadpoles was often compromised by a variety of anthropogenic disturbances. However, the major potential threat to the survival of this amphibian for the entire study area is represented by the isolation of its population mainly due to the scarcity of natural and semi-natural green areas in a highly urbanized territory.

We hope that our research will be helpful to plan management activity for this species in the urban area of Naples.

Keywords: Amphibians, *Bufotes balearicus*, Naples, monitoring, reproductive sites

Riassunto

In questo lavoro sono riportati i risultati di uno studio di campo condotto dal 2002 al 2018 teso ad accertare la presenza e l'attività riproduttiva del rospo smeraldino italiano, *Bufotes balearicus,* nell'area compresa all'interno del territorio comunale della città di Napoli. Abbiamo rilevato siti di riproduzione in 5 sub-aree di Napoli (Bagnoli – ex sito industriale, Mostra d'Oltremare, Parco del Poggio, Scalo Ferroviario – zona orientale, Parco M. Troisi), uno dei quali (Parco M. Troisi) dal 2018. Solo in due sub-aree (Mostra d'Oltremare and Parco del Poggio) abbiamo osservato che l'attività riproduttiva di questo anfibio era avvenuta regolarmente in pressoché tutti gli anni sebbene lo sviluppo larvale spesso risultasse compromesso da diversi tipi di attività antropica. In generale, la principale minaccia per la sopravvivenza del rospo smeraldino italiano nella cinta urbana di Napoli è rappresentata dall'isolamento delle sue metapopolazioni a causa soprattutto della scarsità di ambienti naturali e seminaturali che possano fungere da corridoi ecologici in un ambiente altamente edificato come la città di Napoli. Crediamo che la nostra ricerca possa aiutare a pianificare eventuali azioni di gestione per questa specie nella città di Napoli.

Parole chiave: Anfibi, *Bufotes balearicus*, Napoli, monitoraggio, siti riproduttivi.

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Introduction

The green toads of the Western Palaearctic and Central Asia, formerly ascribed to *Bufo viridis* (*sensu latu*), are currently considered a complex of different evolutionary lineages whose taxonomy and phylogenetic relationships are still intensely debated. In recent years, the different lineages of these green toads were first attributed to the genus *Pseudepidalea* and subsequently to the genus *Bufotes*, as the former has been demonstrated to be synonymous of the latter (Novarini & Bonato 2010; Lo Valvo et al., 2016; Speybroeck et al., 2020). *Bufotes* was accepted as a genus-level taxonomic group as time-calibrated phylogenetic analyses showed its contemporary or even older origin with respect to most of the currently recognized bufonids genera (e.g. *Bufo*, *Epidalea*) (e.g. Speybroeck et al., 2020). According to genetic studies (Stock et al., 2008), the following *Bufotes* species are present in Italy: *B. viridis*, limited to north-eastern Italy (provinces of Udine, Gorizia and Trieste); *B. balearicus* (Boettger, 1880), widespread in the rest of the Italian territory (excluding the Aosta Valley), in Sardinia, north-eastern Sicily and in some minor Tyrrhenian islands (Elba and Ischia); *B. siculus*, endemic to Sicily, excluding the north-east of this island, and to some minor islands (Ustica and Favignana); *B. boulengeri,* only in Lampedusa (Lo Valvo et al., 2016). However, the reproductive isolation between *B. balearicus* and *B. viridis* and between *B. siculus* and *B. boulengeri* needs further confirmation (Lo Valvo et al., 2016).

Besides the green frogs of the genus *Pelophylax*, *B. balearicus* is the only amphibian currently present within the administrative boundaries of Naples (Guarino et al., 2002, 2012) where, other amphibian species were reported up to the early 1980s (*Rana italica*, *Rana dalmatina*, *Lissotriton italicus*) (Dinardo 1990; Guarino et al., 2012). Unfortunately, unlike other Italian cities (e.g. Rome and Milan), the scarcity and the strong fragmentation of ecologically suitable environments for the survival of amphibians in the urban area of Naples make its populations of *B. balearicus* extremely vulnerable and potentially at risk of extinction.

Figure 1: *Bufotes balearicus* from Mostra d'Oltremare in Naples (photo by FM Guarino, June 2016).

In this study, we report the results of a longitudinal field research aimed at monitoring the presence and the breeding activity of the Italian Green Toad, *B. balearicus,* (Fig. 1) in the urban area of Naples. We believe that our research will be helpful to plan any management activity for this species in the Neapolitan urban area.

Materials and Methods

The study area coincides with that defined by the administrative boundaries of the municipality of Naples (Fig 2). The Cratere degli Astroni Natural Reserve located in the municipalities of Pozzuoli and Naples, of which the herpetofauna is well known (Caputo 1989; Guarino et al., 2002, 2012), was not taken into consideration for this study.

We selected the following four sub-areas where the presence of *B. balearicus* had previously been reported (see Guarino et al., 2012): Bagnoli – ex sito industriale, Mostra d'Oltremare, Parco del Poggio and Scalo Ferroviario -zona orientale (Fig. 2).

The Bagnoli – ex sito industriale (localization of the centre of the area: lat. 14 10 39 E, long. 40 48 35 N) is sited southwest of the city and extends over a surface of about 1.8 km² (0 - 4 m a.s.l.) within the larger area of the Campi Flegrei, in the Bagnoli-Fuorigrotta depression. It hosted the Italsider industrial complex until the beginning of the 1990s and now is abandoned (Fig 3). In this part of the city the breeding sites of the Italian green toads were represented by some artificial water bodies of different size

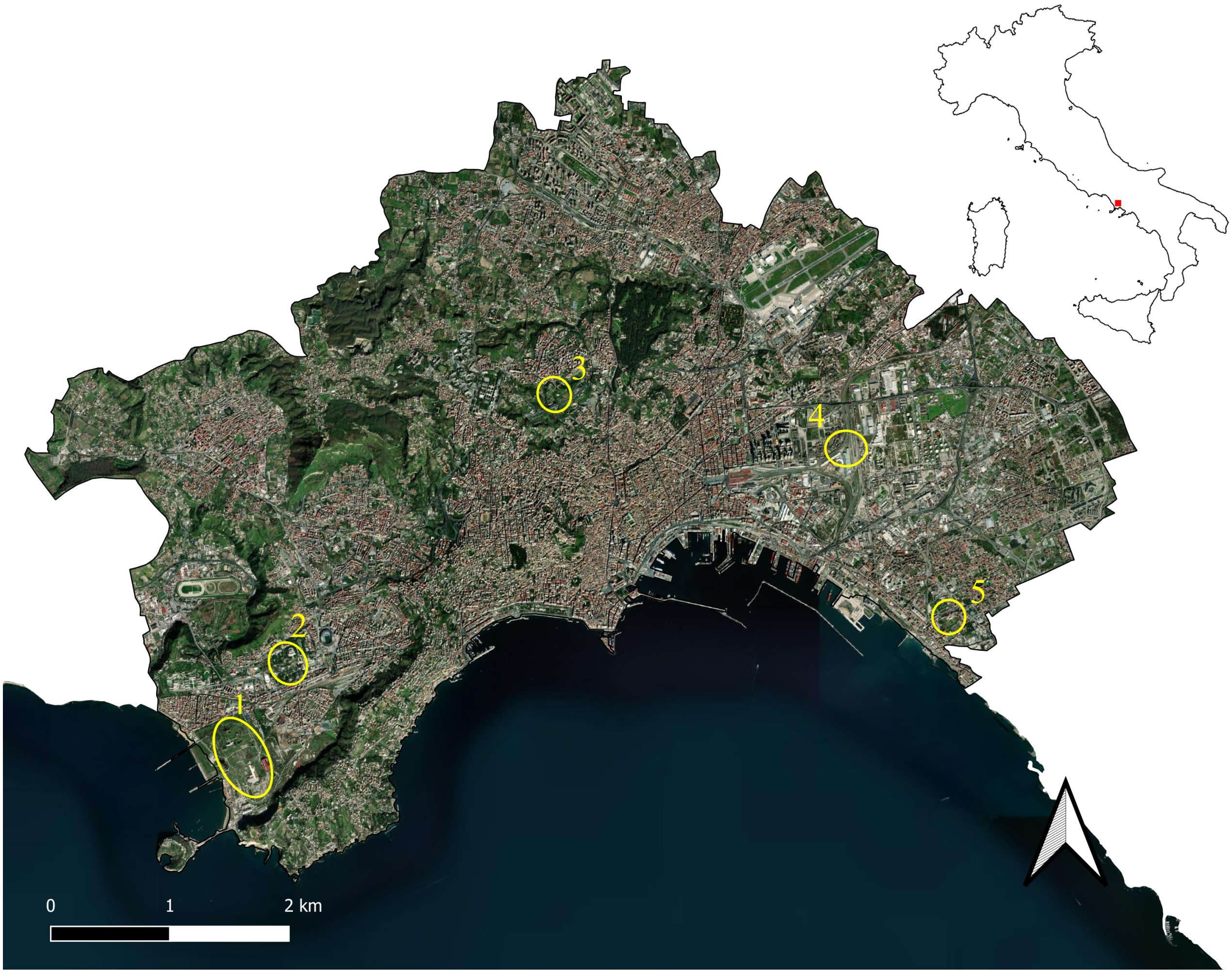

Figure 2: Study area. In the top right insert, location of Naples (red square). In the middle, the five subareas including reproductive sites: 1) Bagnoli- ex sito industriale, 2) Mostra d'Oltremare, 3) Parco del Poggio, 4) Scalo Ferroviario-zona orientale, 5) Parco M. Troisi. (yellow circles) (Picture by ESRI satellite, free edition, 2018, modified by S. Viglietti).

partially surrounded by vegetation. The habitat is characterized by the presence of sub-nitrophilous vegetation, linked to the state of abandonment following the dismantling of the industrial complex, where areas occupied by *Rubus ulmifolius* or *Dittrichia viscosa* are recognizable (pers. comm.). The artificial basins close to the coast-line are surrounded predominantly by *Phragmites australis*. According to the CORINE Biotopes manual, the predominant habitats are: 31.8a Sub-Mediterranean vegetation with *Rubus ulmifolius*, 34.81 Mediterranean sub-nitrophilous grass communities (including Mediterranean and post-cultural sub-Mediterranean vegetation), 53.1 Vegetation of reed beds and similar species (Commission of the European Community, 1991; Angelini et al., 2009). Unfortunately, since 2011 this site could be not investigated because it was subjected to seizure by the Tribunal of Naples (Invitalia 2018).

The Mostra d'Oltremare (localization of the centre of the area: lat. 14 11 12 E, long. 40 49 33 N) is the largest space of the city for trade shows and congresses, located in the western district of the city, a little further

Figure 3: A) Bagnoli area, formerly Italsider industrial complex, in a photo taken in 2019. At the top, in the middle, it is possible to see one of the bodies of water used by the green toad for breeding in this area. Under, on the left, there is the center of Città della Scienza (photo by Guarino, June 2019). B) Educational pond of Città della Scienza with *Carassius carassius* and *Trachemys scripta* (photo by FM Guarino, May 2016).

north of Bagnoli. It covers an area of about 0.7 km² (21 – 31 m a.s.l.) largely occupied by many green spaces, ornamental basins and fountains (Fig. 4). The arboreal species here present are mostly ornamental, while native species are mostly represented in the herbaceous layer. According to the Carta della Natura della Regione Campania (Bagnaia & Viglietti, 2018), this site is categorized as habitat 85 Parks, gardens and green areas.

The Parco del Poggio (localization of the centre of the area: lat. 40° 52' 0.468'' E, long. 14° 14' 22.05'' N) is an urban park located in the North of the city with a surface of approximatively 0.04 km2. It is within an urban area with very varied vegetation, where cultivated areas and small gardens with ornamental species prevail. However, isolated specimens and small nuclei of *Quercus ilex* and *Pinus pinaster* are still found. The spaces no longer cultivated are often occupied by brambles and sub-nitrophilous vegetation ascribable to the category 34.81 Mediterranean sub-nitrophilous grass communities according to the CORINE Biotopes manual (Commission of the European Community, 1991; Angelini et al., 2009). The Parco del Poggio was built on a tuff quarry used in the 1960s for the construction of some surrounding areas. Once the tuff extraction was stopped, in this area an urban park was designed in the 1990s and inaugurated in 2001 (Comune di Napoli 2019). A small lake was built on the bottom of the quarry (167 m a.s.l.) and partially surrounded by ornamental plants such as *Strelizia* sp. and Bambusae gen. sp. (Fig. 5). According to the Carta della Natura della Regione Campania (Bagnaia & Viglietti, 2018), the Parco del Poggio is categorized as habitat 85 Parks, gardens and green areas.

The Scalo Ferroviario- zona orientale (localization of the centre of the area: lat. 14 17 28 E, long. 40 51 53 N) includes several temporary natural ponds and canals extending over a urbanized area (about 0.05 km², about 18 m a.s.l), near the Railway

Figure 4: Reproductive sites of *Bufotes balearicus* in the Mostra d'Oltremare: A) Small artificial lake called Laghetto Fasilides (photo by FM Guarino, May 2015). B) One of the 28 fountains placed at the entrance of the Mostra d'Oltremare (photo by FM Guarino, May 2016) C) Freshly deposited eggs of *B. balearicus*, typically arranged in strings (photo by FM Guarino, April 2016).

Station in the eastern district of the city. The habitat is ascribable to the category 34.81 Mediterranean sub-nitrophilous grass communities according to the CORINE Biotopes manual (Commission of the European Community, 1991; Angelini et al., 2009). It includes sub-anthropic formations with Mediterranean therophytes forming pioneer stages often very extensive on soils rich in nutrients that are affected by past cultivation practices or more recent weeding practices for the management of the railway network. In this subarea, *B. balearicus* constantly reproduced since the end of the last century (Dinardo 1990; pers. comm.).

The data on the presence and reproductive activity of *B. balearicus* were collected by visual encounter survey (VES) from 2002 to

Figure 5: Parco del Poggio. A), B). Temporary pool formed after the emptying of an ornamental basin (photo by Guarino, May 2016). C) Tadpoles of *Bufotes balearicus* (photo by Guarino, April 2016).

2018, especially from March to June, a period corresponding to the breeding season of the species. Our VES was conducted using multiple transects along the suitable water bodies for breeding of this anuran (Heyer et al., 1994) during daytime hours.

We also recorded the presence of the species based on its typical vocalizations.

Results

The breeding activity of *B. balearicus* in the four subareas identified from 2002 is shown in table 1. Unfortunately, for some years it was not possible to record information on all the different reproductive sites, as reported above.

Table 1: Breeding activity of *B. balearicus* in the municipality of Naples. **C**: Presence of adults using calls; **ND**: not investigated; **P**: Presence of several adults/pairs using VES. **PN**: Presence of isolated individuals in the neighbouring areas using VES; **R**: Reproduction successful: presence of numerous tadpoles and toadlets; **TR**: Fruitless attempt of reproduction: presence of few tadpoles and toadlets and many new metamorphosed individuals dead due to exsiccation of the pool; **PE** Probably extinct due to the destruction of the reproductive site.

Study year	Bagnoli ex sito industriale	Mostra d'Oltremare	Parco del Poggio	Scalo ferroviario zona orientale
2002	ND	R/P	ND	R/P
2003	TR	R/P	TR/C	R/P
2004	TR/C	R/P	R/P	R/P
2005	C	R/P	R/P	ND
2006	ND	R/P	R	ND
2007	ND	ND	ND	ND
2008	ND	R/P	ND	ND
2009	ND	R/P	ND	ND
2010	ND	ND	ND	ND
2011	ND	R/P	R/P	ND
2012	ND	R/P	R/P	ND
2013	ND-PN	R/P	R	ND
2014	ND-PN	R/P	R	ND
2015	ND-PN	R/P	R	PE
2016	ND-PN	R/P	R	PE
2017	ND-PN	R/P	TR	PE
2018	ND	R/P	R/P	PE

Concerning Bagnoli- ex sito industriale (Fig. 3A) we collected data until to 2011. Afterwards, we investigated the neighbouring districts, including the Science Centre called Città della Scienza, recording the presence of different erratic individuals and dead specimens. Anyway, we never registered reproductive events of the Italian green toad in the neighbouring districts, including the educational small pond of Città della Scienza, where freshwater fish *Carassius auratus* and turtles *Trachemys scripta* were abundantly introduced (Fig. 3B).
In the Mostra d'oltremare we observed the reproduction of *B. balearicus* throughout the entire study period. Several sites were used by this species for breeding, such as a small artificial lake called Laghetto Fasilides (Fig. 4A) and the fountains at the entrance walkway (Fig. 4B, C).

In the Parco del Poggio we observed spawning, tadpoles and neometamorphosed of *B. balearicus* in temporary pools that were formed when the artificial lake of the Park was almost completely emptied for annual maintenance (Fig. 5A, B). Reproductive events of this species were generally recorded between April-early June in every year surveyed (see Table 1).

Concerning the Scalo Ferroviario- zona orientale the works for the construction of a new railway line (Fig. 6A and B) since the beginning of 2000 resulted in the gradual disappearance of the breeding sites of the Italian green toad. Since the breeding season of 2005 we were no longer able to find spawning or tadpoles in this area.

Interestingly, since 2018 we also recorded a new reproductive site of *B. balearicus*, in the Parco M. Troisi (4 m a.s.l.) (Fig. 2; 6C), located in the San Giovanni district, east of the study area.

Discussion

Our longitudinal field study (2002-2018) led to the identification of breeding sites of *B. balearicus* in five subareas of Naples. In two of these (Parco del Poggio and Mostra d'Oltremare) the oviposition occurred regularly, although the development of tadpoles was often compromised by a variety of anthropogenic factors, including the alteration of the aquatic habitat owing to water withdrawals and water pollution. However, a major potential threat to the survival of this amphibian for the entire study area is represented by the isolation of its metapopulations mainly due to the scarcity of natural and semi-natural green areas in a highly urbanized territory.

Interestingly, the recent discovery of the reproductive site in the Parco M. Troisi as well as the occasional reproductive events in other areas adjacent to those of the municipality of Naples (e.g. at waterfront of Portici, in June 2018), indicate the need of further field surveys to have a more accurate picture of the reproductive sites of the species in the urban area of Naples. On the other hand, the species is ecologically versatile and can colonize a wide range of anthropic environments (Guarino et al., 2012; Maio et al., 2000, 2001). In this regard, the occasional reports of erratic individuals

Figure 6: Scalo Ferroviario- zona orientale subarea. A) Work in progress for the construction of a new railway. B) Temporary pool with tadpoles of *Bufotes balearicus* (photo by N. Maio, April 2004). C) Parco Massimo Troisi.

of *B. balearicus* for other areas of the city, such as Moiarello, in the northern area of the city (pers. comm.), Soccavo district (pers. comm),); Agnano, and Coroglio (the citizen-science platform iNaturalist: https://www.inaturalist.org) also deserve to be mentioned.

Furthermore, in an urban reality such as Naples where the environments suitable for the reproduction of this amphibian are fragmented and isolated by numerous anthropogenic barriers (Guarino et al., 2016), it would be very important to check for possible communication routes between the different metapopulations of the species. It is also worth mentioning that *B. balearicus* is included in the Annex IV of the Directive 92/43/CEE on the conservation of natural habitats and of fauna and flora (Habitats Directive) (Lo Valvo et al., 2016) and that its populations in Campania are considered Vulnerable (VU) in the Red List of the Amphibians and Reptiles of the Region (Guarino & Maio 2013) mainly due to the disappearance, alteration, and fragmentation of habitats. Concerning the Mostra d'Oltremare and the Parco del Poggio we proposed to the respective Managing Bodies the following actions aimed at the conservations of *B. balericus:* to ensure the permanence of the bodies of water used by the species for breeding and carrying out the larval development; to ban the use of biocides in the water bodies and neighbouring areas; to monitor and contrast the possible introduction of alien species such as *Trachemys scripta* and *Carassius auratus*; to install information panels on the importance of protecting this species.

To conclude, this study represents an update on the reproduction sites of *B. balearicus* in Naples and a first step for the planning of future management activities for this amphibian in the study area.

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Author contributions

Conceptualisation: F.M.G., M.M., N.M. Data Curation: F.M.G., M.M., N.M. Formal Analysis: F.M.G., M.M., N.M. Investigation: F.M.G., M.M., N.M. Methodology: F.M.G., M.M., N.M. Writing – Original and Final Draft Preparation and Creation and/or presentation of the published work: F.M.G., M.M., G.O., L.O.A.P., A.P., S.V., N.M.

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Survival of *Salmonella* Typhimurium, *Escherichia coli*, and *Enterococcus faecalis* in poultry manure samples, treated with different concentrations of hydrated calcium hydroxide

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Abstract

The aim of the study was to verify the quality and microbiological safety of poultry manure, a completely natural fertilizer, composed of the manure of hens, poultry, and other birds. The evaluation of the quality and safety of poultry manure was performed following a bactericidal treatment, using different percentages of hydrated calcium hydroxide, inhibiting the growth, proliferation, and survival of bacterial species that can be pathogenic for humans. The evaluations were conducted spiking known concentrations of *Salmonella* spp., *Escherichia coli*, and *Enterococcus* spp. Following the contamination, qualitative and quantitative analysis for the research of the above-mentioned pathogens were performed. In parallel, the variations of pH and humidity in the samples under examination were verified. The experiments consisted on adding different concentrations of hydrated calcium hydroxide, with a percentage ranging from 15% to 25%, followed by the qualitative and quantitative research of the pathogenic microorganisms spiked in increasing ten-fold concentrations (10^2, 10^3, 10^6 CFU/g). The total reduction of the microbial load in a period of time that varies from a few hours to a few days, depending on the microorganism under consideration, was observed.

Keywords: Hydrated calcium hydroxide, poultry manure, microbial reduction, *Salmonella* spp., *Escherichia coli, Enterococcus* spp.

Riassunto

Lo scopo della sperimentazione è stato quello di verificare la qualità e la sicurezza microbiologica della pollina, un fertilizzante completamente naturale, costituito da letame di galline, polli ed altri volatili.
La valutazione della qualità e sicurezza della pollina è stata valutata a seguito di un trattamento battericida, ottenuto utilizzando diverse percentuali di idrossido di calcio idrato (o, calce idrata), in grado di inibire la crescita, la proliferazione e la sopravvivenza di specie batteriche che risultano patogene per l'uomo.
I test sono stati condotti mediante l'inoculazione artificiale di concentrazioni note di *Salmonella* spp., *Escherichia coli*, ed *Enterococcus* spp. Successivamente alla contaminazione, sono state condotte analisi qualitative e quantitative al fine di ricercare i patogeni sopraindicati. In parallelo sono state analizzate le variazioni del pH e dell'umidità nei campioni in esame.
La sperimentazione è consistita dunque nell'aggiunta di diverse concentrazioni di calce idrata, con concentrazioni d'uso comprese nel range 15-25%, seguita dalla ricerca qualitativa e quantitativa dei microrganismi patogeni, inoculati artificialmente con concentrazioni decimali crescenti (10^2, 10^3, 10^6 UFC/g). Dall'analisi dei risultati ottenuti, è stata osservata la riduzione totale del carico microbico in un periodo di tempo che varia da poche ore a pochi giorni, a seconda del microrganismo considerato nella ricerca.

Parole chiave: Idrossido di calcio idrato, letame di pollame, riduzione microbica, *Salmonella* spp., *Escherichia coli, Enterococcus* spp.

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Introduction

It is essential, in order to certify the quality and safety of fertilizers, to verify compliance with current regulations, which mainly require the microbiological safety of soil improvers. The legislation - EC Regulation 142/2011, Annex XI, Chapter I, Section 2, Point D - establishes a detection limit for *Escherichia coli* of 10^3 CFU/g, *Enterococci* of 10^3 CFU/g and the absence of *Salmonella* spp. in 25g of the product.
Poultry manure holds a significant agronomic value (Hutchison et al., 2004), in terms of the

contribution of organic matter and macro, meso- and micro-nutrients (Millner et al., 2014), and is therefore exploited and recovered in agriculture as an organic fertilizer, providing the nutrients subtracted from it to the soil with crops. The most common industrial treatment of poultry manure, useful for reducing humidity and transforming the product into a safe formulation at a sanitary level, involves drying the matrix by rapid heating at high temperature or slow heating at low temperature, to lower the humidity to a range between 10% and 15%. Poultry manure examined is provided by Agriges srl, a company located in the Benevento area that produces special fertilizers for organic and integrated agriculture, carrying out various treatments, including bactericidal approaches by heat treatments.

Poultry manure specimens employed in the present study, following the bactericidal treatment with hydrated calcium hydroxide, intended for use in agriculture, were stored at room temperature in aerobic conditions (Cotta et al., 2003).

The study pointed at assessing the efficacy of bacterial inactivation in poultry manure, using hydrated calcium hydroxide (Ruiz et al., 2008): experiments consisted on artificially spiking poultry manure with known concentrations of three pathogenic microorganisms, verifying how hydrated calcium hydroxide acts on the control of bacterial growth (Więckol-Ryk et al., 2020).

Different percentages of hydrated calcium hydroxide were tested, in relation to the proliferation or survival of *Escherichia coli* ATCC® 25922, *Salmonella* Typhimurium ATCC® 14028, and *Enterococcus faecalis* ATCC®19433 (Bennet et al., 2003; Park et al., 2003). The indicators employed in the present study (*Salmonella* spp., *Escherichia coli*, and *Enterococcus* spp.) play a crucial role in monitoring the health risks connected to fertilizers (Awasthi et al., 2018; Mohmed et al., 2013). Such pathogens furthermore represent the reference indicators for the treatment of residual biomass, such as low-risk animal by-products, and for the agronomic use of commercial organic fertilizer products derived from waste and organic waste. In parallel, the variations of pH and humidity in the samples were verified, since substantial variations of such parameters may support the decrease of the microbial growth (Heinonen-Tanski, et al., 2006; Andersson et al., 2001; Nyberg et al., 2011; Soliman et al., 2018), ensuring the safety and quality of the final fertilizing product.

Materials and Methods

Microbiological analysis of poultry manure

Before proceeding with the spiking of poultry manure with pathogenic microorganisms, samples were subjected to microbiological analyses to evaluate the presence of the pathogens in the matrix.

Microbiological analyses were carried out using standardized protocols: samples were weighed and homogenized, in order to obtain the desired solution. The sub-aliquots of the samples were homogenized in liquid and solid enrichment media, following the specific protocols to highlight the growth of each bacterium, allowing subsequent characterization and enumeration. The parameters were investigated at a temperature of 30-32 °C and aerobic conditions, close to the optimal temperature range for the pathogens examined (ISO 16649:1:2018; ISO 6579:2008; ISO 7899:2:2003) (International Organization for Standardization 2018; International Organization for Standardization 2008; International Organization for Standardization 2003). Sample analysis was performed before the experimental protocol was started. *Salmonella spp.* was not detected, while fecal *Coliforms* and *Enterococci* were isolated at a concentration of about 10^5 CFU/g (Table 1) (International Organization for Standardization 2003; International Organization for Standardization 2004; International Organization for Standardization 2004; International Organization for Standardization 2008; International Organization for Standardization 2013; International Organization for Standardization 2018).

Bacterial inocula preparation

The strains used for artificial contamination of poultry manure were *Escherichia coli* ATCC® 25922, *Salmonella* Typhimurium ATCC® 14028, and *Enterococcus faecalis* ATCC®. The single inocula of the three strains were grown according to the metabolic needs of the microorganisms.

Inocula were kept under constant stirring at 200 rpm in 40 mL of Tryptic Soy Broth (TSB, OXOID) in sterile 50 mL tubes. To obtain a concentration of 10^8 cells/mL of each microorganism, the spectrophotometer was used, and an absorbance value at 560 nm wavelength was measured: a value of 0.125 O.D. indicates a reference concentration of 10^8 cells/mL. The inocula underwent ten-fold dilutions, obtaining the concentrations established for the experiment (10^6, 10^3 and 10^2 cells/mL).

Table 1. Results of the microbiological analyses carried out on the poultry manure samples (t_{PRE}), before proceeding with the artificial contamination using *E. coli, E. faecalis,* and *S.* Typhimurium, before treating the matrix with hydrated calcium hydroxide.

Parameter	Concentration [CFU/g]	Reference method
Total Bacterial Count at 37°C	$1,52*10^6$	UNI EN ISO 4833-1:2013
Enterococci	$3,25*10^5$	UNI EN ISO 21528-2:2004
Escherichia coli	$3,74*10^5$	UNI EN ISO 16649-2:2001
Clostridium perfringens	Absent	UNI EN ISO 7937:2004
***Salmonella* spp.**	Absent	UNI EN ISO 6579:2014
***Campylobacter* spp.**	Absent	UNI EN ISO 10272-1:2017

Contamination of poultry manure and bactericidal treatment

Aliquots of 100 g of poultry manure were weighed and poured into 9 sterile glass bottles with 500 mL each of sterile water. Samples were artificially spiked with serial ten-fold dilutions of the bacteria and incubated with a temperature range of 30-32 °C, in aerobic conditions. The experiment was conducted for 14 days. Before the artificial contamination (t_{PRE}), after the addition of hydrated calcium hydroxide (t_0) and after 1, 2, 7 and 14 days from contamination, the samples were subjected to qualitative and quantitative microbiological analyses in order to verify the concentrations of the three indicators in each sample. Analyses were conducted in triplicate.

The experimental design is following summarized: the manure was contaminated with different concentrations of *Escherichia coli* ATCC® 25922, *Salmonella* Typhimurium ATCC® 14028 and *Enterococcus faecalis* ATCC® 19433 (10^2, 10^3, 10^6 CFU/g). The samples were incubated at 30 °C under aerobic conditions for 16 hours and treated as follows:

- non-treated poultry manure spiked samples, considered as negative control (NC)
- poultry manure spiked samples treated with 15% hydrated calcium hydroxide
- poultry manure spiked samples treated with 25% hydrated calcium hydroxide
- microorganisms inocula in sterile water (to verify microbial growth without the contribution of poultry manure).

In addition, monitoring of temperature, pH and humidity were carried out. The experimental model is showed in detail in Figure 1.

As for Negative Control (NC) samples and bacterial inocula, in accordance with the company, we decided to inoculating microorganisms in sterile water, instead of supplemented growth media (e.g., Tryptone Soya Broth, OXOID), in order to verify the survival of the germs in absence of nutrients. The resulting curve refers to the decrease of microbial count in function of the lack of nutrients: the graph was compared to negative control and treated samples.

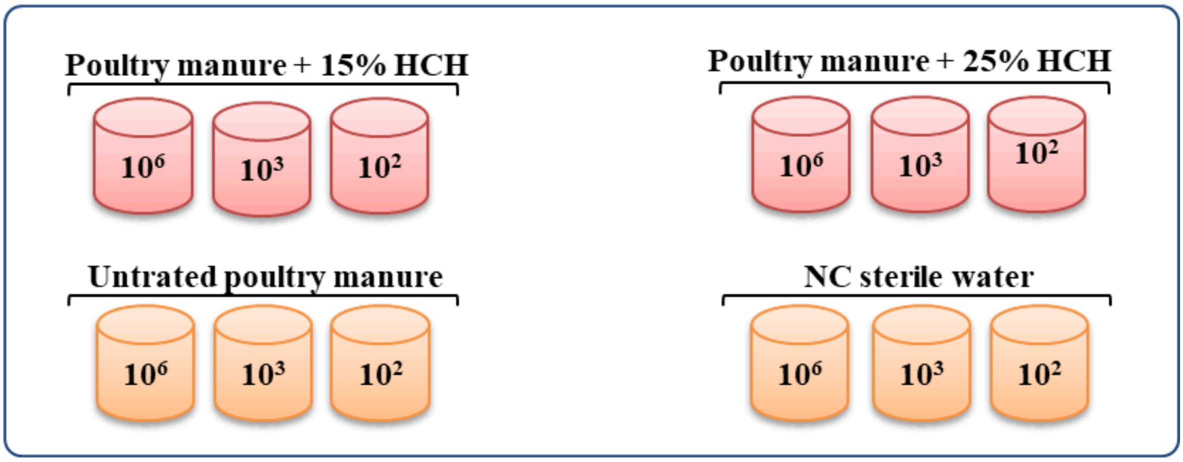
Results and Discussion

The synergistic effect of hydrated calcium hydroxide with the variation of pH and humidity were able to inhibit the growth and replication of the pathogens object of the study: therefore, a reduction in the microbial load of *Salmonella spp., Escherichia coli* and *Enterococci faecalis* was observed.

Salmonella Typhimurium ATCC® 14028

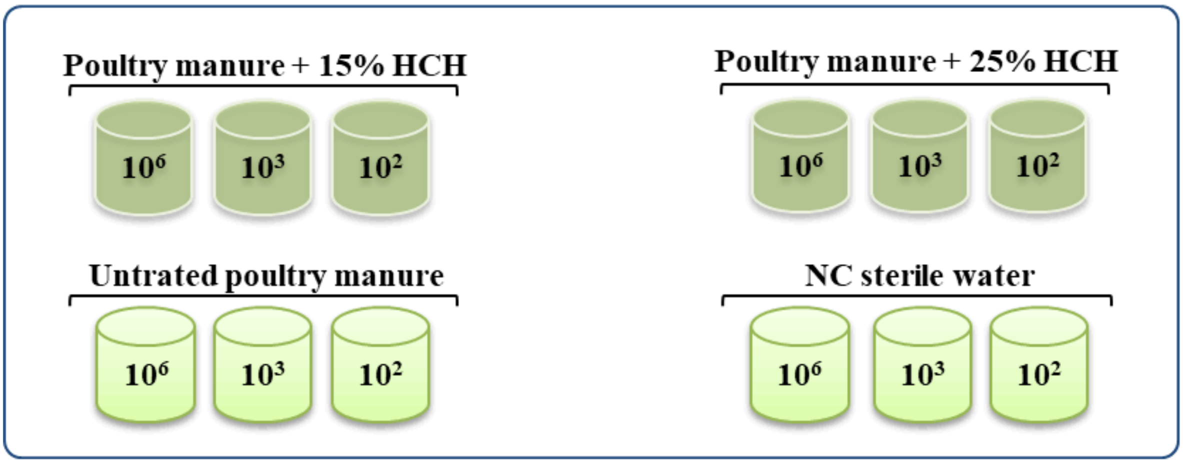
The analysis of manure artificially spiked with 10^6 CFU/g of *Salmonella Typhimurium* is showed in Figure 2A. Analyzing the data of untreated manure, shortly after the artificial contamination, a 2-log decrease in the microbial load was observed. At day 1 (d_2), 72 hours after the artificial contamination, the resulting microbial load of the sample spiked with 10^6 CFU/g *Salmonella* Typhimurium is 10^3 CFU/g, steadily decreasing up to d_{14}. The outcomes may depend on an inhibiting action of the organic and inorganic components of the poultry manure on *Salmonella spp.* In poultry manure treated with 15% and with 25% hydrated calcium hydroxide, the microbial load die-off was evidenced, shortly after the application of hydrated calcium hydroxide.

Escherichia coli ATCC®25922



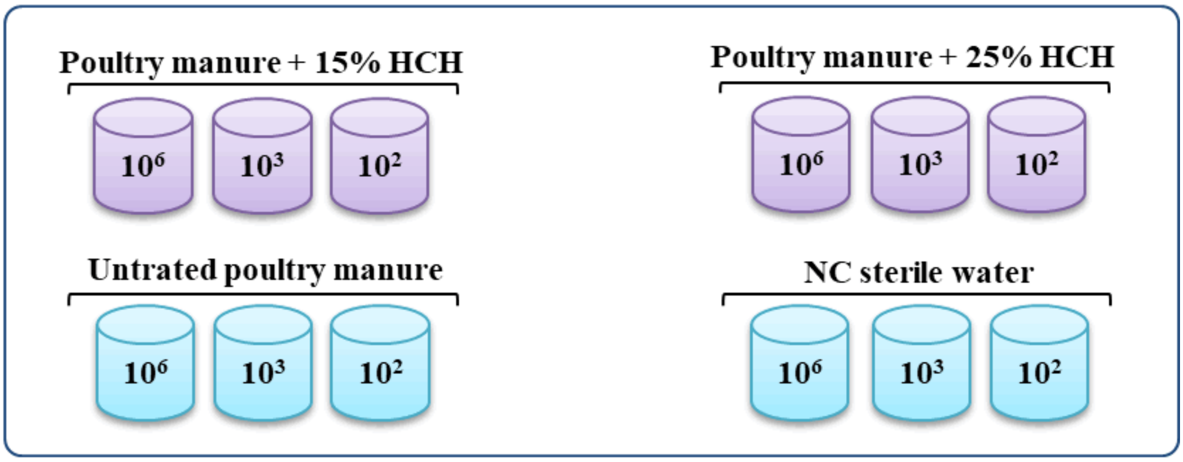
10^n : bacterial concentration, CFU/g. Sample prepared in triplicate.
HCH: Hydrated calcium hydroxide

Enterococcus faecalis ATCC®19433



10^n : bacterial concentration, CFU/g. Sample prepared in triplicate.
HCH: Hydrated calcium hydroxide

Salmonella Typhimurium ATCC®16404



10^n : bacterial concentration, CFU/g. Sample prepared in triplicate.
HCH: Hydrated calcium hydroxide

Figure 1: Experimental design of the samples analysed in the study.

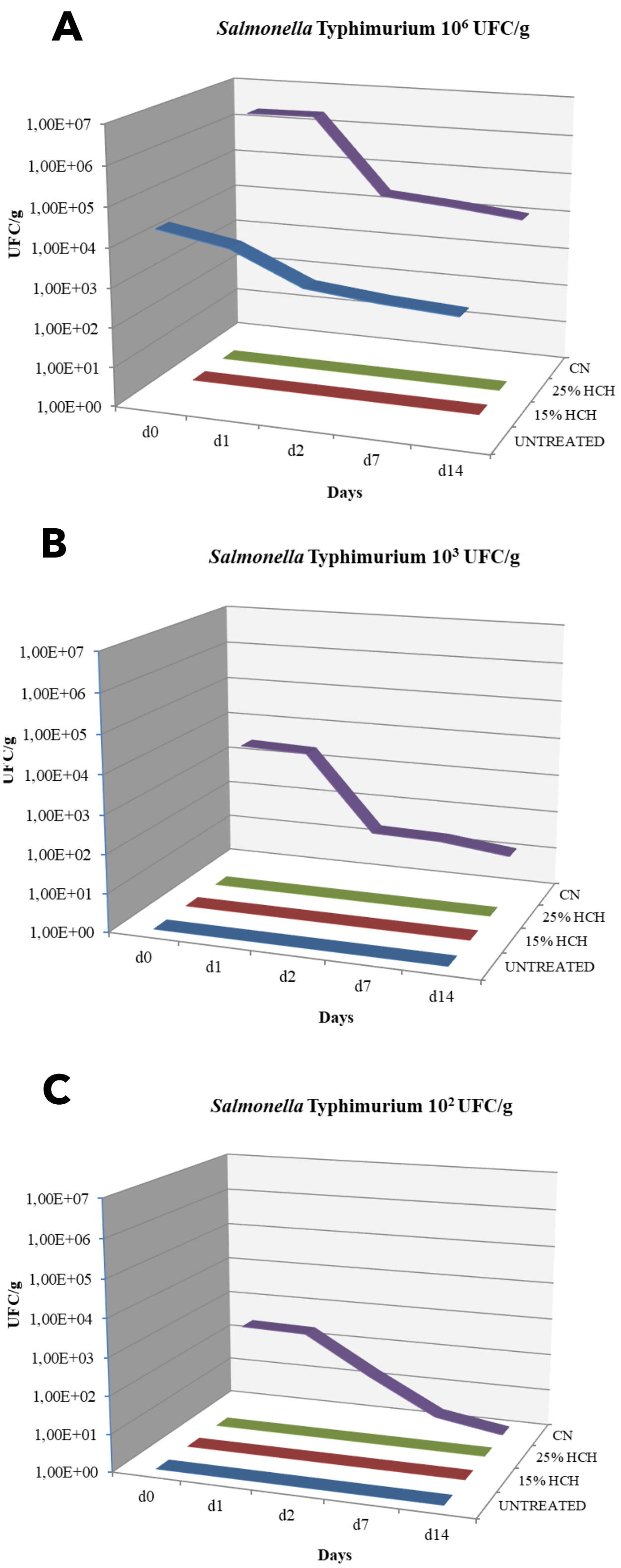


Figure 2: Trend of *Salmonella* Typhimurium in poultry manure starting from a concentration of A) 10^6 CFU/g B) 10^3 CFU/g.

In the negative control, not treated with hydrated calcium hydroxide, microbial loads gradually decrease, although less than in the untreated manure samples: in fact, a microbial load of about 10^4 CFU/g was observed between d_7 and d_{14}.

The analysis of poultry manure spiked with 10^3 CFU/g of *Salmonella Typhimurium* is described in Figure 2B. In the untreated poultry manure, a substantial decrease in the microbial load was observed since d_0. The manure treated with 15% and 25% hydrated calcium hydroxide showed the complete die-off of *Salmonella* spp. after the application of hydrated calcium hydroxide. In the negative control (NC) the load gradually decreases and a microbial load of about 10^2 CFU/g from d_2 was recorded.

The analysis of manure artificially contaminated with 10^2 CFU/g *Salmonella* Typhimurium is showed Figure 2C. Also in this case, the untreated manure, and the poultry manure treated with 15% and 25% hydrated calcium hydroxide, registered a huge decrease in the microbial load from day 0.In the negative control (NC), a microbial load < 10 CFU/g at d_1 was recorded.

Escherichia coli ATCC® 25922

The analysis of poultry manure artificially contaminated with 10^6 CFU/g *Escherichia coli* is showed in Figure 3A. In the untreated manure, the microbial load was doubled, as the artificially added concentration was added to that already present in the manure sample. A 1-log decrease in the microbial load was observed from d_2. At d_7 the resulting microbial load is 10^4 CFU/g, remaining constant until d_{14}. Poultry manure treated with 15% and 25% hydrated calcium hydroxide, showed a microbial die-off, after the application of hydrated calcium hydroxide. In the negative control (NC) the microbial load remains constant, decreasing from d_{14}.

The analysis of manure contaminated with 10^3 UFC/g *Escherichia coli* is showed Figure 3B. Analyzing the untreated manure, that, nonetheless the previous presence of *E. coli* in the sample, a 1-log decrease in the microbial starting from d_2 is evident. At d_7 the resulting load is 500 CFU/g, constant until d_{14}.

The analysis of poultry manure spiked with 10^2 CFU/g *Escherichia coli* is showed in Figure 3C. Untreated manure microbial load decreased from d_2. At d_{14} the resulting charge is 50 CFU/g, constant until d_{14}. Poultry manure treated with 15% and 25% hydrated calcium hydroxide, showed a microbial load of 0 CFU/g after the application. Negative control (CN) loads decreased from d_7.

Enterococcus faecalis ATCC® 19433

In samples spiked with different concentrations of *Enterococcus faecalis,* a higher survival trend was evident, also considering that, at d_0, the microbial load added artificially was summed to that already present in the manure samples. Indeed, *Enterococcus faecalis* is the only microorganism in the study able to survive, although for not more than 48 hours, following the application of hydrated calcium hydroxide to the manure.

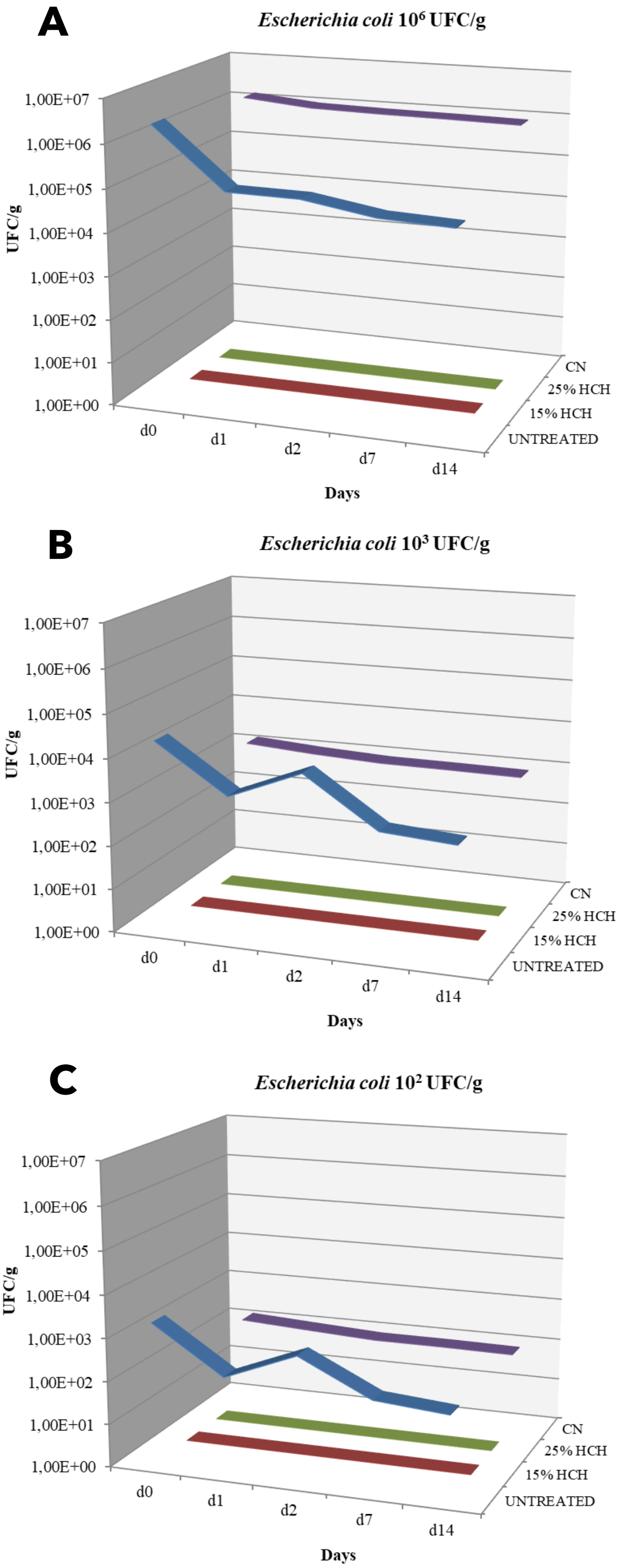


Figure 3: Trend of *Escherichia coli* in poultry manure starting from a concentration of A) 10^6 CFU/g B) 10^3 CFU/g and C) 10^2 CFU/g.

The analysis of manure spiked with 10^6 CFU/g *Enterococcus faecalis* is available in Figure 4A. As for untreated manure, the decrease in microbial load is evident already from d_2. At d_7 the resulting charge is 10^5 CFU/g. In manure treated with 15% and 25% hydrated calcium hydroxide, the microbial load decreased significantly showing a complete

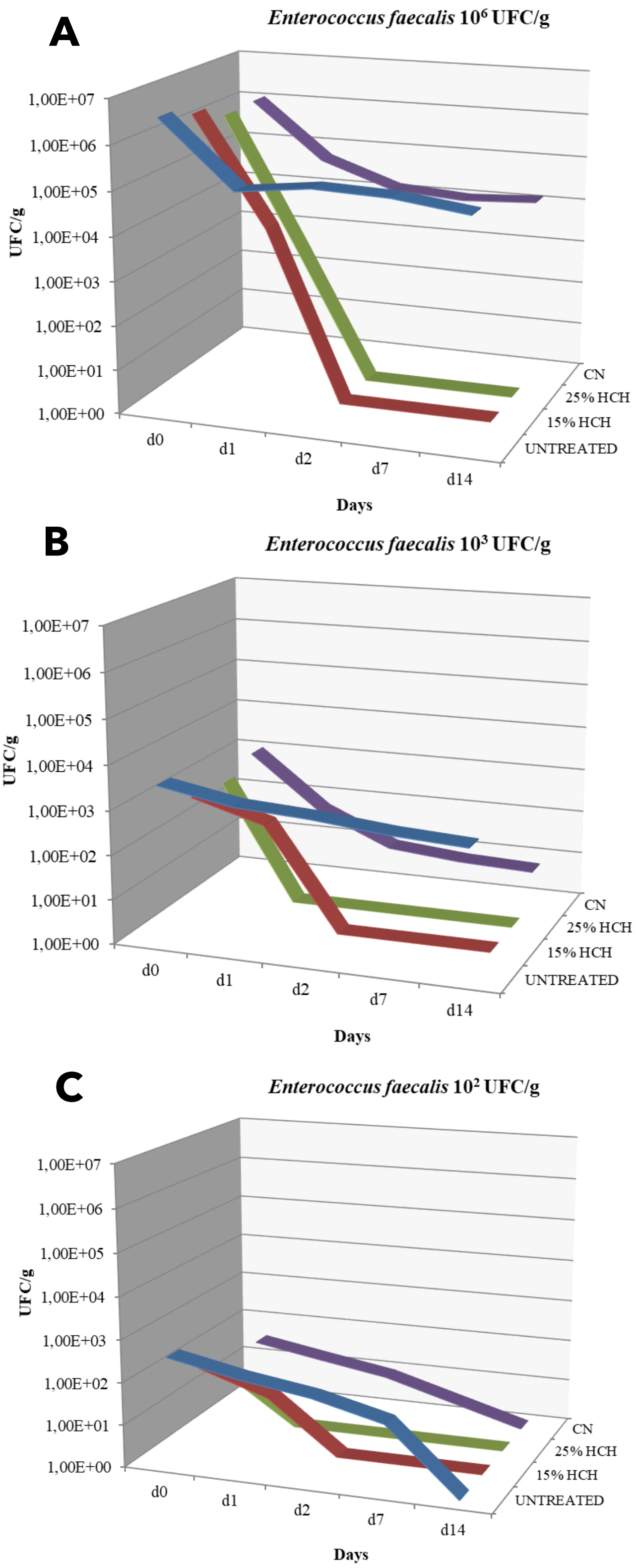


Figure 4: Trend of *Enterococcus faecalis* in poultry manure starting from a concentration of A) 10^6 CFU/g B) 10^3 CFU/g and C) 10^2 CFU/g.

die off at d_2. The microbial load of the negative control (NC) is constant and decreases from d_2.

The analysis of manure artificially contaminated with 10^3 CFU/g of *Enterococcus faecalis* is showed in the Figure 4B. The untreated manure showed a decrease in the microbial load from d_7. Microbial load of poultry manure treated with 15% and 25% hydrated calcium hydroxide, decreases significantly.

Analysis of manure spiked with 10^2 CFU/g *Enterococcus faecalis* is showed in Figure 4C. The untreated manure showed a starting microbial load < 400 CFU/g; load resulted reduced between d_7 and d_{14}. As for poultry manure treated with 15% and 25% hydrated calcium hydroxide, at d_1, microorganisms decrease significantly: the microbial die-off is obtained in 24 hours with 25%, and after 48 hours with 15% hydrated calcium hydroxide. In the negative control (NC) sample, microbial load decreases from d_2.

pH and Humidity

In parallel with microbiological analysis, the variations of pH and humidity in the samples of poultry manure treated with hydrated calcium hydroxide were measured (Soliman et al., 2018).

The graphs showed in Figures 5 and 6 describe the trend of the pH and humidity parameters registered in the samples spiked with the three pathogenic microorganisms and subjected to bactericidal treatment, employing different percentages of hydrated calcium hydroxide.

The pH values of artificially contaminated and non-treated poultry manure samples are between 8 and 10 over time,

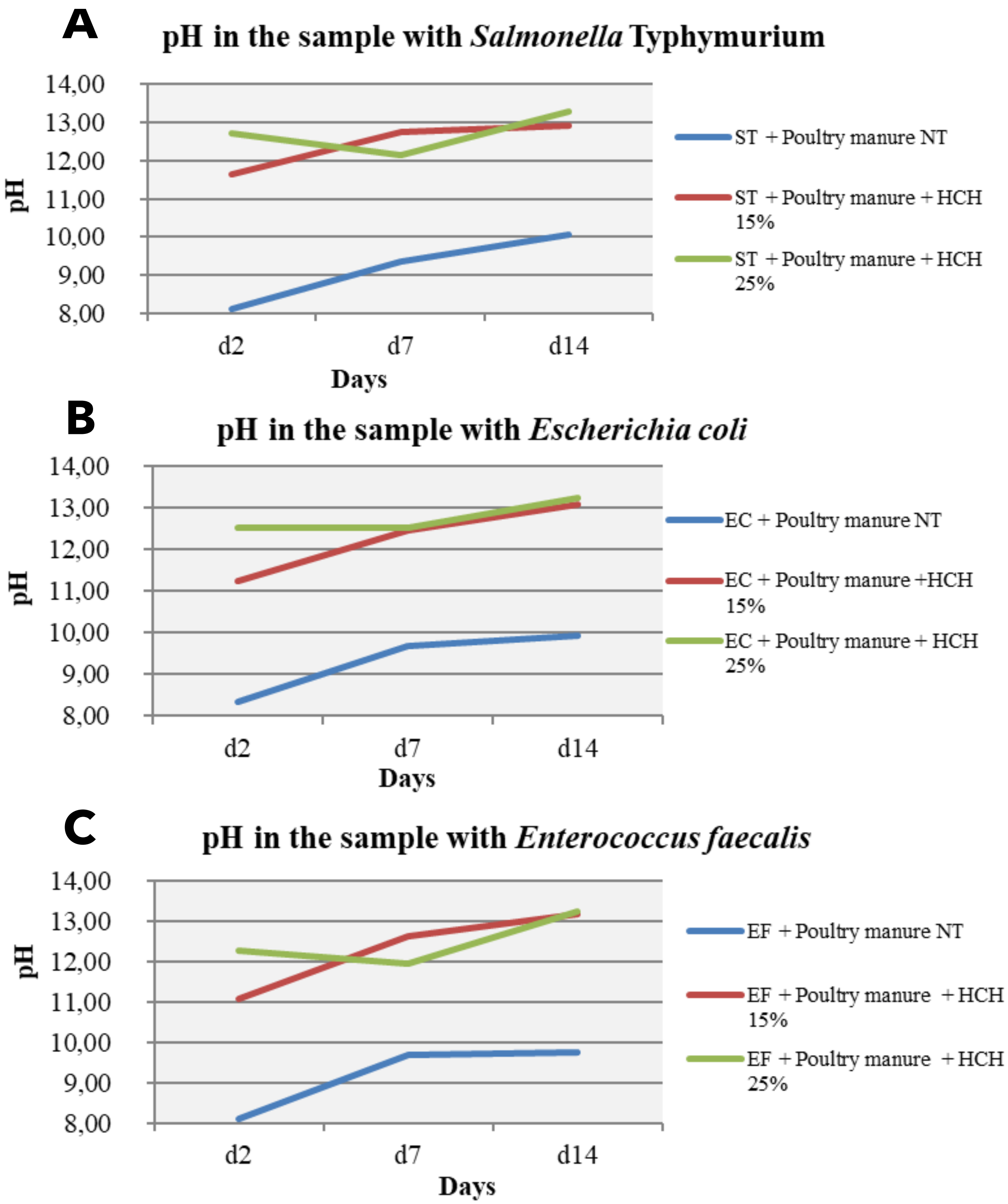


Figure 5: Trend of pH in poultry manure spiked with A) *Salmonella* Typhimurium [ST: *Salmonella* Typhimurium; NT: Not Treated; HCH: hydrated calcium hydroxide], B) *Escherichia coli* [EC: *Escherichia coli*; NT: Not Treated; HCH: hydrated calcium hydroxide] and C) *Enterococcus faecalis* [EF: *Enterococcus faecalis*; NT: Not Treated; HCH: hydrated calcium hydroxide].

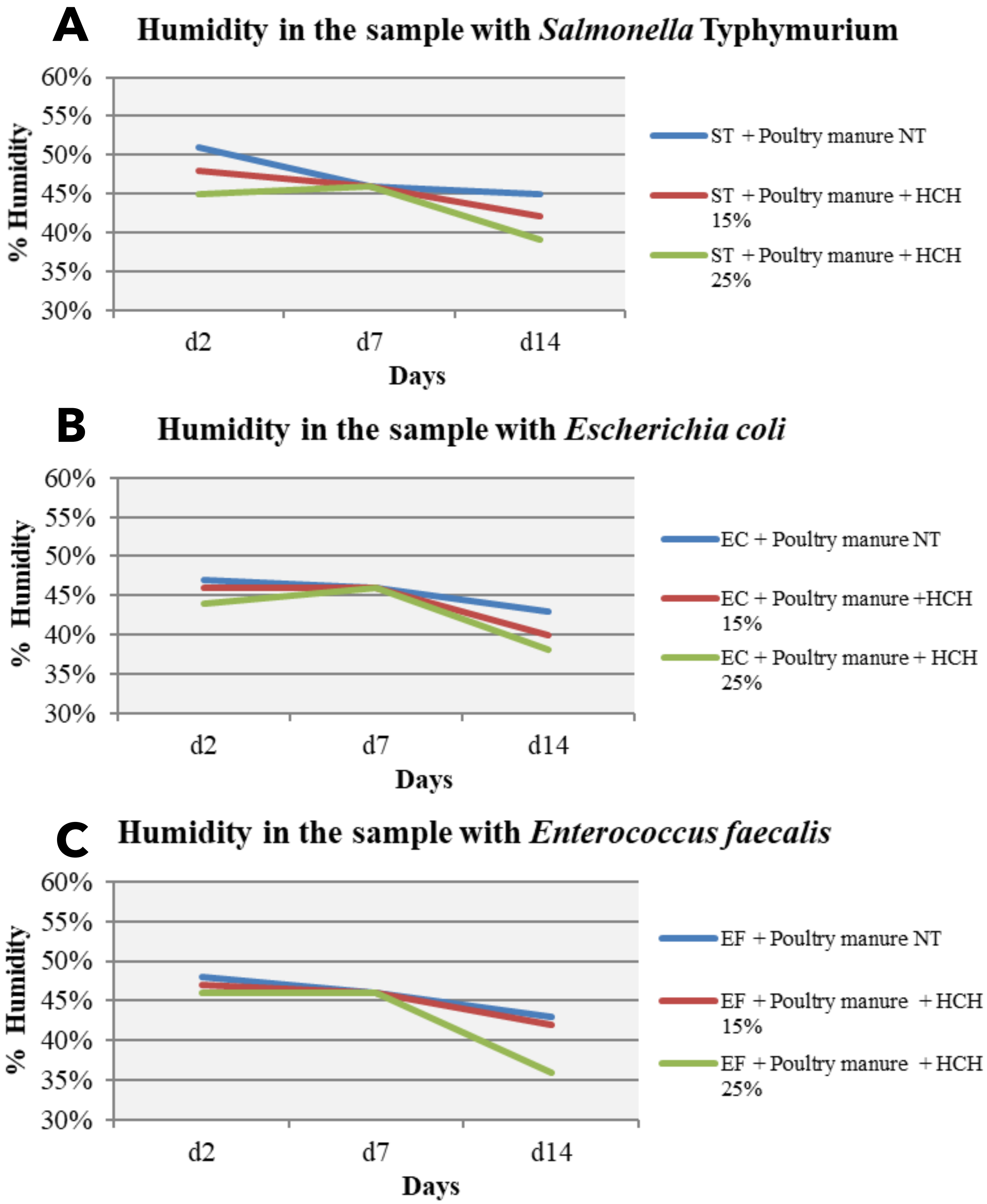


Figure 6: Trend of humidity in poultry manure spiked with A) *Salmonella* Typhimurium [ST: *Salmonella* Typhimurium; NT: Not Treated; HCH: hydrated calcium hydroxide], B) *Escherichia coli* [EC: *Escherichia coli*; NT: Not Treated; HCH: hydrated calcium hydroxide] and C) *Enterococcus faecalis* [EF: *Enterococcus faecalis*; NT: Not Treated; HCH: hydrated calcium hydroxide].

precisely between d_2, with a pH at 8, and d_{14}, with a pH at 9. The addition of 15% hydrated calcium hydroxide to manure samples, artificially contaminated with the three bacteria, causes an increase of the pH to values between 11 (d_2) and 13.1 (d_{14}). Evaluating the samples in which 25% hydrated calcium hydroxide was added, pH values between 12.5 (d_2) and 13.3 (d_{14}) were recorded.

With regards to humidity, in artificially contaminated samples treated with hydrated calcium hydroxide, a decrease from an average value of 49% (d_2), to 43.5% (d_{14}) was observed.

Conclusions

The components of the manure enhance the rapid elimination of the microbial load of *Salmonella* Typhimurium (Dai Pra et al., 2009), *Escherichia coli*, and *Enterococcus faecalis*.

The application of hydrated calcium hydroxide as a sanitizing and microbicidal agent, and the consequent variations in pH (alkaline) and humidity (which decreases) (Nyberg et al.,2011), confirm the low risk of survival of the indicator germs in the matrix under examination over 24 hours following the treatment. Analysing the obtained data, nevertheless the pH increase strongly inhibits the microbial proliferation and survival, it is essential to underline that pH higher than 8-9 may damage the manure, following the treatment. As a practical application, the exploitation of the treated poultry manure as a fertilizer could be performed by employing pH correctors, such as citric acid (also a food supplement), able to stabilize the pH at a 7-8 value. Salmonella Typhimurium loads < 10^3 CFU/g are able to survive less time than higher loads (10^6 CFU/g), both in untreated and treated poultry manure: the condition contributes to reducing the microbiological risk from Salmonella spp. Escherichia coli and Enterococcus faecalis are able to resist for higher time at the experimental conditions, especially at high microbial loads (> 10^6 CFU/g). Nevertheless, the survival risk of Escherichia coli in the matrix is low, considering that the contaminating load is completely removed within 2 hours of treatment with hydrated calcium hydroxide. The survival in the treated matrix is higher for Enterococcus faecalis, which, especially at high concentrations (10^6 CFU/g), survives in the hours following the treatment: however, the microorganism is no longer detectable within the 24 hours following the treatment with hydrated calcium hydroxide.

Considering that the experimental protocol included microbial loads of pathogens and indicators far higher than those potentially detected in real environmental conditions, it is evident that the survival of the pathogens and indicators is strongly limited in the process of manure storage, following the treatment with hydrated calcium hydroxide at the 15% and 25% concentrations; consequently, the risk of survival of the microorganisms evaluated has to be considered low.

Author contributions

Conceptualisation, M. Guida, F. Carraturo, and M. Di Santo; data curation, F. Carraturo; formal analysis, F. Carraturo and M. Guida; investigation, F. Carraturo; methodology, F. Carraturo, P. Ambrosino and M. Morelli; project administration, M. Guida, F. Carraturo and M. Di Santo; resources, P. Ambrosino, M.

Di Santo and M. Guida; supervision, M. Guida and P. Ambrosino; validation, F. Carraturo and M. Morelli; visualization, P. Ambrosino and T. Crovella; writing—original draft preparation, F. Carraturo and M. Morelli; writing—review and editing, M. Guida and F. Carraturo.

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Checklist

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The Ornithological Collection of the Agricultural Sciences Museum housed in the Bourbon Palace of Portici (Italy)

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Abstract

The ornithological collection of the Agricultural Sciences Museum, hosted at the Department of Agricultural Sciences at the Bourbon Palace of Portici, was started in 1889. In 1920, under the direction of Filippo Silvestri, there was a notable increase in the number of specimens. This increase continued in the following years, until the collection reached around 400 specimens in 1976. In the same year, Professors Domenico Scaramella and Luigi Filippo Russo published the first and, until now, only complete analysis of the single specimens, classifying them with the systematic criteria of the time. After 45 years, the Agricultural Sciences Museum Direction felt it was appropriate to review the status of the collection, both to ascertain the presence of the specimens mentioned in previous works, and to verify the preservation status of such specimens. A species check-list was compiled, of the 437 specimens found, belonging to 271 species, 70 families, and 25 orders. It is worth noting the presence of some extinct species - Moloka'i Creeper (*Paroreomyza flammea*) and Leysan Rail (*Zapornia palmeri*) – and probably extinct species: Ou (*Psittirostra psittacea*) and Slender–billed Curlew (*Numenius tenuirostris*).

Keywords: Ornithological collection, Agricultural Science Museum, extinct species.

Riassunto

La collezione ornitologica del Museo delle Scienze Agrarie, ospitata nel Dipartimento di Agraria presso la Reggia borbonica di Portici, è stata avviata a partire dal 1889. Nel 1920, sotto la direzione di Filippo Silvestri, ebbe un notevole incremento nel numero degli esemplari. Incremento continuato nel tempo, fino a raggiungere i circa 400 esemplari nel 1976, anno in cui i professori Domenico Scaramella e Luigi Filippo Russo pubblicarono la prima, e finora unica, analisi completa dei singoli reperti classificandoli con i criteri sistematici del periodo. A distanza di circa 45 anni la Direzione del Museo delle Scienze Agrarie ha ritenuto opportuno operare una revisione dello stato della collezione sia per constatare la presenza o meno degli esemplari citati nei precedenti lavori, sia per verificare lo stato di conservazione degli stessi. Sono stati rinvenuti 437 esemplari relativi a 271 specie, 70 famiglie e 25 ordini e compilata la check-list delle specie presenti. Spiccano le presenze di alcune specie estinte – Fringuello rampichino di Molokai (*Paroreomyza flammea*) e Schiribilla di Layson (*Zapornia palmeri*) – e probabilmente estinte: Ou (*Psittirostra psittacea*) e Chiurlottello (*Numenius tenuirostris*).

Parole chiave: Collezione ornitologica, Museo delle Scienze Agrarie, Specie estinte.

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Introduction

In recent years, antique ornithological collections present in our country have become subject of attention and study by ornithologists, because of the amount of information they can provide, contributing to creating a knowledge framework, as precise as possible, on Italian birdlife from late XIX century and the first decades of XX century. In this period, ornithological publications were limited to massive, fundamental works, usually at a national scale, with a corresponding lack of studies on local birdlife which would allow the collection of point data for single territories.

This shortage is even more pronounced in the Campania region where, after the faunal studies of Costa during the Bourbon period, there has been a lack of continuation in the late 1800s and early 1900s (Fraissinet, 2015). This knowledge vacuum can be, in part, remedied by antique ornithological collections present in the Region.

Zapornia palmeri (Frohawk, 1892)

Photo © Claudio Labriola

The ornithological collection of the Agricultural Sciences Museum, hosted at the Department of Agricultural Sciences at the Bourbon Palace of Portici, was started in 1889, when Prof. Antonio Berlese, a passionate hunter, came to Portici. It was in 1920, however, under the direction of Filippo Silvestri, that there was a notable increase in the number of specimens. This increase continued in the following years, until the collection reached around 400 specimens in 1976. In the same year, Professors Domenico Scaramella and Luigi Filippo Russo published the first and, until now, only complete analysis of the single specimens, classifying them with the systematic criteria of the time (Scaramella & Russo, 1976) and, at the same time, an analysis of the most important species found in the collection (Russo & Scaramella, 1976). Afterwards, these two authors published a follow-up work, reporting some new additions to the collection (Scaramella & Russo, 1979). Since then, no other revisions or updates have been made. In the 1976 revision, Scaramella and Russo reported around 400 specimens belonging to 251 forms, 16 orders and 53 families (Scaramella & Russo, 1976). In the following years, the collection was enriched with 18 more specimens (Scaramella & Russo, 1979).

After 45 years, the Agricultural Sciences Museum Direction of the Department of Agricultural Sciences felt it was appropriate to review the status of the collection, assigning the task to the Authors, both to ascertain the presence of the specimens mentioned in previous works, and to verify the preservation status of such specimens.

At the same time, species nomenclature and classification was updated, moving the specimens between cabinets to reassemble a systematic order.

Psittirostra psittacea (Gmelin, 1789) Photo © Claudio Labriola

Materials and Methods

Taxonomic assignment

For the taxonomy we followed the IOC World Bird List, using the latest version 11.1 (Gill et al., 2021). The choice to follow this taxonomy is determined by the decision to use same taxonomy present in previous checklists in order to carry out assessments and comparisons, primarily with the last version of the regional checklist (Fraissinet & Usai, 2021).

English names of birds reported in the list follow the recommended bird names present in IOC World Bird List (Gill et al., 2021). The Italian name of species primarily refers to the national checklist (Brichetti & Fracasso 2015), excluding *Columba livia var. domestica* that we named "Colombo domestico", according to Boano et al. (2018).

Assessment of the state of preservation

For the preservation status, we adopted 5 levels of rating: Poor, Inadequate, Barely Acceptable, Adequate, Satisfactory. "Poor" status was attributed to specimens with structural damage and grave alterations of plumage. "Inadequate" status was attributed to specimens with plumage alterations due to neglect in the past decades. Some of these can probably be salvaged with cleaning and restoration operations. "Barely Acceptable" status was attributed to specimens with light plumage alterations due to neglect, that can be recovered through cleaning and restoration. "Acceptable" status was assigned to specimens whose plumage has retained original colors, which can be certainly be restored with a thorough cleaning. "Satisfactory" status was assigned to specimens with fully preserved plumage, which only require a light cleaning to be completely restored.

Results and Discussion

Check-list

437 specimens relating to 271 species, 70 families and 25 orders were found in the collection. The check-list of species and of the number of specimens for each species is reported in Table S1.

The number of specimens is more or less consistent with that reported in previous lists by Scaramella and Russo (1976, 1979). Differences in order and family numbers are ascribable both to the presence of specimens belonging to families not reported in the original lists, both to new systematic attributions.

In particular, compared to the previous lists, we did not retrieve a Teal (*Anas crecca*) and one specimen of Northern Raven (*Corvux corax*), as Scaramella and

Paroreomyza flammea (Wilson, 1889)

Photo © Claudio Labriola

Russo (1976) reported at least 2 individuals for this species, with one referring to the subspecies *Corvus corax tingitanus*, distributed in Northern Africa and vagrant in Sicily and Sardinia. Preservation status does not currently allow to determine which of the two subspecies remains in the collection.

Similar considerations apply to the Hooded Crow (*Corvus cornix*). At present, only one specimen belonging to this species was found, whereas the previous authors reported at least two, specifying that one belongs to the subspecies *sardonius*, typical of Sardinia. Currently, Sardinian and Southern Italian populations are considered to belong to the same subspecies: *C.c. sharpii*. The same is true for the Western Jackdaw (*Coloeus monedula*), currently represented by one specimen, and previously reported as at least two specimens, one of which belonging to the nominal subspecies, distributed in Scandinavia (*C.monedula monedula*). In this case also, the current preservation status is not good enough to understand which of the two species remains in the collection.

A similar case concerns the Eurasian Jay (*Garrulus glandarius*), currently represented by one specimen, compared to the two reported by Scaramella and Russo and classified as two different subspecies - *G. g. glandarius*, present in Northern and Central Europe, and *G. g. albipectus*, present in the Italian peninsula. Preservation status does not allow a correct identification of the subspecies remaining in the collection.

A different situation concerns the two specimens of Eurasian Magpie (*Pica pica*) previously reported of which only one remains today, as the subspecies *P. p. galliae* is no longer distinct from the nominal subspecies.

New species not previously reported were found: European Nightjar (*Caprimulgus europaeus*), Squacco Heron (*Ardeola ralloides*), Marsh Sandpiper (*Tringa stagnatilis*), Pied Avocet (*Recurvirostra avosetta*), Collared Pratincole (*Glareola pratincola*), Orange-winged Amazon (*Amazona amazonica*) along with some specimens of the Drepanididae family, endemic to Hawaii and one specimen of the Rallidae family, also endemic to Hawaii: the Laysan Rail (*Zapornia palmeri*) .

In particular, the collection hosts 5 specimens of the Drepanididae family, referring to 4 species: Hawaii Creeper (*Manucerthia mana*), Ou (*Psittirostra psittacea*), Apapane (*Himatione sanguinea*), Moloka'i Creeper (*Paroreomyza flammea*) .

It is worth noting that the Moloka'i Creeper and the Laysan Rail are declared extinct and that the Ou is also probably extinct, with the latest sighting dating back to 1975. The latter species is considered by IUCN (International Union for the Conservation of Nature) as "Critically endangered", as it has not yet been 50 years since the latest sighting.

From the interpretation of the calligraphy present on the specimen tags, not easy to decipher, which also report the places of origin, it is believed that these belonged to or originated from a Perkins collection.

Foto © Claudio Labriola

Our research lead us to believe it refers to Robert Cyril Layton Perkins (1866-1955), an illustrious British entomologist and naturalist, known for his work on the fauna of Hawaii. His numerous works are collected in the volumes "FAUNA HAWAIIENSIS" and in different publications.

It is not known why these specimens are not reported in the lists of Scaramella and Russo (1976, 1979).

Also worth noting is the presence of a Slender-billed Curlew (*Numenius tenuirostris*), species considered as probably extinct, found in the 1970s in the Campania region, at the Volturno river mouth, and which represents one of the 5 known sightings for Campania (Fraissinet, 2015).

Furthermore, a specimen of Pallas's Sandgrouse (*Syrrhaptus paradoxus*) is also very interesting, although sadly in a terrible preservation status. Scaramella and Russo (1979) state that it originates from a farmhouse in the Abruzzo region, probably 50 years before, they consider it captured in Italy but have doubts about the statement. The interest is rooted in the fact that this species is considered vagrant in Italy, with four sightings considered valid for the XX century (Brichetti & Fracasso, 2015), with the only Abruzzo sighting referring to a specimen captured in the Teramo municipality in

1971 (Santone and Di Carlo, 1994), subsequently discredited by Brichetti and Fracasso (2006). If the attribution was correct, dating back to 1929, it would be new to the literature, otherwise we would be dealing with a specimen known to Santone and Di Carlo and later not considered as Italian.

Preservation status

Figure 1 reports the percentage of the 5 categories used to verify the preservation status, calculated on the total of the collection specimens.

Sadly, only 3% of the specimens is in a "Satisfactory" condition and 28% in an "Adequate" and "Barey Acceptable" status. The majority of specimens is in a "Poor" or "Inadequate" condition, for a total of 69%. Fortunately, some of the specimens in an "Inadequate" status could be recoverable, with a careful operation of restoration and cleaning.

The species in good condition have been selected for the new museum layout that is preparing the Museum of Agricultural Sciences. To these could also be added a part of the species with adequate conservation status after a recovery intervention. For the other species, a new relocation and specific

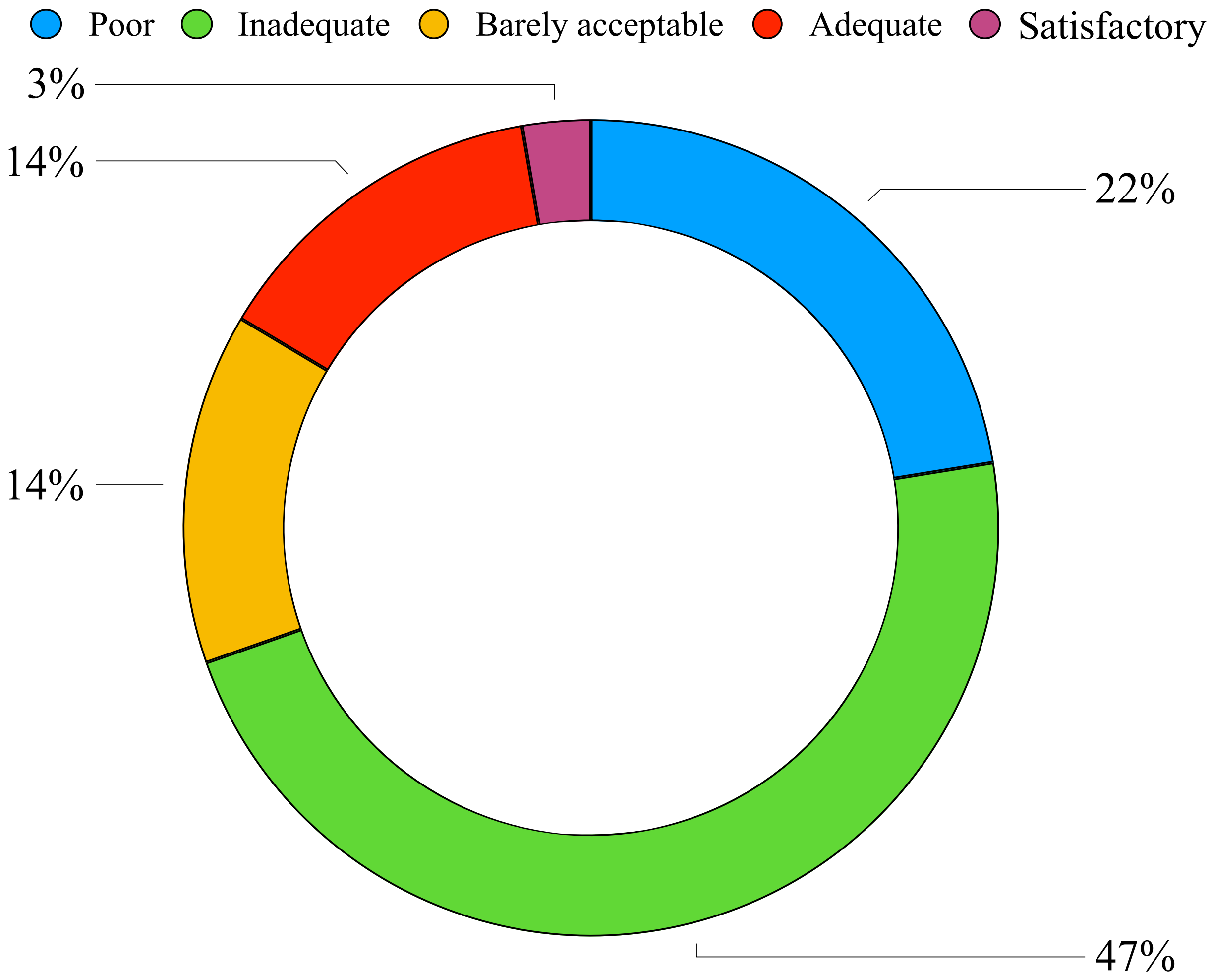

Figure 1: State of preservation of the specimens.

recovery interventions will have to be provided.

Author contributions

Maurizio Fraisisnet and Claudio Labriola cured all steps for the composition of the manuscript

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Table S1: Check-list of species and number of specimens for each species. N: number; (*), extinct; (**), probably extinct.

Scientific name	English common name	Italian common name	N. of specimens
ANSERIFORMES			
Anatidae			
Anser fabalis	Taiga Bean Goose	Oca granaiola	2
Cygnus cygnus	Whooper Swan	Cigno selvatico	1
Tadorna tadorna	Common Shelduck	Volpoca	1
Tadorna ferruginea	Ruddy Shelduck	Casarca	1
Spatula querquedula	Garganey	Marzaiola	1
Spatula clypeata	Northern Shoveler	Mestolone	1
Mareca strepera	Gadwall	Canapiglia	1
Mareca penelope	Eurasian Wigeon	Fischione	1
Anas platyrhynchos	Mallard	Germano reale	3
Anas acuta	Northern Pintail	Codone	1
Aythya ferina	Common Pochard	Moriglione	3
Aythya nyroca	Ferruginous Duck	Moretta tabaccata	1
Melanitta fusca	Velvet Scoter	Orco marino	1
Bucephala clangula	Common Goldeneye	Quattrocchi	1
Mergellus albellus	Smew	Pesciaiola	2
Mergus serrator	Red-breasted Merganser	Smergo minore	2
Mergus merganser	Goosander	Smergo maggiore	1
GALLIFORMES			
Phasianidae			
Tetrastes bonasia	Hazel Grouse	Francolino di monte	3
Lagopus muta	Ptarmigan	Pernice bianca	1
Lyrurus tetrix	Black Grouse	Fagiano di monte	2
Tetrao urogallus	Capercaillie	Gallo cedrone	3
Alectoris graeca	Rock Partridge	Coturnice	2
Alectoris rufa	Red-legged Partridge	Pernice rossa	1
Alectoris barbara	Barbary Partridge	Pernice sarda	1
Perdix perdix	Grey Partridge	Starna	3
Coturnix coturnix	Common Quail	Quaglia	5
CAPRIMULGIFORMES			
Caprimulgidae			
Caprimulgus europaeus	European Nightjar	Succiacapre	2
APODIFORMES			
Apodidae			
Tachymarptis melba	Alpine Swift	Rondone maggiore	1
Apus apus	Common Swift	Rondone comune	1
OTIDIFORMES			
Otididae			
Tetrax tetrax	Little Bustard	Gallina prataiola	1
CUCULIFORMES			
Cuculidae			
Clamator glandarius	Great Spotted Cuckoo	Cuculo dal ciuffo	1

Cuculus canorus	Common Cuckoo	Cuculo	2
COLUMBIFORMES			
Columbidae			
Columba livia var. *domestica*	Rock Dove	Colombo domestico	2
Columba oenas	Stock Dove	Colombella	1
Columba palumbus	Common Wood Pigeon	Colombaccio	1
Streptopelia turtur	European Turtle Dove	Tortora selvatica	2
Streptopelia decaocto	Eurasian Collared Dove	Tortora dal collare	1
GRUIFORMES			
Rallidae			
Rallus aquaticus	Water Rail	Porciglione	2
Crex crex	Corn Crake	Re di quaglie	1
Porzana porzana	Spotted Crake	Voltolino	1
Gallinula chloropus	Common Moorhen	Gallinella d'acqua	3
Fulica atra	Eurasian Coot	Folaga	1
Porphyrio porphyrio	Western Swamphen	Pollo sultano	1
Zapornia pusilla	Baillon's Crake	Schiribilla grigiata	1
Zapornia parva	Little Crake	Schiribilla	1
Zaporna palmeri (*)	Laysan Rail	Schiribilla di Layson	1
Gruidae			
Grus grus	Common Crane	Gru	1
PODICIPEDIFORMES			
Podicipedidae			
Tachybaptus ruficollis	Little Grebe	Tuffetto	2
Podiceps cristatus	Great Crested Grebe	Svasso maggiore	2
Podiceps nigricollis	Black-necked Grebe	Svasso piccolo	3
PHOENICOPTERIFORMES			
Phoenicopteridae			
Phoenicopterus roseus	Greater Flamingo	Fenicottero	2
CHARADRIIFORMES			
Burhinidae			
Burhinus oedicnemus	Eurasian Stone-curlew	Occhione	1
Haematopodidae			
Haematopus ostralegus	Eurasian Oystercatcher	Beccaccia di mare	1
Recurvirostridae			
Himantopus himantopus	Black-winged Stilt	Cavaliere d'Italia	2
Recurvirostra avosetta	Pied Avocet	Avocetta	1
Charadriidae			
Vanellus vanellus	Northern Lapwing	Pavoncella	2
Pluvialis apricaria	European Golden Plover	Piviere dorato	2
Pluvialis squatarola	Grey Plover	Pivieressa	2
Charadrius hiaticula	Common Ringed Plover	Corriere grosso	1
Charadrius dubius	Little Ringed Plover	Corriere piccolo	1
Charadrius alexandrinus	Kentish Plover	Fratino	1
Charadrius morinellus	Eurasian Dotterel	Piviere tortolino	1
Scolopacidae			
Numenius phaeopus	Eurasian Whimbrel	Chiurlo piccolo	1

Numenius tenuirostris (**)	Slender-billed Curlew	Chiurlottello	1
Numenius arquata	Eurasian Curlew	Chiurlo maggiore	3
Limosa lapponica	Bar-tailed Godwit	Pittima minore	1
Limosa limosa	Black-tailed Godwit	Pittima reale	1
Arenaria interpres	Ruddy Turnstone	Voltapietre	1
Calidris pugnax	Ruff	Combattente	5
Calidris ferruginea	Curlew Sandpiper	Piovanello comune	2
Calidris temminckii	Temminck's Stint	Gambecchio nano	1
Calidris alpina	Dunlin	Piovanello pancianera	1
Calidris minuta	Little Stint	Gambecchio comune	4
Scolopax rusticola	Eurasian Woodcock	Beccaccia	2
Lymnocryptes minimus	Jack Snipe	Frullino	1
Gallinago media	Great Snipe	Croccolone	1
Gallinago gallinago	Common Snipe	Beccaccino	1
Actitis hypoleucos	Common Sandpiper	Piro piro piccolo	2
Tringa ochropus	Green Sandpiper	Piro piro culbianco	1
Tringa totanus	Common Redshank	Pettegola	1
Tringa stagnatilis	Marsh Sandpiper	Albastrello	1
Tringa glareola	Wood Sandpiper	Piro piro boschereccio	2
Tringa erythropus	Spotted Redshank	Totano moro	1
Tringa nebularia	Common Greenshank	Pantana	1
Glareolidae			
Glareola pratincola	Collared Pratincole	Pernice di mare	2
Laridae			
Chroicocephalus ridibundus	Black-headed Gull	Gabbiano comune	3
Hydrocoloeus minutus	Little Gull	Gabbianello	1
Ichthyaetus melanocephalus	Mediterranean Gull	Gabbiano corallino	1
Larus canus	Mew Gull	Gavina	1
Larus cachinnans	Caspian Gull	Gabbiano reale pontico	1
Larus michahellis	Yellow-legged Gull	Gabbiano reale	2
Larus fuscus	Lesser Black-backed Gull	Zafferano	1
Gelochelidon nilotica	Gull-billed Tern	Sterna zampenere	1
Hydroprogne caspia	Caspian Tern	Sterna maggiore	1
Thalasseus sandvicensis	Sandwich Tern	Beccapesci	1
Sternula albifrons	Little Tern	Fraticello	2
Sterna hirundo	Common Tern	Sterna comune	3
Chlidonias leucopterus	White-winged Tern	Mignattino alibianche	2
Chlidonias niger	Black Tern	Mignattino comune	3
Stercorariidae			
Stercorarius pomarinus	Pomarine Jaeger	Stercorario mezzano	1
Stercorarius parasiticus	Parasitic Jaeger	Labbo	1
Alcidae			
Alca torda	Razorbill	Gazza marina	2
PTEROCLIFORMES			
Pteroclidae			
Syrrhaptes paradoxus	Pallas's Sandgrouse	Sirratte	1
GAVIIFORMES			

Gaviidae			
Gavia arctica	Black-throated Loon	Strolaga mezzana	1
PROCELLARIIFORMES			
Procellariidae			
Calonectris diomedea	Scopoli's Shearwater	Berta maggiore	1
Puffinus yelkouan	Yelkouan Shearwater	Berta minore	1
CICONIIFORMES			
Ciconiidae			
Ciconia ciconia	White Stork	Cicogna bianca	1
SULIFORMES			
Sulidae			
Morus bassanus	Northern Gannet	Sula	2
Phalacrocoracidae			
Phalacrocorax carbo	Great Cormorant	Cormorano	2
PELECANIFORMES			
Threskiornithidae			
Plegadis falcinellus	Glossy Ibis	Mignattaio	1
Platalea leucorodia	Eurasian Spoonbill	Spatola	2
Ardeidae			
Botaurus stellaris	Eurasian Bittern	Tarabuso	1
Ixobrychus minutus	Little Bittern	Tarabusino	3
Nycticorax nycticorax	Black-crowned Night Heron	Nitticora	2
Ardeola ralloides	Squacco Heron	Sgarza ciuffetto	1
Ardea cinerea	Grey Heron	Airone cenerino	1
Ardea purpurea	Purple Heron	Airone rosso	2
Ardea alba	Great Egret	Airone bianco maggiore	1
Egretta garzetta	Little Egret	Garzetta	1
ACCIPITRIFORMES			
Pandionidae			
Pandion haliaetus	Western Osprey	Falco pescatore	1
Accipitridae			
Pernis apivorus	European Honey Buzzard	Falco pecchiaiolo	1
Gyps fulvus	Griffon Vulture	Grifone	1
Circaetus gallicus	Short-toed Snake Eagle	Biancone	1
Clanga clanga	Greater Spotted Eagle	Aquila anatraia maggiore	1
Aquila chrysaetos	Golden Eagle	Aquila reale	2
Aquila fasciata	Bonelli's Eagle	Aquila di Bonelli	1
Accipiter nisus	Eurasian Sparrowhawk	Sparviere	4
Accipiter gentilis	Northern Goshawk	Astore	2
Circus aeruginosus	Western Marsh Harrier	Falco di palude	1
Circus cyaneus	Hen Harrier	Albanella reale	2
Milvus milvus	Red Kite	Nibbio reale	1
Buteto lagopus	Long-Legged Buzzard	Poiana calzata	1
Buteo buteo	Common Buzzard	Poiana	1
STRIGIFORMES			
Tytonidae			
Tyto alba	Western Barn Owl	Barbagianni	2

Strigidae			
Athene noctua	Little Owl	Civetta	1
Otus scops	Eurasian Scops Owl	Assiolo	1
Asio otus	Long-eared Owl	Gufo comune	2
Asio flammeus	Short-eared Owl	Gufo di palude	1
Bubo bubo	Eurasian Eagle-Owl	Gufo reale	1
Strix aluco	Tawny Owl	Allocco	2
BUCEROTIFORMES			
Upupidae			
Upupa epops	Eurasian Hoopoe	Upupa	1
CORACIIFORMES			
Alcedinidae			
Alcedo atthis	Common Kingfisher	Martin pescatore	2
Meropidae			
Merops apiaster	European Bee-eater	Gruccione	1
PICIFORMES			
Picidae			
Jynx torquilla	Eurasian Wryneck	Torcicollo	2
Dendrocoptes medius	Middle Spotted Woodpecker	Picchio rosso mezzano	1
Dryobates minor	Lesser Spotted Woodpecker	Picchio rosso minore	2
Dendrocopos major	Great Spotted Woodpecker	Picchio rosso maggiore	3
Dryocopus martius	Black Woodpecker	Picchio nero	2
Picus viridis	European Green Woodpecker	Picchio verde	2
Picus canus	Grey-Headed Woodpecker	Picchio cenerino	2
FALCONIFORMES			
Falconidae			
Falco tinnunculus	Common Kestrel	Gheppio	3
Falco vespertinus	Red-footed Falcon	Falco cuculo	3
Falco columbarius	Merlin	Smeriglio	1
Falco subbuteo	Eurasian Hobby	Lodolaio	2
Falco peregrinus	Peregrine Falcon	Falco pellegrino	1
PSITTACIFORMES			
Psittacidae			
Amazona amazonica	Orange-winged Amazon	Amazzona dell'Amazzonia	1
PASSERIFORMES			
Laniidae			
Lanius collurio	Red-backed Shrike	Averla piccola	1
Lanius minor	Lesser Grey Shrike	Averla cenerina	2
Lanius excubitor	Great Grey Shrike	Averla maggiore	1
Lanius senator	Woodchat Shrike	Averla capirossa	2
Oriolidae			
Oriolus oriolus	Eurasian Golden Oriole	Rigogolo	3
Corvidae			
Garrulus glandarius	Eurasian Jay	Ghiandaia	1
Pica pica	Eurasian Magpie	Gazza	1
Nucifraga caryocatactes	Spotted Nutcracker	Nocciolaia	1
Pyrrhocorax graculus	Alpine chough	Gracchio alpino	1

Pyrrhocorax pyrrhocorax	Red-billed Chough	Gracchio corallino	3
Coloeus monedula	Western Jackdaw	Taccola	1
Corvus frugilegus	Rook	Corvo comune	3
Corvus cornix	Hooded Crow	Cornacchia grigia	1
Corvus corone	Black Crow	Cornachia nera	1
Corvus corax	Northern Raven	Corvo imperiale	1
Bombycillidae			
Bombycilla garrulus	Bohemian Waxwing	Beccofrusone	1
Paridae			
Periparus ater	Coal Tit	Cincia mora	1
Lophophanes cristatus	European Crested Tit	Cincia dal ciuffo	1
Poecile palustris	Marsh Tit	Cincia bigia	1
Cyanistes caeruleus	Eurasian Blue Tit	Cinciarella	3
Parus major	Great Tit	Cinciallegra	3
Remizidae			
Remiz pendulinus	Eurasian Penduline Tit	Pendolino	1
Panuridae			
Panurus biarmicus	Bearded Reedling	Basettino	1
Alaudidae			
Lullula arborea	Woodlark	Tottavilla	1
Alauda arvensis	Eurasian Skylark	Allodola	3
Galerida cristata	Crested Lark	Cappellaccia	2
Calandrella brachydactyla	Greater Short-toed Lark	Calandrella	1
Melanocorypha calandra	Calandra Lark	Calandra	1
Hirundinidae			
Riparia riparia	Sand Martin	Topino	1
Hirundo rustica	Barn Swallow	Rondine	1
Delichon urbicum	Common House Martin	Balestruccio	1
Cettiidae			
Cettia cetti	Cetti's Warbler	Usignolo di fiume	1
Aegithalidae			
Aegithalos caudatus	Long-tailed Tit	Codibugnolo	2
Phylloscopidae			
Phylloscopus sibilatrix	Wood Warbler	Luì verde	1
Phylloscopus trochilus	Willow Warbler	Luì grosso	2
Phylloscopus collybita	Common Chiffchaff	Luì piccolo	1
Acrocephalidae			
Acrocephalus arundinaceus	Great Reed Warbler	Cannareccione	1
Acrocephalus scirpaceus	Eurasian Reed Warbler	Cannaiola comune	1
Hippolais polyglotta	Melodious Warbler	Canapino comune	2
Cisticolidae			
Cisticola juncidis	Zitting Cisticola	Beccamoschino	1
Sylviidae			
Sylvia atricapilla	Eurasian Blackcap	Capinera	3
Sylvia borin	Garden Warbler	Beccafico	1
Sylvia nisoria	Barred Warbler	Bigia padovana	1
Curruca hortensis	Western Orphean Warbler	Bigia grossa occidentale	1

Curruca melanocephala	Sardinian Warbler	Occhiocotto	2
Curruca cantillans	Eastern Subalpine Warbler	Sterpazzolina comune	1
Curruca communis	Common Whitethroat	Sterpazzola	2
Curruca conspicillata	Spectacled Warbler	Sterpazzola della Sardegna	1
Curruca undata	Dartford Warbler	Magnanina comune	1
Regulidae			
Regulus ignicapilla	Common Firecrest	Fiorrancino	1
Regulus regulus	Goldcrest	Regolo	2
Troglodytidae			
Troglodytes troglodytes	Eurasian Wren	Scricciolo	3
Sittidae			
Sitta europaea	Eurasian Nuthatch	Picchio muratore	2
Tichodromidae			
Tichodroma muraria	Wallcreeper	Picchio muraiolo	1
Certhiidae			
Certhia familiaris	Eurasian Treecreeper	Rampichino alpestre	1
Sturnidae			
Pastor roseus	Rosy Starling	Storno roseo	3
Sturnus vulgaris	Common Starling	Storno	3
Sturnus unicolor	Spotless Starling	Storno nero	2
Turdidae			
Turdus torquatus	Ring Ouzel	Merlo dal collare	2
Turdus merula	Common Blackbird	Merlo	5
Turdus pilaris	Fieldfare	Cesena	2
Turdus philomelos	Song Thrush	Tordo bottaccio	1
Turdus viscivorus	Mistle Thrush	Tordela	3
Muscicapidae			
Muscicapa striata	Spotted Flycatcher	Pigliamosche	2
Erithacus rubecula	European Robin	Pettirosso	2
Luscinia megarhynchos	Spotted Flycatcher	Usignolo	1
Ficedula albicollis	Collared Flycatcher	Balia dal collare	1
Phoenicurus ochruros	Black Redstart	Codirosso spazzacamino	3
Phoenicurus phoenicurus	Common Redstart	Codirosso comune	2
Monticola saxatilis	Common Rock Thrush	Codirossone	1
Monticola solitarius	Blue Rock Thrush	Passero solitario	1
Saxicola rubetra	Whinchat	Stiaccino	1
Saxicola rubicola	European Stonechat	Saltimpalo	1
Oenanthe oenanthe	Northern Wheatear	Culbianco	2
Oenanthe hispanica	Western Black-eared Wheatear	Monachella	3
Cinclidae			
Cinclus cinclus	White-throated Dipper	Merlo acquaiolo	1
Passeridae			
Passer domesticus	House Sparrow	Passera oltremontana	1
Passer italiae	Italian Sparrow	Passera d’Italia	4
Passer hispaniolensis	Spanish Sparrow	Passera sarda	1
Passer montanus	Eurasian Tree Sparrow	Passera mattugia	3
Petronia petronia	Rock Sparrow	Passera lagia	1

Montifringilla nivalis	White-winged Snowfinch	Fringuello alpino	1
Ploceidae			
Ploceus sp.			1
Prunellidae			
Prunella collaris	Alpine Accentor	Sordone	1
Prunella modularis	Dunnock	Passera scopaiola	1
Motacillidae			
Motacilla flava	Western Yellow Wagtail	Cutrettola	3
Motacilla cinerea	Grey Wagtail	Ballerina gialla	1
Motacilla alba	White Wagtail	Ballerina bianca	1
Anthus richardi	Richard's Pipit	Calandro maggiore	1
Anthus campestris	Tawny Pipit	Calandro	1
Anthus pratensis	Meadow Pipit	Pispola	1
Anthus spinoletta	Water Pipit	Spioncello	1
Fringillidae			
Fringilla coelebs	Common Chaffinch	Fringuello	4
Fringilla montifringilla	Brambling	Peppola	1
Coccothraustes coccothraustes	Hawfinch	Frosone	2
Pyrrhula pyrrhula	Eurasian Bullfinch	Ciuffolotto	2
Chloris chloris	European Greenfinch	Verdone	4
Linaria cannabina	Common Linnet	Fanello	2
Acanthis flammea	Common Redpoll	Organetto	2
Loxia curvirostra	Red Crossbill	Crociere	4
Carduelis carduelis	European Goldfinch	Cardellino	3
Carduelis citrinella	Citril Finch	Venturone alpino	1
Serinus serinus	European Serin	Verzellino	2
Spinus spinus	Eurasian Siskin	Lucherino	1
Drepanididae			
Manucerthia mana	Hawaii Creeper	Fringuello rampichino delle Hawaii	2
Psittirostra pisttacea (**)	Ou	Ou	1
Himatione sanguinea	Apapane	Apapane	1
Paroreomyza flammea (*)	Moloka'i Creeper	Fringuello rampichino di Molokai	1
Calcariidae			
Plectrophenax nivalis	Snow Bunting	Zigolo delle nevi	1
Emberizidae			
Emberiza calandra	Corn Bunting	Strillozzo	1
Emberiza citrinella	Yellowhammer	Zigolo giallo	2
Emberiza cia	Rock Bunting	Zigolo muciatto	1
Emberiza hortulana	Ortolan Bunting	Ortolano	2
Emberiza cirlus	Cirl Bunting	Zigolo nero	1
Emberiza schoeniclus	Common Reed Bunting	Migliarino di palude	3

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Death, sex, and immortality

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Abstract

DNA is intrinsically unstable due to spontaneous mutation and degradation. Yet, life has thrived for about four billion years, adapting to most diverse environmental conditions. The ultimate reason for the striking resilience and versatility of life is sex, here defined as any mechanism that recombines DNA from separate organisms. Sex is a universal property of life that originally emerged as a spontaneous by-product of the machinery for gene duplication and repair. Sex counteracts genetic erosion (Muller's ratchet), thus stabilizing biological information across time. Concurrently, sex builds novel genes and novel genomes, thus fostering genetic innovation and evolution. Bacterial sex is independent of reproduction, generally involves short DNA sequences, and encompasses a relatively high frequency of horizontal gene transfer between distantly related taxa. Because of this, bacterial sex produces large pangenomes, fosters population ecological flexibility, and blurs species demarcation. Sex in eukaryotes is associated with reproduction and involves an alternance of cellular fusion and meiosis, each cycle setting whole-genome recombination. Sexual reproduction involves major additional costs relative to bacterial sex and is probably an ancestral trait of eukaryotes, but its origin is a matter of speculation. Sexual reproduction maintains sharp inter-species boundaries, prevents the development of pangenomes, and favours ecological specialization. Except for gene transfer from endosymbionts, horizontal gene transfer has had a marginal role in genome evolution in eukaryotes. Eukaryotes lacking sexual reproduction might use a bacterial sort of sex as demonstrated for bdelloid rotifers. The soma of complex multicellular eukaryotes has three hierarchical levels of organization (systemic, organ and cellular) and three related states of death.

Keywords: Biological information, Genetic recombination, Horizontal gene transfer, Pangenome, Sexual reproduction.

Riassunto

Il DNA è intrinsecamente instabile a causa di una spontanea tendenza a mutare e degradarsi. Ciò nonostante, la vita esiste sulla Terra da circa quattro miliardi di anni e si è adattata alle più diverse condizioni ambientali. La ragione ultima della straordinaria resilienza e versatilità della vita è il sesso, termine che comprende qualsiasi meccanismo che ricombina DNA proveniente da organismi distinti. Probabilmente nato come uno spontaneo sottoprodotto del macchinario biochimico preposto alla duplicazione e riparazione del materiale genetico, il sesso è una proprietà universale della vita. Il sesso conserva l'informazione biologica nel tempo, contrastando l'erosione genetica dovuta all'accumulo di mutazioni (Muller's ratchet). In parallelo, il sesso promuove l'innovazione genetica e l'evoluzione attraverso la creazione di nuovi geni e nuovi genomi. Il sesso nei batteri non è associato alla riproduzione, di solito coinvolge simultaneamente uno o pochi geni, e comporta il trasferimento orizzontale di geni anche fra taxa filogeneticamente lontani. Nei batteri, perciò, il sesso tende a produrre pangenomi di grandi dimensioni, amplifica la flessibilità ecologica delle popolazioni, e confonde la separazione fra specie. Il sesso negli eucarioti è associato alla riproduzione, comporta l'alternanza di fusione cellulare e meiosi, e ciascun ciclo ricombina l'intero genoma. La riproduzione sessuale comporta notevoli costi aggiuntivi rispetto al sesso nei batteri ed è probabilmente un tratto ancestrale degli eucarioti, ma le sue origini sono incerte. La riproduzione sessuale mantiene una netta separazione fra le specie, previene lo sviluppo di pangenomi e favorisce la specializzazione ecologica. Con l'eccezione dell'acquisizione di geni da endosimbionti, il trasferimento orizzontale ha avuto un ruolo marginale nell'evoluzione dei genomi negli eucarioti. La perdita della riproduzione sessuale in alcuni eucarioti potrebbe essere compensata da meccanismi sessuali di tipo batterico, come dimostrato nei rotiferi bdelloidi. Il soma degli eucarioti multicellulari complessi ha tre livelli gerarchici di organizzazione (sistemico, di organo, cellulare) e tre corrispondenti stati di morte.

Parole chiave: Informazione biologica, Pangenoma, Ricombinazione genetica, Riproduzione sessuale, Trasferimento orizzontale di geni.

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1. Introduction

Living organisms get old and die. This is a most obvious consideration for multicellular organisms like humans or oaks, less so for unicellular organisms.

A multicellular organization has evolved multiple times both in bacteria and eukaryotes under selection pressure for labour division and cellular specialization (Nicklas and Newman 2013; West et al. 2015). In eukaryotic multicellular organisms (henceforth referred to as "multicells"), the ability to produce offspring is restricted to germ cells, the rest (somatic cells) only performing ancillary functions and eventually dying. In weismannist multicells, the germ line separates from the somatic line early in development. The somatic line produces the body tissues and organs, whereas the germ line produces the reproductive cells (either gametes or meiospores). Weismannist multicells are not common: some animal clades (nematodes, arthropods, and vertebrates) and volvocine algae, a green algal line including *Volvox* and its relatives (Gilbert 2006; Hallmann 2011). In nematodes, arthropods and frogs, the germ line is pre-determined by cytoplasmic inducers at a specific position in the egg cell, whereas in mammals the germ line is positionally induced during early embryo development (Gilbert 2006). Separation of the germ line in *Volvox* is associated with genetically determined asymmetrical division during embryo development (Kirk 2001). In most multicells, including many invertebrates and land plants, there is no clear-cut separation between a soma and germ line, new germ cells continuously developing from stem cells in the adult individuals. In both weismannist and non-weismannist multicells, however, the germ line is potentially immortal, in the sense that it perpetuates itself across generations. In contrast, the soma remains alive only for a limited time varying with the species and environmental conditions. Most animals are short-lived, with a life cycle lasting a few months or less. Others can live for over a year, and some for over a century.

Why does the soma of multicells die whereas the germ line is potentially immortal? Arguably, remaining alive indefinitely would be highly adaptive for an organism fit enough to have reached reproductive maturity. The ultimate reason why this is not possible is that genomes tend to mutate with time, accumulating errors that reduce their functionality. Mutations may be as small as the replacement of a single nucleotide or as large as the deletion of million nucleotides. Mutations may occur at any time, either spontaneously or because of exposition to mutagens such as high-energy radiations or chemicals. Among chemical mutagens, of special importance are reactive oxygen species (e.g., the superoxide radical, hydroxyl radical and hydrogen peroxide) that are spontaneous by-products of the aerobic metabolism (Dizdaroglu and Jaruga 2012). Estimates vary, but it is possible that as many as tens of thousands genetic lesions occur in each cell of a multicellular organism daily (Lindahl 1993). A particularly critical phase in the cell cycle is genome replication, during which mutations arise from errors in DNA duplication. In other words, the very mechanism that perpetuates biological information also contributes to its degradation. Cells have a diversity of DNA repair mechanisms that correct at least a part of the damages from mutation (Vijg 2014). With time, however, mutations unavoidably impair cellular viability. It is known, for example, that human fetal cells can divide between 40 and 60 times, after which they enter a senescence phase and die. This is known as the Hayflick limit from the name of the senior researcher who discovered it (Hayflick and Moorhead 1961). Many unicellular eukaryotes have life cycles that recall the separation of a soma and a germ line as observed in multicells, so what said for multicells also applies to them.

Bacteria appear to be virtually immortal because they keep proliferating as long as there are favourable environmental conditions. Some bacteria can even produce special resting cells that survive unfavourable conditions and return active when conditions are again permissive. If, however, we could follow every single cell in a bacterial population, we would see that at a point most cells die out. This can easily be proved in culture by maintaining the concentration of essential metabolites at a low constant level. The bacterial population will grow up to a certain size and then will remain stable although cells continue dividing, indicating that the number of newly formed cells equals the number of cells that die per unit time. In this condition, known to microbiologists as the “stationary phase”, the population size depends on the level of essential nutrients, provided that all other relevant parameters such as temperature, pH or redox potential are adequate (Prescott 2005). Thus, despite the lack of a separation between a soma and a germ line, healthy cells continuously replace aged cells, and bacterial populations may remain viable indefinitely.

2. Sex is essential for genome maintenance

What ensures the potential immortality of the germ line in multicells and of populations of bacteria and unicellular eukaryotes despite the intrinsic instability of genetic information?

The answer is *sex*, here defined as any mechanism that produces novel genomes by combining DNA from separate organisms.

Sexual mechanisms in bacteria encompass *transformation*, *transduction*, and *conjugation* (Redfield 2001; de La Cruz et al. 2010; Borgeaud 2015), with transformation likely playing a predominant role (Takeuchi et al. 2014). Analogous mechanisms are documented in the archaea but are still poorly known (van Wolferen 2015). Because sexual processes in prokaryotes do not involve cellular fusion or meiosis as is the case in eukaryotes, they are here collectively referred to as *non-meiotic sex*. DNA acquired by non-meiotic sex may be recognized as foreign DNA and degraded, or may be retained, expressed, and transmitted to next generations. In the latter case, newly acquired DNA may be conserved as an independent plasmid or be inserted in the main chromosome, either as an additional sequence (a process called *illegitimate* or *non-homologous recombination*) or in lieu of a pre-existing homologue sequence (*legitimate* or *homologous recombination,* Fig 1). These processes are under the control of the same enzymatic machinery responsible for DNA replication and repair, notably RecA and RecBCD enzymes (Redfield 2001; Hoff et al. 2018). A detailed description of the molecular mechanisms underlying sexual processes in bacteria is accessible in molecular biology textbooks such as Krebs et al. (2017). It suffices here to note that random sequence shuffling by non meiotic sex permits the recovery of functional genes and functional genomes in bacterial populations (Takeuchi et al. 2014).

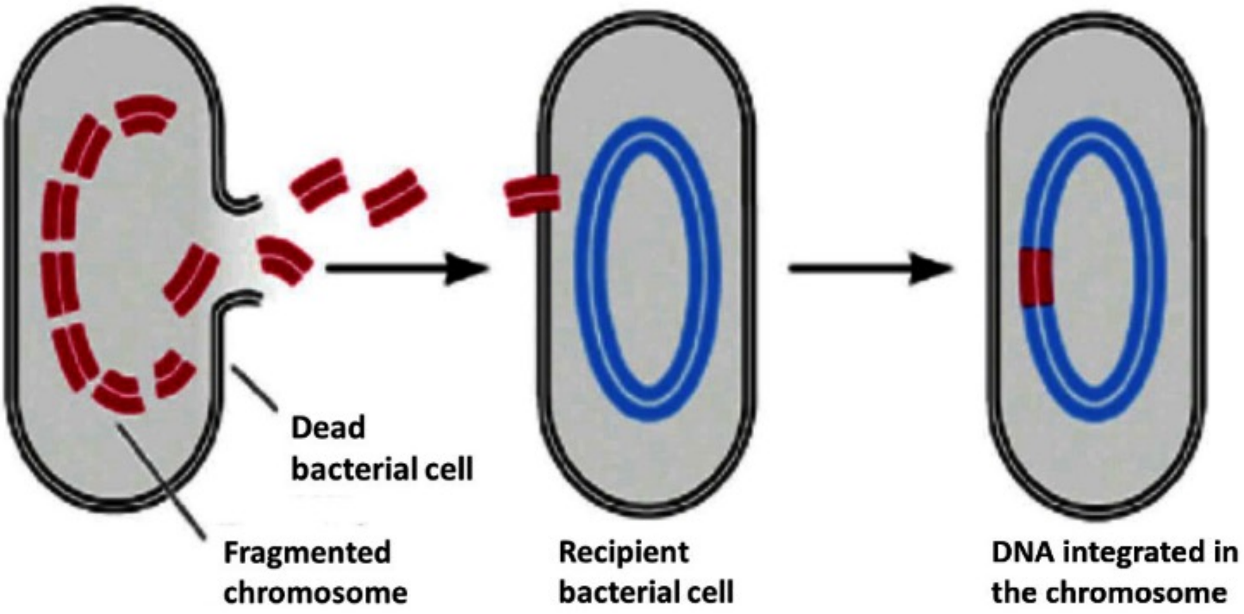

Figure 1: Bacterial transformation. A DNA fragment from a dead cell is captured by a recipient cell and incorporated into its chromosome by legitimate recombination. If the original DNA segment contained a genetic lesion and the novel one (in red) was intact, recombination repristinates the function impaired. As shown in this figure, bacterial sex usually involves relatively short DNA segments.

Meiotic sex is a process unique to eukaryotes, consisting in the formation of a *zygote* by fusion (*syngamy*) of two specialized cells, the *gametes*. Unlike sexual processes in bacteria and archaea, meiotic sex is associated with reproduction and is therefore more commonly referred to as *sexual reproduction*. A distinctive property of meiotic sex is that the zygote receives a complete chromosome set from each gamete. For the process to be reiterated over time it is necessary that, after each syngamy and before the formation of new gametes, *meiosis* re-establishes the haploid chromosome number.

Either random and usually limited to short DNA sequences in prokaryotes or involving the whole genome at each round in eukaryotes, sex is essential for the preservation of biological information. In both cases, legitimate recombination permits the replacement of altered sequences with correct sequences from other cells (Fig. 1). In the absence of homologous recombination, genomes

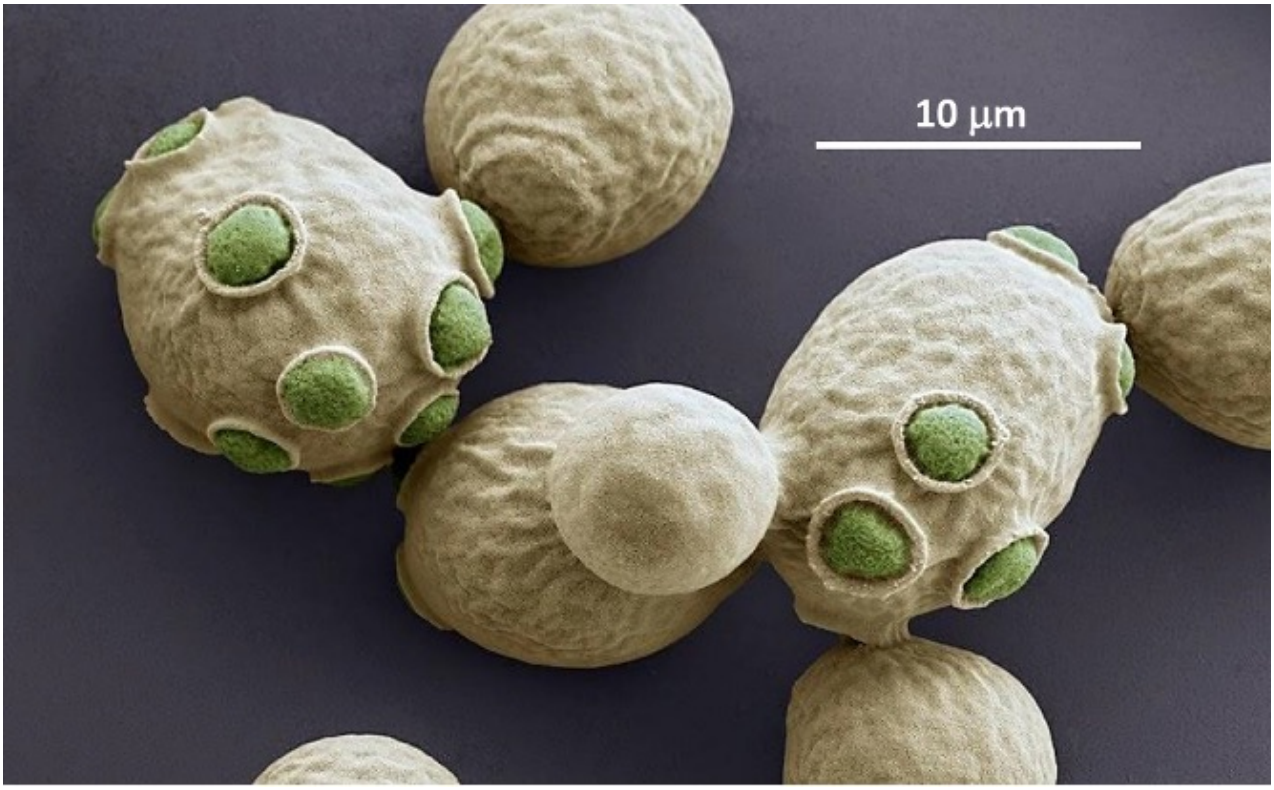

Figure 2: Cells of *Saccharomyces cerevisiae*, an ascomycetous yeast with a haplo-diplobiontic life cycle. Both haploid and diploid cells reproduce asexually by gemmation. The cup-shaped structures visible on the surface of cells are scars left by past gemmation events; when their whole surface is covered with scars, the cells stop dividing and die. Vegetative cells are therefore equivalent to the soma of a multicellular organism. Cells with a full reproductive potential are re-formed by meiotic sex.

would accumulate a growing load of deleterious mutations, an effect known in evolutionary genetics as Muller's ratchet from the name of the researcher who first recognized its relevance in evolution (Muller 1932). Under the control of natural selection, sex ensures the persistence of functional genomes across generations (Maynard Smith and Szathmàry 1995; Narra and Ochman 2006; Szöllősi et al. 2007; Vos 2009; Takeuchi et al. 2014; Rocha 2016).

Somatic cells in multicells cannot use sex for repairing genetic damage. The accumulation of genetic lesions translates into morphological and functional aging, eventually causing the death of the soma (Ren et al. 2017). Germ cells in weismannist organisms are less prone to genetic damage than somatic cells because they are protected within the organism body and have low metabolic activity until they engage in reproduction. Germ cells in non-Weismannist organisms develop from the same stem cells that produce the soma, and do not benefit from protective mechanisms present in weismannist organisms. The evolutionary significance of the two strategies is not clear. A recent model suggests that selection for mitochondrial quality drives either early or late germline separation, depending on high or low mutation rate of mitochondrial DNA, respectively (Radzvilavičius et al. 2016). In either case, germs cells are subject to genetic damage that on the long term would stop perpetuation if there were not sex.

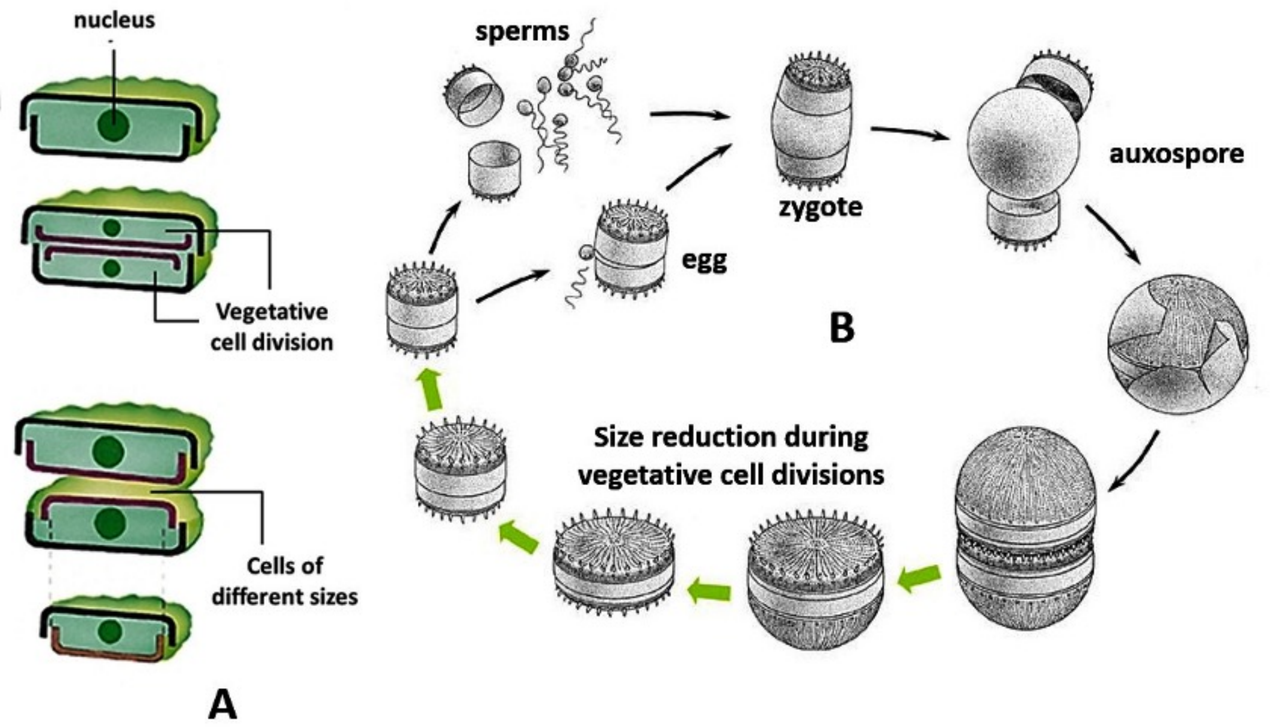

Figure 3: Life cycle of centric diatoms. (A) Vegetative cells (equivalent to the soma of a multicellular organism) are diploid; cell sizes progressively reduce during cell division. When size attains a minimum, the cells divide by meiosis and produce gametes (either sperms or an egg). The zygote gets rid of the rigid siliceous cell wall and expands to form an auxospore, which starts a new sequence of vegetative cell divisions.

Because sex is a random process, a (conspicuous) part of reproductive cells do fail to repristinate functional genomes and are eliminated by natural selection.

Much the same occurs in populations of unicellular eukaryotes, in which vegetative cells can divide a limited number of times, and cells with a full reproductive potential are periodically regenerated by meiotic sex (Figs 2 and 3).

A most dramatic example of clonal aging and sexual rejuvenation occurs in ciliates, a group of unicellular aquatic eukaryotes known for their nuclear dualism. Ciliate cells possess two sorts of nucleus, a tiny diploid micronucleus and a large "ampliploid" macronucleus containing only a part of the genome, amplified many times. The micronucleus is inactive in genetic expression, its only function being genome storage and duplication. The macronucleus takes care of cell functioning, expressing the organism phenotype. Monoclonal cultures of ciliates gradually lose vitality and expire after a number of divisions (200-350 in *Paramecium aurelia*, and up to 1,500 in *Tetrahymena*) because they are not able to perform meiotic sex (which requires genetically distinct mating types). When macronuclei of clonally young cells were injected into aged cells, the vitality of the recipient cell (expressed as the number of subsequent clonal fissions) was increased, indicating that DNA damage in the macronucleus is the cause of aging (Aufderheide 1986; Holmes and Holmes 1986). Meiotic sex, based on the exchange of a micronucleus between cells of compatible mating types, re-starts the cycle. It is pertinent to note that, because recombination is a random process, only a fraction of the cells resulting from meiotic sex receives a functional genome, the rest being swiftly eliminated by natural selection.

As in unicellular eukaryotes, most bacterial cells die after several rounds of cell division because of the accumulation of genetic lesions, but some manage to maintain a functional genome by randomly incorporating DNA segments from other cells, thus ensuring survival. The bacteria can incorporate DNA not only from genetically related cells but also from taxonomically distant donors. Sex between distantly related taxa is referred to as *horizontal gene transfer* (HGT), although the underlying mechanisms are the same as for genome maintenance within homogeneous populations. HGT enables bacteria to acquire novel metabolic pathways and colonize novel niches. Events of HGT have been responsible, for example, for the spread of photosynthesis and aerobic respiration across a wide taxonomic spectrum in bacteria (Hohmann-Marriott and Blankenship 2011; Schoepp-Cothenet et al. 2013). HGT is the main mechanism underpinning the expansion of genomes and protein diversity in prokaryotes (Treangen and Rocha 2011; Takeuchi et al. 2014; Vos et al. 2015), whereas gene duplication and neofunctionalization of gene copies is the prevalent mechanism in eukaryotes (see section 3). HGT in eukaryotes is much less frequent than in prokaryotes and does not contribute to long-term genome evolution, except for gene transfer from endosymbionts (Ku et al. 2015), notably those that generated the mitochondrion and the chloroplast (Timmis et al. 2004).

3. Sex drives genetic innovation

If legitimate recombination is essential for the conservation of biological information, illegitimate recombination permits genes to move from a genotype[1] to another, thus "experimenting" interaction with novel genes and novel environments. From the perspective of genes, it does not matter that most gene copies dispersed in the environment are lost or enter unfavourable genotypes: a single copy that happens to benefit from above-average fitness will rapidly spread. A fitness-improving mutation is a most rare event, and even more unlikely is the appearance of multiple favourable mutations in the same cell. Sex-mediated illegitimate recombination permits favourable mutations appeared separately to associate in the same genotype and sum their effects. Widening the perspective, illegitimate recombination potentially enables genes to interact with all other genes in the surrounding environment. Indeed, the notion of *selfish gene* by Richard Dawkins (1976) is rooted in gene shuffling among genomes. Illegitimate recombination not only creates new genomes, but also makes new, chimeric genes. A particularly effective mechanism for making new genes is random re-arrangement of sequences encoding for domains of separate proteins, a process known as "domain shuffling" (Long et al. 2003). Sex is not the only mechanism capable of producing novel genes, yet its contribution in expanding the genetic repertoire is biologically important (Rocha 2003).

By reducing selection pressure against large genome sizes (Section 5), sexual reproduction has given a dramatic contribution to genetic innovation in eukaryotes. The mechanism involved is gene duplication and neofunctionalization of redundant gene copies (Van de Peers et al. 2009; Holland et al. 2017). Many eukaryotic lineages went through whole-genome duplications that have created thousands of new genes. Early in their evolutionary history, the vertebrates underwent two whole-genome duplications that probably underpinned their outstanding biological success (Bertrand and Escriva 2011). Nothing of this would have been possible without sexual reproduction.

That said, one should not assume that sex is always beneficial. Quite the opposite (Goodenough and Heitman 2014). Extant genomes are the product of million or billion years of evolution. As for mutations, sex-mediated alterations in genomic structure are much more likely to be for the worse than for the better. Sex, however, is an essential biological mechanism because it works over large numbers.

[1] The term genotype indicates the set of genes present in a single cell or individual, whereas a genome is the set of genes that characterizes a whole species (including allelic variants). For many bacteria it is necessary to distinguish between genome and pangenome (see section 4).

4. Sex blurs interspecific boundaries in bacteria but fosters species isolation in eukaryotes

Sex has opposite collateral consequences in bacteria and eukaryotes. Bacteria can acquire DNA not only from relatives but also from distantly related sources. Because of this, natural bacterial populations usually present greater genetic diversity than single strains or isolates. For bacteria, therefore, it is necessary to distinguish between genome and *pangenome*, the first referring to the set of genes in a single isolate or strain, the latter to the global gene repertoire present in all strains and isolates attributed to the same species (Medini et al. 2005; Tettelin 2008; Lapierre and Gogarten 2009; Mira et al. 2010). The pangenome usually encompasses a set of genes common to all strains (*core* or *backbone genome*), plus a vast pool of genes specific to some strains (*accessory genome*). The core genome consists of genes controlling essential functions such as gene duplication/ expression and fundamental metabolic pathways. The accessory genome consists of genes involved in facultative functions such as the use of certain metabolites or antibiotic resistance. The fact that bacterial pangenomes are usually much larger than the genome of single isolates or strains greatly enhances the chance of gene recombination through sex. On the other hand, genetic promiscuity makes species demarcation a most difficult task in bacterial taxonomy. By convention, bacterial strains or isolates are currently assigned to the same species if sequence divergence in their 16S rRNAs is below 1% (Cohan and Perry 2007). Apparently low, this is the average level of divergence found in 18 S rRNA (the eukaryotic homologue of bacterial 16S rRNA) of mammals belonging to different orders, for example a goat and a dog.

Meiotic sex in eukaryotes depends on mechanisms of gamete recognition for preventing syngamy between incompatible cells. This is the reason why, for example, bull sperm cannot fertilize a mare. Moreover, chromosome sorting during meiosis requires high levels of synteny[2] and sequence similarity in homologs. If homologs are not sufficiently similar, they do not pair and meiosis is disrupted. Because of this, only closely related individuals can interbreed. Under unnatural conditions, for example in captivity, individuals belonging to different species may overcome pre-zygotic barriers and interbreed, yet the hybrids are usually sterile because of meiotic failure. Sexual reproduction, therefore, establishes strong boundaries between eukaryotic species. The biological notion of species currently applied to multicellular eukaryotes defines the species as *a cohesive, monophyletic group irreversibly isolated from other populations by reproductive and ecological barriers*.

Because of rampant HGT and the lack of meiotic sex, the above definition is not appliable to prokaryotes.

5. Why did eukaryotes evolve sexual reproduction?

Sexual reproduction is almost universal in eukaryotes, there being very few asexual eukaryotic lineages, most of which are unicellular. In several cases, closer scrutiny of eukaryotic organisms originally reported as asexual has revealed signs of sexual reproduction. Notably, *Giardia* and *Trichomonas*, two taxa placed at the base of the eukaryote tree and apparently lacking meiotic sex, were found to have genes involved in meiosis, suggesting that the lack of meiotic sex is a derived condition in extant eukaryotes (Rallenh et al. 2005; Malik et al. 2007; Speijer et al. 2015).

Sexual reproduction requires two organisms (or two cells) for making a new one. This is the so-called two-for-one cost (Maynard Smith and Szathmàry 1995). Additional costs include gamete loss, the need for flagella and chemo-sensorial mechanisms, the production of sexual attractors and inductors, the involvement of vectors (e.g., in flowering plants) or courtship (in many vertebrates) and the transmission of parasites (Lehtonen et al. 2012). A further cost of sexual reproduction is the dissolution of well-adapted genotypes, a negative effect exacerbated by cross-fertilization and often mitigated in nature by regular reliance on asexual reproduction (Goodenough and Heitman 2014). This is probably the main reason why numerous eukaryotes, either uni- or multicellular, use sexual reproduction only in response to stress, whilst they stick to asexual reproduction under favourable conditions.

Why did eukaryotes evolve sexual reproduction despite heavy cost? The question has been addressed several times and given a diversity of tentative explanations, all stemming from the recognition that the maintenance of eukaryotic genomes is particularly problematic. Indeed, eukaryotic genomes are on average three orders of magnitude larger than bacterial genomes (10^9 *vs* 10^6 base pairs) and have expanded considerably in number of protein-coding genes, size of genes, number of gene families, regulatory DNA content, and extent of non-coding repetitive sequences (Elliott and Gregory 2015). This large amount of DNA is distributed in several chromosomes, probably because it could not be handled in a single chromosome as is generally the case in bacteria. For a discussion of the possible

[2] Synteny is the physical co-localization of homologous sequences (or genetic loci) along homologs in an individual or a species.

adaptive significance of eukaryote genome expansion, see Cavalier-Smith 2005.

Cavalier-Smith (2002, 2010) suggests that meiosis evolved in parallel with mitosis in ancestral eukaryotes, initially to correct errors in chromosome segregation during mitosis, and subsequently to shift from diploidy to haploidy in response to environmental signals. In Cavalier-Smith's narrative, eukaryotes diverged from a prokaryotic ancestor as phagotrophic predators of other cells. Ancestral eukaryotes lived predominantly as haploid cells under favourable conditions, whereas they shifted to diploidy by endoreduplication (genome duplication not followed by cellular division) and formed dormant cysts to survive food scarcity or other types of stress. Doubling the chromosome set helped dormant cells to retain a functional genome after prolonged exposition to ultraviolet or other damaging agents. Meiosis not only repristinated fast-growing haploid cells but also recovered functional genomes by chromosome sorting. Endoreduplication was later replaced by cell fusion, which greatly enhanced genetic polymorphism and recombination.

Several alternative models are linked to mitochondrial evolution. The mitochondrion, one of the most distinctive traits of extant eukaryotes, derived from an alpha-proteobacterial endosymbiont (Martijn et al. 2018). Under selection pressure for better integration, a large chunk of the endosymbiont genome was transferred to the host genome and a part was completely lost. Mitochondria, however, retain a small genome that is essential for their functioning (Allen 2003).

Tilquin et al. (2018) propose that sexual reproduction evolved in eukaryotes to permit mitochondrial complementation by fusion of non-clonal cells (i.e., gametes from different parents). This avoided the decay of the mitochondrial genome, which can no longer be rescued by HGT because of isolation from free-living bacterial populations. The hypothesis implies by-parental mitochondrial inheritance, thus contrasting with almost universal uniparental inheritance in extant eukaryotes (Greiner et al. 2014; Radzvilavičius et al. 2017).

Hörandl and Speijer (2018) propose that increased production of ROS from mitochondrial metabolism set the stage for meiotic sex under selection pressure to reduce host genome erosion. Theoretical modelling suggests that the benefits from HGT in contrasting the Muller's ratchet decline with increasing genome size (Colnaghi et al. 2020). Based on this result, Colnaghi et al. (2020) reason that sexual reproduction replaced HGT in ancestral eukaryotes to ensure the maintenance of expanding genomes. Considering that larger genomes are at greater risk from ROS, the two models fit well with each other and could be nicely combined.

Brandeis (2021) suggests that meiosis evolved in parallel with the mitochondrion to "purify" the host genome from random insertions of mitochondrial sequences that altered pre-existing host genes. This is a questionable hypothesis because natural selection could have easily eliminated deleterious insertions without requiring a complex and expensive mechanism such as sexual reproduction. As a matter of fact, early eukaryotes had their genome massively invaded by group II introns of likely mitochondrial origin, and managed to avoid disaster by evolving the spliceosome, a molecular machine that removes the introns from transcripts before translation (Martin and Koonin 2006).

In conclusion, the most convincing hypothesis is that sexual reproduction fixed in eukaryotes because it permitted the maintenance of large-sized multi-chromosome genomes. It is debated, however, if sexual reproduction emerged in the outcome of mitochondrial evolution or was an earlier event in eukaryogenesis (Ligrone 2018).

6. Are there exceptions to the universality of sex?

Sexual reproduction is the rule in eukaryotes, with a minority of taxa that lost it and seemingly reproduce only asexually. Bdelloid rotifers (Bdelloidea), minute animals living in freshwater habitats all over the world, are a most remarkable example. Unlike other rotifers, bdelloid rotifers reproduce exclusively by parthenogenesis, *viz.* by division of unfertilized diploid eggs formed without meiosis. A second remarkable trait of these animals is their ability to survive drought by activating desiccation-induced dormancy (Ricci and Fontaneto 2009; Boschetti et al. 2011). Despite the absence of sexual reproduction, bdelloid rotifers have evolved at a quick pace, producing over 450 species in about 35 MY from their divergence from a sexual progenitor. How did bdelloid rotifers manage to maintain functional genomes? The trick seems to be in part rooted in desiccation tolerance. To repair genetic damage after prolonged permanence in a dried condition, bdelloid rotifers have evolved a particularly effective DNA repair system (Hespeels et al. 2014). Crucially, however, these singular animals have a surprising ability to pick up foreign DNA and insert it in their genome, thus performing a bacterial sort of sex (Gladyshev et al. 2008; Eires et al. 2015). The loss of meiosis and of the associated requirement for homologs with high sequence homology probably facilitates the acquisition of DNA by HGT.

A possible reason for the loss of sexual reproduction in some eukaryotes is its heavy biological cost (Section 5). By analogy with bdelloid rotifers, it is likely that other eukaryotes that lost sexual reproduction also reverted to bacterial-like sex. Because asexual reproduction should lead to genetically homogeneous clonal populations, the impact of HGT in asexual eukaryotes might be assessed by evaluating genetic diversity within natural populations. Moreover, based on the apparent link between large genome size and sexual reproduction (Section 5), one might predict that asexual eukaryotes have reduced genome sizes compared with their sexual relatives.

The case of colonial anthozoa (Cnidaria) is somewhat different. These animals form extensive monoclonal colonies by asexual reproduction. Anthozoan colonies, but not single polyps, can live much longer than any known non-colonial animal, perhaps for thousand years. The reason is probably that novel polyps can develop from few stem cells of parent polyps (Sköld et al. 2009). Because the colonies lack the highly integrated homeostatic mechanisms present in the body of complex animals, genetic lesions may impair the survival of single polyps but not of the whole colony. This, for a while. No reef could survive for ever without sex. Indeed, although these simple animals largely rely on asexual reproduction for colony extension, they routinely use meiotic sex for spreading. Moreover, genetic polymorphism in natural colonies suggests multiclonal composition (Maier 2012; Schweinsberg et al 2016) or fusion of non-clonal juvenile conspecifics during embryogenesis (Jiang et al. 2015). Intra-colony genetic diversity may contribute to elongating the lifetime of coral colonies.

The free-swimming sexual stage (medusa) of the hydrozoan *Turritopsis nutricola* (now named *T. dohrnii*) is able to revert to the asexual polyp stage, forming a new polyp colony. *Turritopsis* is one of the few instances of animals that revert to a sexually immature, colonial stage after having reached sexual maturity as a solitary individual (Piraino et al. 1996). Hydrozoans have a lifespan ranging from few hours to several months. Because of the ability to reiterate the medusa-to-polyp reversal multiple times, *Turritopsis* is considered to be potentially immortal. *Turritopsis*, however, also reproduces sexually and does so in response to the same unfavourable conditions that induce reversal to the asexual stage. The unique reproductive strategy of *Turritopsis*, therefore, appears to combine the two processes, with reversal to the asexual stage affording adult individuals a long subsistence, and sex ensuring genomic maintenance.

Land plants are typical non-weismannist multicells. They grow by the activity of apical meristems made of one to several initial cells and numerous derivatives. The derivative cells have high metabolic activity and high division rates. They divide a finite number of times and eventually differentiate into mature tissues. In contrast, the initial cells have low metabolic activity, low division rates and can divide indefinitely. Their function is to produce novel derivatives that replace those that differentiate and stop dividing. If for any reason an initial cell stops functioning, one of the other initials or an immediate derivative replaces it, re-establishing the correct geometry of the meristem. Theoretically, plants can keep growing indefinitely. By no means, however, this implies that they are immortal. Plants do die of old age, although their life span varies from few months or less to several hundred or thousand years (https://en.wikipedia.org/wiki/List_of_oldest_trees). Independently of the natural life span of single individuals, plants can be easily cloned, and many species do so spontaneously in nature. A colony of about 48,000 *Populus tremuloides* trees (nicknamed "Pando"), covering 43 ha in the Fishlake National Forest of Utah (USA), is considered one of the oldest and largest organisms in the world. Recent estimates set the colony's age at several thousand (up to 14,000) years (DeWoody et al. 2008). Pando's probably owes its existence to favourable conditions persisting locally from the end of the last glaciation. The recent increase in herbivore populations due to the elimination of predators by humans, and worsening climatic conditions due to global change are now seriously threatening its survival (Rogers and McAvoy 2018). Plants' ability to live for long times essentially depends on their extreme morphogenetic flexibility. Novel meristems may develop from stem cells in mature shoots, roots and leaves, and even mature cells can be induced to resume meristematic activity (Steeves and Sussex 1989). The Pando clone deploys a large reserve of stem cells stored in its root system. Significantly, individual stems rarely live over 130 years (Rogers and McAvoy 2018), probably because light, cold and other harmful agents cause more genetic damage in aerial parts. Despite unusual morphogenetic flexibility, plants including "Pando" ultimately depend on sex for genome maintenance.

7. Complex multicells have three states of death

Death is the loss of homeostatic mechanisms that maintain living systems far from thermodynamic equilibrium. This transition coincides with cellular death in unicellular organisms, but not necessarily so in multicellular organisms. Here, in fact, death is the outcome of alterations of the supra-cellular organization that precede the loss of intracellular homeostasis. In other words, a multicellular organism may be dead whilst at least a part of its cells are still alive. A most remarkable example is HeLa cells, a cellular line derived from cervical cancer cells taken in 1951 from Henrietta Lacks, a patient who died the same year. Since then, HeLa cells have been kept in culture and multiplied, becoming an enormous boon to medical and biological research. HeLa cells developed by horizontal gene transfer from the papilloma virus 18 to human cervical cells, and their genome is different from Henrietta Lacks' genome in various ways, including the number of chromosomes. HeLa cells recall the hypothetical "cancer-like" cells devised by Levin (2021), which attain immortality by reversibly shifting from a unicellular to a multicellular life style. HeLa cells can live only in culture condition and do not form multicellular structures. Since their isolation, they have undergone numerous mutations, and most likely a vast number of lines have already extinguished.

Complex multicellular organisms have three hierarchically interlinked levels of organization, each depending on a specific set of homeostatic interactions. The first is the whole organism, whose existence in life depends on mechanisms controlling the interactions of organs and systems of organs (Levin 2021). The second is the single organs, which remain functional for a while after the first level of organization has been lost. The third is tissues and cells, which remain alive for some time after the loss of organ function and may even be isolated and kept in culture under appropriate conditions, as is the case for HeLa cells. We can therefore conclude that complex multicellular organisms die in three steps - systemic, organ and cellular - following each other in this order.

Legal determination of death in the developed world is made by medical professionals after checking irreversible cessation of heartbeat and breathing (*cardiopulmonary death*), or irreversible cessation of functions of the brain (*brain death*), both assumed to signal systemic death (Bernat et al. 2010; Goila and Pawar 2009). In the immediate aftermath of systemic death, organs such as the heart, liver or kidneys can be explanted and integrated into a recipient systemic network. Organ ability to survive transplant depends on their homeostatic interactions with the rest of the organism. The heart has an autonomous pacemaker and can resume beating after transplant although it has no connection with the recipient nervous system. Organs such as the kidneys, liver and lungs are mainly under the control of the endocrine system, which facilitates integration after transplant (Hill et al. 2016). Transplant of blood, skin, cornea, and bone marrow is even easier, as these tissues are under feeble system and organ homeostatic control. Attempts at brain transplant in animals have met with significant success and might pave the way to exciting progress in bioengineering (Levin 2021). In humans, tissues may be recovered from donors up to 24 h after the cessation of heartbeat. Because of somatic aging, there are some general age guidelines for the different organs that can be donated, but in life-and-death instances there are no strict cut-off ages for donation.

8. Conclusions

Richard Dawkins (Dawkins 1976) provocatively described living organisms as ephemeral vehicles for immortal genes. What makes genes potentially immortal despite their intrinsic fragility is sex, which (a) permits the recovery of functional genes and functional genomes across generations, (b) creates new genes by recombining pre-existing sequences, and (c) enables genes to explore association with other genes present in the surrounding environment, thus creating novel genotypes and novel genomes. Sex, therefore, ensures the conservation of biological information and simultaneously drives genetic innovation. The emergence of new genotypes has an immediate positive impact in the ceaseless war against parasites in which all organisms are engaged (Lively 2010). Yet, sex is much more than this. Sex underpins life ability to perpetuate itself indefinitely and to adapt to changing conditions (Ligrone 2021).

It is important to correct the potential circularity of this reasoning. Genomes evolve thanks to sex (and occasional favourable mutations). Nevertheless, sex by itself is not a product of natural selection. Rather, sex emerged as a spontaneous by-product of the biochemical machinery for the duplication and repair of biological information at an early, probably pre-cellular stage of evolution. Only later did natural selection add the mechanisms specific to prokaryotic and eukaryotic sex.

The occurrence of meiotic sex in eukaryotes and non-meiotic sex in prokaryotes is not a mere difference in the mechanism of genome maintenance. Rather, it reflects a deep divergence in the life strategy of the two types of cellular organization. Prokaryotic sex leads to pangenomes and ecological flexibility, eukaryotic sex leads to vertical inheritance, species isolation and ecological specialization.

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Actual spreading and future evolution of alien population of Coypus (*Myocastor coypus*) in Campania region

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Abstract

This study has two main objectives: to define the presence of an alien species, the coypu (*Myocastor coypus*), in the Campania region and to develop a demographic projection in the absence of management plans. It was possible to highlight the areas in which the species is currently present on the territory and, once the biological and ecological aspects of it have been analysed, to observe whether favourable environmental conditions are present in the Campania region for its survival and proliferation. The results obtained from the environmental suitability model have effectively highlighted the presence of variables that can affect the survival of the species and that the synergy between these can lead to unexpected results. Therefore, to decipher the actual danger of the species it was necessary to develop a demographic projection to observe whether the latter may increase over time. The outcome highlighted an exponential increase in the population over time, thus highlighting the need to intervene in the short term to mitigate the negative impacts that the coypu already perpetuates on the environment.

Keywords: *Myocastor coypus*, Campania, population dynamics, suitable habitats, alien species

Riassunto

Questo studio ha due obiettivi principali: definire la presenza di una specie aliena, la nutria (*Myocastor coypus*), sul territorio campano e sviluppare una proiezione demografica in assenza di piani di gestione. È stato possibile evidenziare le zone in cui la specie è attualmente presente sul territorio e una volta analizzati gli aspetti biologici ed ecologici di essa, osservare se sul territorio campano sono presenti condizioni ambientali favorevoli per la sua sopravvivenza e proliferazione. I risultati ottenuti dal modello di idoneità ambientale hanno effettivamente messo in evidenza la presenza di variabili che possono condizionare la sopravvivenza della specie e che la sinergia tra queste può condurre a risultati inattesi. Dunque, per decifrare l'effettiva pericolosità della specie è stato necessario sviluppare una proiezione demografica in modo da osservare se quest'ultima possa aumentare nel tempo. L'esito ha evidenziato un aumento esponenziale della popolazione nel tempo mettendo quindi in luce il bisogno di intervenire nel breve periodo per mitigare gli impatti negativi che la nutria già perpetua nei confronti dell'ambiente.

Parole chiave: *Myocastor coypus*, Campania, dinamica di popolazione, habitat idonei, specie aliene

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Introduction

Alien species are represented by populations that are found outside their range of origin following voluntary or accidental action by humans (IUCN 2000; CBD 2002). They usually cause damage to the ecosystem and economic systems. In fact, the practical and normative sense, invasive alien species are those that threaten biodiversity and related ecosystem services (CBD 2000, 2002; IUCN 2000). Invasive alien species are second to habitat destruction in the causes of biodiversity loss (Wilson 2003). The coypu (*Myocastor coypus* (Molina, 1782) is a rodent mammal native to South America, the only living species of the genus *Myocastor* and of the family *Myocastoridae*. it has spread to Europe, Asia and North America due to escapes and/or liberations from fur farms (Woods et al., 1992). This animal usually inhabits swamps, lake shores and slow streams, especially in areas where riparian vegetation is abundant (Greer 1966; Nowak 1991). Its sexual maturity is reached around 6 months of age; it does not have a specific reproductive period and has the possibility of reproducing all year round, as the factors influencing the reproductive potential of the coypu are the type and availability of food, weather conditions, predators and diseases. Litter size usually ranges from 3 to 6 cubs (Gosling 1981; Gosling & Backer 1981; Woods et al., 1992). The coypu is herbivorous; its diet consists largely of aquatic vegetation: stems, leaves, roots and even bark, but it occasionally also feeds on bivalve mollusks. (Woods et al., 1992).

In Italy, this species was introduced starting from the 1960s. It is present in almost all regions and many populations are in a phase of active expansion. The distribution of the coypus in Italy has had a strong increase in recent decades, passing from small, localized populations to two areas with an almost continuous distribution: one in Northern Italy, in the Po Valley and along the Adriatic coast down to Abruzzo, and the second along the Tyrrhenian coast of Liguria and Tuscany down to Campania. Along the middle Adriatic coast (Marche, Abruzzo), the lower Tyrrhenian coast and in Southern Italy and the islands, apparently isolated cores of smaller dimensions were present (Cochi & Riga 2001). In Italy, population densities ranging from 1 to 4 individuals per hectare have been detected (Vellatta & Ragni 1991; Reggiani et al., 1993). In Campania, the species was reported generally spotted, but also with connected population along the Sele-Tanagro river axis that crosses areas of high naturalistic interest.

The damage caused by this species through the excavation of the burrows along the banks and canals represents a threat to the hydraulic works and to water regulation and it can increase the risk of flooding. As for the impacts on the fauna, the coypu has a negative effect on several species of water birds that build floating nests and competes with the otter (*Lutra lutra*) for space. Food activity can lead to a strong contraction of the vegetation of wetlands and consequently to a strong decrease of many plant species, which in turn can negatively affect the natural dynamics of habitats (Bertolino & Cocchi 2018).

In our study we aim to:

- Analyze the coypu (*Myocastor coypus*) distribution of population in Campania region;
- Characterize the biotic and abiotic variables that make up the suitable habitat for this species;
- Model the demographic forecast for the next 20 years, considering that at present there are not management plans that can mitigate the impact of this animal.

Materials and Methods

Presence data collection

To identify the presence of coypus in the Campania region were carried out direct and indirect observations.

Direct sampling included the monitoring of specific areas of the Campania region, in the period 2020-2021 such as: Matese lake, Campolattaro lake, Picentino river, Volturno river, Sele river, Alento river, Tanagro river, Garigliano river, Sarno river, Calore river (BN), Calore river (SA), Bussento river (Fig.1). Once a direct presence sign (observation of the animal) or indirect (slides, excretions and/or footprints) was identified, its location was recorded using a GPS device and recorded in a spreadsheet. As for the indirect field activity, this included the study of publications or reports through citizen size activities.

Environmental suitability modelling

The presence of coypus and arbitrariness environmental variables were used to develop a map of environmental suitability. We built a model of maximum entropy using software MaxEnt (Phillips et al., 2006; Phillips

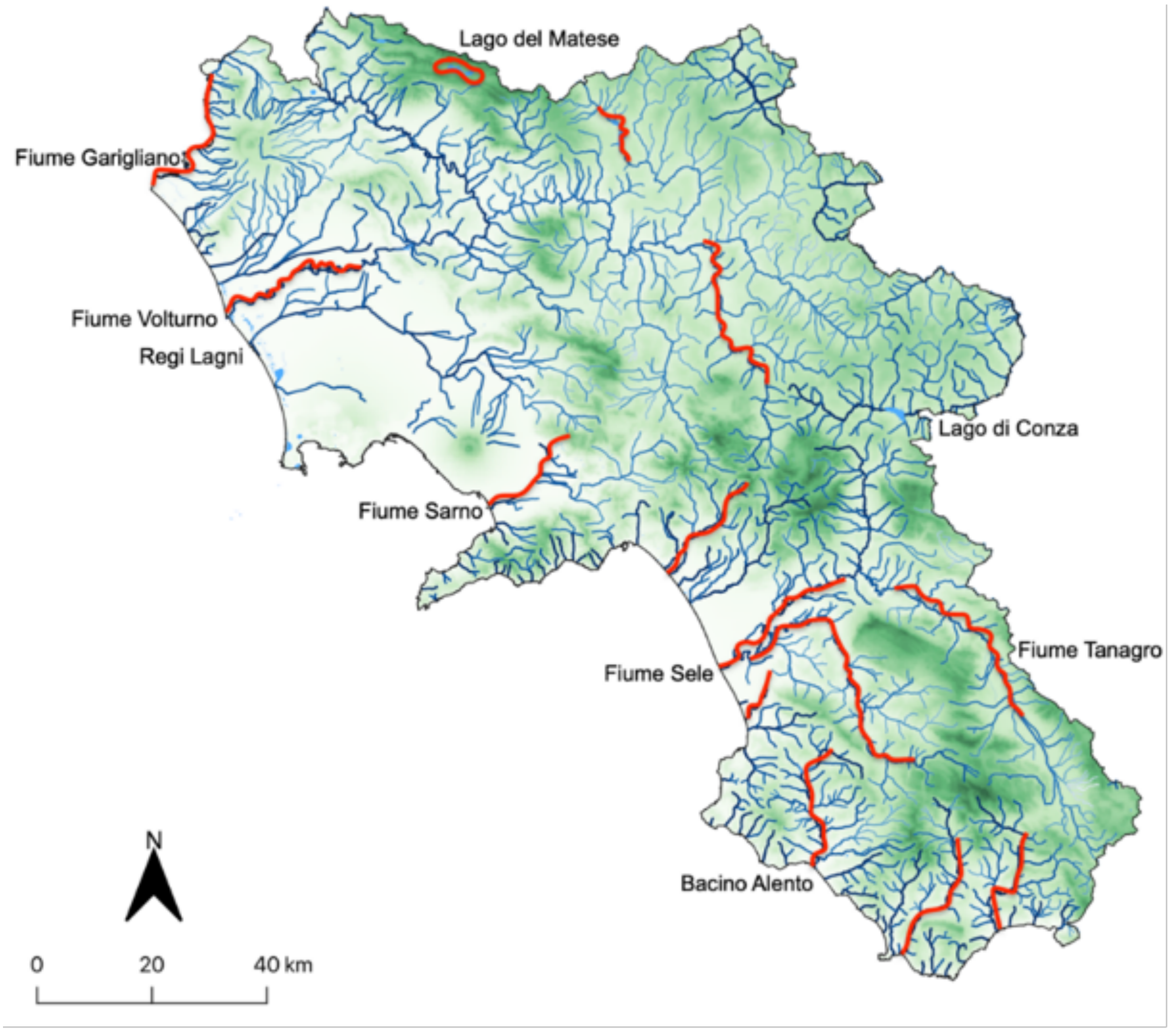

Figure 1: Sampling areas in Campania.

& Dudik 2008). It analyzes the relationship between environmental factors and the presence of species and is often used to predict the potential distribution of a species from presence-only data. It is possible to interpret MaxEnt predictions simply as environmental suitability indices, which could be useful for exploratory qualitative analyses, especially if sampling is not based on rigorous assumptions that allow the model output to be interpreted probabilistically (Merow et al., 2013).

To carry out this type of analysis, the work was follows three steps:

1. Assign UTM-WGS 84 33N coordinates to the presence signs.
2. Elaborate the environmental layers through QGis v.3.12.
3. Submit the coordinates file and the layers to the MaxEnt program.

In total, 73 occurrences were used to generate the model.

The variables chosen for the environmental suitability of *Myocastor coypus* are 13 (Tab. 1). Altitude, rivers, and roads and railways were obtained from the Campania Region Geoportal (https://sit2.regione.campania.it/ http://www.pcn.minambiente.it). All the other layers were generated from the Nature Charter system, available on the Superior Institute for Environmental Protection and Research (https://www.isprambiente.gov.it/).

Table 1: variables used for the environmental suitability of *Myocastor coypus*

Type	Name	Source
Geological		DTM Campania Region
	Altitude **Slope** **Exposition**	
Environmental		Nature Charter [ISPRA]
	Brackish environments	[COD.: 15.1; 15.5]
	Canals	[COD.: 89.2; 89.1]
	Reed	[COD.: 53.1; 53.6]
	Estuaries	[COD.: 13.2]
	Lakes	[COD.: 22.4]
	Beaches	[COD.: 4.12pm]
	Urban fabric	[COD.: 86.1]
	Riparian vegetation	[COD.: 44.12; 44.14; 44.513; 44.61; 44. D2cn]
	Rivers	Geoportal Campania Region
	Roads and railways	Geoportal Campania Region

The environmental layers were processed using the QGis v.3.12 software. Each layer corresponds to a type of variable chosen for the analyses. Environmental layers relative to specific site were chosen based on the ecological preferences of the species.

Altitude data, slope, and exposition were obtained as quantitative variables. Altitude was determined using the DTM model at 20 m, aspect and slope were calculated using the GDAL functions “Aspect” and “Slope” in QGIS 3.4.2. The remaining variables were rendered as continuous raster by considering the Euclidean distance from each feature, using the GDAL function Proximity (raster distance), and considering geographical units. All layers were rendered as raster maps with a resolution of 100 x 100 m.

In Maxent v. 3.4 models were generated using default settings. A regularization parameter of 1.0 was used, the maximum number of iterations was set at 500 and a jackknife procedure was used to assess variable importance. To estimate model performance, the average test AUC (the area under the receiver operating characteristic curve) was considered, through fivefold cross-validation (Swets 1988).

Demographic forecast for the next 20 years

Population Viability Analysis (PVA) is a species-specific risk assessment method frequently used in conservation biology. Each PVA is developed individually for a target population or species and, consequently, each PVA is unique (Sanderson 2006). PVA is also used to identify factors driving population dynamics (Manlik et al., 2018). The current PVA has become a quantitative analysis of the probability of persistence of a population subjected to a set of assumptions and circumstances (Lacy et al., 2015).

The PVA of the *Myocastor coypus* population was made using the VORTEX 10.1.6.0 software (Lacy et al., 2015). VORTEX is based on an individual-based model, in which a virtual representation of each individual animal is created and its fate is followed in each year of its life, keeping track of sex, age and grade of kinship. The simulations are performed as a series of events describing the life cycle of a diploid organism (Miller & Lacy 2005). The analysis is based on Monte Carlo simulations (Lacy 1993; Lacy et al., 2015). The software models demographic processes as discrete and sequential events and with probabilistic results. Random processes (gene transmission, number of offspring produced by each female, natural disasters, etc.) generating fluctuations in population demographics will influence their fate (Miller & Lacy 2005).

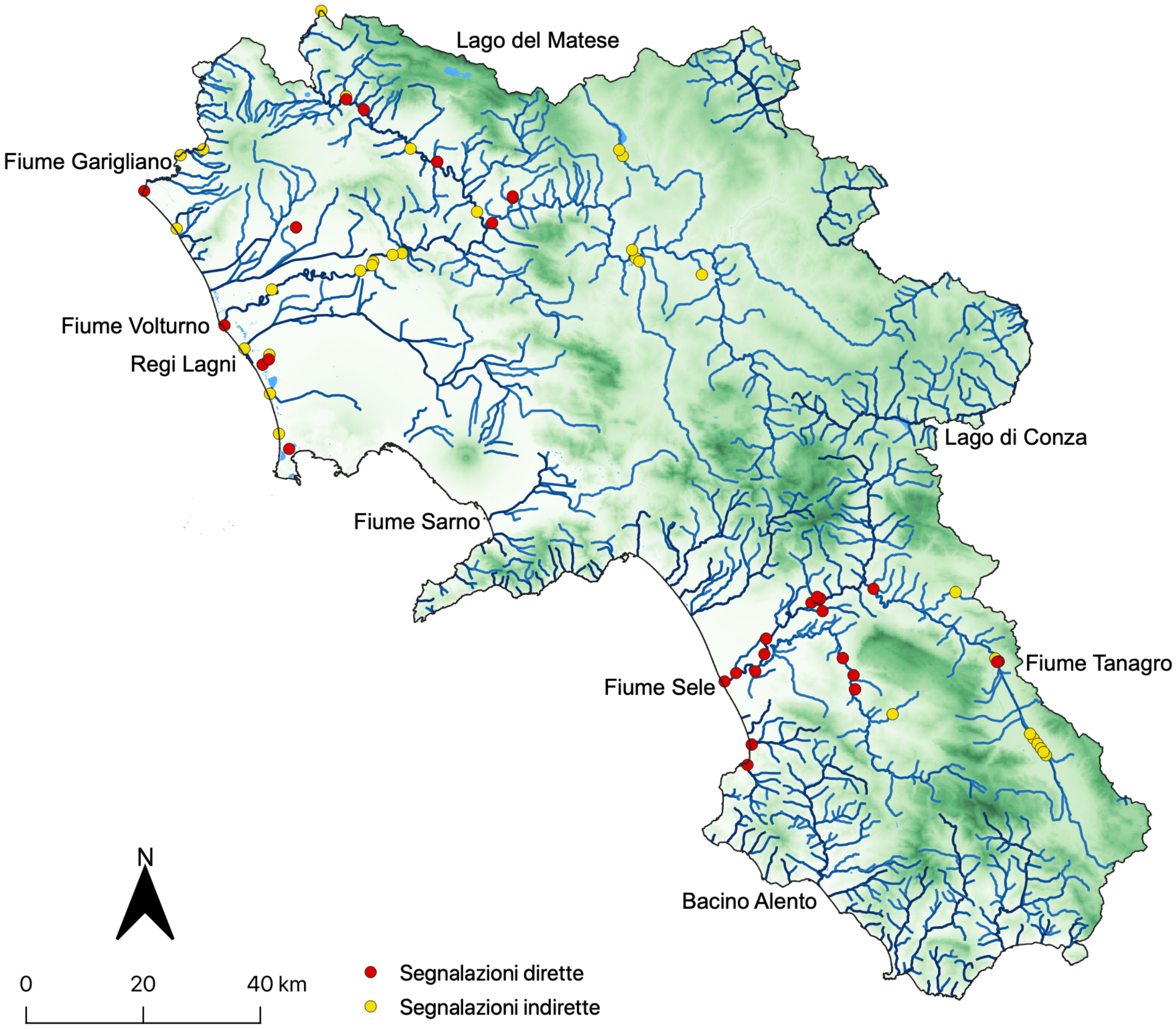

Figure 2: Signs of presence of *Myocastor coypus*.

For each year, the specific mortality rates for each age group are calculated as well as the fertility of individuals who acquire sexual maturity. Inbreeding depression, on the other hand, is expressed as a decrease in the survival of newborns. Based on the parameters entered, which must be as faithful as possible to the biology of the studied population, the statistical results of the simulations are returned with reference to the population growth rate, the probability of extinction and the average

Table 2: The scenarios used for the simulation in VORTEX.

Parameter	Value	Reference
Reproductive system	polygamy	Guichon et al., 2003
Inbreeding depression (no. of lethal equivalents)	6,29	Setting Default (Lacy et al., 2015)
Life span (years)	6	HGAR*
Male fertile interval (days)	130**	HGAR*
Female fertile interval (days)	130**	HGAR*
Maximum number of cubs per year	3	HGAR*
Sex ratio at birth as % of males	50	Pagnoni & Santolini, 2011
% of fertile females	67	Iori et al., 2013Cocchi & Riga, 2008: Guichón et al., 2003
Number of young per female	6	HGAR*
Fatalities rate (%) 0-1 years	50%	Carter et al., 1999
Fatalities rate (%) >1 years	20%	Carter et al., 1999
Abundance of the initial population (n° individuals)	150***	This study
Carrying capacity (n° individuals)	1490	This study
Female sexual maturity (days)	152**	HGAR*
Male sexual maturity (days)	152**	HGAR*
Number of iterations	1000	Operator's choice
Number of years (timesteps)	20	Operator's choice

*https://genomics.senescence.info/species/entry.php?species=Myocastor_coypus
**Compared to the literature data we have set the fertility interval and sexual maturity to 1 year to be more conservative and have a more reality-aware estimate also because coypu is located outside its original range and may have expanded the time of sexual maturation.
***Considering that there are 73 points of presence reported and that the average Italian density of coypu is= 2.0Individuals/1ha (Vellata & Ragni, 1991; Reggiani et al., 1993) an initial population of 150 individuals has been hypothesized.

time of extinction, considering the user-defined time interval (Lacy et al., 2015). Since the increase or decline of a population is strongly influenced by random events, the interactions of the same data can produce different results (Lacy 1993). The scenarios used for the simulation in VORTEX are based on a 20-year projection, on data collected during this research project and on bibliographic data known for the species (Tab. 2).

Results

Presence data collection

The direct field activities led to the identification of 38 signaling points, while the indirect activities (i.e., those deriving from citizen size) led to the identification of 35 signaling points for a total of 73 points of presence.

In the map (Fig. 2) we can see the direct signaling points in red and the indirect ones in yellow. Considering that there are 73 reporting points and that the Italian average is = 2.0individuals / 1ha (Vellatta & Ragni 1991; Reggiani et al., 1993), the initial assumed population is 150 individuals.

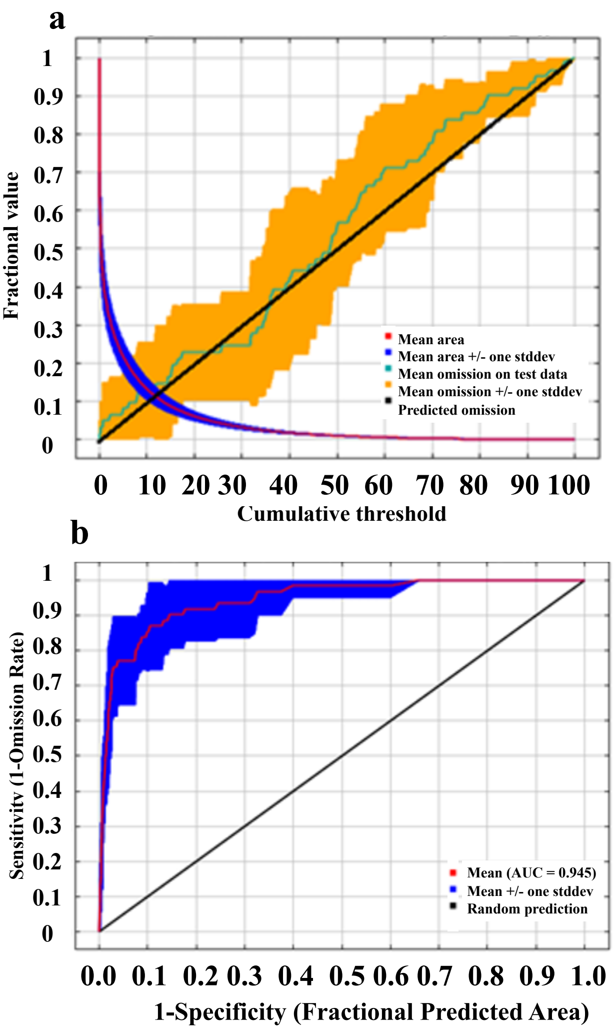

Figure 3: a) Average Omission and Predicted area and b) Average Sensitivity vs.1 Specificity for *Myocastor coypus*.

Environmental suitability modeling

The signs of the presence of the coypus collected from the different sources represented the data base for the elaboration of the spatial model of environmental suitability on the presence of the species relating to the 13 variables (3 geological and 13 environmental) taken into consideration.

The relationship between the environmental suitability values predicted for coypus and the proportion of selected presences (Phillips et al., 2006), indicates that the model approximates the real data quite well, given that the trend of the omission rate on the testing dataset (green line) is close to the predicted omission line (Fig. 3a).

The receiver operating characteristic (ROC) curve indicates the performance of the model. The value of the area under the ROC curve, the AUC (area under the curve), is equal to 0.945 ± 0.042 (SD). The obtained values indicate that the model is very efficient (Manel et al., 2001) and therefore the relative predictions can be considered reliable (Fig. 3b).

The weight of the ecogeographic variables is measured based on their contribution through the Percent contribution and Permutation importance measures (Tab.3).

It is clear, from the calculations of the percentage contribution, that the slope variable ('Slope') contributes to defining most of the environmental suitability of the species.

A separate comments must be made on the "Altitude" variable, as this seems to have a small percentage contribution, but also

Table 3: The weight of the ecogeographic variables. Con. %, Contribution (%); Per.imp., Permutation importance.

Variable	Con. %	Per.imp.
Slope	32.9	49.7
Rivers	22.9	11.2
Riparian vegetation	20	5.3
Reed	12.7	2.3
Canals	2.1	13
Altitude	2.1	10.3
Lakes	1.8	4.7
Roads and railways	1.7	1.7
Estuaries	1.5	0.1
Brackish environments	1.5	1
Exposition	0.3	0.1
Urban fabric	0.3	0.3
Beaches	0.1	0.4

observing the data on the importance of permutation, it still plays a certain weight in the analysis of the model; the same goes for the distance from the reeds.

The variables that, on the other hand, generally play a scarcely relevant role in the model are: distance from lakes, estuaries, brackish environments, beaches and the distance from the road and rail network, urban fabric and exposure.

The MaxEnt software also returns graphs in logistic format ("response curves") that illustrate how each variable affects the forecasts of environmental suitability. Each graph relates to each single covariant and two types are observed: a) the first graph

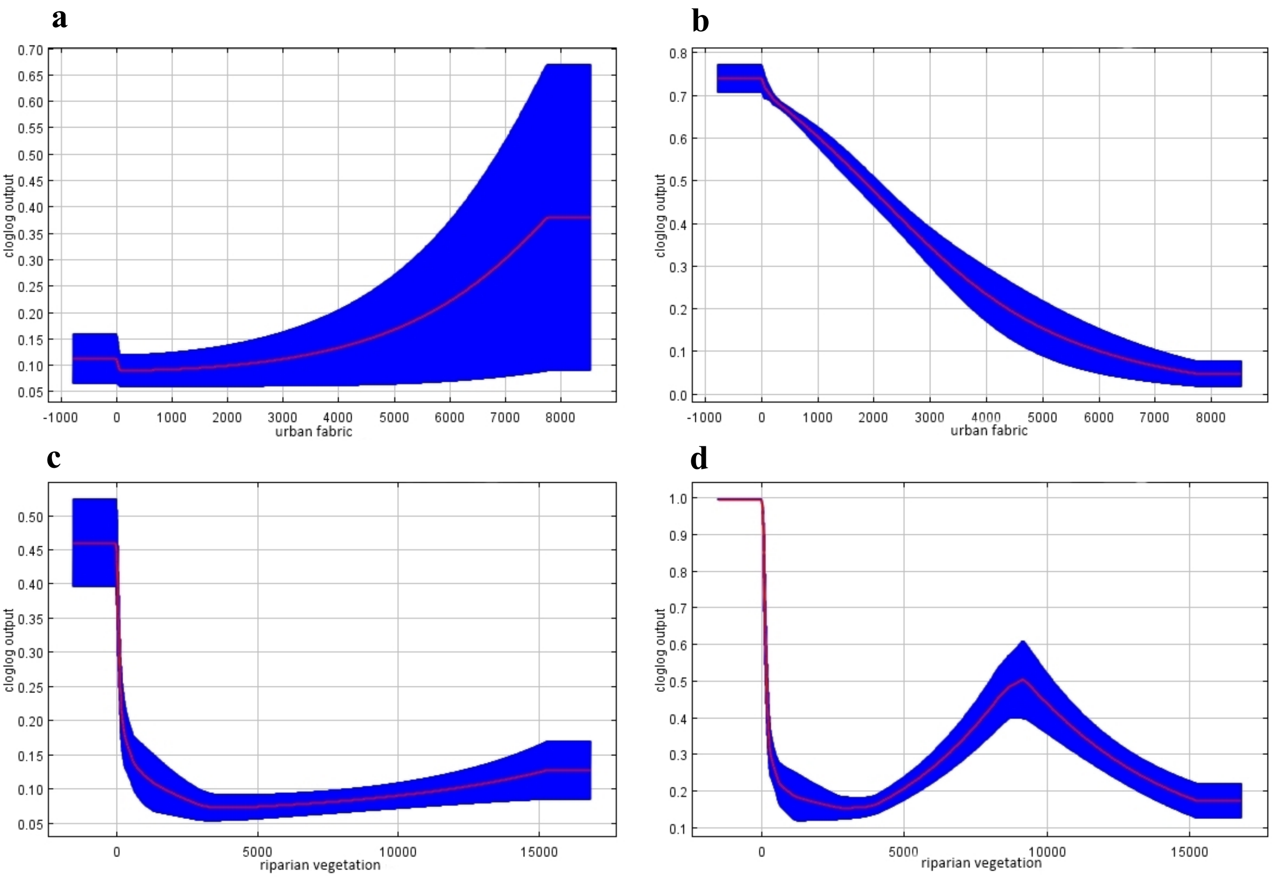

Figure 4: Average values of environmental suitability in response to a) distance from urban fabric, considering the other variables at their average value; b) distance from urban fabric as a single isolated variable; c) distance from riparian vegetation, considering the other variables at their average value; d) distance from riparian vegetation as a single isolated variable.

shows the average values of environmental suitability obtained by keeping the average value of all the other variables constant, except for the target variable and letting the value of the target variable only; b) the second graph shows the completion of the model by varying only the indicated environmental variable and excluding all the other variables (Phillips et al., 2006). The curves explain the response of each variable on the mean of 5 replicates (in red) ± the standard deviation (in blue).

It is particularly interesting to observe the evolution of the variables 'urban fabric' (Fig. 4a and b) and 'riparian vegetation' (Fig.4c and d). It is assumed that the discrepancy we have for the distance from the urban fabric (Fig. 4a and b) is because an intrinsic distinction must be made between the urbanized fabric and anthropization. In the first case we are talking about those areas in which man carries out most of his activities (e.g., homes, offices, schools, universities, etc.) in which the coypus, in Campania, tends not to colonize for what is the habitat

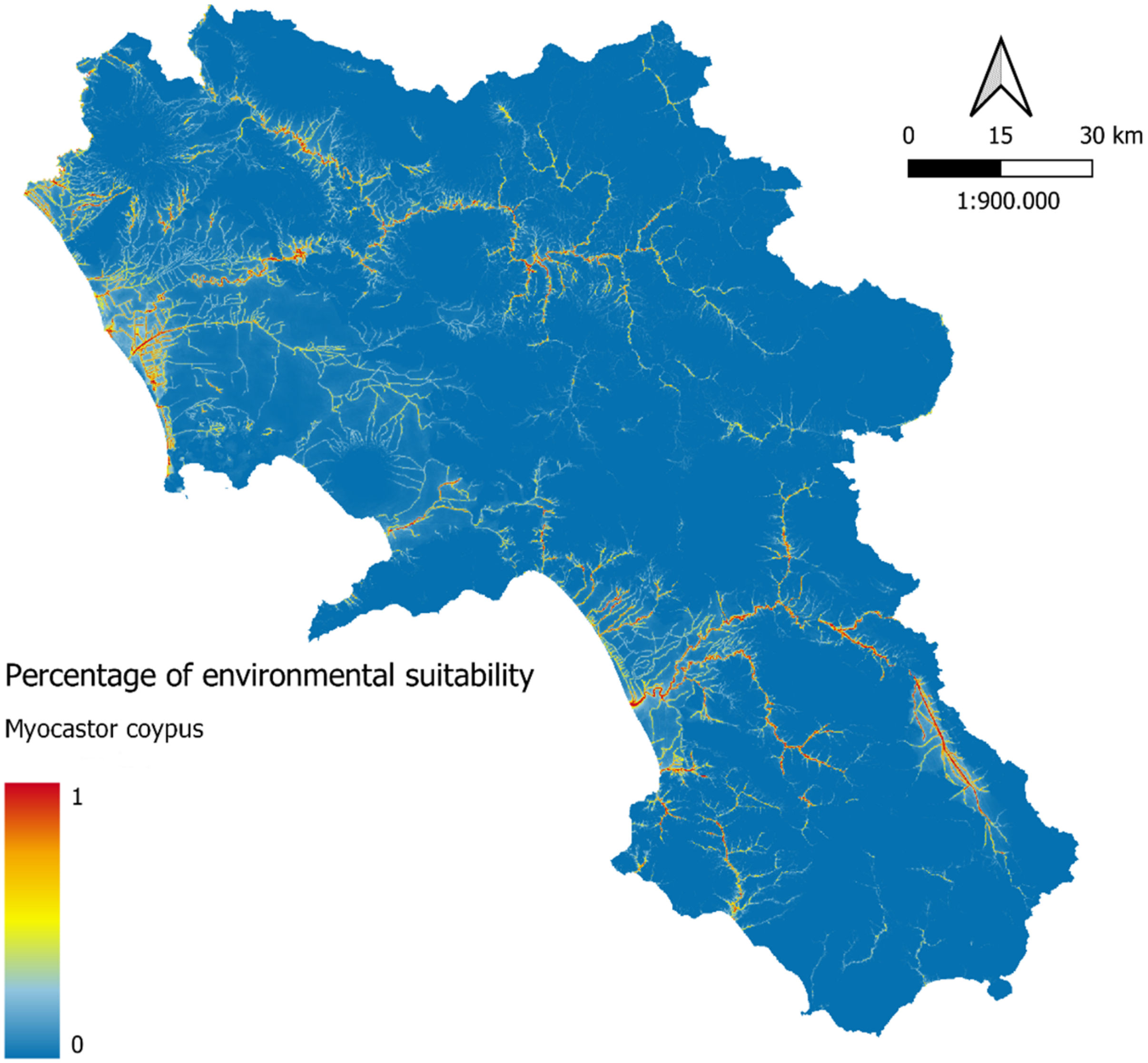

Figure 5: Environmental suitability map for *Myocastor coypus*.

Table 4: Demographic parameters derived from the VORTEX simulation.

nRuns	det-r	stoch-r	SD(r)	PE	N-extant
1000	0,1636	0,1348	0,1924	0,0000	1247,18

fragmentation (e.g., inability to find food due to building cementation). In the case of anthropization, reference is made to those areas where, although man acts, he does not particularly disturb the suitable habitat. Instead, as regards the distance from riparian vegetation, the fact that the suitability is greater both when one is close to and at a medium distance from this variable (Fig. 4c and d) is explained by studying the ecology of the species. In fact, the coypus does not prefer only riparian woods (e.g., forest composed so much of willow grove, poplar grove, etc.) but prefers those environments in which we have a riparian forest interrupted by a clearing and then by a hygrophilous forest, which leaves the possibility of formations of ecological corridors.

The result generated by the MaxEnt software given to the interaction between the ecogeographic variables and the signaling points returns the environmental suitability map of the coypus (Fig. 5).

Demographic forecast for the next 20 years

The result of the demographic projection of the coypu in Campania over the next 20 years without any control plan shows a probability of survival of 100% and therefore a zero probability of extinction (Fig. 6a) and an increasing trend (Fig.6b) of the population which at the end of the simulation is made up of 1247 individuals (Tab. 4).

Discussion

This research has highlighted how the monitoring of this species has been little followed over the years, so much so that at the time of the direct censuses the initial population present in the area was unknown. Based on the observable results in the distribution chart (Fig. 2), it was thus possible

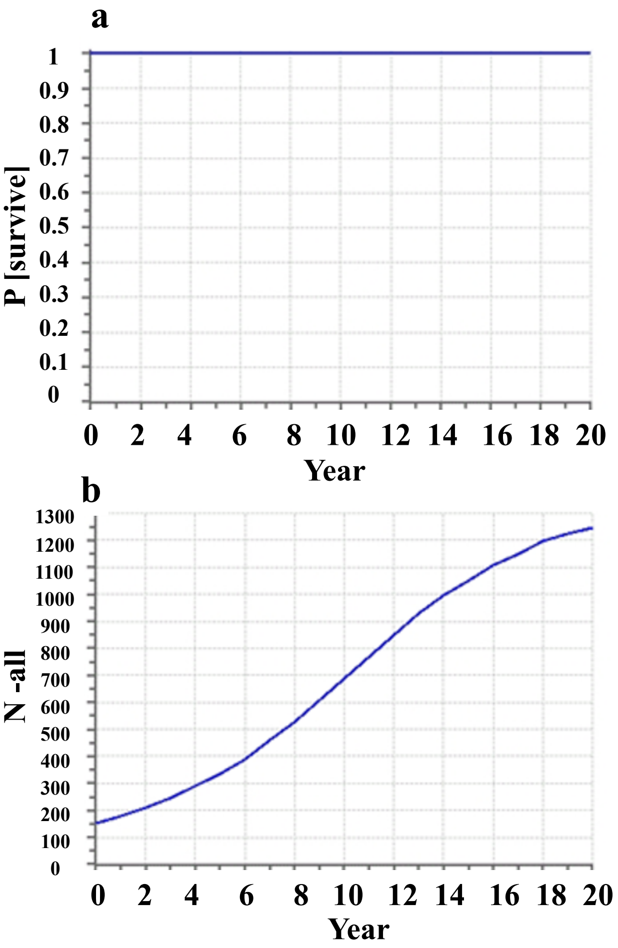

Figure 6: a) Probability of permanence of *Myocastor coypus* population and b) Final result of population growth in 20 years after 1000 iterations.

to estimate a current population of 150 individuals.

One of the main objectives of this study, in addition to knowing the current population, was also to understand if in Campania there is indeed to worry about a real expansion of the species and if there is therefore a need for adequate management plans. To do this, it was necessary to understand if there is the suitable habitat for coypus in the area and this analysis was made possible thanks to the elaboration of the environmental suitability modelling using the MaxEnt software. As can be seen from the results obtained, in Campania there are different levels of environmental suitability and the areas of highest environmental suitability are identified along the rivers (Fig.5, in red). This result brings to light important evidence, first of all in Campania there are biotic and abiotic elements necessary for the survival and expansion of this species and, in addition, the areas with the highest environmental suitability are also identifiable as ecological corridors that allow displacement of individuals from one area of the territory to another, so as to create different sub-populations.

Consequently, once this result has been obtained and knowing what are the negative effects that an alien species can produce on the territory, in our opinion it was necessary to predict a future evolution of the population in the absence of management plans by developing a population viability analysis, which analyses population dynamics taking into consideration various factors (e.g., ecology of the species, reproductive strategy, bearing capacity of the territory, etc.). The result highlighted that in the absence of disturbances, apart from the intrinsic ones already taken into consideration such as environmental variability or predation, which here in Campania seems to be perpetuated by the wolf (*Canis lupus*), the species tends to grow in 20 years of simulation (Fig. 6b) until reaching a final population of 1247 individuals (Tab. 4) thus having a population increase of 730% compared to the initial one.

In the face of what this research has highlighted, it is strongly recommended to intervene in the short term to mitigate the negative impacts that the coypu now has on the territory, mainly: disruption of the embankments and disturbance towards other animal species such as: aquatic birds that nest near riparian vegetation or its competition for space with the otter (*Lutra lutra*).

Author contributions

Conceptualization: A.M.B and D.F.; Data curation: A.M.B, D.F, C.T., G.d.F; Formal analysis: A.M.B; C.T.; M.B., S.P. Investigation: A.M.B; D.F., C.T.; M.B., S.P. G.d.F. Methodology: A.M.B; D.F., C.T.; M.B., S.P. G.d.F. Project Administration: D.F.; Resources: D.F.; Writing – original draft: A.M.B; D.F., C.T.; M.B., S.P. G.d.F.; Writing – final draft preparation: A.M.B; D.F., C.T.; M.B., S.P. G.d.F.

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Bulletin for the Year 1990: Meteorological Observatory of the University of Naples Federico II

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Abstract

This report contains the meteorological bulletin for the year 1990. The data were measured at the Meteorological Observatory of the University of Naples Federico II located in Largo San Marcellino, 10, in the Historic Center of Naples.
The weather report is organized as follows:

- a meteorological report for the year 1990;
- 12 monthly reports and annual trends with monthly averages;
- a cataloging of the average daily values and related graphs, for each month, with an indication of the extreme values recorded.

Keywords: Meteorological bulletin; Historical Center of Naples

Riassunto

Questo rapporto contiene il bollettino meteorologico per l'anno 1990. I dati sono stati rilevati presso l'Osservatorio Meteorologico dell'Università degli Studi di Napoli Federico II situato in Largo San Marcellino, 10, nel Centro Storico di Napoli.
Il bollettino meteorologico è così organizzato:

- un rapporto meteorologico per l'anno 1990;
- 12 rapporti mensili e tendenze annuali con medie mensili;
- una catalogazione dei valori medi giornalieri e dei relativi grafici, per ogni mese, con l'indicazione dei valori estremi registrati.

Parole chiave: Bollettino meteorologico; Centro Storico di Napoli

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Introduction

The Campania coast of Caserta, Naples, Salerno is characterized by a Mediterranean climate. It has mild and rainy winters and hot and dry summers. The most inland and mountainous areas of Campania are characterized by a more continental and rigid climate. In the province of Naples the Min/Max temperature ranges roughly from 4°C/12°C in January to 18°C/30°C in August and the annual mean temperature is 11°C/20°C. The rain varies roughly from 50/100 mm in summer (June, July and August) to 400 mm in Autumn (October, November and December); the mean annual rain amount is roughly 800-1000 mm. The relative humidity varies between 55% and 70%. Much of the Campania coast is exposed to humid westerly or south-westerly winds. In the urban center of Naples the temperatures could be 1 or 2 °C warmer than the surrounding rural regions because of the local urban heat island (Palumbo and Mazzarella, 1981, 1984; Fortelli et al., 2016).

The *Osservatorio Meteorologico Federiciano* (Meteorological Observatory of the University of Naples Federico II) is currently annexed to the *Dipartimento di Scienze della Terra, dell'Ambiente e delle Risorse* (DiSTAR, http://www.distar.unina.it) and is located in the historical center of Naples, Italy, in Largo San Marcellino n. 10 (Fig. 1). General information about the Meteorological Observatory, recent research activity and the meteorological daily records collected since 2011 are available at the observatory website at: http://www.meteo.unina.it.

The Observatory was established as a *Specola Universitaria* according to a dictatorial decree of Giuseppe Garibaldi, on October 29th, 1860, at the request of Prof. Luigi Palmieri who was the first professor of Meteorology in the united Italy. The Specola was located on the terrace "A" of the former *Istituto di Zoologia*.

With the death of Palmieri, on September 9th, 1896, the Specola was directed by prof. Eugenio Semmola until 1902, the year in which it took the name of *Osservatorio Meteorologico*, directed by prof. Emilio Villari and from 1905 by prof. Ciro Chistoni. In the same year the prof. Chistoni transformed the *Osservatorio Meteorologico* into the *Istituto di Fisica Terrestre*.

In 1908, due to the partial collapse of the Specola, Chistoni moved the *Osservatorio Meteorologico* to San Marcellino. Chistoni placed in the garden of the cloister "B", protected by a meteorological roof of his own invention, the minimum and maximum thermometers, the Asmann vacuum psychrometer and the thermo-hygrograph. On the terrace "C" of the building above the cloister, he placed the anemometer, the pluviometer, and the solar radiation and atmospheric radioactivity devices. In 1970 all the instruments placed in the cloister garden were moved to the "C" terrace inside a meteorological screen. In 1972 the *Istituto di Fisica Terrestre* merged into the new *Istituto di Geologia e Geofisica*.

Figure 1: Historic sites of the Meteorological Observatory of San Marcellino. A) Terrace of the former Istituto di Zoologia (1860-1908); B) Garden inside the Cloister of San Marcellino (1908-1970). C) Terrace below the DiSTAR tower (1970-1980). D) Terrace on DiSTAR tower (1980-date), detailed in box below.

Following the University's reform of 1980, part of the *Istituto di Geologia e Geofisica* became the *Dipartimento di Geofisica e Vulcanologia*. The tower of the same was renovated and all the meteorological instruments were moved to its terrace "D" together with a new SIAP automatic meteorological station, which began to record the same variables. In 2000 the *Dipartimento di Geofisica e Vulcanologia* merged with the *Dipartimento di Scienze della Terra* to form the current DiSTAR and the SIAP was replaced with the SIAP-MICROS meteorological automatic station.

Currently on the tower of the building of San Marcellino (lat. 40 ° 50'49 "N; long 14 ° 15'28" E, 50 m asl) three automatic stations are operational (SIAP-MICROS, DAVIS Vantage Pro 2, CAMPBELL). They manage the following weather sensors with a frequency of 10 minutes to measure: air temperature (°C); atmospheric pressure (hPa); relative humidity (%); wind speed (m/s); wind direction (°North); precipitation (mm); global and direct solar radiation (W/m^2); UV index (0-11).

The Meteorological Observatory of San Marcellino keeps data since 1872. From 1872 to 1980 the data were transcribed regularly for each day at 9.00, 15.00 and at 20.00 on dedicated registers. These registers also show the observer's annotations regarding thunders, city smog, Vesuvio's plume, etc. From 1980 to 2000, the data were automatically detected by the SIAP station and reported on special bulletins of the University of Naples Federico II for each year, although the data from 1980 to 1989 are largely incomplete. From 2004 onwards the meteorological bulletins have been published in the *Rendiconto dell'Accademia delle Scienze Fisiche e Matematiche*.

The Observatory owns a collection of meteorological manual instruments used in the 20th century (barometer of Fortin, microbarograph, thermograph, pluviometer, various thermometers, and some anemometer) which could be used also for periodical and manual comparison operations with the automatic measurements.

Figure 2 shows how the climate has changed in Naples since 1872 to 2020. The figure depicts the annual means of the temperature (T), rain amount (R), relative humidity (RH) and atmospheric pressure (P) recorded at the *Osservatorio Meteorologico Federiciano* from 1872 to 2020. The mean meteorological values during the entire observational period were: T = 17.5 °C; R = 837 mm; RH = 62.3%; P = 1008.7 hPa. The mean meteorological values during the 30-year period 1872-1901 (usually referred to as the *pre-industrial* period) were: T = 16.8 °C; R = 922.7 mm; RH = 61%; P = 1006.2 hPa. The mean meteorological values during the 30-year period 1941-1970 were: T = 17.9 °C; R = 817.4 mm; RH = 60.9%; P = 1007.9 hPa. The mean meteorological values during the latest 30 years, from 1991 to 2020, were: T = 18.1 °C; R = 795.5 mm; RH = 65.3%; P = 1011.4 hPa; while the mean meteorological values during the latest 11 years, from 2010 to 2020, were: T = 18.4 °C; R = 814.3 mm; RH = 69.1%; P = 1010.1 hPa. Thus, since 1872 historical center of Naples has experienced a warming by 1.3 °C (or 1.6 °C using the latest 11-year period) while the rain amount decreased by 127.2 mm (or 108 mm using the latest 11-year period).

Thus, since the pre-industrial period, Naples has experienced a climatic change that has been characterized by a secular warming and a reduction of rain amount (which is confirmed also by the slight increase of the atmospheric pressure). However, also the period from 1941 to 1970 was relatively warm. Actually, in the middle of the 20th century, the mean temperatures were nearly as warm as during the latest decades. In fact, during the entire observational period, the hottest years were 1947, 1950 and 2018 with an annual mean temperature of 18.8 °C. Most of the warming occurred during the first half of the 20th century, while the second half of the 20th century was characterized by an initial slight cooling until 1980, followed by a warming from 1990 to 2020, which could also reveal an oscillatory pattern found in other global and local meteorological data, in particular where a warming bias due to urbanization development is missing (cf.: Scafetta 2013, 2021; Scafetta and Ouyang, 2019).

The present work aims to provide to the public the meteorological daily data collected at the Observatory of San Marcelino in the year 1990. These data were

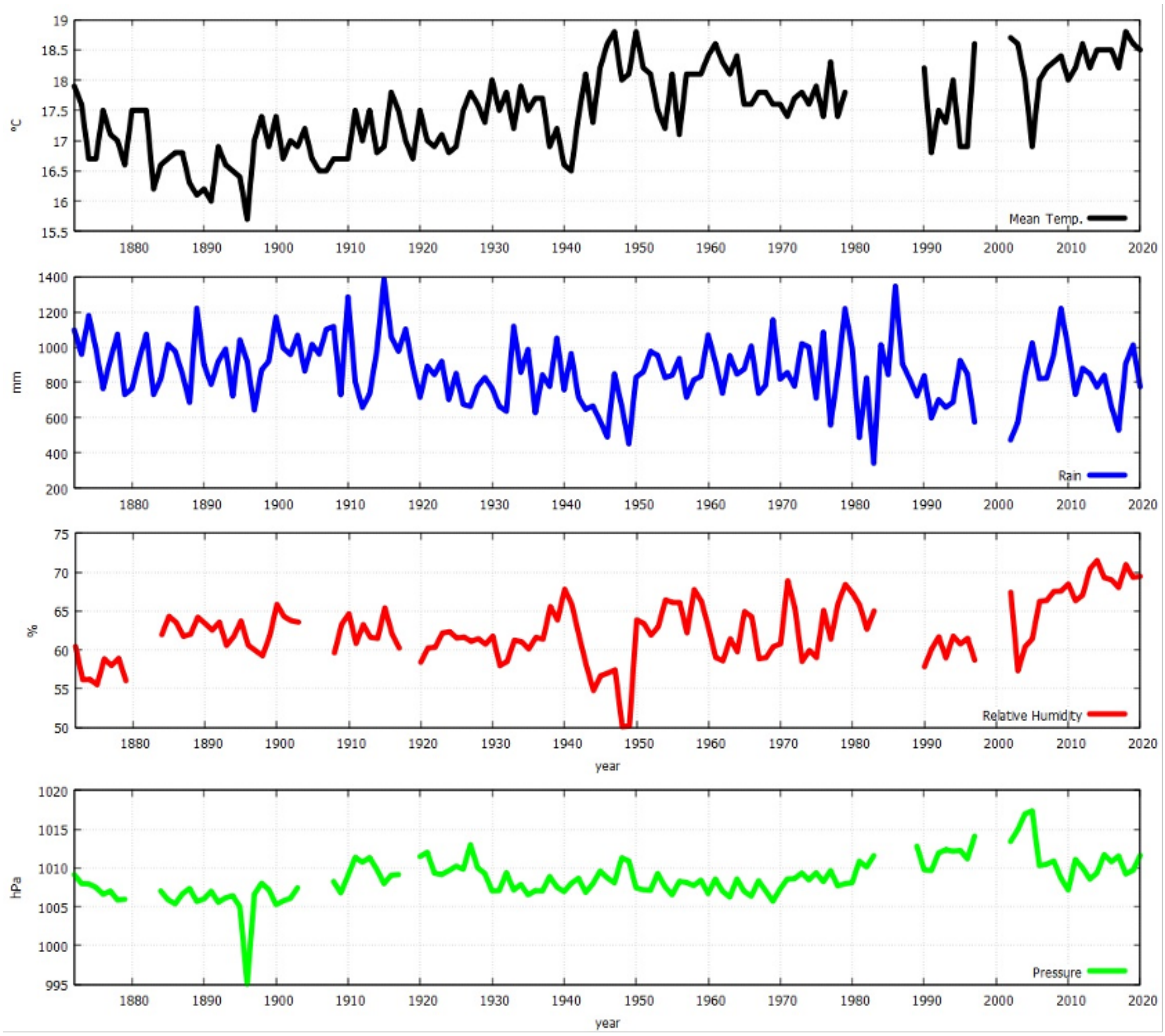

Figure 2: Annual mean of the main meteorological records collected at the historic sites of the Meteorological Observatory of San Marcellino.

currently available only on paper and published as *Dati Meteorologici dell'Universiità degli Studi di Napoli Federico II* prepared by Gennaro Scarano and published by the *Dipartimento di Geofisica e Vulcanologia*. The digitization of the data were conducted by the students Alessandro Gambardella and Mauro Rea during their internship in meteorology and climatology.

Bulletin 1990: details

This bulletin contains the results of the meteorological observations, relating to the period 1 January 1990 - 31 December 1990 carried out at the Meteorological Observatory of the Department of Earth Sciences, Environment and Georesources (former department of Geophysics and Volcanology) of the University of Naples "Federico II" located in Largo San Marcellino in the Historic Center of Naples.

The coordinates of the station are: Lat. 40 ° 50'48 '' North Long. 14°15'31 '' East, Altitude 50 m a.s.l.

The data were obtained by means of a SIAP automatic station equipped with the following sensors:

- TM7720 temperature 830111 (°C);
- atmospheric pressure PA 5750 N.952100 (units mmHg; 1 mmHg = 1333 hPa);
- relative humidity UM 9730 N.932026 (units %);
- wind speed VT 7705 N.900721 (m/s);
- wind direction VT7710 N.901662;
- precipitation Mod. UM 7515 N.967069 (mm);
- solar radiation Mod. SO 3700 N.871218 (Langley/min; 1 Langley/min = 697.8 W/m^2).

The data were acquired every 30 minutes and sampled on an IBM PS / 2 MOD Personal Computer 8560/41.

Annual weather report

From the analysis of all the weather parameters of the year 1990 the following emerges:

(a) the average monthly air temperature oscillates between 9.7 °C in December and 26.9 °C in July, with an annual average of 18.2 °C, with an absolute minimum of 3.0 °C recorded on December 27 and with an absolute maximum 34.8 °C recorded on July 22;

(b) the monthly average relative humidity oscillates between 51.3% in May and 67.3% in October, with an annual average of 57.8%, with an absolute minimum of 14.5% recorded on January 31 and with an absolute maximum of 92.6% recorded on February 26;

(c) the monthly average atmospheric pressure oscillates between 754.7 mmHg in April and 766.8 mmHg in January, with an annual average of 759.2 mmHg, with an absolute minimum of 732.4 mmHg recorded on February 26 and with an absolute maximum of 775.2 mmHg recorded on February 11 and 12;

(d) the monthly average wind intensity oscillates between 1.8 m/s in January and September and 2.7 m/s in November, with an annual average of 2.2 m/s and with the most intense gust of 23.6 m/s recorded on December 9;

(e) the wind direction presents a main orientation from the South in January, February, March, May, June, July, August, September, October, November and December and from the South-West in April;

(f) the monthly cumulative rainfall oscillates between 0 mm in June and 192.2 mm in April, with a cumulative annual value of 794.0 mm and with an absolute daily maximum of 66.4 mm recorded on April 29.

(g) the solar radiation was missing in January, February, March April and December.

Monthly weather reports

January

Average monthly temperature: 10.2 °C; Maximum average temperature 11.6 °C on day 11; Minimum average temperature 7.7 °C. on day 26.

Average monthly humidity: 54.6%; Maximum average humidity 70.8% on day 22; Minimum average humidity 30.4% on day 31.

Monthly mean atmospheric pressure: 766.5 mmHg; Maximum mean pressure 771.0 mmHg on day 7; Minimum mean pressure 758.1 mmHg on day 22.

Average monthly wind speed: 1.8 m/s; Maximum average wind 3.5 m/s on day 24; Minimum average wind on day 1.1 m/s on days 10 and 21.

Monthly rainfall: 23.2 mm.

Average solar radiation: N.P.

Maximum temperature: 17.0 °C on day 31; Minimum temperature: 5.8 °C on day 20.

Maximum humidity: 80.3% on day 22; Minimum humidity: 14.5% on day 31.

Maximum atmospheric pressure: 772.4 mmHg on day 7; Minimum pressure: 756.3 mmHg on day 22.

Maximum wind: 9.8 m/s on day 2.

Maximum rainfall: 18.6 mm on day 22.

February

Average monthly temperature: 11.6 °C; Maximum average temperature 14.6 °C on day 24; Minimum average temperature 9.1 °C. on day 16.

Average monthly humidity: 56.7%; Maximum average humidity 76.6% on day 25; Minimum average humidity 37.3% on day 14.

Monthly mean atmospheric pressure: 763.4 mmHg; Maximum mean pressure 773.9 mmHg on day 12; Minimum mean pressure 736.6 mmHg on day 26.

Average monthly wind speed: 2.3 m/s; Maximum average wind 5.4 m/s on days 26 and 27; Minimum average wind on day 1.0 m/s on day 21.

Monthly rainfall: 75.2 mm.

Average solar radiation: N.P.

Maximum temperature: 18.4 °C on day 24; Minimum temperature: 5.5 °C on day 16.

Maximum humidity: 92.6% on day 26; Minimum humidity: 14.8% on day 14.

Maximum atmospheric pressure: 775.2 mmHg on days 11 and 12; Minimum pressure: 732.4 mmHg on day 26.

Maximum wind: 17.2 m/s on day 26.

Maximum rainfall: 33.4 mm on day 26.

March

Average monthly temperature: 15.0 °C; Maximum average temperature 19.3 °C on day 31; Minimum average temperature 11.6 °C. on day 9.

Average monthly humidity: 54.1%; Maximum average humidity 76.1% on day 3; Minimum average humidity 29.6% on day 25.

Monthly mean atmospheric pressure: 758.3 mmHg; Maximum mean pressure 764.4 mmHg on day 30; Minimum mean pressure 749.3 mmHg on day 21.

Average monthly wind speed: 2.2 m/s; Maximum average wind 4.1 m/s on day 24; Minimum average wind on day 1.2 m/s on day 18.

Monthly rainfall: 26.6 mm.

Average solar radiation: N.P.

Maximum temperature: 25.5 °C on day 31; Minimum temperature: 8.9 °C on day 8.

Maximum humidity: 87.9% on day 1; Minimum humidity: 19.7% on day 26.

Maximum atmospheric pressure: 765.4 mmHg on day 30; Minimum pressure: 748.1 mmHg on day 21.

Maximum wind: 10.6 m/s on day 24.

Maximum rainfall: 18.8 mm on day 9.

April

Average monthly temperature: 16.1 °C; Maximum average temperature 20.1 °C on day 26; Minimum average temperature 11.9 °C. on days 14 and 29.

Average monthly humidity: 55.7%; Maximum average humidity 75.4% on day 29; Minimum average humidity 36.8% on day 10.

Monthly mean atmospheric pressure: 754.7 mmHg; Maximum mean pressure 762.3 mmHg on day 7; Minimum mean pressure 747.2 mmHg on day 13.

Average monthly wind speed: 2.5 m/s; Maximum average wind 4.5 m/s on day 5; Minimum average wind on day 1.4 m/s on day 10.

Monthly rainfall: 192.2 mm.

Average solar radiation: N.P.

Maximum temperature: 25.7 °C on day 10; Minimum temperature: 9.3 °C on day 18.

Maximum humidity: 88.2% on day 17; Minimum humidity: 20.9% on day 25.

Maximum atmospheric pressure: 763.8 mmHg on day 7; Minimum pressure: 744.6 mmHg on day 4.

Maximum wind: 15.8 m/s on day 3.

Maximum rainfall: 66.4 mm on day 29.

May

Average monthly temperature: 19.5 °C; Maximum average temperature 23.0 °C on day 12; Minimum average temperature 13.4 °C. on days 1 and 2.

Average monthly humidity: 51.3%; Maximum average humidity 66.9% on day 14; Minimum average humidity 32.6% on day 8.

Monthly mean atmospheric pressure: 759.0 mmHg; Maximum mean pressure 761.0 mmHg on day 30; Minimum mean pressure 752.2 mmHg on day 13.

Average monthly wind speed: 2.2 m/s; Maximum average wind 3.3 m/s on day 24; Minimum average wind on day 1.4 m/s on day 11.

Monthly rainfall: 26.8 mm.

Average solar radiation: 0.4

Maximum temperature: 28.5 °C on day 12; Minimum temperature: 10.5 °C on day 2.

Maximum humidity: 85.7% on day 31; Minimum humidity: 22.0% on day 7.

Maximum atmospheric pressure: 761.6 mmHg on days 19 and 25; Minimum pressure: 750.7 mmHg on days 12 and 13.

Maximum wind: 9.6 m/s on days 21 and 23.

Maximum rainfall: 14.0 mm on day 1.

June

Average monthly temperature: 24.3 °C; Maximum average temperature 28.3 °C on day 26; Minimum average temperature 20.8 °C. on days 1 and 3.

Average monthly humidity: 56.9%; Maximum average humidity 68.7% on day 8; Minimum average humidity 33.6% on day 1.

Monthly mean atmospheric pressure: 757.6 mmHg; Maximum mean pressure 761.9 mmHg on day 1; Minimum mean pressure 751.4 mmHg on day 4.

Average monthly wind speed: 2.1 m/s; Maximum average wind 3.4 m/s on day 9; Minimum average wind on day 1.3 m/s on days 19 and 20.

Monthly rainfall: 0.0 mm.

Average solar radiation: 0.4

Maximum temperature: 33.0 °C on day 26; Minimum temperature: 16.1 °C on day 1.

Maximum humidity: 87.1% on day 7; Minimum humidity: 25.3% on day 1.

Maximum atmospheric pressure: 762.9 mmHg on day 1; Minimum pressure: 748.2 mmHg on day 4.

Maximum wind: 10.1 m/s on day 12.

Maximum rainfall: 0.0 mm.

July

Average monthly temperature: 26.9 °C; Maximum average temperature 29.3 °C on days 28 and 29; Minimum average temperature 24.8 °C. on day 6.

Average monthly humidity: 56.4%; Maximum average humidity 73.8% on day 24;

Minimum average humidity 37.3% on day 22.

Monthly mean atmospheric pressure: 757.8 mmHg; Maximum mean pressure 761.4 mmHg on day 29; Minimum mean pressure 755.2 mmHg on day 2.

Average monthly wind speed: 1.9 m/s; Maximum average wind 2.8 m/s on day 19; Minimum average wind on day 1.1 m/s on day 30.

Monthly rainfall: 1.1 mm.

Average solar radiation: 0.4 Langley/min.

Maximum temperature: 34.8 °C on day 22; Minimum temperature: 21.8 °C on day 20.

Maximum humidity: 86.9% on day 23; Minimum humidity: 27.5% on day 8.

Maximum atmospheric pressure: 762.2 mmHg on day 29; Minimum pressure: 754.7 mmHg on days 2 and 4.

Maximum wind: 8.3 m/s on day 19.

Maximum rainfall: 1.1 mm on day 31.

August

Average monthly temperature: 26.3 °C; Maximum average temperature 29.7 °C on day 3; Minimum average temperature 20.8 °C. on day 22.

Average monthly humidity: 56.1%; Maximum average humidity 74.5% on day 21; Minimum average humidity 38.1% on day 10.

Monthly mean atmospheric pressure: 759.1 mmHg; Maximum mean pressure 761.5 mmHg on day 24; Minimum mean pressure 756.9 mmHg on day 22.

Average monthly wind speed: 1.9 m/s; Maximum average wind 3.6 m/s on day 22; Minimum average wind on day 1.3 m/s on day 31.

Monthly rainfall: 59.4 mm.

Average solar radiation: 0.4 Langley/min.

Maximum temperature: 34.4 °C on day 4; Minimum temperature: 18.3 °C on day 22.

Maximum humidity: 90.0% on day 7; Minimum humidity: 28.0% on day 5.

Maximum atmospheric pressure: 762.6 mmHg on day 24; Minimum pressure: 754.5 mmHg on day 22.

Maximum wind: 12.0 m/s on day 23.

Maximum rainfall: 32.6 mm on day 8.

September

Average monthly temperature: 23.3 °C; Maximum average temperature 25.8 °C on day 2; Minimum average temperature 20.3 °C. on day 29.

Average monthly humidity: 61%; Maximum average humidity 74% on days 18 and 23; Minimum average humidity 39% on day 28.

Monthly mean atmospheric pressure: 758.9 mmHg; Maximum mean pressure 764.9 mmHg on day 29; Minimum mean pressure 753.8 mmHg on day 21.

Average monthly wind speed: 1.8 m/s; Maximum average wind 3.3 m/s on days 24 and 28; Minimum average wind on day 1.1 m/s on day 30.

Monthly rainfall: 54.0 mm.

Average solar radiation: 0.3 Langley/min.

Maximum temperature: 29.8 °C on day 26; Minimum temperature: 16.3 °C on day 29.

Maximum humidity: 88.8% on day 18; Minimum humidity: 26.3% on day 28.

Maximum atmospheric pressure: 765.8 mmHg on day 29; Minimum pressure: 752.5 mmHg on day 21.

Maximum wind: 8.0 m/s on day 5.

Maximum rainfall: 33.4 mm on day 18.

October

Average monthly temperature: 20.9 °C; Maximum average temperature 25.9 °C on day 14; Minimum average temperature 15.5 °C. on day 23.

Average monthly humidity: 67.3%; Maximum average humidity 83.0% on day 31; Minimum average humidity 45.5% on day 25.

Monthly mean atmospheric pressure: 758.3 mmHg; Maximum mean pressure 764.8 mmHg on day 12; Minimum mean pressure 748.6 mmHg on day 29.

Average monthly wind speed: 2.0 m/s; Maximum average wind 3.5 m/s on day 9; Minimum average wind on day 1.1 m/s on day 2.

Monthly rainfall: 143.5 mm.

Average solar radiation: 0.2 Langley/min.

Maximum temperature: 30.8 °C on day 14; Minimum temperature: 12.5 °C on day 23.

Maximum humidity: 91.2% on day 31; Minimum humidity: 34.2% on day 13.

Maximum atmospheric pressure: 765.5 mmHg on day 12; Minimum pressure: 746.1 mmHg on day 29.

Maximum wind: 11.6 m/s on day 29.

Maximum rainfall: 46.6 mm on day 7.

November

Average monthly temperature: 15.1 °C; Maximum average temperature 20.8 °C on day 1; Minimum average temperature 11.3 °C. on day 8.

Average monthly humidity: 61.8%; Maximum average humidity 77.7% on day 1; Minimum average humidity 43.4% on day 8.

Monthly mean atmospheric pressure: 758.4 mmHg; Maximum mean pressure 766.0 mmHg on day 10; Minimum mean pressure 752.6 mmHg on day 31.

Average monthly wind speed: 2.7 m/s; Maximum average wind 6.3 m/s on day 23; Minimum average wind on day 1.5 m/s on day 19.

Monthly rainfall: 96.0 mm.

Average solar radiation: 0.2 Langley/min.

Maximum temperature: 23.1 °C on day 1; Minimum temperature: 7.4 °C on day 28.

Maximum humidity: 85.7% on day 1; Minimum humidity: 28.3% on day 6.

Maximum atmospheric pressure: 767.3 mmHg on day 11; Minimum pressure: 749.3 mmHg on day 30.

Maximum wind: 11.7 m/s on day 22, 23 and 24.

Maximum rainfall: 18.8 mm on day 27.

December

Average monthly temperature: 9.7 °C; Maximum average temperature 15.7 °C on day 9; Minimum average temperature 6.0 °C. on the days 2, 3 and 7.

Average monthly humidity: 62.2%; Maximum average humidity 74.8% on the days 28 and 31; Minimum average humidity 44.7% on the days 1 and 6.

Monthly mean atmospheric pressure: 758.5 mmHg; Maximum mean pressure 770.0 mmHg on day 30; Minimum mean pressure 740.5 mmHg on day 13.

Average monthly wind speed: 2.7 m/s; Maximum average wind 10.2 m/s on day 9; Minimum average wind on day 0.8 m/s on day 31.

Monthly rainfall: 96.0 mm.

Average solar radiation: N.P.

Maximum temperature: 17.7 °C on the days 9 and 10; Minimum temperature: 3.0 °C on day 27.

Maximum humidity: 86.9% on day 10; Minimum humidity: 33.3% on day 6.

Maximum atmospheric pressure: 771.4 mmHg on day 11; Minimum pressure: 737.8 mmHg on day 13.

Maximum wind: 23.6 m/s on day 9.

Maximum rainfall: 17.6 mm on day 24.

Conclusion

The attached file contains the tables and figures collecting daily meteorological data for each month for the year 1990. The reported observables are:

- Temperature - mean, max and min;
- Relative Humidity - mean, max and min;
- Atmospheric pressure - mean, max ans min; Wind - mean speed, mean direction, maximum speed;
- Solar radiation;
- Rain.

The meteorological records are provided for general use.

Author contributions

Collection of data: A.G. and M.R.; Writing – original draft (in Italian): A.G. and M.R.; Writing – final draft preparation (in English): N.S. Figures and Tables curation: N.S.; Checked the data and the final draft: R.V.

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ISSN 2724-4393.

Supplementary material: The annual summary of meteorological data for the year 1990 and collecting daily meteorological data for each month for the year 1990.

Each data set consisted of two tables and a six-paneled figures:

Table A: Mean temperature; Mean relative humidity; mean atmospheric pressure; mean wind speed and direction; solar radiation; rain.

Table B: Min and max temperature; min and max relative humidity; min and max atmospheric pressure; max wind speed.

Figure: ***panel 1***, temperature - mean, max and min; ***panel 2***, relative humidity - mean, max and min; ***panel 3***, atmospheric pressure - mean, max ans min; ***panel 4***, wind - mean speed, maximum speed; ***panel 5***, rain; ***panel 6***, wind direction.

Annual Means

Table A

Monthly Means

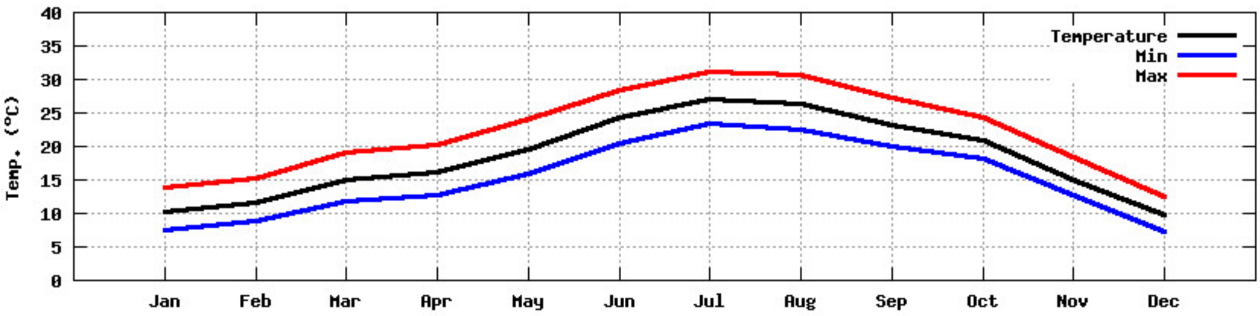
Month	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
Jan	10.2	54.6	766.5	1.8	177	NP	23.2
Feb	11.6	56.7	763.4	2.3	195	NP	75.2
Mar	15.0	54.1	758.3	2.2	178	NP	26.6
Apr	16.1	55.7	754.7	2.5	206	NP	192.2
May	19.5	51.3	759.0	2.2	175	0.4	26.8
Jun	24.3	56.9	757.6	2.1	196	0.4	0.0
Jul	26.9	56.4	757.8	1.9	178	0.4	1.1
Aug	26.3	56.1	759.1	1.9	167	0.4	59.4
Sep	23.3	61.0	758.9	1.8	180	0.3	54.0
Oct	20.9	67.3	758.3	2.0	180	0.2	143.5
Nov	15.1	61.8	758.4	2.7	196	0.2	96.0
Dec	9.7	62.2	758.5	2.7	182	NP	96.0
mean	18.3	57.9	759.2	2.2	184	NP	66.2
max	26.9	67.3	766.5	2.7	206	NP	192.2
min	9.7	51.3	754.7	1.8	167	NP	0.0
sum							794.0

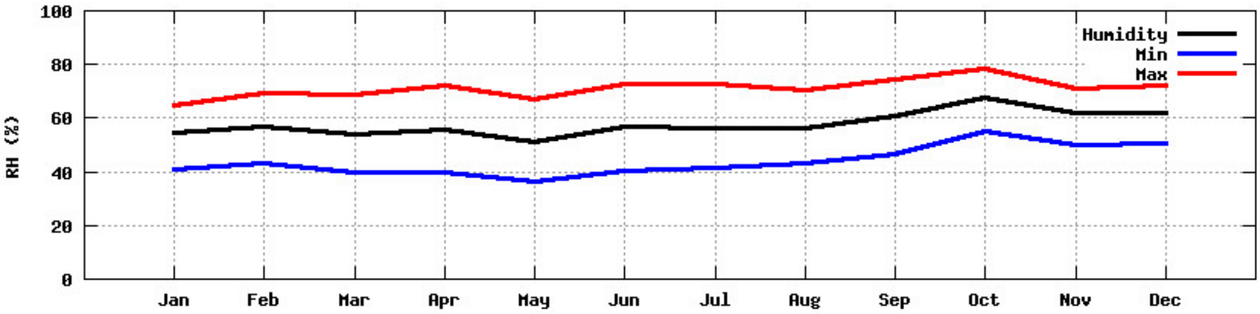
Table B

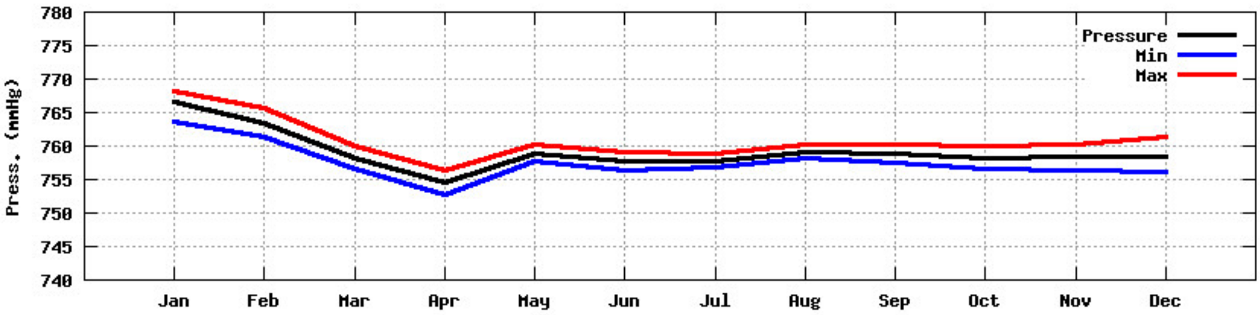
daily extreme

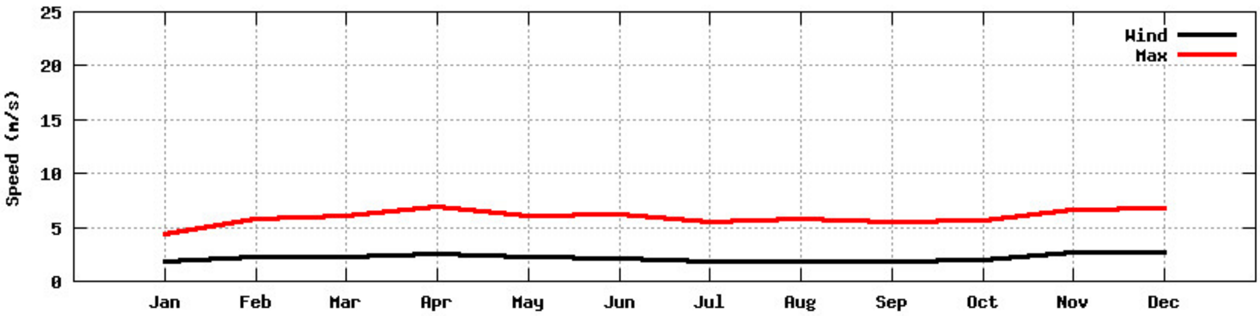
Month	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
Jan	5.8	17.0	14.5	80.3	756.3	772.4	9.8
Feb	5.5	18.4	14.8	92.6	732.4	775.2	17.2
Mar	8.9	25.5	19.7	87.9	748.1	765.4	10.6
Apr	9.3	25.7	20.9	88.2	744.6	763.8	15.8
May	10.5	28.5	22.0	85.7	750.7	761.6	9.6
Jun	16.1	33.0	25.3	87.1	748.2	762.9	10.1
Jul	21.8	34.8	27.5	86.9	754.7	762.2	8.3
Aug	18.3	34.4	28.0	90.0	754.5	762.6	12.0
Sep	16.3	29.8	26.3	88.8	752.5	765.8	8.0
Oct	12.5	30.8	34.2	91.2	746.1	765.5	11.6
Nov	7.4	23.1	28.3	85.7	749.3	767.3	11.7
Dec	3.0	17.7	33.3	86.9	737.8	771.4	23.6
mean	11.3	26.6	24.6	87.6	747.9	766.3	12.4
max	21.8	34.8	34.2	92.6	756.3	775.2	23.6
min	3.0	17.0	14.5	80.3	732.4	761.6	8.0

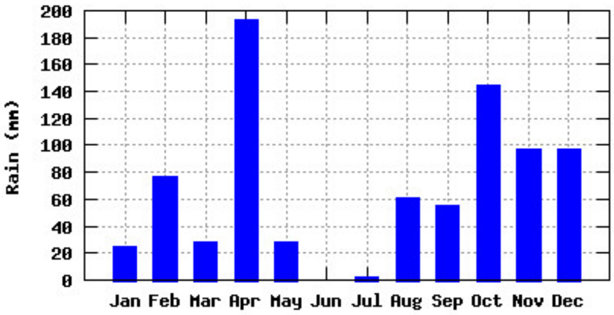
Annual Means

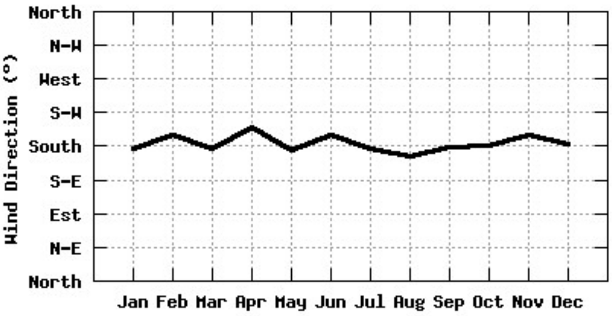












January

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
1/1/1990	10.5	47.6	767.1	1.6	217	NP	0
1/2/1990	10.6	41.0	767.8	3.0	120	NP	0
1/3/1990	9.0	43.9	768.1	3.2	91	NP	0
1/4/1990	9.2	44.4	770.2	2.1	220	NP	0.2
1/5/1990	9.9	55.9	770.2	1.6	170	NP	0
1/6/1990	9.9	62.7	770.2	1.5	220	NP	0
1/7/1990	10.3	62.6	771.0	1.4	222	NP	0
1/8/1990	10.8	56.3	767.7	1.8	203	NP	0
1/9/1990	10.6	68.1	767.7	1.5	210	NP	0
1/10/1990	11.5	64.8	767.8	1.1	116	NP	0
1/11/1990	11.6	58.8	766.4	1.5	121	NP	0
1/12/1990	10.8	56.3	767.5	1.5	204	NP	0
1/13/1990	10.4	64.0	767.5	1.4	167	NP	0.2
1/14/1990	10.8	59.0	767.5	1.2	199	NP	0
1/15/1990	10.0	62.4	767.7	1.2	143	NP	0
1/16/1990	10.2	60.3	767.4	1.4	173	NP	0
1/17/1990	11.1	65.9	767.1	1.5	226	NP	0
1/18/1990	10.7	57.4	765.0	1.5	145	NP	0
1/19/1990	10.1	53.0	764.6	1.6	231	NP	0
1/20/1990	9.8	50.5	765.5	1.5	156	NP	0
1/21/1990	10.3	57.9	763.8	1.1	156	NP	0
1/22/1990	10.0	70.8	758.1	1.5	140	NP	18.6
1/23/1990	10.3	59.3	759.1	3.1	62	NP	4.2
1/24/1990	11.1	47.1	761.2	3.5	161	NP	0
1/25/1990	9.4	45.6	762.5	2.5	193	NP	0
1/26/1990	7.7	52.1	765.1	2.1	242	NP	0
1/27/1990	9.7	50.3	767.8	1.5	209	NP	0
1/28/1990	9.3	53.4	767.2	1.6	212	NP	0
1/29/1990	9.3	47.1	766.7	1.9	172	NP	0
1/30/1990	10.1	43.6	768.4	2.3	223	NP	0
1/31/1990	11.2	30.4	768.9	1.7	166	NP	0
mean	10.2	54.6	766.5	1.8	177	NP	1
max	11.6	70.8	771.0	3.5	242	NP	18.6
min	7.7	30.4	758.1	1.1	62	NP	0.0
cum							23.2

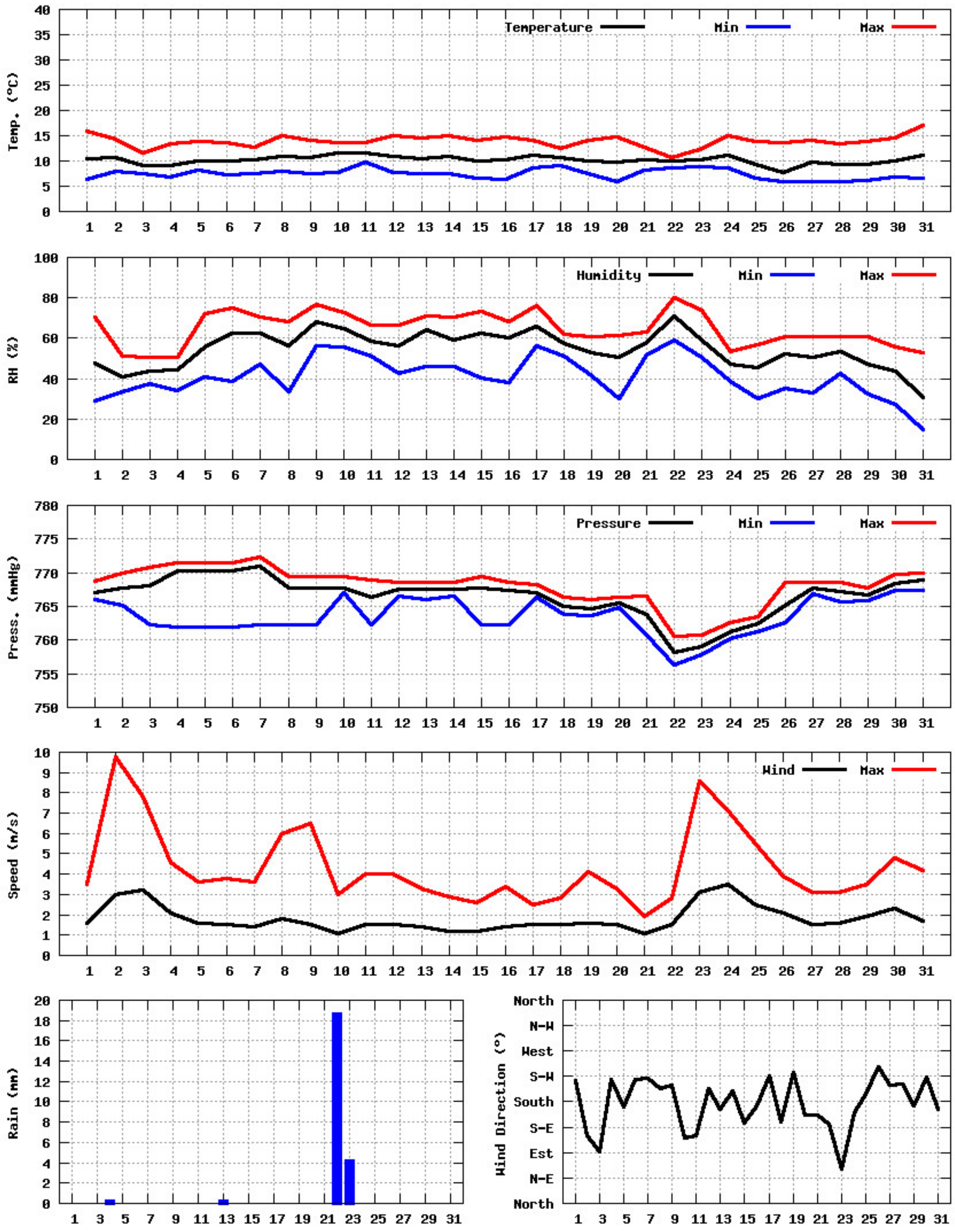
January

Table B

daily extreme

Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
1/1/1990	6.3	15.8	28.7	70.6	766.0	768.8	3.5
1/2/1990	8.0	14.3	33.5	51.4	765.1	769.9	9.8
1/3/1990	7.5	11.7	37.7	50.3	762.3	770.8	7.8
1/4/1990	6.8	13.3	33.9	50.5	762.0	771.4	4.6
1/5/1990	8.2	13.8	40.8	72.2	762.0	771.4	3.6
1/6/1990	7.3	13.6	38.9	75.0	762.0	771.4	3.8
1/7/1990	7.5	12.7	46.9	70.6	762.3	772.4	3.6
1/8/1990	7.9	15.0	33.8	67.9	762.3	769.5	6.0
1/9/1990	7.4	14.1	56.2	76.7	762.3	769.5	6.5
1/10/1990	7.8	13.7	55.8	72.9	767.0	769.5	3.0
1/11/1990	9.7	13.6	51.0	66.7	762.3	769.0	4.0
1/12/1990	7.7	14.9	42.7	66.3	766.5	768.6	4.0
1/13/1990	7.5	14.5	45.9	71.3	766.0	768.6	3.3
1/14/1990	7.6	15.0	45.9	70.3	766.5	768.6	2.9
1/15/1990	6.7	14.1	40.5	73.3	762.3	769.5	2.6
1/16/1990	6.3	14.8	38.2	68.1	762.2	768.5	3.4
1/17/1990	8.6	14.2	56.5	76.2	766.3	768.2	2.5
1/18/1990	9.1	12.4	51.3	61.7	763.8	766.3	2.8
1/19/1990	7.4	14.2	41.5	60.8	763.6	766.0	4.1
1/20/1990	5.8	14.8	30.2	61.3	764.8	766.4	3.3
1/21/1990	8.1	12.8	51.9	63.2	760.8	766.5	1.9
1/22/1990	8.7	10.6	59.1	80.3	756.3	760.5	2.8
1/23/1990	8.8	12.2	50.5	74.0	757.8	760.8	8.6
1/24/1990	8.7	14.9	38.5	53.5	760.2	762.6	7.1
1/25/1990	6.5	13.9	30.3	56.7	761.3	763.5	5.5
1/26/1990	5.9	13.6	35.2	60.7	762.6	768.6	3.9
1/27/1990	5.9	14.0	32.8	60.7	766.8	768.6	3.1
1/28/1990	5.9	13.4	42.7	60.7	765.7	768.6	3.1
1/29/1990	6.2	13.8	32.6	60.8	765.8	767.7	3.5
1/30/1990	6.9	14.6	27.5	55.7	767.4	769.8	4.8
1/31/1990	6.6	17.0	14.5	53.1	767.4	769.9	4.2
mean	7.4	13.9	40.8	65.0	763.5	768.1	4.3
max	9.7	17.0	59.1	80.3	767.4	772.4	9.8
min	5.8	10.6	14.5	50.3	756.3	760.5	1.9

January


Temp. (°C)
Temperature
Min
Max
0 5 10 15 20 25 30 35 40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
RH (%)
Humidity
Min
Max
0 20 40 60 80 100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Press. (mmHg)
Pressure
Min
Max
750 755 760 765 770 775 780
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Speed (m/s)
Wind
Max
0 1 2 3 4 5 6 7 8 9 10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Rain (mm)
0 2 4 6 8 10 12 14 16 18 20
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Wind Direction (°)
North
N-W
West
S-W
South
S-E
Est
N-E
North
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31

February

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
2/1/1990	11.3	41.8	772.1	1.4	211	NP	0.0
2/2/1990	11.6	65.4	771.0	1.4	195	NP	0.0
2/3/1990	11.5	66.4	770.8	1.5	229	NP	0.0
2/4/1990	10.9	63.4	770.2	1.5	192	NP	0.0
2/5/1990	10.9	65.8	769.7	1.1	229	NP	0.0
2/6/1990	11.3	47.9	771.2	2.5	170	NP	0.0
2/7/1990	12.0	42.0	769.9	2.4	112	NP	0.0
2/8/1990	11.3	49.2	767.3	1.5	194	NP	0.0
2/9/1990	11.5	56.1	764.4	1.4	195	NP	0.0
2/10/1990	11.9	43.9	767.4	2.3	170	NP	0.0
2/11/1990	11.8	45.4	772.9	2.6	116	NP	4.4
2/12/1990	10.9	52.7	773.9	1.9	201	NP	0.0
2/13/1990	10.9	63.8	766.9	1.3	181	NP	0.0
2/14/1990	9.5	37.3	760.8	2.5	150	NP	0.0
2/15/1990	9.3	39.3	760.8	3.9	74	NP	0.0
2/16/1990	9.1	38.6	762.7	2.2	238	NP	0.0
2/17/1990	11.4	54.5	763.3	1.6	206	NP	0.0
2/18/1990	11.9	55.1	765.8	1.4	191	NP	0.0
2/19/1990	12.0	66.5	769.8	1.2	213	NP	0.0
2/20/1990	12.2	71.5	769.8	1.4	295	NP	0.0
2/21/1990	12.1	67.7	766.0	1.0	180	NP	0.0
2/22/1990	12.4	67.5	763.4	1.3	142	NP	0.0
2/23/1990	13.6	64.6	759.8	1.4	202	NP	0.0
2/24/1990	14.6	60.9	752.2	2.9	191	NP	0.0
2/25/1990	13.1	76.6	742.8	5.0	204	NP	14.2
2/26/1990	12.6	69.5	736.6	5.4	233	NP	33.4
2/27/1990	11.5	55.3	743.2	5.4	287	NP	15.8
2/28/1990	12.8	59.3	750.2	3.8	264	NP	7.4
mean	11.6	56.7	763.4	2.3	195	NP	2.7
max	14.6	76.6	773.9	5.4	295	NP	33.4
min	9.1	37.3	736.6	1.0	74	NP	0.0
cum							75.2

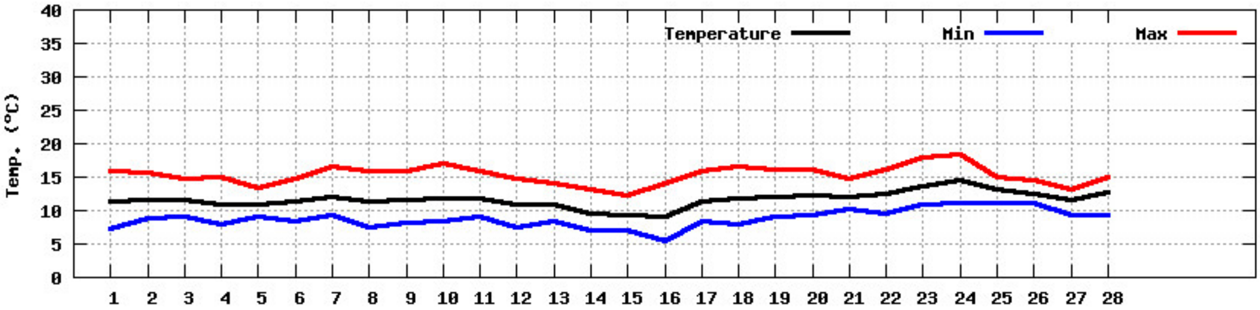
February

Table B

daily extreme

Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
2/1/1990	7.2	15.9	26.7	63.6	770.7	773.6	2.6
2/2/1990	8.8	15.7	54.2	75.0	770.2	772.0	3.8
2/3/1990	9.1	14.7	51.3	78.3	769.6	771.8	4.3
2/4/1990	7.9	15.0	50.3	73.4	769.2	771.1	3.8
2/5/1990	9.1	13.5	56.9	71.1	768.8	770.7	2.2
2/6/1990	8.3	14.7	32.5	68.3	770.4	772.4	4.6
2/7/1990	9.4	16.6	28.8	54.8	768.9	770.8	4.5
2/8/1990	7.4	15.8	35.4	66.7	765.2	769.2	3.3
2/9/1990	8.2	15.9	41.4	74.4	763.3	765.4	3.7
2/10/1990	8.4	17.0	32.2	50.9	765.5	769.9	5.7
2/11/1990	9.0	16.0	31.4	53.8	770.1	775.2	6.1
2/12/1990	7.5	14.8	41.5	65.2	771.7	775.2	4.9
2/13/1990	8.4	14.1	50.4	74.6	763.9	771.5	4.4
2/14/1990	7.1	13.1	14.8	49.1	758.1	763.9	8.3
2/15/1990	7.1	12.2	33.3	45.3	759.5	762.5	9.3
2/16/1990	5.5	14.2	28.9	49.7	761.7	763.8	4.3
2/17/1990	8.5	15.9	43.7	63.1	762.2	764.1	4.6
2/18/1990	8.0	16.6	33.5	67.2	764.1	768.0	3.7
2/19/1990	9.0	16.2	54.9	74.6	768.0	770.8	3.4
2/20/1990	9.4	16.1	58.2	81.0	768.5	771.1	4.2
2/21/1990	10.3	14.7	57.8	78.4	764.5	768.5	2.8
2/22/1990	9.5	16.2	54.8	76.2	762.0	764.8	4.0
2/23/1990	10.8	17.9	42.4	77.3	757.8	762.2	4.2
2/24/1990	11.1	18.4	44.0	80.7	747.8	757.9	7.8
2/25/1990	11.1	15.1	66.4	84.2	739.5	748.7	14.8
2/26/1990	11.1	14.6	51.5	92.6	732.4	739.9	17.2
2/27/1990	9.3	13.2	45.9	69.4	738.6	748.4	12.1
2/28/1990	9.4	14.9	48.6	76.2	748.2	752.6	7.9
mean	8.8	15.3	43.3	69.1	761.4	765.6	5.8
max	11.1	18.4	66.4	92.6	771.7	775.2	17.2
min	5.5	12.2	14.8	45.3	732.4	739.9	2.2

February


Temp. (°C)
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5
10
15
20
25
30
35
40
Temperature
Min
Max
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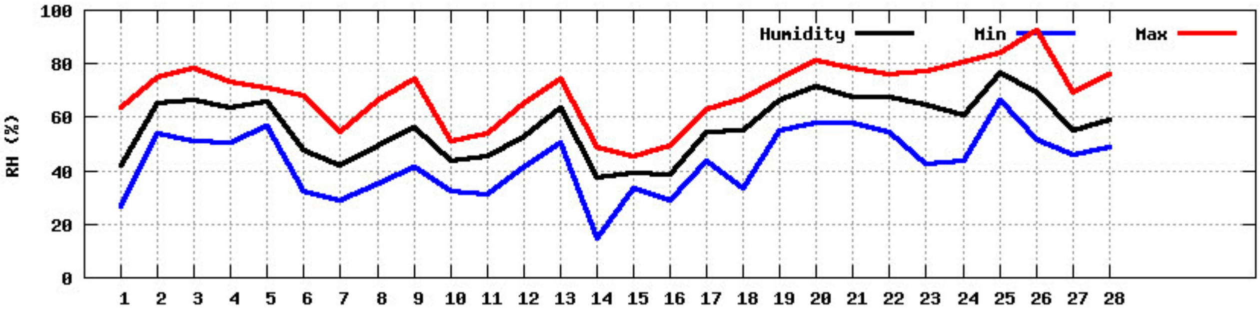
RH (%)
0
20
40
60
80
100
Humidity
Min
Max
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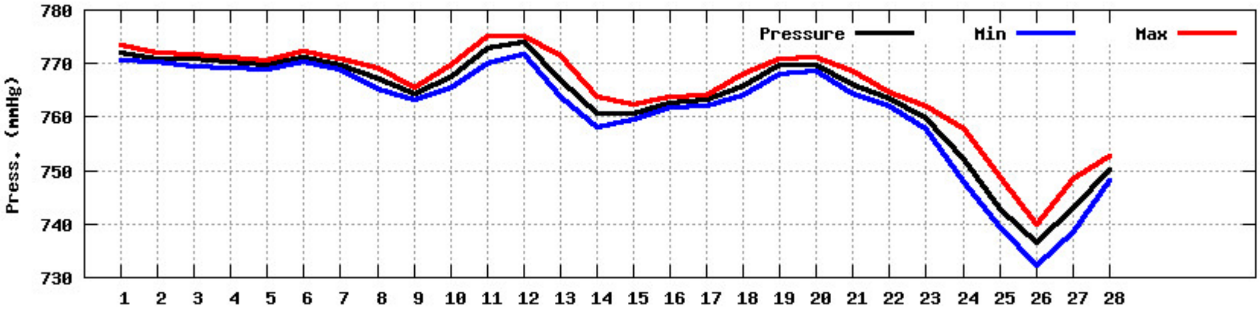
Press. (mmHg)
730
740
750
760
770
780
Pressure
Min
Max
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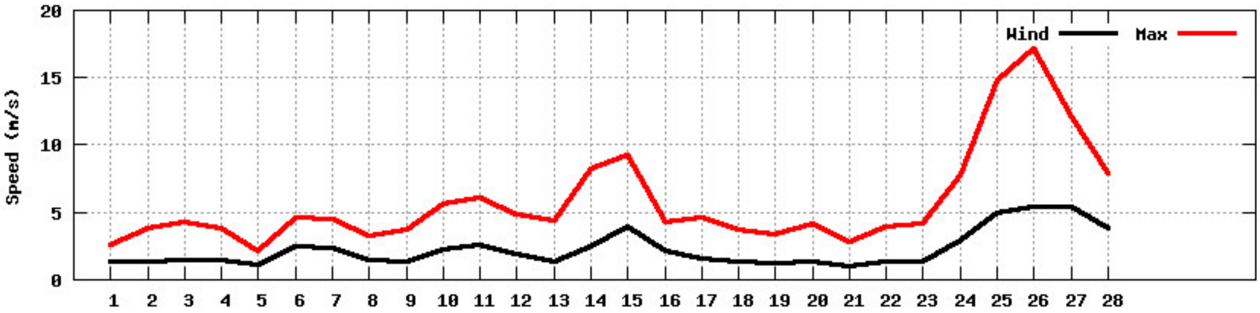
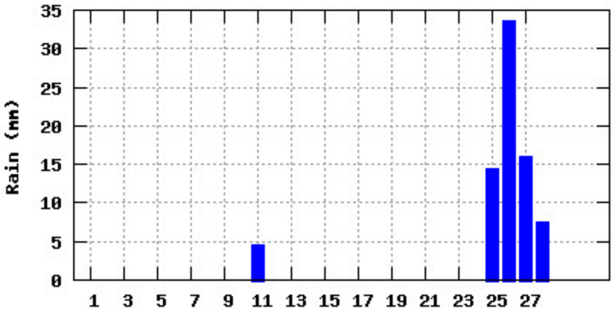
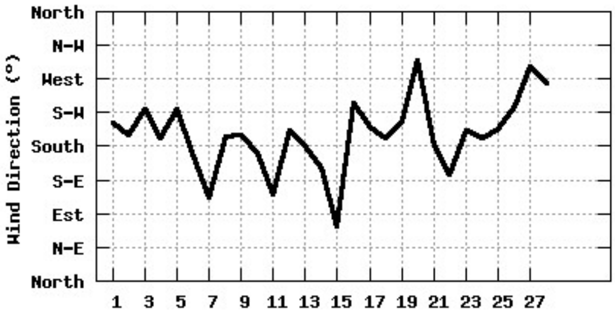

Speed (m/s)
0
5
10
15
20
Wind
Max
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28


Rain (mm)
0
5
10
15
20
25
30
35
1 3 5 7 9 11 13 15 17 19 21 23 25 27


Wind Direction (°)
North
N-W
West
S-W
South
S-E
Est
N-E
North
1 3 5 7 9 11 13 15 17 19 21 23 25 27

March

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
3/1/1990	13.8	75.4	752.9	2.8	237	NP	6.2
3/2/1990	13.1	54.7	757.5	4.0	276	NP	0.0
3/3/1990	13.2	76.1	756.3	3.5	215	NP	0.8
3/4/1990	13.4	52.4	755.0	2.5	173	NP	0.2
3/5/1990	13.3	38.2	762.2	2.8	179	NP	0.0
3/6/1990	12.7	38.2	762.7	2.6	96	NP	0.0
3/7/1990	12.2	42.3	762.1	2.1	189	NP	0.0
3/8/1990	12.5	61.2	760.4	1.9	206	NP	0.0
3/9/1990	11.6	68.3	757.7	2.5	126	NP	18.8
3/10/1990	14.5	52.0	761.7	3.1	98	NP	0.0
3/11/1990	14.8	40.7	762.5	2.5	136	NP	0.0
3/12/1990	15.1	42.9	761.6	2.0	191	NP	0.0
3/13/1990	14.5	65.4	758.3	1.6	170	NP	0.0
3/14/1990	13.9	65.6	757.0	1.4	176	NP	0.0
3/15/1990	14.2	65.3	756.4	1.8	199	NP	0.0
3/16/1990	14.6	65.7	756.4	2.1	217	NP	0.0
3/17/1990	15.0	51.5	755.7	1.5	182	NP	0.0
3/18/1990	16.8	48.5	757.2	1.2	175	NP	0.0
3/19/1990	17.4	57.5	756.1	1.5	179	NP	0.0
3/20/1990	18.1	52.6	751.1	2.8	191	NP	0.0
3/21/1990	16.1	66.4	749.3	2.2	217	NP	0.2
3/22/1990	15.1	63.1	754.8	1.9	183	NP	0.0
3/23/1990	15.0	53.7	755.2	2.6	194	NP	0.0
3/24/1990	14.1	38.7	754.0	4.1	91	NP	0.4
3/25/1990	15.1	29.6	756.2	2.6	226	NP	0.0
3/26/1990	18.6	31.7	759.9	1.9	155	NP	0.0
3/27/1990	16.8	58.1	762.1	1.7	193	NP	0.0
3/28/1990	15.9	71.5	762.9	1.5	175	NP	0.0
3/29/1990	16.8	60.7	763.7	1.5	138	NP	0.0
3/30/1990	17.7	49.4	764.4	1.3	149	NP	0.0
3/31/1990	19.3	39.6	763.1	1.5	179	NP	0.0
mean	15.0	54.1	758.3	2.2	178	NP	0.9
max	19.3	76.1	764.4	4.1	276	NP	18.8
min	11.6	29.6	749.3	1.2	91	NP	0.0
cum							26.6

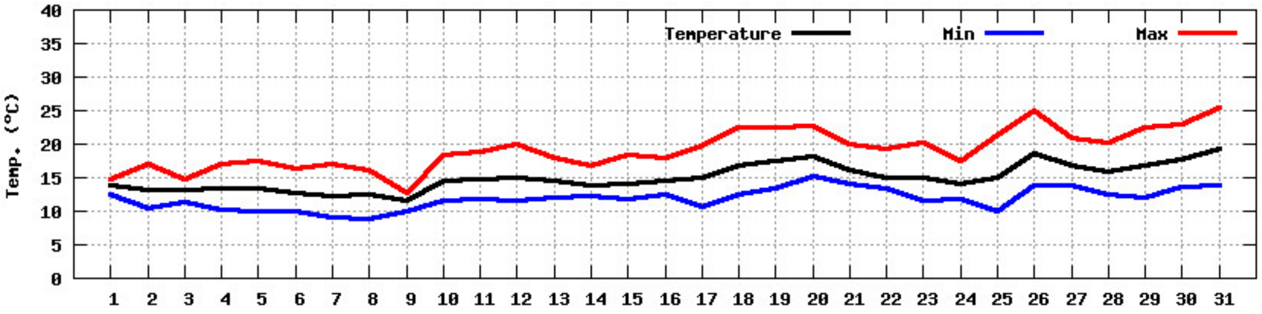
March

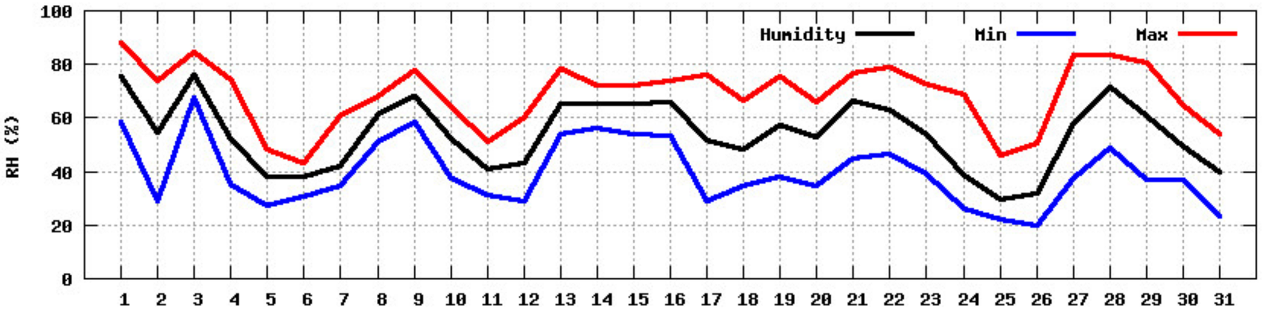
Table B

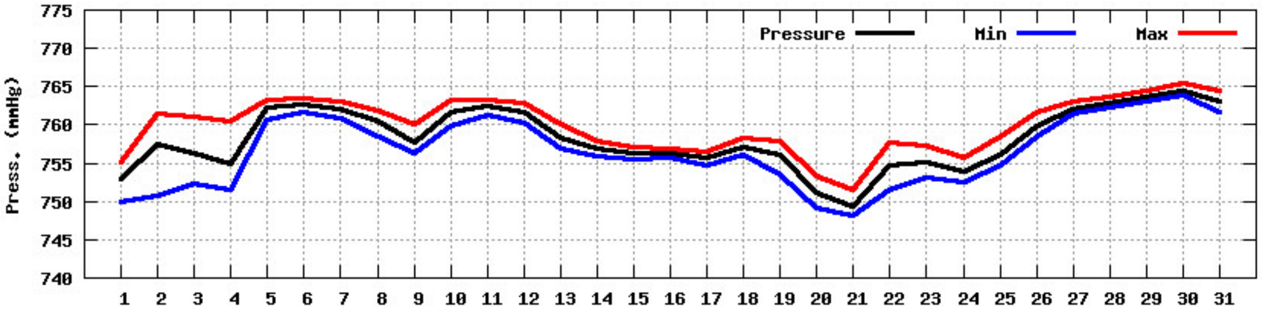
daily extreme

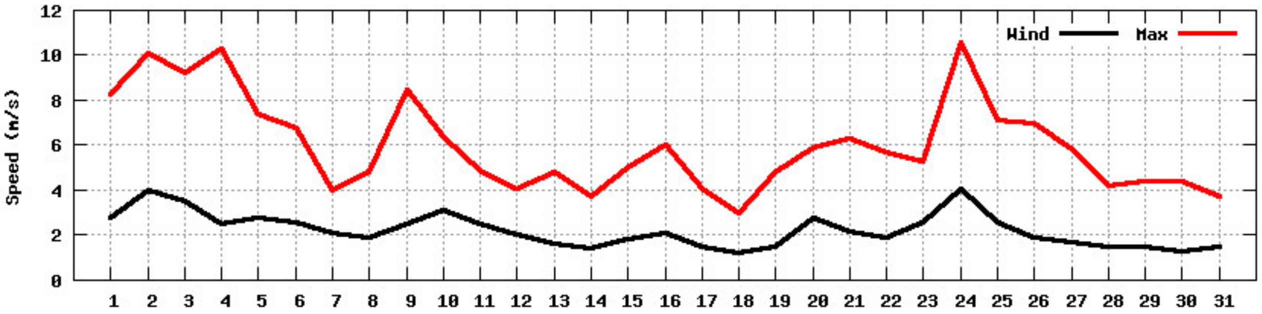
Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
3/1/1990	12.4	14.8	58.5	87.9	749.9	755.1	8.3
3/2/1990	10.5	17.1	28.9	74.1	750.7	761.4	10.1
3/3/1990	11.3	14.8	67.6	84.9	752.4	761.1	9.2
3/4/1990	10.3	17.0	35.3	74.4	751.6	760.4	10.3
3/5/1990	10.0	17.5	27.2	48.2	760.6	763.3	7.4
3/6/1990	10.0	16.3	30.9	43.0	761.7	763.5	6.8
3/7/1990	9.2	17.0	34.9	60.7	760.9	763.0	4.0
3/8/1990	8.9	16.1	51.4	68.4	758.4	761.9	4.8
3/9/1990	10.0	12.8	58.6	77.9	756.3	760.0	8.5
3/10/1990	11.7	18.5	37.4	64.1	759.8	763.2	6.4
3/11/1990	11.9	18.8	31.5	51.2	761.3	763.3	4.9
3/12/1990	11.6	20.1	29.1	60.3	760.3	762.9	4.1
3/13/1990	12.1	17.9	53.7	78.3	757.0	760.1	4.8
3/14/1990	12.2	16.8	56.2	72.2	755.9	757.9	3.7
3/15/1990	11.9	18.3	53.7	72.2	755.6	757.2	5.0
3/16/1990	12.6	18.0	53.4	74.0	755.7	757.0	6.0
3/17/1990	10.7	19.8	29.1	76.3	754.8	756.5	4.1
3/18/1990	12.4	22.5	34.6	66.3	756.2	758.2	3.0
3/19/1990	13.4	22.6	37.9	75.7	753.5	757.9	4.8
3/20/1990	15.3	22.7	34.6	66.1	749.1	753.4	5.9
3/21/1990	14.1	20.0	44.7	76.7	748.1	751.5	6.3
3/22/1990	13.3	19.4	46.8	78.8	751.6	757.6	5.7
3/23/1990	11.7	20.3	39.1	72.9	753.2	757.3	5.3
3/24/1990	11.8	17.5	26.3	68.9	752.5	755.7	10.6
3/25/1990	10.1	21.4	22.0	45.8	754.8	758.5	7.1
3/26/1990	13.9	25.1	19.7	50.3	758.4	761.6	7.0
3/27/1990	13.8	20.9	37.4	83.5	761.4	763.0	5.8
3/28/1990	12.6	20.2	48.8	83.6	762.3	763.6	4.2
3/29/1990	12.1	22.5	37.2	80.6	763.0	764.4	4.4
3/30/1990	13.6	22.9	37.2	65.0	763.8	765.4	4.4
3/31/1990	13.9	25.5	23.2	53.8	761.6	764.4	3.7
mean	11.9	19.2	39.6	68.9	756.5	760.0	6.0
max	15.3	25.5	67.6	87.9	763.8	765.4	10.6
min	8.9	12.8	19.7	43.0	748.1	751.5	3.0

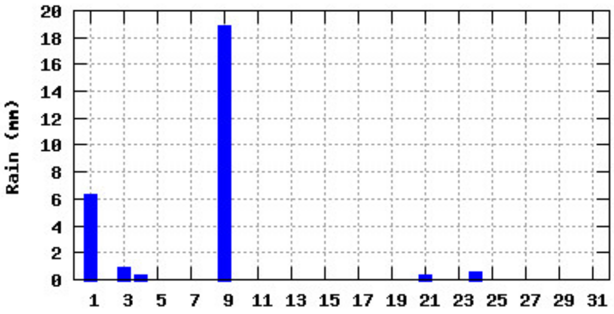
March

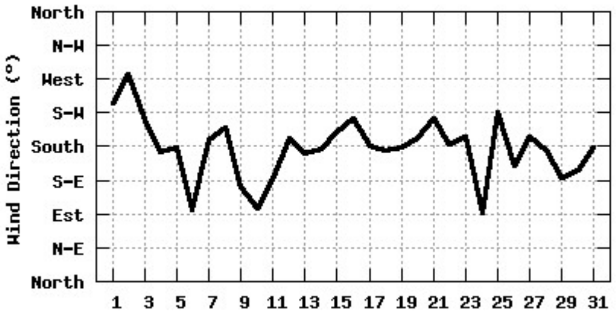

Temp. (°C)
Temperature
Min
Max
0
5
10
15
20
25
30
35
40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


RH (%)
Humidity
Min
Max
0
20
40
60
80
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Press. (mmHg)
Pressure
Min
Max
740
745
750
755
760
765
770
775
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Speed (m/s)
Wind
Max
0
2
4
6
8
10
12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Rain (mm)
0
2
4
6
8
10
12
14
16
18
20
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31


Wind Direction (°)
North
N-W
West
S-W
South
S-E
Est
N-E
North
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31

April

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
4/1/1990	18.4	46.7	758.6	1.6	209	NP	0.0
4/2/1990	16.0	65.7	754.7	2.6	242	NP	0.0
4/3/1990	17.2	54.8	752.4	3.4	172	NP	0.2
4/4/1990	20.0	52.9	748.1	4.0	200	NP	0.0
4/5/1990	16.5	57.9	752.8	4.5	212	NP	0.8
4/6/1990	13.5	59.7	756.1	3.7	254	NP	11.4
4/7/1990	14.8	60.0	762.3	2.1	211	NP	0.2
4/8/1990	15.7	54.9	762.0	1.6	161	NP	0.0
4/9/1990	17.3	43.7	759.6	1.6	173	NP	0.0
4/10/1990	19.7	36.8	755.5	1.4	210	NP	0.0
4/11/1990	18.3	45.8	753.6	3.8	179	NP	1.2
4/12/1990	17.8	57.2	751.6	2.9	203	NP	0.0
4/13/1990	14.3	65.5	747.2	3.9	251	NP	39.8
4/14/1990	11.9	66.4	747.5	2.1	192	NP	46.2
4/15/1990	13.8	60.9	751.5	2.6	244	NP	0.0
4/16/1990	15.7	63.4	754.9	2.7	213	NP	0.0
4/17/1990	15.0	59.3	754.1	3.7	236	NP	2.6
4/18/1990	14.1	55.6	756.7	2.4	189	NP	4.6
4/19/1990	15.3	53.5	759.5	1.7	190	NP	0.0
4/20/1990	16.8	48.5	758.7	1.7	197	NP	0.0
4/21/1990	18.0	51.3	756.9	2.0	218	NP	0.0
4/22/1990	16.5	61.3	757.1	2.4	223	NP	0.0
4/23/1990	14.4	56.8	757.4	1.8	213	NP	13.0
4/24/1990	15.7	49.3	759.0	1.7	177	NP	0.0
4/25/1990	17.9	43.4	756.7	1.5	199	NP	0.0
4/26/1990	20.1	46.1	751.3	2.7	216	NP	0.0
4/27/1990	18.1	61.7	750.4	2.3	204	NP	0.0
4/28/1990	15.5	55.2	751.5	3.1	243	NP	1.6
4/29/1990	11.9	75.4	750.5	1.8	196	NP	66.4
4/30/1990	13.5	62.7	751.3	1.7	161	NP	4.2
mean	16.1	55.7	754.7	2.5	206	NP	6.4
max	20.1	75.4	762.3	4.5	254	NP	66.4
min	11.9	36.8	747.2	1.4	161	NP	0.0
cum							192.2

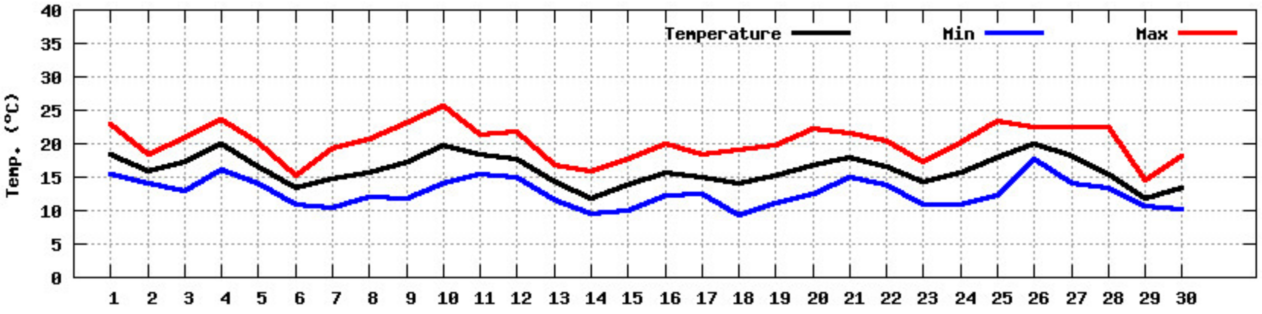
April

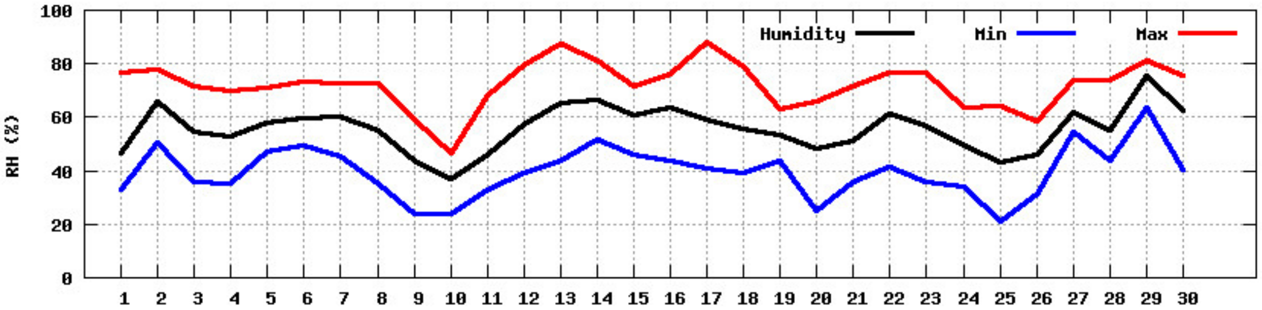
Table B

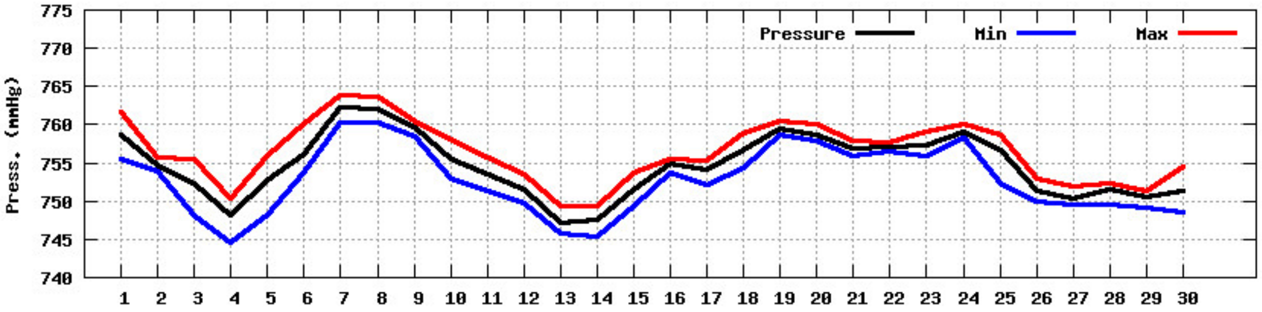
daily extreme

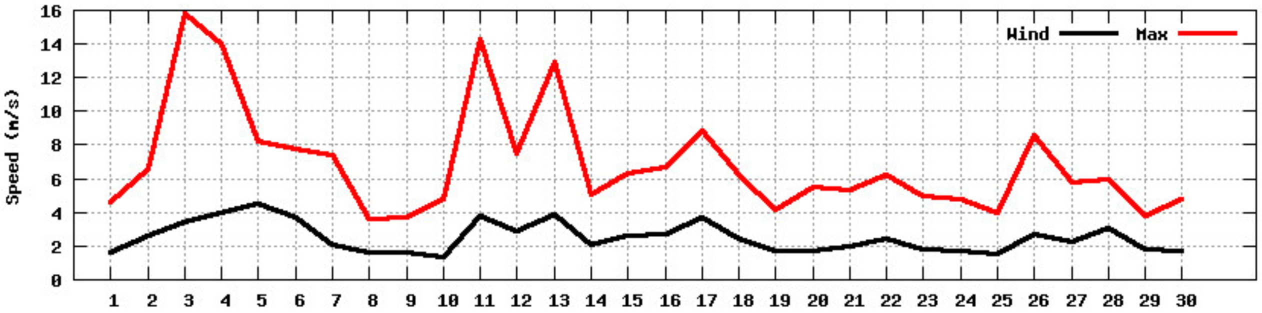
Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
4/1/1990	15.5	22.9	33.0	76.8	755.6	761.6	4.6
4/2/1990	14.2	18.4	50.4	77.7	754.0	755.7	6.6
4/3/1990	12.9	21.0	35.7	71.8	748.2	755.6	15.8
4/4/1990	16.2	23.7	35.3	69.8	744.6	750.3	14.0
4/5/1990	14.0	20.2	47.3	71.3	748.1	755.9	8.2
4/6/1990	10.8	15.2	49.2	73.1	753.8	760.0	7.8
4/7/1990	10.5	19.3	45.5	72.6	760.3	763.8	7.4
4/8/1990	12.0	20.7	35.2	72.6	760.3	763.6	3.6
4/9/1990	11.9	23.1	24.1	59.2	758.4	760.4	3.7
4/10/1990	14.0	25.7	23.7	46.8	752.9	758.1	4.8
4/11/1990	15.5	21.3	32.7	68.1	751.3	755.7	14.3
4/12/1990	15.0	21.9	39.3	79.4	749.7	753.5	7.5
4/13/1990	11.6	16.9	43.8	87.7	745.8	749.4	12.9
4/14/1990	9.5	16.0	51.6	81.3	745.3	749.3	5.1
4/15/1990	10.0	17.8	45.8	71.7	749.3	753.8	6.3
4/16/1990	12.3	19.9	44.0	76.3	753.7	755.6	6.7
4/17/1990	12.6	18.4	41.0	88.2	752.1	755.3	8.9
4/18/1990	9.3	19.2	39.2	78.8	754.4	758.8	6.2
4/19/1990	11.1	19.8	43.8	62.8	758.7	760.4	4.2
4/20/1990	12.4	22.3	24.8	66.1	757.8	760.0	5.5
4/21/1990	14.9	21.6	36.0	71.8	755.9	757.8	5.3
4/22/1990	13.8	20.4	41.5	76.8	756.6	757.6	6.2
4/23/1990	10.8	17.3	36.0	76.6	755.9	759.1	5.0
4/24/1990	11.0	20.3	34.2	63.5	758.2	760.0	4.8
4/25/1990	12.2	23.5	20.9	64.1	752.4	758.7	4.0
4/26/1990	17.8	22.4	31.5	58.5	750.0	752.9	8.6
4/27/1990	14.2	22.5	54.7	74.1	749.6	751.9	5.8
4/28/1990	13.5	22.5	43.7	74.1	749.6	752.4	6.0
4/29/1990	10.7	14.6	63.4	81.1	749.1	751.3	3.8
4/30/1990	10.3	18.1	40.2	75.5	748.5	754.5	4.8
mean	12.7	20.2	39.6	72.3	752.6	756.4	6.9
max	17.8	25.7	63.4	88.2	760.3	763.8	15.8
min	9.3	14.6	20.9	46.8	744.6	749.3	3.6

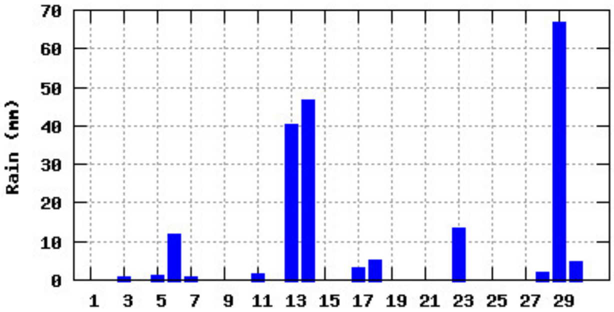
April

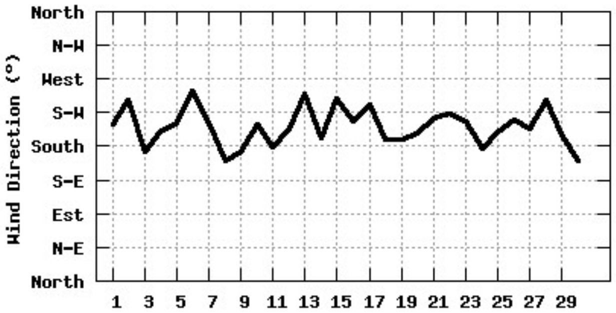

Temperature
Min
Max
Temp. (°C)
0
5
10
15
20
25
30
35
40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Humidity
Min
Max
RH (%)
0
20
40
60
80
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Pressure
Min
Max
Press. (mmHg)
740
745
750
755
760
765
770
775
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Wind
Max
Speed (m/s)
0
2
4
6
8
10
12
14
16
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Rain (mm)
0
10
20
30
40
50
60
70
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29


Wind Direction (°)
North
N-W
West
S-W
South
S-E
Est
N-E
North
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29

May

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
5/1/1990	13.4	66.5	755.8	1.8	184	0.4	14.0
5/2/1990	13.4	56.5	757.1	1.9	84	0.4	0.0
5/3/1990	14.6	54.3	757.3	2.2	97	0.4	0.0
5/4/1990	17.4	45.9	758.5	2.4	168	0.4	0.0
5/5/1990	19.0	44.5	760.3	2.2	185	0.3	0.0
5/6/1990	19.5	46.9	759.2	2.2	223	0.4	0.0
5/7/1990	17.5	44.3	756.9	2.9	116	0.4	0.0
5/8/1990	17.3	32.6	759.1	2.6	131	0.5	0.0
5/9/1990	18.0	43.3	760.3	1.9	209	0.4	0.0
5/10/1990	19.1	47.1	760.3	1.6	154	0.4	0.0
5/11/1990	20.4	42.8	758.0	1.4	177	0.4	0.0
5/12/1990	23.0	41.1	753.8	1.6	181	0.3	0.0
5/13/1990	22.7	58.8	752.2	2.6	214	0.4	0.0
5/14/1990	20.1	66.9	757.8	1.9	213	0.4	0.0
5/15/1990	19.2	60.2	759.8	2.2	205	0.4	0.0
5/16/1990	18.4	62.6	760.4	2.1	219	0.3	0.0
5/17/1990	18.4	60.7	760.3	2.1	202	0.4	0.6
5/18/1990	18.6	58.8	760.1	1.8	195	0.4	0.0
5/19/1990	19.2	59.6	760.8	2.1	192	0.4	0.0
5/20/1990	19.4	63.8	760.8	2.0	212	0.3	0.0
5/21/1990	20.7	51.4	760.4	2.5	143	0.3	0.0
5/22/1990	21.1	58.7	759.4	1.7	173	0.3	0.0
5/23/1990	22.3	39.4	759.4	2.7	134	0.3	0.0
5/24/1990	21.9	35.2	760.6	3.3	107	0.5	0.0
5/25/1990	21.8	42.5	761.0	3.0	179	0.3	0.0
5/26/1990	21.3	47.4	760.8	2.2	193	0.4	0.0
5/27/1990	21.5	50.7	760.4	2.1	207	0.4	0.0
5/28/1990	22.0	51.6	759.9	1.9	194	0.4	0.0
5/29/1990	21.6	57.6	759.5	2.8	150	0.4	0.2
5/30/1990	22.1	41.4	761.0	2.6	176	0.4	0.0
5/31/1990	20.7	56.5	756.8	2.6	205	0.3	12.0
mean	19.5	51.3	759.0	2.2	175	0.4	0.9
max	23.0	66.9	761.0	3.3	223	0.5	14.0
min	13.4	32.6	752.2	1.4	84	0.3	0.0
cum							26.8

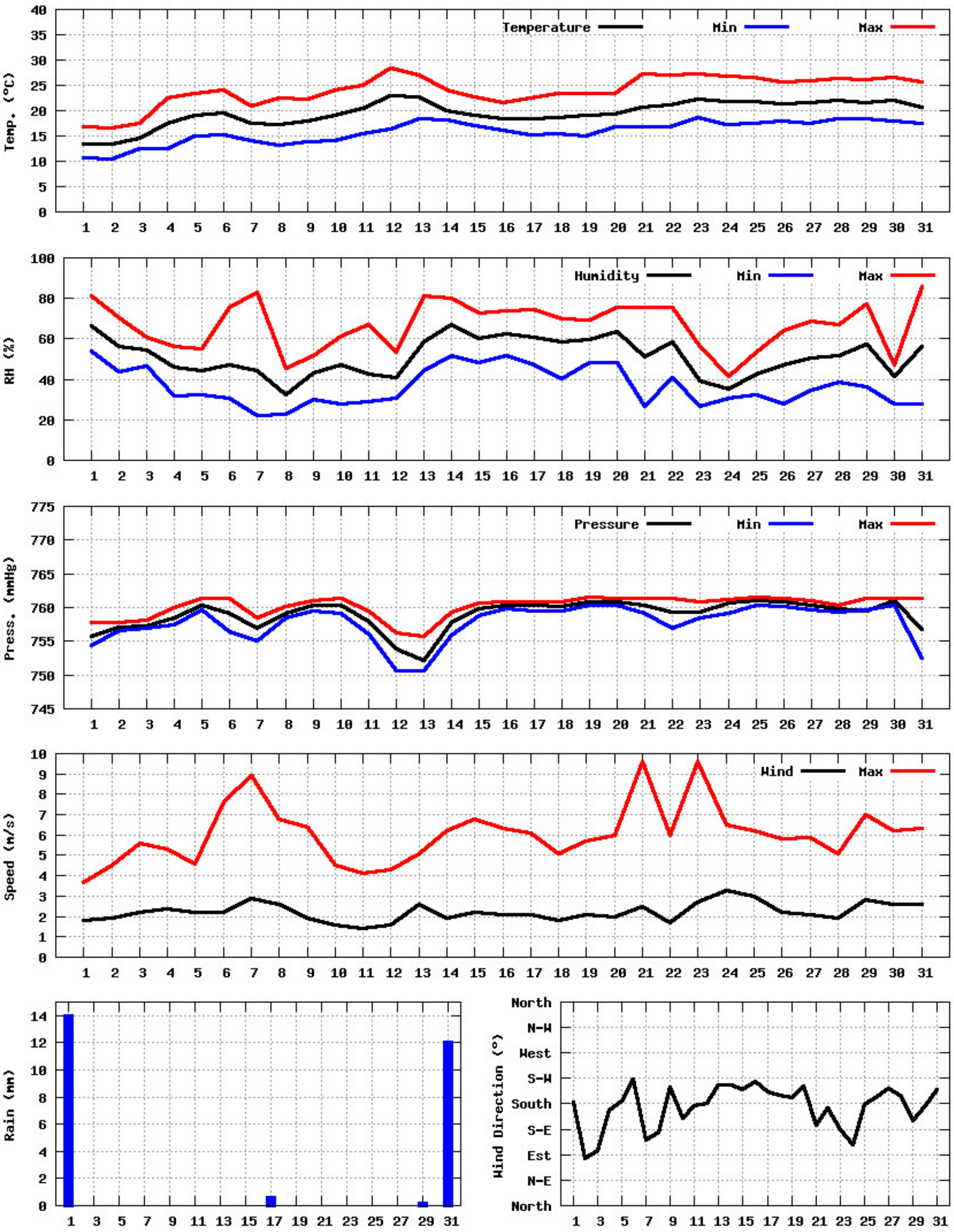
May

Table B

daily extreme

Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
5/1/1990	10.7	16.8	53.7	81.1	754.4	757.8	3.7
5/2/1990	10.5	16.7	43.5	70.5	756.6	757.8	4.5
5/3/1990	12.4	17.4	46.4	60.6	756.9	758.2	5.6
5/4/1990	12.5	22.6	31.6	56.5	757.5	760.0	5.3
5/5/1990	15.0	23.5	32.5	55.2	759.7	761.3	4.6
5/6/1990	15.3	24.1	30.8	75.8	756.5	761.4	7.6
5/7/1990	14.2	21.0	22.0	82.9	755.1	758.5	8.9
5/8/1990	13.2	22.4	22.7	45.2	758.4	760.1	6.8
5/9/1990	13.9	22.2	30.0	51.8	759.5	761.0	6.4
5/10/1990	14.2	24.0	28.1	61.2	759.2	761.4	4.5
5/11/1990	15.5	24.9	29.1	67.2	756.0	759.5	4.1
5/12/1990	16.4	28.5	30.4	53.6	750.7	756.2	4.3
5/13/1990	18.3	27.1	44.2	81.2	750.7	755.7	5.1
5/14/1990	18.1	24.1	51.9	80.1	755.9	759.4	6.2
5/15/1990	17.1	22.7	48.5	72.8	758.8	760.7	6.8
5/16/1990	16.1	21.7	51.8	73.9	759.8	760.9	6.3
5/17/1990	15.2	22.4	47.1	74.2	759.5	760.9	6.1
5/18/1990	15.4	23.5	40.4	69.8	759.5	760.9	5.1
5/19/1990	15.1	23.4	48.2	69.1	760.4	761.6	5.7
5/20/1990	16.9	23.4	48.2	75.6	760.4	761.3	6.0
5/21/1990	16.9	27.3	26.5	75.6	759.1	761.3	9.6
5/22/1990	16.9	27.1	41.0	75.6	756.9	761.3	6.0
5/23/1990	18.7	27.3	26.5	56.4	758.4	760.9	9.6
5/24/1990	17.3	26.8	30.5	41.5	759.2	761.2	6.5
5/25/1990	17.4	26.6	32.2	53.6	760.3	761.6	6.2
5/26/1990	17.9	25.6	28.0	64.2	760.1	761.3	5.8
5/27/1990	17.6	25.9	34.9	68.9	759.7	761.1	5.9
5/28/1990	18.4	26.3	38.5	67.3	759.4	760.4	5.1
5/29/1990	18.3	26.1	36.5	77.0	759.7	761.4	7.0
5/30/1990	17.9	26.6	28.0	47.4	760.3	761.4	6.2
5/31/1990	17.5	25.6	28.0	85.7	752.5	761.3	6.3
mean	15.8	24.0	36.5	66.8	757.8	760.3	6.1
max	18.7	28.5	53.7	85.7	760.4	761.6	9.6
min	10.5	16.7	22.0	41.5	750.7	755.7	3.7

May


Temperature
Min
Max
Temp. (°C)
0
5
10
15
20
25
30
35
40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Humidity
Min
Max
RH (%)
0
20
40
60
80
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Pressure
Min
Max
Press. (mmHg)
745
750
755
760
765
770
775
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Wind
Max
Speed (m/s)
0
1
2
3
4
5
6
7
8
9
10
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Rain (mm)
0
2
4
6
8
10
12
14
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Wind Direction (°)
North
N-E
Est
S-E
South
S-W
West
N-W
North
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31

June

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
6/1/1990	20.8	33.6	761.9	2.7	187	0.4	0.0
6/2/1990	21.2	56.1	759.4	2.1	192	0.5	0.0
6/3/1990	20.8	68.1	755.6	2.1	199	0.2	0.0
6/4/1990	24.4	64.0	751.4	3.1	227	0.4	0.0
6/5/1990	24.9	36.3	751.7	2.8	128	0.4	0.0
6/6/1990	23.0	53.1	753.2	2.8	209	0.2	0.0
6/7/1990	22.8	67.8	755.1	2.1	244	0.5	0.0
6/8/1990	21.6	68.7	755.8	3.0	239	0.3	0.0
6/9/1990	23.2	64.4	756.1	3.4	207	0.5	0.0
6/10/1990	22.4	60.7	756.2	2.4	248	0.4	0.0
6/11/1990	22.3	52.4	758.2	1.5	182	0.4	0.0
6/12/1990	23.4	55.3	756.1	2.4	211	0.4	0.0
6/13/1990	22.3	63.0	756.9	2.3	237	0.4	0.0
6/14/1990	22.9	63.7	758.6	1.8	194	0.5	0.0
6/15/1990	22.7	63.3	756.5	1.6	201	0.4	0.0
6/16/1990	22.9	62.4	757.1	1.9	204	0.4	0.0
6/17/1990	23.1	65.3	758.5	2.2	209	0.4	0.0
6/18/1990	23.6	63.0	759.3	1.4	184	0.5	0.0
6/19/1990	25.5	51.9	760.5	1.3	165	0.5	0.0
6/20/1990	27.7	40.1	758.9	1.3	172	0.5	0.0
5/21/1990	25.5	66.2	756.9	2.1	207	0.4	0.0
6/22/1990	25.1	61.2	757.9	2.2	209	0.5	0.0
6/23/1990	25.4	60.9	760.0	2.0	201	0.5	0.0
6/24/1990	25.8	61.0	760.6	1.5	217	0.5	0.0
6/25/1990	27.1	59.8	759.9	1.7	130	0.4	0.0
6/26/1990	28.4	37.6	759.2	2.5	187	0.5	0.0
6/27/1990	28.1	39.3	758.1	2.0	184	0.5	0.0
6/28/1990	27.5	52.7	758.9	1.7	179	0.4	0.0
6/29/1990	27.8	57.0	760.4	1.7	147	0.4	0.0
6/30/1990	27.8	56.7	760.0	1.6	177	0.4	0.0
mean	24.3	56.9	757.6	2.1	196	0.4	0.0
max	28.4	68.7	761.9	3.4	248	0.5	0.0
min	20.8	33.6	751.4	1.3	128	0.2	0.0
cum							0.0

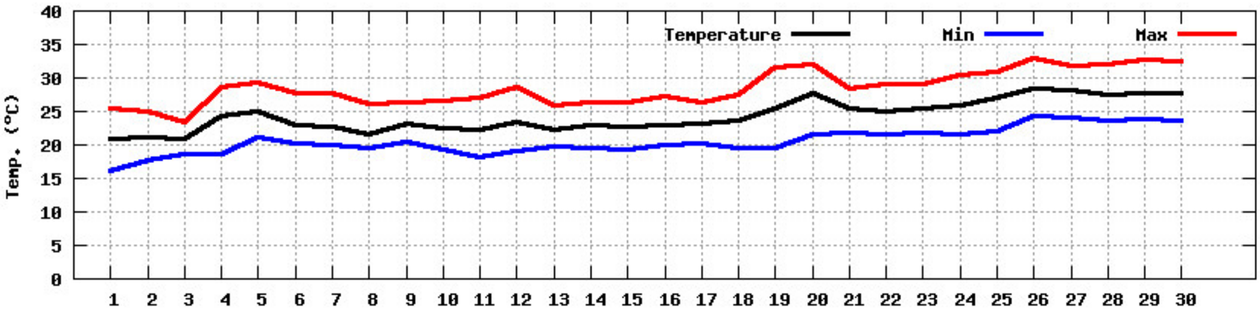
June

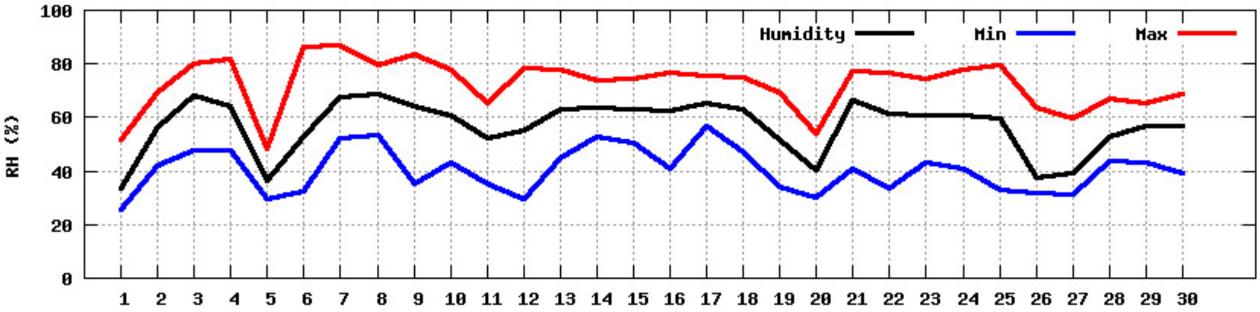
Table B

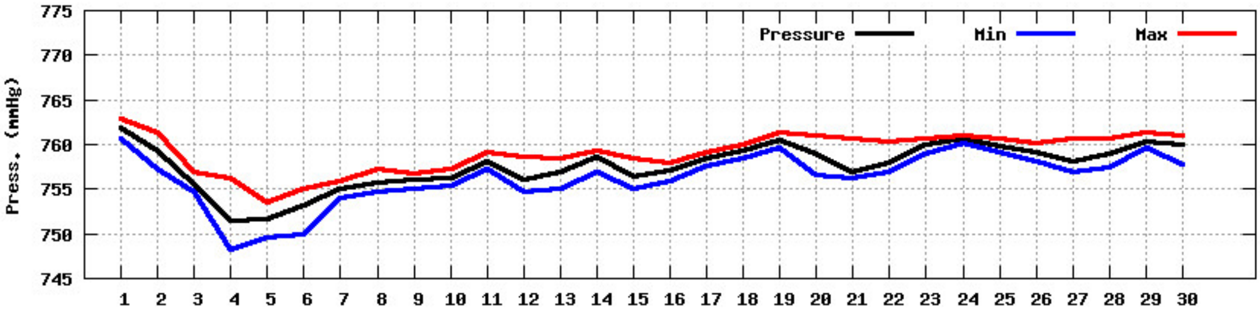
daily extreme

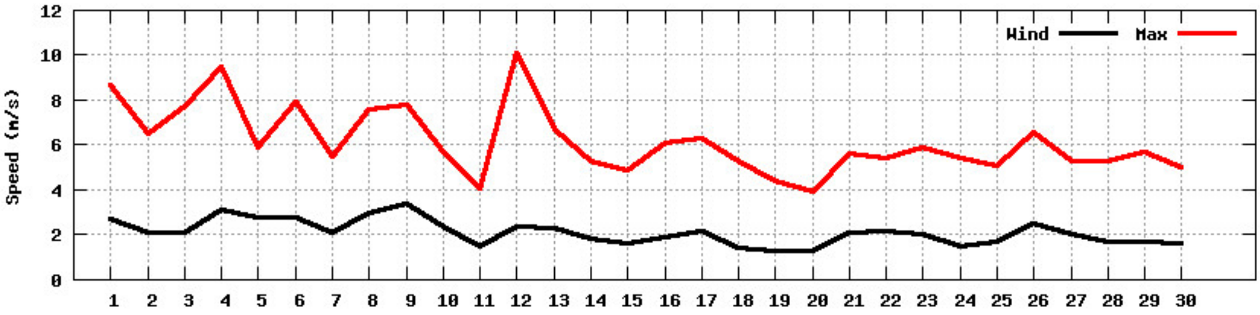
Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
6/1/1990	16.1	25.5	25.3	51.5	760.7	762.9	8.7
6/2/1990	17.7	25.1	42.1	69.5	757.2	761.3	6.5
6/3/1990	18.7	23.5	47.5	80.0	754.7	757.0	7.7
6/4/1990	18.6	28.7	47.5	81.6	748.2	756.3	9.5
6/5/1990	21.2	29.4	29.7	48.5	749.6	753.5	5.9
6/6/1990	20.2	27.7	32.6	86.4	750.0	755.0	7.9
6/7/1990	19.9	27.7	52.0	87.1	754.0	755.9	5.5
6/8/1990	19.5	26.1	53.4	79.7	754.7	757.2	7.6
6/9/1990	20.5	26.4	35.2	83.8	755.0	756.7	7.8
6/10/1990	19.3	26.5	43.0	78.0	755.4	757.3	5.7
6/11/1990	18.1	27.0	35.5	65.1	757.3	759.1	4.1
6/12/1990	19.0	28.6	29.7	78.5	754.7	758.7	10.1
6/13/1990	19.8	26.0	45.1	77.8	755.1	758.4	6.7
6/14/1990	19.5	26.4	53.1	73.9	757.0	759.4	5.3
6/15/1990	19.3	26.3	50.3	74.2	755.0	758.5	4.9
6/16/1990	19.9	27.2	41.1	76.7	755.9	757.9	6.1
6/17/1990	20.2	26.4	56.7	75.5	757.6	759.1	6.3
6/18/1990	19.5	27.4	47.1	74.8	758.5	760.0	5.3
6/19/1990	19.6	31.5	34.1	69.4	759.7	761.3	4.4
6/20/1990	21.7	32.1	30.2	54.0	756.6	761.0	3.9
6/21/1990	21.8	28.5	41.0	77.0	756.2	760.7	5.6
6/22/1990	21.6	29.0	33.3	76.8	757.0	760.3	5.4
6/23/1990	21.9	29.0	43.1	74.6	758.9	760.7	5.9
6/24/1990	21.7	30.5	40.9	78.0	760.1	761.1	5.4
6/25/1990	22.1	30.9	33.1	79.7	759.1	760.6	5.1
6/26/1990	24.3	33.0	31.6	63.6	758.2	760.1	6.6
6/27/1990	24.1	31.8	31.4	59.8	757.0	760.6	5.3
6/28/1990	23.7	32.0	43.6	66.9	757.5	760.6	5.3
6/29/1990	23.8	32.7	43.2	65.6	759.7	761.3	5.7
6/30/1990	23.7	32.4	39.2	68.5	757.8	761.1	5.0
mean	20.6	28.5	40.4	72.6	756.3	759.1	6.2
max	24.3	33.0	56.7	87.1	760.7	762.9	10.1
min	16.1	23.5	25.3	48.5	748.2	753.5	3.9

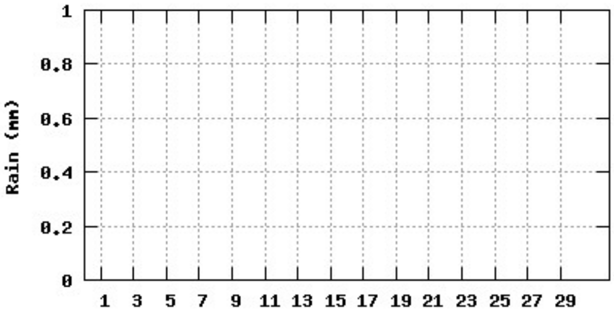
June

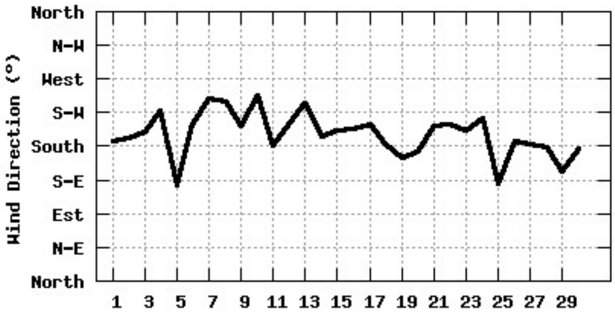

Temperature
Min
Max
Temp. (°C)
0
5
10
15
20
25
30
35
40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Humidity
Min
Max
RH (%)
0
20
40
60
80
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Pressure
Min
Max
Press. (mmHg)
745
750
755
760
765
770
775
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Wind
Max
Speed (m/s)
0
2
4
6
8
10
12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Rain (mm)
0
0.2
0.4
0.6
0.8
1
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29


Wind Direction (°)
North
N-W
West
S-W
South
S-E
Est
N-E
North
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29

July

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
7/1/1990	27.7	59.7	757.4	1.5	183	0.4	0.0
7/2/1990	26.6	62.8	755.2	1.8	225	0.4	0.0
7/3/1990	26.3	61.2	755.8	2.0	207	0.5	0.0
7/4/1990	25.0	61.6	755.7	1.9	224	0.4	0.0
7/5/1990	25.5	61.8	756.6	2.3	201	0.4	0.0
7/6/1990	24.8	62.7	755.9	1.8	234	0.3	0.0
7/7/1990	26.3	48.0	757.8	2.4	146	0.4	0.0
7/8/1990	26.1	40.5	758.7	2.2	139	0.4	0.0
7/9/1990	27.5	46.9	759.1	1.9	173	0.4	0.0
7/10/1990	26.8	62.4	757.1	2.0	197	0.4	0.0
7/11/1990	26.6	54.1	756.0	2.4	102	0.4	0.0
7/12/1990	26.2	49.8	757.8	2.7	146	0.4	0.0
7/13/1990	26.7	49.6	756.8	1.4	168	0.4	0.0
7/14/1990	26.7	60.0	756.0	1.3	184	0.4	0.0
7/15/1990	26.4	66.2	758.9	2.0	222	0.4	0.0
7/16/1990	27.6	57.7	761.2	1.6	174	0.4	0.0
7/17/1990	27.2	64.6	760.0	1.8	182	0.4	0.0
7/18/1990	26.9	66.7	756.4	1.9	180	0.4	0.0
7/19/1990	26.1	45.2	755.7	2.8	90	0.4	0.0
7/20/1990	26.4	43.0	758.3	2.5	152	0.4	0.0
7/21/1990	27.5	39.8	759.3	2.0	189	0.4	0.0
7/22/1990	28.9	37.3	758.8	2.0	179	0.4	0.0
7/23/1990	27.8	59.5	758.8	1.9	165	0.4	0.0
7/24/1990	26.9	73.8	758.5	2.2	197	0.4	0.0
7/25/1990	27.0	68.0	756.9	1.6	171	0.4	0.0
7/26/1990	27.0	65.8	756.4	1.7	217	0.4	0.0
7/27/1990	27.6	61.8	757.4	1.3	158	0.4	0.0
7/28/1990	29.3	51.3	759.4	1.5	140	0.4	0.0
7/29/1990	29.3	42.2	761.4	1.7	182	0.4	0.0
7/30/1990	27.6	57.0	760.1	1.1	168	0.2	0.0
7/31/1990	27.0	68.8	759.1	1.9	210.0	0.2	1.1
mean	26.9	56.4	757.8	1.9	178	0.4	0
max	29.3	73.8	761.4	2.8	234	0.5	1.1
min	24.8	37.3	755.2	1.1	90	0.2	0.0
cum							1.1

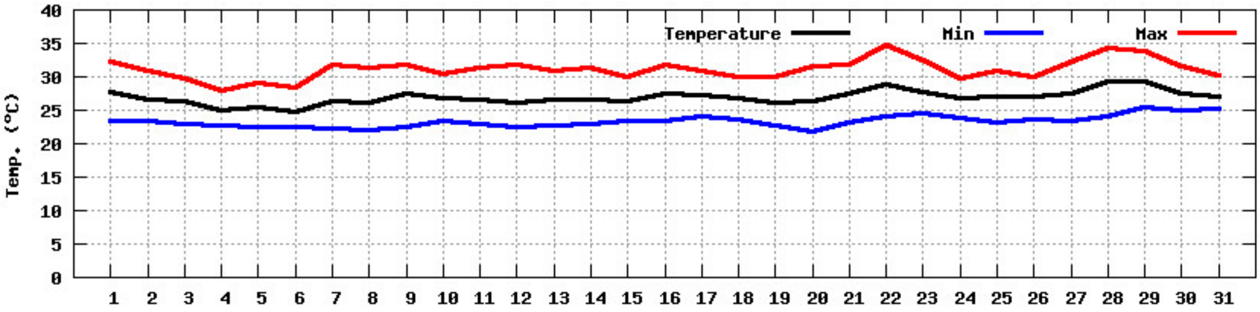
July

Table B

daily extreme

Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
7/1/1990	23.4	32.2	33.1	78.8	755.7	759.1	5.7
7/2/1990	23.5	30.9	45.2	75.6	754.7	756.2	4.9
7/3/1990	22.9	29.7	51.8	74.7	755.1	756.5	6.7
7/4/1990	22.8	27.9	48.0	78.8	754.7	756.9	6.2
7/5/1990	22.6	29.0	49.8	74.4	755.1	757.6	6.6
7/6/1990	22.4	28.5	48.8	71.2	754.8	757.0	5.3
7/7/1990	22.2	31.8	32.1	74.1	756.6	759.1	5.7
7/8/1990	22.0	31.4	27.5	65.7	757.9	759.5	5.8
7/9/1990	22.6	31.9	32.6	65.7	758.4	759.7	5.6
7/10/1990	23.5	30.5	40.9	80.6	755.9	758.5	7.1
7/11/1990	22.9	31.3	42.0	75.6	755.4	757.5	6.2
7/12/1990	22.4	31.8	40.0	65.0	757.0	758.2	6.5
7/13/1990	22.8	30.8	38.5	58.9	755.9	757.8	2.9
7/14/1990	22.9	31.4	43.8	72.3	755.4	757.3	3.3
7/15/1990	23.4	30.0	47.9	78.0	757.3	760.9	4.2
7/16/1990	23.4	31.9	38.3	77.0	760.6	761.7	6.0
7/17/1990	24.1	30.8	44.1	80.3	758.5	761.4	5.6
7/18/1990	23.7	30.1	50.1	78.5	755.1	758.5	5.9
7/19/1990	22.7	30.0	35.9	64.0	755.0	757.6	8.3
7/20/1990	21.8	31.5	34.2	53.5	757.2	759.7	5.9
7/21/1990	23.1	31.9	32.5	55.8	758.2	760.0	5.9
7/22/1990	24.2	34.8	28.2	60.3	757.9	759.4	5.1
7/23/1990	24.5	32.4	39.9	86.9	758.2	759.4	4.3
7/24/1990	23.9	29.7	64.7	86.8	757.5	759.2	6.5
7/25/1990	23.2	31.0	41.8	85.2	756.0	757.9	4.8
7/26/1990	23.7	30.1	48.4	83.9	755.7	757.3	4.2
7/27/1990	23.5	32.2	43.6	73.1	756.5	758.4	4.3
7/28/1990	24.2	34.4	36.1	75.6	755.4	761.1	4.2
7/29/1990	25.4	33.9	29.3	58.6	760.7	762.2	5.8
7/30/1990	25.0	31.6	40.5	73.5	758.0	761.0	4.0
7/31/1990	25.3	30.2	55.8	80.2	758.5	760.1	5.4
mean	23.4	31.1	41.5	73.0	756.7	758.9	5.4
max	25.4	34.8	64.7	86.9	760.7	762.2	8.3
min	21.8	27.9	27.5	53.5	754.7	756.2	2.9

July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Min
Max
Temp. (°C)
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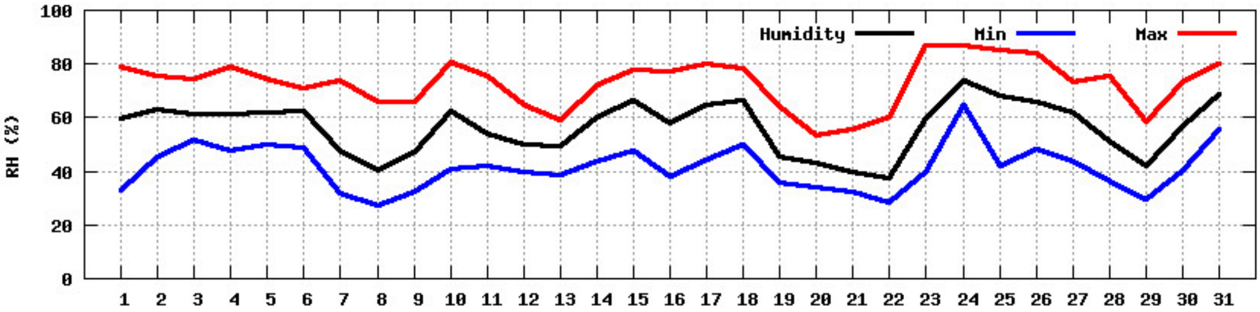
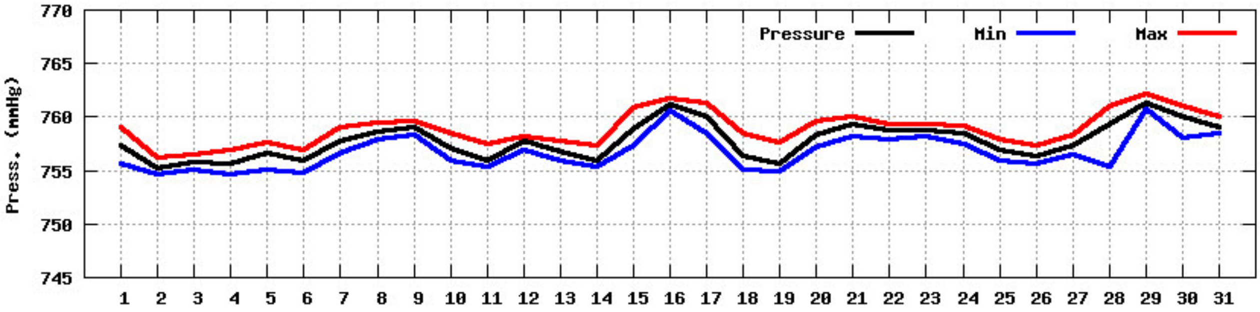
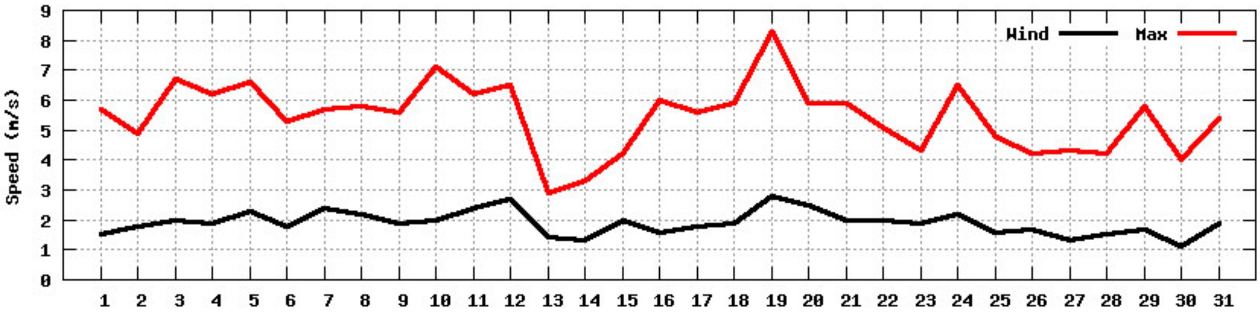
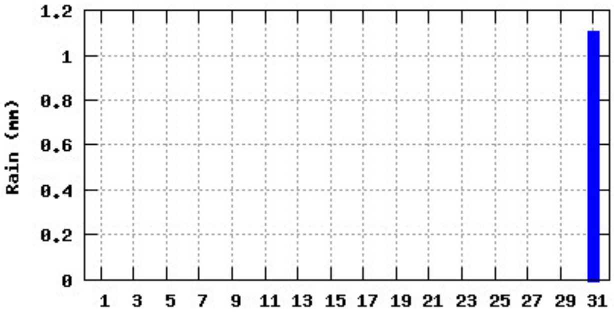
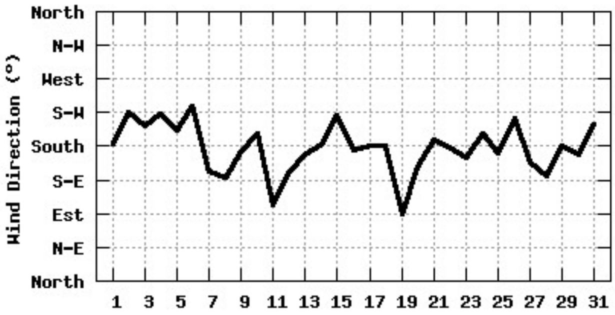
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Humidity
Min
Max
RH (%)
0 20 40 60 80 100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Pressure
Min
Max
Press. (mmHg)
745 750 755 760 765 770
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Wind
Max
Speed (m/s)
0 1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Rain (mm)
0 0.2 0.4 0.6 0.8 1 1.2
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31


Wind Direction (°)
North
N-W
West
S-W
South
S-E
Est
N-E
North
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31

August

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
8/1/1990	27.4	58.5	758.3	1.4	150	0.4	0.0
8/2/1990	28.0	58.6	758.6	1.4	161	0.3	0.0
8/3/1990	29.7	48.1	759.2	1.7	166	0.3	0.0
8/4/1990	29.5	39.5	759.9	1.8	165	0.4	0.0
8/5/1990	28.9	40.2	759.7	1.9	151	0.4	0.0
8/6/1990	27.7	63.6	758.1	1.9	171	0.4	0.0
8/7/1990	25.9	71.1	757.3	2.9	186	0.3	25.6
8/8/1990	25.4	68.2	758.3	2.1	190	0.4	32.6
8/9/1990	25.2	56.7	759.3	2.3	144	0.4	0.0
8/10/1990	25.8	38.1	760.7	2.2	95	0.4	0.0
8/11/1990	25.9	41.4	760.6	1.9	170	0.4	0.0
8/12/1990	27.0	43.1	761.1	1.7	207	0.4	0.0
8/13/1990	27.2	52.1	760.9	1.5	186	0.4	0.0
8/14/1990	27.1	59.6	759.8	1.4	181	0.4	0.0
8/15/1990	26.8	63.8	758.6	1.7	178	0.4	0.0
8/16/1990	26.8	65.3	758.5	1.4	191	0.4	0.0
8/17/1990	26.6	68.1	759.2	1.7	207	0.4	0.0
8/18/1990	26.6	59.4	759.3	1.9	189	0.4	0.0
8/19/1990	26.5	55.7	759.1	1.9	170	0.4	0.0
8/20/1990	27.0	58.1	759.4	1.5	202	0.4	0.0
8/21/1990	25.1	74.5	758.6	2.1	209	0.3	0.0
8/22/1990	20.8	54.8	756.9	3.6	87	0.0	1.2
8/23/1990	23.7	40.5	759.5	3.1	108	0.4	0.0
8/24/1990	24.9	46.6	761.5	2.1	149	0.4	0.0
8/25/1990	25.3	55.9	760.3	1.6	178	0.4	0.0
8/26/1990	25.4	64.3	757.7	1.7	196	0.3	0.0
8/27/1990	25.2	61.9	757.1	1.4	160	0.3	0.0
8/28/1990	25.7	56.6	758.3	1.7	165	0.3	0.0
8/29/1990	26.2	53.3	759.4	1.6	154	0.3	0.0
8/30/1990	25.8	57.8	759.1	1.4	164	0.3	0.0
8/31/1990	26.0	64.9	758.3	1.3	157	0.3	0.0
mean	26.3	56.1	759.1	1.9	167	0.4	1.9
max	29.7	74.5	761.5	3.6	209	0.4	32.6
min	20.8	38.1	756.9	1.3	87	0.0	0.0
cum							59.4

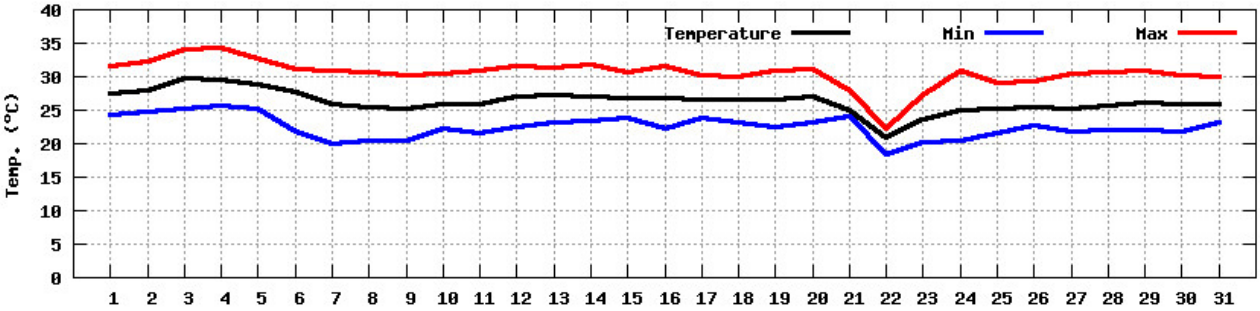
August

Table B

daily extreme

Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
8/1/1990	24.4	31.6	45.0	76.0	757.6	758.9	5.0
8/2/1990	24.8	32.3	44.0	71.0	757.8	759.5	4.0
8/3/1990	25.2	34.2	35.0	67.0	758.4	760.4	5.0
8/4/1990	25.7	34.4	33.0	62.0	759.1	760.9	4.0
8/5/1990	25.2	32.8	28.0	57.0	758.4	760.6	6.0
8/6/1990	21.8	31.2	56.0	76.0	756.9	759.2	6.0
8/7/1990	19.9	31.0	61.0	90.0	756.3	758.2	7.0
8/8/1990	20.4	30.6	51.0	86.0	757.8	759.1	6.0
8/9/1990	20.5	30.2	41.0	81.0	758.4	760.7	7.0
8/10/1990	22.2	30.5	30.0	51.0	759.5	761.3	6.0
8/11/1990	21.5	30.9	31.0	60.0	759.8	761.4	5.0
8/12/1990	22.4	31.7	33.0	62.0	760.4	761.7	7.0
8/13/1990	23.1	31.3	37.0	63.0	760.3	761.6	6.0
8/14/1990	23.5	31.9	37.0	71.0	759.1	760.6	5.0
8/15/1990	23.9	30.7	52.0	73.0	757.6	759.4	5.0
8/16/1990	22.3	31.6	45.0	77.0	757.8	759.4	5.0
8/17/1990	23.8	30.2	50.0	81.0	758.4	759.7	6.0
8/18/1990	23.2	29.9	49.0	74.0	758.8	760.0	6.0
8/19/1990	22.5	31.0	43.0	70.0	758.4	759.8	5.0
8/20/1990	23.1	31.1	42.0	74.0	758.8	760.0	5.0
8/21/1990	24.0	28.0	63.0	79.0	758.4	759.2	6.0
8/22/1990	18.3	22.3	39.0	74.0	754.5	761.3	10.0
8/23/1990	20.2	27.3	33.0	52.0	757.8	761.4	12.0
8/24/1990	20.5	30.8	34.0	65.0	759.2	762.6	5.0
8/25/1990	21.7	29.2	47.0	67.0	758.9	761.4	5.0
8/26/1990	22.7	29.3	55.0	72.0	756.9	758.9	7.0
8/27/1990	21.8	30.5	47.0	77.0	756.3	758.1	4.0
8/28/1990	22.0	30.7	45.0	66.0	757.3	759.4	5.0
8/29/1990	22.1	30.8	44.0	61.0	758.7	760.1	5.0
8/30/1990	21.9	30.3	45.0	76.0	758.2	760.1	4.0
8/31/1990	23.2	30.1	43.0	78.0	757.6	759.1	4.0
mean	22.5	30.6	43.2	70.6	758.2	760.1	5.7
max	25.7	34.4	63.0	90.0	760.4	762.6	12.0
min	18.3	22.3	28.0	51.0	754.5	758.1	4.0

August


Temperature
Min
Max
Temp. (°C)
0
5
10
15
20
25
30
35
40
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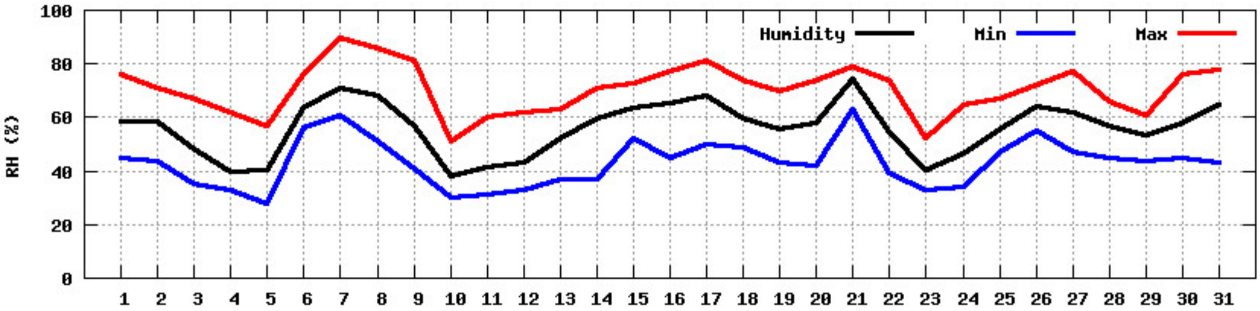
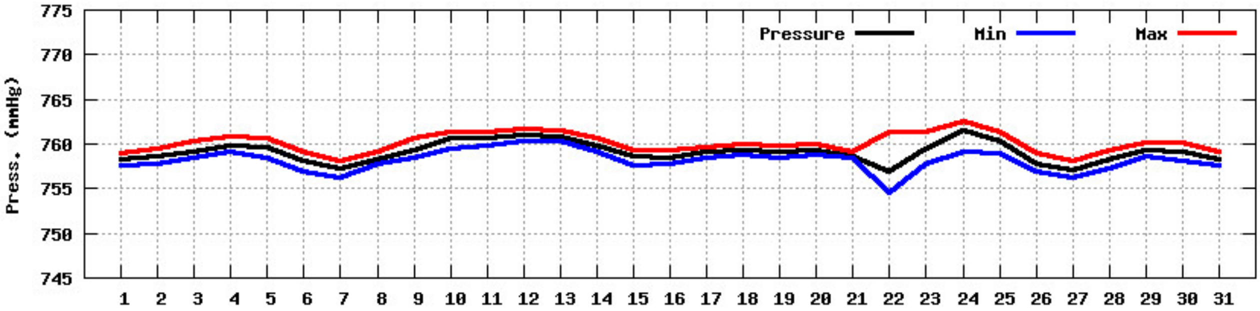
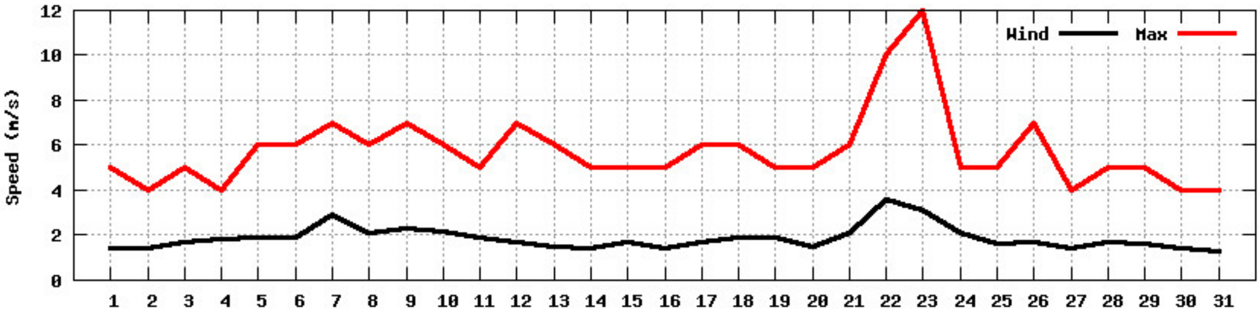
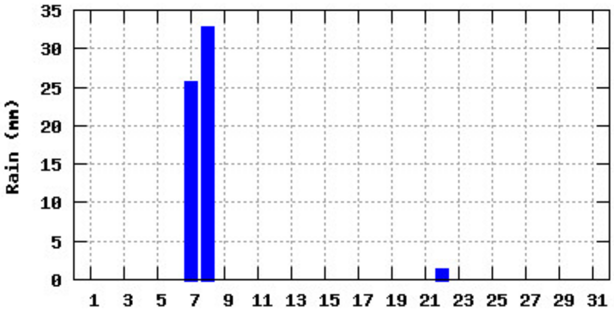
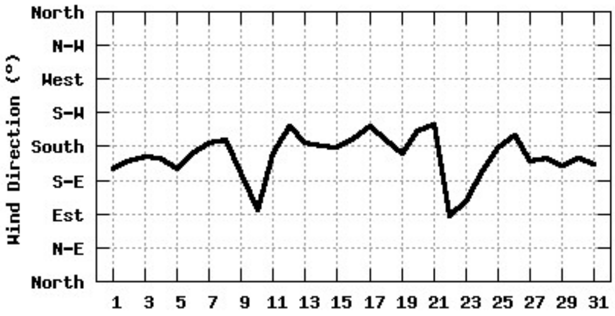

Humidity
Min
Max
RH (%)
0
20
40
60
80
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Pressure
Min
Max
Press. (mmHg)
745
750
755
760
765
770
775
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Wind
Max
Speed (m/s)
0
2
4
6
8
10
12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Rain (mm)
0
5
10
15
20
25
30
35
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31


Wind Direction (°)
North
N-W
West
S-W
South
S-E
Est
N-E
North
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31

September

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
9/1/1990	25.1	68.0	758.2	1.4	150	0.2	0.2
9/2/1990	25.8	72.0	758.4	1.5	192	0.3	0.0
9/3/1990	23.9	63.0	756.7	1.9	178	0.3	5.2
9/4/1990	24.2	54.0	757.3	1.9	184	0.4	0.0
9/5/1990	24.2	67.0	754.8	2.0	230	0.3	9.2
9/6/1990	24.7	65.0	754.6	1.4	172	0.4	0.0
9/7/1990	24.6	63.0	756.2	1.8	208	0.3	0.0
9/8/1990	25.1	59.0	757.7	1.8	184	0.3	0.0
9/9/1990	24.3	54.0	761.5	1.7	156	0.3	0.0
9/10/1990	24.3	57.0	759.2	1.5	188	0.3	0.0
9/11/1990	22.3	62.0	754.5	2.1	119	0.2	0.0
9/12/1990	21.2	40.0	758.7	2.4	120	0.3	0.0
9/13/1990	21.0	41.0	763.7	2.4	127	0.3	0.0
9/14/1990	22.5	56.0	764.8	1.3	179	0.3	0.0
9/15/1990	22.3	60.0	763.9	1.1	154	0.2	0.0
9/16/1990	21.9	63.0	760.4	1.5	171	0.3	5.6
9/17/1990	23.3	63.0	760.7	1.2	200	0.3	0.0
9/18/1990	22.8	74.0	759.3	1.8	188	0.3	33.4
9/19/1990	23.6	64.0	758.8	1.4	186	0.3	0.0
9/20/1990	23.2	70.0	757.6	2.0	194	0.3	0.0
9/21/1990	23.5	69.0	753.8	2.0	244	0.3	0.2
9/22/1990	23.3	70.0	754.4	2.0	177	0.2	0.2
9/23/1990	23.5	74.0	756.3	1.8	218	0.2	0.0
9/24/1990	24.0	70.0	755.2	3.3	233	0.2	0.0
9/25/1990	23.6	57.0	759.5	1.8	217	0.3	0.0
9/26/1990	24.3	66.0	760.0	1.7	175	0.2	0.0
9/27/1990	23.6	71.0	760.5	1.8	198	0.2	0.0
9/28/1990	21.4	39.0	762.9	3.3	97	0.3	0.0
9/29/1990	20.3	42.0	764.9	2.0	193	0.3	0.0
9/30/1990	20.8	57.0	763.6	1.1	156	0.3	0.0
mean	23.3	61.0	758.9	1.8	180	0.3	54.0
max	25.8	74.0	764.9	3.3	244	0.4	33.4
min	20.3	39.0	753.8	1.1	97	0.2	0.0
cum							54.0

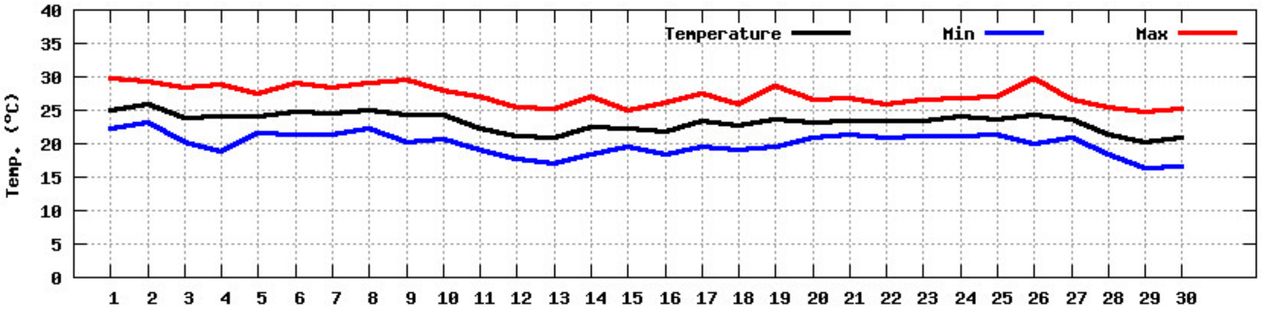
September

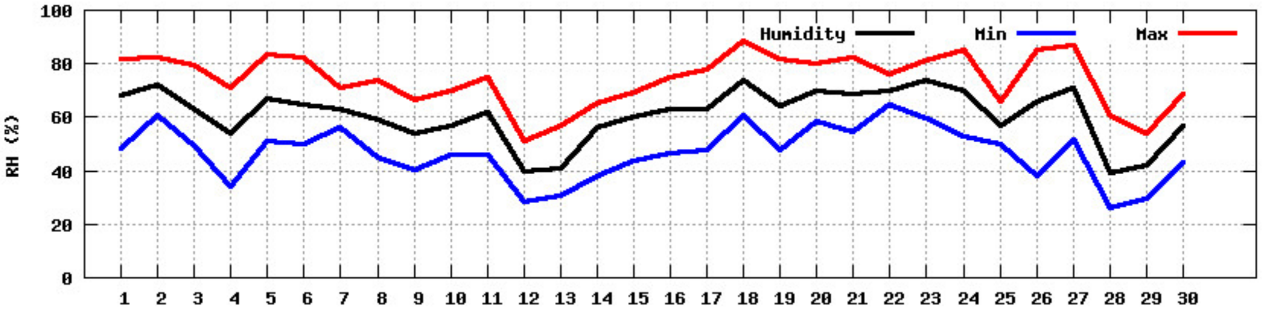
Table B

daily extreme

Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
9/1/1990	22.2	29.8	48.5	82.1	757.2	758.9	4.9
9/2/1990	23.1	29.3	60.7	82.4	757.5	759.4	4.9
9/3/1990	20.3	28.3	49.2	79.4	755.4	757.6	6.5
9/4/1990	18.9	28.9	34.2	70.9	756.6	758.1	4.3
9/5/1990	21.5	27.6	51.4	83.5	753.8	756.6	8.0
9/6/1990	21.4	29.1	50.1	82.4	753.5	756.5	4.9
9/7/1990	21.4	28.4	56.2	71.1	755.6	756.9	5.8
9/8/1990	22.2	29.1	45.1	73.9	755.4	760.9	5.0
9/9/1990	20.3	29.5	40.5	66.5	760.7	762.3	4.5
9/10/1990	20.6	28.0	46.0	70.1	756.5	761.1	5.3
9/11/1990	19.2	27.0	46.0	75.1	752.6	756.6	7.4
9/12/1990	17.7	25.5	28.3	51.0	755.6	762.5	7.7
9/13/1990	17.1	25.2	30.5	56.7	762.6	764.5	7.0
9/14/1990	18.5	27.0	38.3	65.4	764.1	765.7	5.6
9/15/1990	19.5	25.1	43.5	69.6	761.9	765.2	4.5
9/16/1990	18.3	26.1	46.8	75.2	759.2	761.9	3.2
9/17/1990	19.6	27.4	47.7	77.8	760.0	761.4	3.6
9/18/1990	19.2	26.0	60.9	88.8	758.5	760.9	5.4
9/19/1990	19.5	28.6	47.6	81.6	757.9	759.5	5.1
9/20/1990	20.8	26.7	58.5	80.1	754.7	758.7	6.4
9/21/1990	21.4	26.8	54.8	82.2	752.5	755.3	6.8
9/22/1990	21.0	25.8	64.7	75.9	752.8	755.9	5.1
9/23/1990	21.1	26.5	59.8	81.2	755.3	757.0	4.3
9/24/1990	21.1	26.8	53.0	85.2	753.1	757.6	7.6
9/25/1990	21.4	27.0	49.9	65.8	757.0	761.0	5.4
9/26/1990	19.9	29.8	38.0	85.2	758.9	761.0	4.7
9/27/1990	20.8	26.6	51.8	87.1	759.7	761.1	4.6
9/28/1990	18.4	25.4	26.3	60.9	761.3	765.0	6.8
9/29/1990	16.3	24.8	29.8	53.7	764.2	765.8	5.0
9/30/1990	16.7	25.3	43.2	68.6	762.9	764.5	4.5
mean	20.0	27.2	46.7	74.3	757.6	760.3	5.5
max	23.1	29.8	64.7	88.8	764.2	765.8	8.0
min	16.3	24.8	26.3	51.0	752.5	755.3	3.2

September


Temp. (°C)
Temperature
Min
Max
0 5 10 15 20 25 30 35 40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


RH (%)
Humidity
Min
Max
0 20 40 60 80 100
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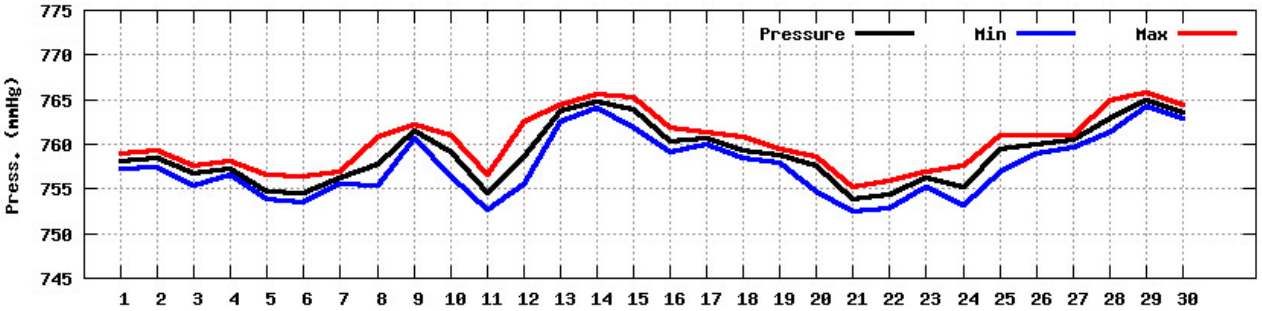
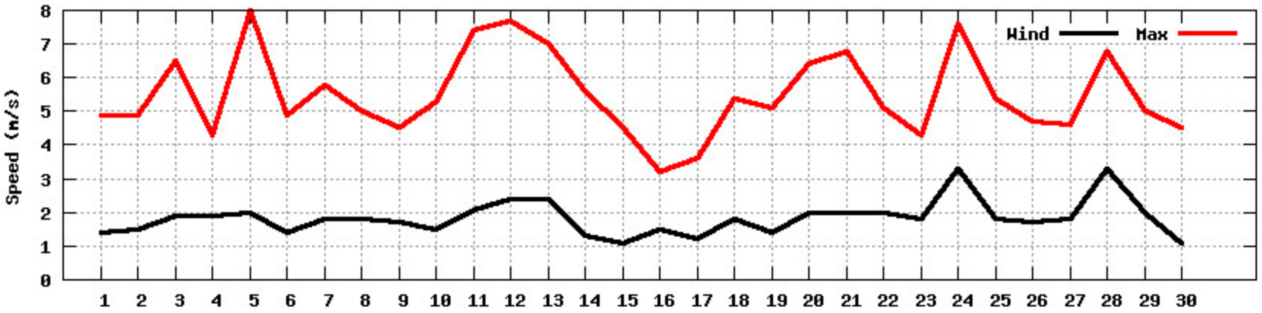

Press. (mmHg)
Pressure
Min
Max
745 750 755 760 765 770 775
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Speed (m/s)
Wind
Max
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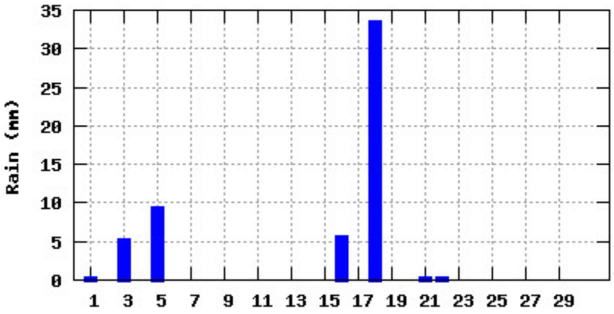
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Rain (mm)
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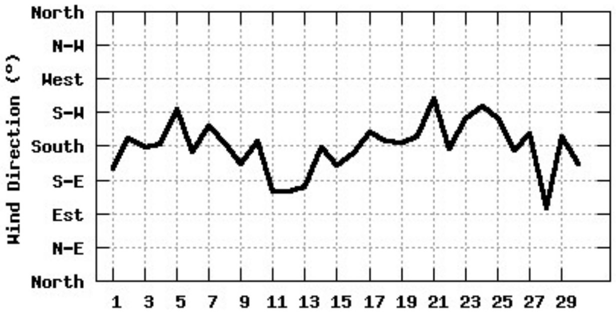

Wind Direction (°)
North
N-W
West
S-W
South
S-E
Est
N-E
North
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29

October

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
10/1/1990	21.6	68.8	762.4	1.2	177	0.3	0.0
10/2/1990	22.9	74.8	761.1	1.1	185	0.2	0.0
10/3/1990	23.1	74.3	759.3	1.5	162	0.2	0.0
10/4/1990	23.2	74.8	758.0	1.7	157	0.2	0.0
10/5/1990	21.7	74.8	759.0	1.3	169	0.2	2.8
10/6/1990	22.0	70.5	760.1	1.7	163	0.2	2.0
10/7/1990	19.9	79.6	755.4	2.8	172	0.1	46.6
10/8/1990	20.4	77.5	755.0	1.5	168	0.1	8.6
10/9/1990	20.5	61.1	760.5	3.5	190	0.2	0.0
10/10/1990	20.1	52.2	763.4	3.1	212	0.1	0.0
10/11/1990	22.9	54.4	763.9	1.2	167	0.2	0.0
10/12/1990	25.1	49.5	764.8	1.5	186	0.2	0.0
10/13/1990	25.1	50.3	763.8	1.1	200	0.1	0.0
10/14/1990	25.9	50.6	761.3	2.0	177	0.2	0.0
10/15/1990	23.9	54.6	760.7	1.5	191	0.2	0.0
10/16/1990	23.0	63.9	760.9	1.6	196	0.2	0.0
10/17/1990	21.5	74.1	758.5	1.3	156	0.1	0.0
10/18/1990	21.9	75.2	758.4	1.9	170	0.2	0.0
10/19/1990	21.7	71.4	756.0	2.5	198	0.1	0.0
10/20/1990	19.3	76.6	751.5	2.2	197	0.1	0.0
10/21/1990	19.7	72.5	754.6	1.7	217	0.2	0.0
10/22/1990	17.4	50.8	760.0	3.0	68	0.1	0.0
10/23/1990	15.5	45.5	761.7	3.0	79	0.2	0.0
10/24/1990	17.7	61.5	758.8	2.4	134	0.2	8.7
10/25/1990	17.5	69.5	758.3	2.6	205	0.2	24.8
10/26/1990	18.2	70.0	756.5	1.9	241	0.2	3.6
10/27/1990	16.9	80.8	755.5	1.9	212	0.0	38.4
10/28/1990	17.4	70.3	752.6	1.2	212	0.1	0.0
10/29/1990	18.4	74.5	748.6	2.3	205	0.1	8.0
10/30/1990	21.4	80.4	750.2	2.3	229	0.1	0.0
10/31/1990	21.3	83.0	755.5	3.4	192.0	0.1	0.0
mean	20.9	67.3	758.3	2.0	180	0.2	4.6
max	25.9	83.0	764.8	3.5	241	0.3	46.6
min	15.5	45.5	748.6	1.1	68	0.0	0.0
sum							143.5

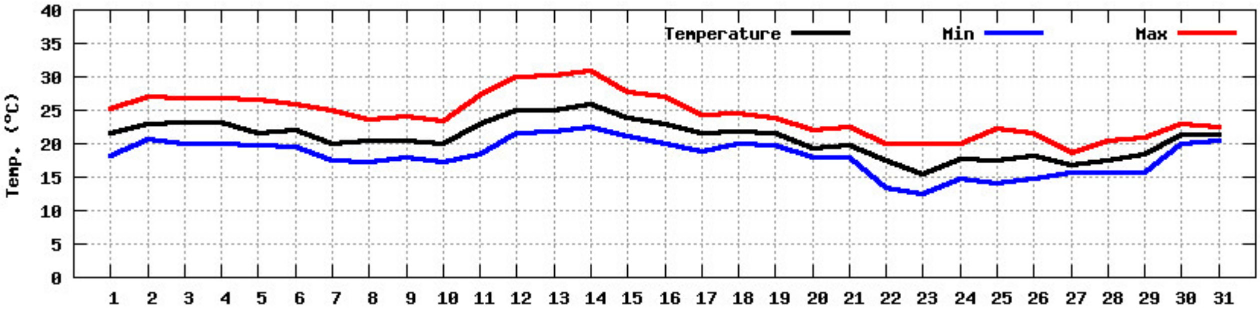
October

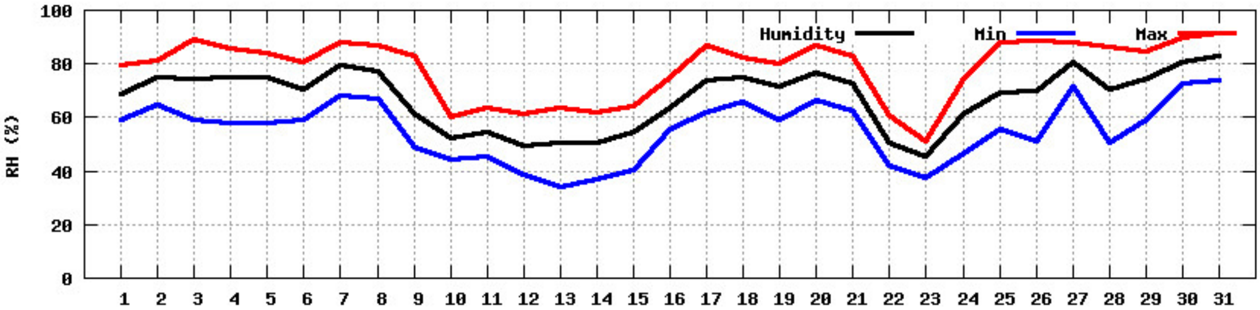
Table B

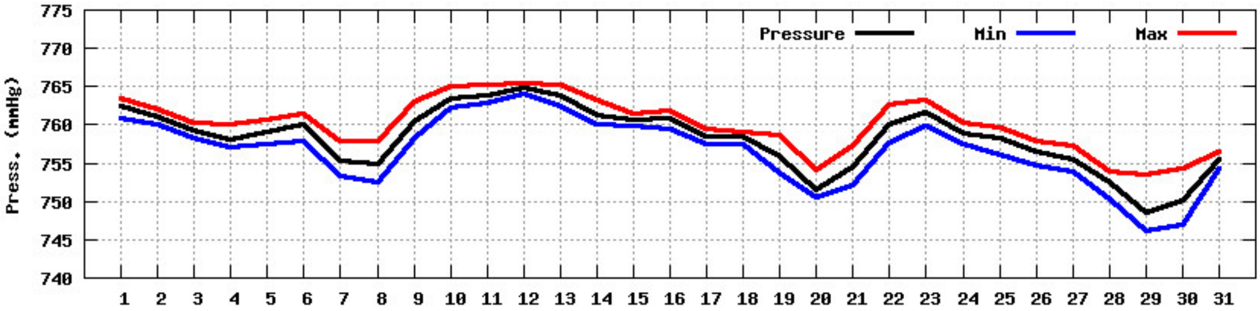
daily extreme

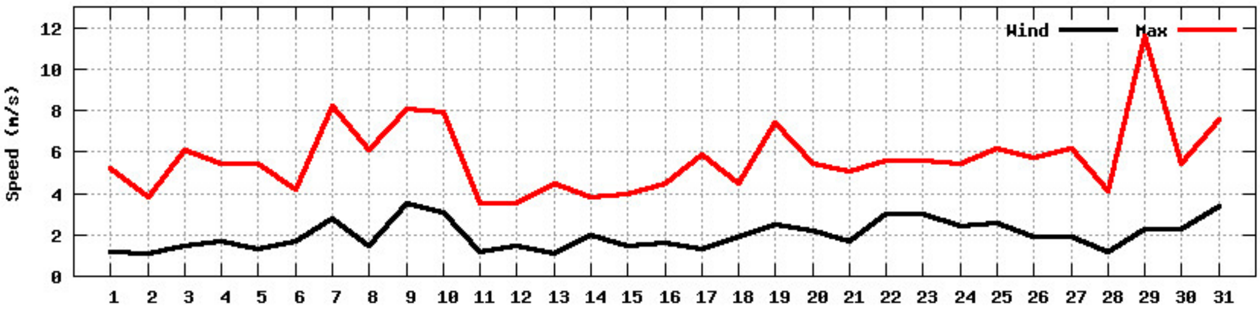
Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
10/1/1990	18.2	25.2	59.0	79.4	760.9	763.5	5.2
10/2/1990	20.7	27.1	64.6	81.3	760.0	762.0	3.8
10/3/1990	20.1	26.8	59.2	89.3	758.2	760.3	6.1
10/4/1990	20.0	26.8	58.1	86.0	757.2	760.1	5.4
10/5/1990	19.8	26.5	58.1	84.1	757.5	760.7	5.4
10/6/1990	19.6	26.0	58.9	80.5	757.9	761.4	4.2
10/7/1990	17.5	24.9	68.4	87.8	753.4	757.9	8.2
10/8/1990	17.2	23.6	66.8	86.8	752.6	757.9	6.1
10/9/1990	17.9	24.2	48.7	82.8	758.2	763.0	8.1
10/10/1990	17.2	23.5	44.2	60.0	762.3	765.0	7.9
10/11/1990	18.5	27.2	45.4	63.5	762.8	765.2	3.5
10/12/1990	21.6	30.0	38.6	61.5	764.1	765.5	3.5
10/13/1990	21.8	30.2	34.2	63.6	762.5	765.2	4.5
10/14/1990	22.5	30.8	37.1	61.7	760.1	763.2	3.8
10/15/1990	21.1	27.8	40.3	64.1	759.8	761.4	4.0
10/16/1990	20.1	27.1	55.4	74.8	759.4	761.9	4.5
10/17/1990	18.9	24.3	62.1	87.2	757.5	759.4	5.9
10/18/1990	20.1	24.5	65.7	82.4	757.5	759.1	4.5
10/19/1990	19.8	23.9	59.0	80.2	753.7	758.7	7.4
10/20/1990	18.0	22.0	66.2	87.2	750.6	754.1	5.4
10/21/1990	18.0	22.6	62.3	82.9	752.2	757.3	5.1
10/22/1990	13.3	19.9	41.8	60.7	757.7	762.6	5.6
10/23/1990	12.5	19.9	37.6	51.4	759.8	763.2	5.6
10/24/1990	14.8	20.0	46.4	74.5	757.5	760.3	5.4
10/25/1990	14.2	22.3	55.8	88.3	756.2	759.7	6.2
10/26/1990	14.7	21.6	51.2	88.6	754.8	757.9	5.7
10/27/1990	15.6	18.6	71.6	87.9	754.0	757.3	6.2
10/28/1990	15.6	20.4	50.8	86.1	750.3	754.0	4.1
10/29/1990	15.6	20.9	59.1	84.6	746.1	753.5	11.6
10/30/1990	20.1	22.9	72.6	89.5	746.9	754.4	5.4
10/31/1990	20.5	22.6	73.6	91.2	754.3	756.6	7.6
mean	18.2	24.3	55.3	78.4	756.6	760.1	5.7
max	22.5	30.8	73.6	91.2	764.1	765.5	11.6
min	12.5	18.6	34.2	51.4	746.1	753.5	3.5

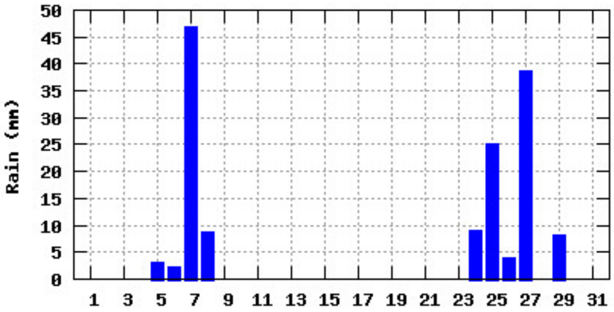
October

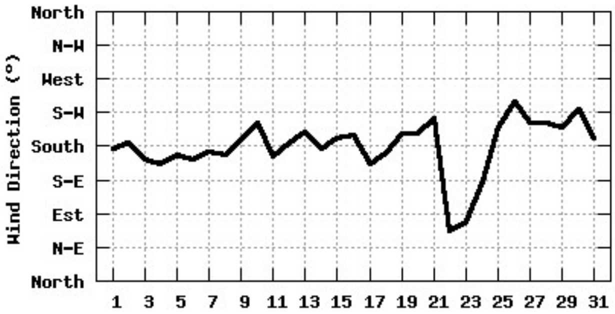

Temp. (°C)
Temperature
Min
Max
0
5
10
15
20
25
30
35
40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


RH (%)
Humidity
Min
Max
0
20
40
60
80
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Press. (mmHg)
Pressure
Min
Max
740
745
750
755
760
765
770
775
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Speed (m/s)
Wind
Max
0
2
4
6
8
10
12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


Rain (mm)
0
5
10
15
20
25
30
35
40
45
50
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31


Wind Direction (°)
North
N-W
West
S-W
South
S-E
Est
N-E
North
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31

November

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
11/1/1990	20.8	77.7	754.9	3.4	217	0.1	0.2
11/2/1990	18.1	57.3	755.8	2.3	270	0.1	0.0
11/3/1990	17.4	66.5	754.0	2.5	237	0.1	6.2
11/4/1990	15.8	63.0	753.4	1.7	238	0.2	0.0
11/5/1990	13.9	57.3	757.0	1.8	181	0.1	2.6
11/6/1990	14.0	49.7	761.3	1.9	231	0.2	0.0
11/7/1990	11.8	47.9	762.1	2.7	143	0.2	0.0
11/8/1990	11.3	43.4	763.6	2.9	138	0.2	0.0
11/9/1990	11.7	47.0	764.9	2.9	144	0.2	0.0
11/10/1990	12.1	46.0	766.0	2.1	216	0.2	0.0
11/11/1990	13.0	47.9	765.9	2.0	219	0.2	0.0
11/12/1990	13.0	48.2	762.8	2.1	144	0.1	0.0
11/13/1990	14.1	52.0	762.6	3.1	120	0.2	0.0
11/14/1990	13.9	53.7	760.9	3.0	196	0.2	0.0
11/15/1990	14.2	55.9	759.3	3.3	204	0.2	0.0
11/16/1990	16.7	64.8	760.3	3.1	98	0.1	1.4
11/17/1990	17.1	61.1	761.4	2.0	129	0.1	0.4
11/18/1990	17.2	72.3	759.0	1.9	213	0.2	0.0
11/19/1990	17.3	69.1	754.0	1.5	171	0.1	0.0
11/20/1990	16.6	71.2	754.6	2.0	255	0.1	3.2
11/21/1990	17.8	70.2	756.7	2.9	212	0.1	0.0
11/22/1990	18.3	70.1	757.7	5.7	171	0.2	0.0
11/23/1990	19.1	70.8	757.2	6.3	191	0.2	12.0
11/24/1990	12.5	70.5	755.1	2.9	204	0.2	7.2
11/25/1990	16.6	71.6	756.1	2.2	195	0.2	2.4
11/26/1990	16.6	72.9	757.0	2.2	195	0.2	0.0
11/27/1990	15.0	70.5	755.3	2.7	196	0.2	18.8
11/28/1990	12.6	69.8	755.7	2.7	222	0.2	16.8
11/29/1990	12.8	67.3	754.0	2.9	246	0.2	14.8
11/30/1990	11.6	67.9	752.6	1.7	290	0.0	10.0
mean	15.1	61.8	758.4	2.7	196	0.2	3.2
max	20.8	77.7	766.0	6.3	290	0.2	18.8
min	11.3	43.4	752.6	1.5	98	0	0.0
sum							96.0

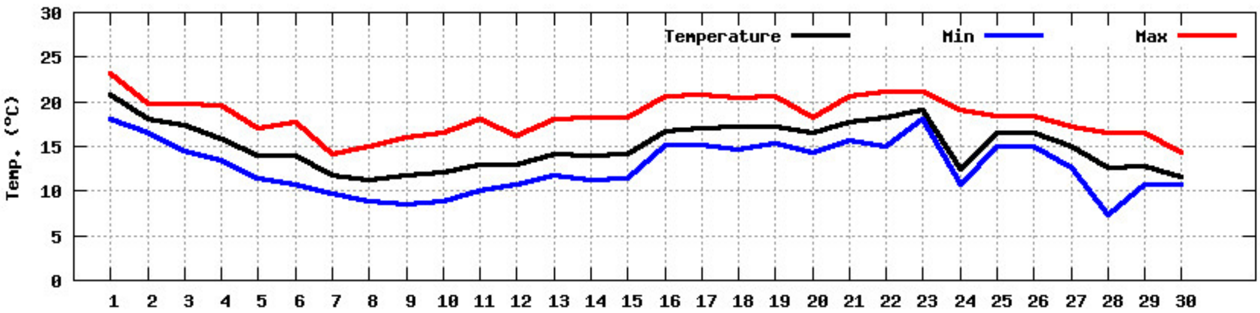
November

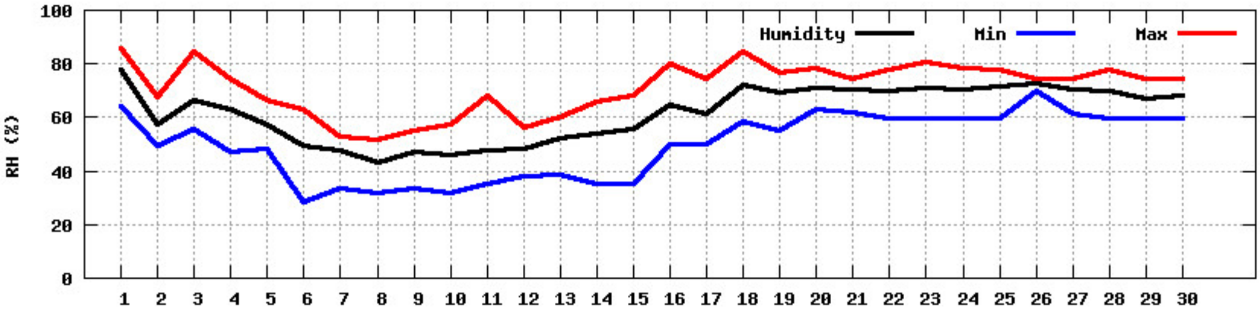
Table B

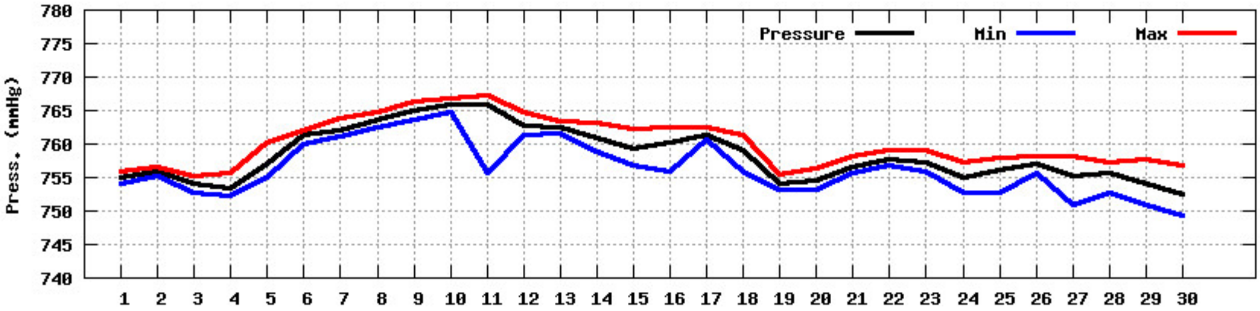
daily extreme

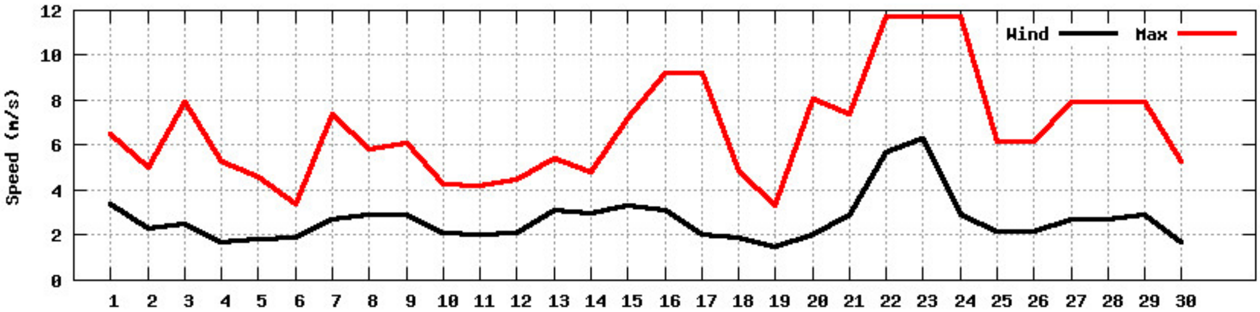
Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
11/1/1990	18.0	23.1	64.0	85.7	754.0	756.0	6.5
11/2/1990	16.6	19.8	49.3	67.4	755.3	756.7	5.0
11/3/1990	14.5	19.8	55.7	84.9	752.8	755.3	7.9
11/4/1990	13.5	19.6	47.4	74.6	752.2	755.6	5.3
11/5/1990	11.4	17.1	48.4	66.3	755.1	760.3	4.6
11/6/1990	10.7	17.8	28.3	62.9	760.1	762.0	3.4
11/7/1990	9.7	14.1	33.6	53.1	761.1	763.8	7.4
11/8/1990	8.8	15.0	32.1	51.8	762.5	764.7	5.8
11/9/1990	8.5	16.0	33.7	55.3	763.6	766.4	6.1
11/10/1990	8.8	16.6	32.0	57.3	764.8	766.9	4.3
11/11/1990	10.0	18.1	35.3	68.3	755.6	767.3	4.2
11/12/1990	10.7	16.2	38.2	56.5	761.3	764.7	4.5
11/13/1990	11.7	18.1	38.6	60.4	761.7	763.3	5.4
11/14/1990	11.2	18.3	35.5	65.8	758.8	763.2	4.8
11/15/1990	11.5	18.3	35.5	67.9	756.9	762.3	7.2
11/16/1990	15.2	20.7	50.2	79.9	756.0	762.6	9.2
11/17/1990	15.2	20.8	50.2	74.2	760.6	762.6	9.2
11/18/1990	14.6	20.4	58.5	84.7	755.9	761.3	4.9
11/19/1990	15.3	20.7	55.2	76.7	753.1	755.4	3.3
11/20/1990	14.4	18.2	62.9	78.6	753.1	756.3	8.1
11/21/1990	15.6	20.7	62.1	74.7	755.7	758.1	7.4
11/22/1990	15.0	21.1	59.8	77.7	756.9	759.1	11.7
11/23/1990	18.1	21.1	59.8	80.6	755.9	759.1	11.7
11/24/1990	10.8	19.1	59.6	78.3	752.8	757.3	11.7
11/25/1990	15.0	18.4	59.6	77.7	752.8	757.9	6.2
11/26/1990	15.0	18.4	70.0	74.7	755.7	758.1	6.2
11/27/1990	12.6	17.3	61.2	74.7	751.0	758.1	7.9
11/28/1990	7.4	16.5	59.6	77.7	752.8	757.3	7.9
11/29/1990	10.8	16.5	59.6	74.7	751.0	757.8	7.9
11/30/1990	10.8	14.3	59.6	74.2	749.3	756.9	5.3
mean	12.7	18.4	49.9	71.2	756.3	760.2	6.7
max	18.1	23.1	70.0	85.7	764.8	767.3	11.7
min	7.4	14.1	28.3	51.8	749.3	755.3	3.3

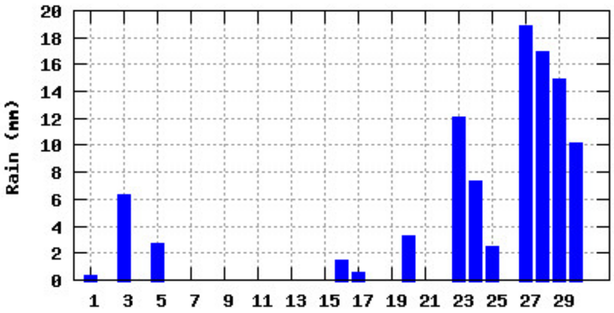
November

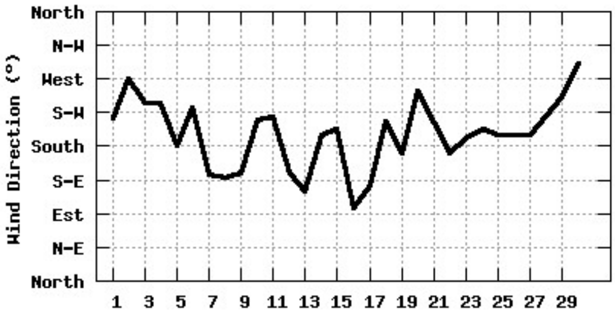

Temp. (°C)
0 5 10 15 20 25 30
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Temperature
Min
Max


RH (%)
0 20 40 60 80 100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Humidity
Min
Max


Press. (mmHg)
740 745 750 755 760 765 770 775 780
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Pressure
Min
Max


Speed (m/s)
0 2 4 6 8 10 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
Wind
Max


Rain (mm)
0 2 4 6 8 10 12 14 16 18 20
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29


Wind Direction (°)
North
N-W
West
S-W
South
S-E
Est
N-E
North
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29

December

Table A

Daily Means

Date	Temperature	Humidity	Pressure	Wind		Solar Rad.	Rain
	°C	%	mmHg	m/s	dir.	langley/min	mm
12/1/1990	7.8	44.7	756.0	4.0	113	NP	9.2
12/2/1990	6.0	59.0	758.9	1.7	151	NP	0.0
12/3/1990	6.0	59.0	758.9	1.7	151	NP	0.0
12/4/1990	9.2	59.4	758.9	1.4	153	NP	0.0
12/5/1990	9.2	58.0	756.5	2.0	99	NP	0.0
12/6/1990	7.8	50.7	756.0	4.0	113	NP	0.0
12/7/1990	6.0	59.0	758.9	1.7	151	NP	8.2
12/8/1990	9.1	67.3	760.0	3.0	212	NP	6.6
12/9/1990	15.7	71.2	753.4	10.2	179	NP	0.6
12/10/1990	13.0	59.7	749.0	6.5	238	NP	11.4
12/11/1990	12.1	57.7	750.5	4.5	231	NP	15.6
12/12/1990	9.4	71.2	744.8	2.5	163	NP	5.4
12/13/1990	8.8	70.6	740.5	3.4	169	NP	5.6
12/14/1990	8.9	65.8	749.3	1.9	201	NP	0.4
12/15/1990	9.4	55.3	756.3	2.1	214	NP	0.2
12/16/1990	7.9	59.2	759.1	2.4	166	NP	0.0
12/17/1990	8.2	50.3	760.8	3.0	158	NP	0.0
12/18/1990	8.8	55.0	761.4	2.5	169	NP	0.0
12/19/1990	9.6	59.8	762.3	2.5	273	NP	0.0
12/20/1990	9.0	61.1	764.4	1.8	207	NP	0.0
12/21/1990	8.7	59.6	765.0	1.7	206	NP	0.0
12/22/1990	8.8	55.0	761.4	2.5	169	NP	0.0
12/23/1990	10.3	54.5	763.0	2.6	154	NP	0.0
12/24/1990	9.8	68.0	759.1	3.8	174	NP	17.6
12/25/1990	10.1	69.0	760.8	3.6	241	NP	0.0
12/26/1990	11.1	64.8	760.9	1.2	153	NP	0.0
12/27/1990	11.1	74.7	760.3	1.4	194	NP	13.6
12/28/1990	12.3	74.8	761.3	1.8	211	NP	1.6
12/29/1990	10.8	66.4	768.2	1.6	220	NP	0.0
12/30/1990	12.2	72.7	770.0	1.0	207	NP	0.0
12/31/1990	13.5	74.8	767.2	0.8	207	NP	0.0
mean	9.7	62.2	758.5	2.7	182	NP	3.1
max	15.7	74.8	770.0	10.2	273	NP	17.6
min	6.0	44.7	740.5	0.8	99	NP	0.0
sum							96

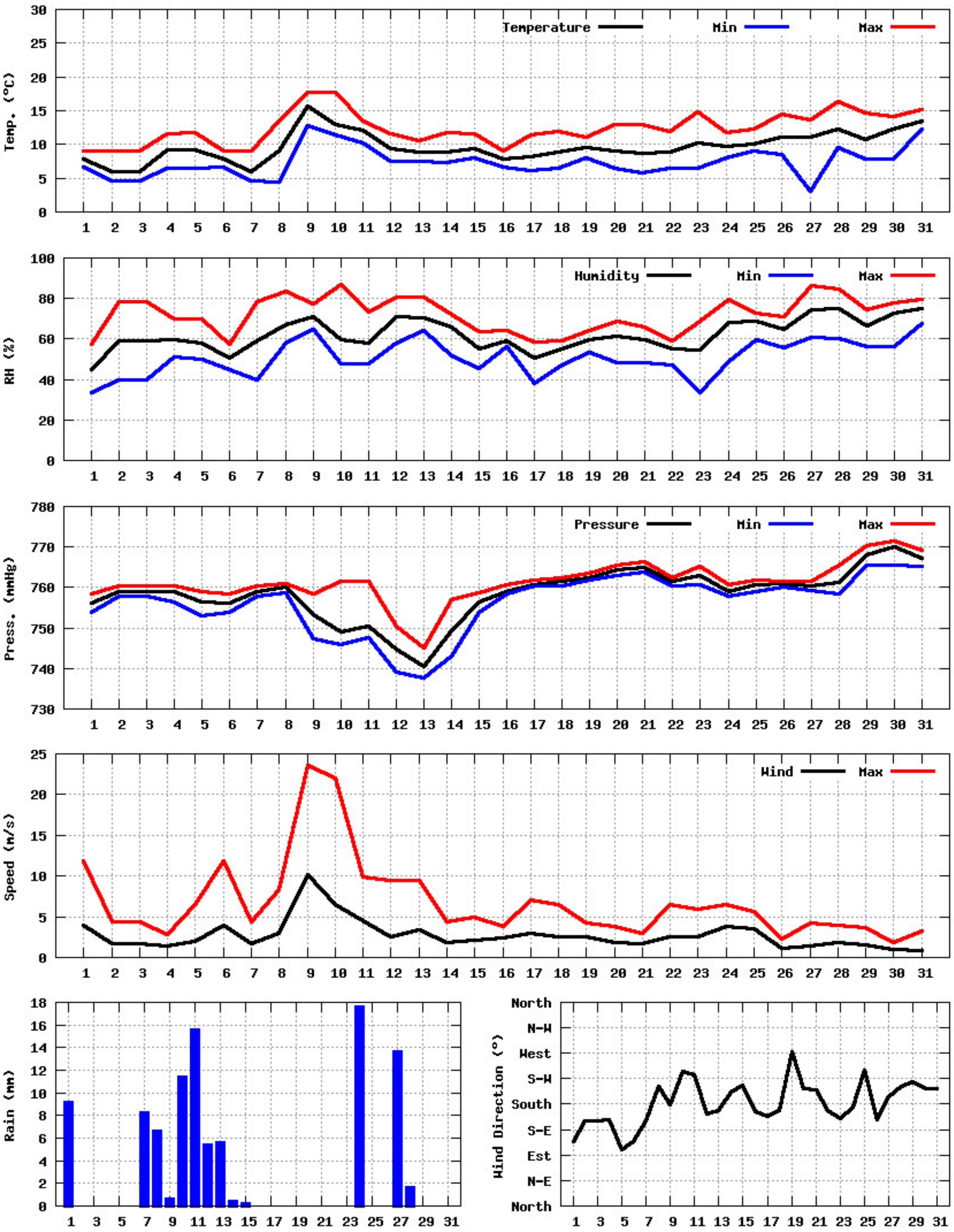
December

Table B

daily extreme

Date	Temperature °C		Humidity %		Pressure mmHg		Wind m/s
	min	max	min	max	min	max	max
12/1/1990	6.6	9.1	33.3	57.4	753.8	758.4	11.9
12/2/1990	4.6	9.0	40.0	78.3	757.8	760.3	4.4
12/3/1990	4.6	9.0	40.0	78.3	757.8	760.3	4.4
12/4/1990	6.5	11.6	51.3	69.7	756.3	760.3	2.8
12/5/1990	6.5	11.7	49.8	69.7	753.1	759.1	6.5
12/6/1990	6.6	9.1	44.7	57.4	753.8	758.4	11.9
12/7/1990	4.6	9.0	40.0	78.3	757.8	760.3	4.4
12/8/1990	4.4	13.4	57.8	83.6	758.7	761.0	8.4
12/9/1990	12.8	17.7	64.6	77.3	747.2	758.4	23.6
12/10/1990	11.5	17.7	48.0	86.9	745.9	761.4	22.0
12/11/1990	10.3	13.5	48.0	73.3	747.5	761.4	9.9
12/12/1990	7.5	11.6	58.0	80.5	739.0	750.4	9.5
12/13/1990	7.5	10.6	64.2	80.5	737.8	745.0	9.5
12/14/1990	7.3	11.7	51.9	72.2	743.0	757.0	4.4
12/15/1990	8.0	11.6	45.4	63.9	754.0	758.7	5.0
12/16/1990	6.7	9.0	56.0	64.0	758.4	760.6	3.8
12/17/1990	6.2	11.4	37.9	58.4	760.4	761.9	7.0
12/18/1990	6.5	11.9	47.4	59.3	760.4	762.5	6.5
12/19/1990	8.0	11.0	53.6	64.1	761.7	763.5	4.3
12/20/1990	6.4	13.0	48.1	68.9	763.0	765.5	3.8
12/21/1990	5.8	13.0	48.1	65.8	763.8	766.3	3.0
12/22/1990	6.5	11.9	47.4	59.3	760.4	762.5	6.5
12/23/1990	6.4	14.9	33.7	68.9	760.7	765.2	5.9
12/24/1990	8.0	11.8	48.8	79.7	757.8	760.6	6.5
12/25/1990	9.0	12.3	59.7	72.8	758.9	761.7	5.7
12/26/1990	8.6	14.5	55.4	71.1	760.1	761.6	2.3
12/27/1990	3.0	13.6	60.9	86.3	759.4	761.4	4.2
12/28/1990	9.6	16.3	60.4	84.6	758.5	765.4	3.9
12/29/1990	7.9	14.7	56.2	74.2	765.4	770.4	3.7
12/30/1990	7.9	14.2	56.2	78.0	765.4	771.4	1.9
12/31/1990	12.3	15.1	67.5	79.4	765.1	769.1	3.3
mean	7.4	12.4	50.8	72.3	756	761.3	6.8
max	12.8	17.7	67.5	86.9	765.4	771.4	23.6
min	3.0	9.0	33.3	57.4	737.8	745.0	1.9

December


Temp. (°C)
Temperature
Min
Max
0
5
10
15
20
25
30
RH (%)
Humidity
0
20
40
60
80
100
Press. (mmHg)
Pressure
730
740
750
760
770
780
Speed (m/s)
Wind
0
5
10
15
20
25
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
Rain (mm)
0
2
4
6
8
10
12
14
16
18
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31
Wind Direction (°)
North
N-E
Est
S-E
South
S-W
West
N-W
North