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Final Thesis

THE ARTIFICIAL CREEKS IN SANT'ERASMO ISLAND (VENICE LAGOON): PRESENT STATUS AND SUGGESTIONS FOR MANAGEMENT BASED ON TWO INDICATOR SPECIES

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1Introduction

1.1 The Venice Lagoon as habitat system for fish assemblages:the role of artificial creeks

Estuaries and coastal lagoons show high levels of habitat heterogeneity and support a large fish production (Elliott & Hemingway, 2002). Hosting a wide variety of biodiversity, the Venice lagoon is the biggest lagoon in the Mediterranean basin and with its 550 km2 is connected to the Adriatic Sea by the port entrances of Lido, Malamocco and Chioggia (Ghetti, 1974). The lagoon has an average depth of 0.6 m and a salinity in the range 28-36°/oo (Donazzolo et al., 1984),

The salt marshes represent one of the main habitats for many fish species of the Venice lagoon, characterized by seagrass meadows, bare sand areas, intertidal flats, sandy and muddy subtidal beds, and tidal marshes.

Salt marshes are important from an ecological point of view because they are habitats for native migratory fish and they are also feeding and nursery grounds. They provide protection to smaller fishes from bigger predators present in deeper waters..

The ecological importance of these habitats is mainly due to the high level of trophic resources available and to the refuge function from predation deriving from a complex morphological structure (Rountree et al., 2007)

Land claim, erosion, pollution, and relative sea level rise determined the alteration or the complete destruction of these habitats. A major loss of salt marsh habitats occurred also within the Venice lagoon, the largest Mediterranean coastal lagoon, with salt marsh surface reduction from about 149 km2 in 1912 to 37 km2 in 2003 (Cucchini, 1928; Silvestri et al., 2003).

During the last century, the phenomenon of erosion has been further aggravated by the construction of the piers at the harbour's mouth of Lido, Malamocco and Chioggia, which has increased the loss of sediments towards the sea during the high tidal cycles, generating an increase of the erosion effect.

Subsidence and relative sea level rise have been addressed as among the major causes of salt marsh loss (Bock et al., 2012; Kirwan et al., 2013), particularly in situation with a lower income of sediments such as in the case of the Venice lagoon. For the Adriatic Sea, during the XX century, sea level rose at a rate of 1.3 mm y-1, and for the 2100 it could rise of 14-49 cm (Scarascia et al., 2013).

Climate change impacts to salt marshes and their wildlife will vary both temporally and spatially and may be irreversible and severe. Synergistic effects caused by combining stressors with anthropogenic land-use patterns could create areas of significant biodiversity loss and extinction, especially in urbanized estuaries that are already heavily degraded(Thorn et al., 2012).

An important role is played by the artificial creeks, present in many islands of the lagoon, once used for aquaculture and transport means. Nowadays, even though the use has changed in many cases, these artificial sites gained an ecological value as alternative refuge habitats to natural salt marsh creeks.

Most of these man made creeks are now abandoned, and therefore free of pollution and partly renaturalised, others allow navigation to small boats.

One of the advantages of this type of habitat is given by the isolation of these artificial creeks that works as a refuge from aquatic predators present in shallow water creeks, thus determining fish density in artificial sites.

These artificial habitats have always been considered marginal because supporting only few species and environmental conditions are limited. Only few studies have been conducted about them although their role could become relevant in the next future due to climate change effects since they will possibly host part of the salt marshes population.

These creeks currently host a fish fauna, which is mostly belonging to brackish-water environments. Since the fish fauna can be associated to a certain type of environmental conditions, this project leads to investigate two fish species that can be considered indicator species: *Aphanius fasciatus* (Valenciennes, 1821) and *Gambusia holbrooki* (Girard, 1859).

The two fish species we considered can be defined as indicator species for several reasons.

They emphasize environmental health:

In biology an indicator is an organism so intimately associated with particular environmental conditions that it's presence indicates the existence of those conditions (Patton 1987).

They also can be defined indicators because they emphasize responses to specific taxa:

A. fasciatus and *G. holbrooki* respond predictably, in ways that are readily observed and quantified, to environmental disturbance or to a change in environmental state (McGeoch 2007)

Managers also use indicators for other reasons. First because their presence and fluctuations are believed to reflect those of other species in the community; and second because they are believed to reflect chemical and/or physical changes in the environment (Simberloff 1998). In this case, the two species taken into consideration are used to detect mostly physical changes in the environment such as temperature and salinity.

Another definition of indicator species, which in this case incorporates biodiversity, environmental health, and responses of specific taxa states that an indicator species is an organism whose characteristics (e.g., presence or absence, population density, dispersion, reproductive success) are used as an index of attributes too difficult, inconvenient, or expensive to measure for other species or environmental conditions of interests (Landres et al. 1988).

1.2 Objectives of the thesis

A. fasciatus is an autochthonous species, being mostly associated with salt marsh habitats of the lagoon of Venice, but it can be found also in the artifical creeks of some lagoon islands. Considering that many studies have been carried out on *A. fasciatus*, and we know the chemical and physical characteristics of its habitat, one of the objectives of this work is to determine what is the cause of absence or presence of *A. fasciatus* in Sant'Erasmo creeks (Venice lagoon).

As the salt marshes, the artificial creeks offer favorable conditions and protection from predators for *A. fasciatus*, but recently this species in Sant'Erasmo island, started to slightly decrease.

Despite both species can survive in a wide range of salinty conditions, *A. fasciatus* shows a more aggressive behavior at higher salinity conditions compared to *G. holbrooki*, thus we expect to find a higher concentration of *A. fasciatus* in sea water conditions (Alcaraz et al. 2008).

According to the literature, the mosquitofish efficiency is reduced at high salinity but we won't be able to investigate a situation like the Sant'Erasmo one, where the salinity and the temperature can vary along the seasons.

Defining *G. holbrooki* (Porte et al., 1992) and *A. fasciatus* (Messaoudi et al., 2009) as indicator species and knowing their habitat, then it will be possible to indicate which watercourses have faced a change by observing their presence or absence.

Aiming to confirm the previous studies on the habitats and ecological niches of the two species, this study will allow us to identify which creeks are suitable for *A. fasciatus* and *G. holbrooki* populations, and therefore, suitable for other species with the same ecological preferences. This way it will be given more importance to the artificial creeks, considering it as a biological reservoir.

The intrinsic objective of the work, is to give more importance to the potential role of biological reservoir of the artificial creeks of Sant'Erasmo, which could possibly host part of the salt marshes population in view of sea level rise. Therefore, the artificial creeks are supposed to be mostly brackish water.

In order to understand better the situation of presence and absence of the two species, and the salinity and temperature levels, a map of the island plus some graphics will be provided together with some considerations on the use of these habitats.

2 Material and methods

2.1 The study area

The island of Sant'Erasmo is the second biggest island of the Venice lagoon. Its southern part was once facing the open sea directly, but after the construction of Punta Sabbioni (early XX century), the Sant'Erasmo island is now entirely surrounded by the lagoon. The artificial creeks of the island, once used for aquaculture or built up as defense lines are now mostly abandoned and used as drainage ditches. Fishery was a very important activity. There was a fish farm operating on the north east of the island but also many other watercourses were used to breed eels, sea breams, mullets.

Nowadays the fishery activity has diminished drastically or even abandoned and agriculture has become the main activity. The whole island is covered by a dense network of artificial creeks crossing through the cultivated fields, most of them have been built during the XIX/XX century as defense of military buildings. The watercourses present in Sant'Erasmo, since they have been abandoned, have become a natural habitat for some fish species and they can be divided in two main groups: the open systems and the closed systems.

The whole system is regulated by gates that can be closed by the inhabitants in case of high tide phenomenon. Some of the gates are permanently closed and therefore a complete drainage of the water doesn't occur.

The open systems include watercourses directly connected to the sea water through gates faced on the lagoon. Their depth can reach the two meters and the navigation to small boats is allowed. The salinity here is approximately the same encountered in the open lagoon and, mostly, hosts marine species and typical marine vegetation such as green algae which constitutes the preferred habitat of *A. fasciatus* (Pontremolesi et al., 2011).

The open systems communicates with other smaller creeks through gates which used to be open in order to drain the water and closed to avoid floods during high tides. Some of these gates are still working but some others are permanently closed and abandoned, generating closed system of sweeter water allowing both terrestrial and aquatic habitats to prosper.

2.2 The study species

A. fasciatus, is a small euryhaline killifish inhabiting shallow brackish waters in the central and eastern coastal zones of the Mediterranean Sea. The species showed a widespread decline and sometimes local population extinction, due to habitat degradation and competition with the introduced poeciliid *G. holbrooki* . With a few exceptions, *A. fasciatus* is currently extinct in inland waters, being mainly present in coastal brackish-water habitats (Valdesalici, S., et al. 2015).A. *Fasciatus* species are basically micropredators feeding on small aquatic crustaceans, worms, insect larvae and other zooplankton although algae and other plant material is also taken at times. As with all members of the genus sexual dimorphism is pronounced. Males exhibit a series of 8-15 blue/greyish vertical bars on the flanks. The anal fin usually contains some dark streaking and the dorsal somespot-like markings near the base and the finnage in general is usually a yellow/green colour. Females are larger and much plainer possessing only a series of brown vertical bars on the body (which the occasional specimenmay lack) along with some irregular dark spotting above the lateral line and completely hyaline finnage.

Depending on the population the number and width of the vertical bars in males can vary and there may or may not be a dark submarginal band in the caudal fin (Leonardos, 2008). It can show strong fluctuations in chemicalphysical parameters such as dissolved oxygen, temperature, and salinity (Gandolfi et al., 1991).

G. holbrooki is an invasive species. Over its natural range, it is usually found in shallow, heavily-vegetated marginal areas of still or sluggish bodies of water. It can also be found in brackish conditions in some areas.

It has been introduced directly into ecosystems in many parts of the world as a biocontrol to lower the mosquitos populations but it turned out to affect negatively many other species in the ecosystems. Sadly, this has often resulted in detrimental effects on ecosystems, as they are also voracious predators of small crustaceans and the eggs, little amphibious (they are able to do massive attacks towards species much bigger than them) and young of other fish species. Although they do feed on the aquatic larvae and pupal forms of mosquitos, it is now thought that they are no more effective than native species in many instances. *G. holbrooki* is smaller than *A. fasciatus* and as *A. fasciatus* the dimorphism is pronounced. The female can reach 7cm of length, while males can reach only 4 cm. Sexual dimorphism can also be detected in the physiologically structure of the body. The females are larger and more rounded than the males. Pregnant females are also easily recognizable by their gravid spot. The ability of G. holbrooki to tolerate a wide range of temperature and salinity levels, as well as

low levels of dissolved oxygen, have allowed this species to its diffusion (Alistair Becker et al.,2005).

Previous studies found that the possibility of a heavy impact of *G. holbrooki* on killifish in some area is important (Duchi, 2006): with the outcome of competition apparently depending on environmental characteristics: in the more stable environments only

G. holbrooki has been found, in the harsher ones only the killifish and in those with intermediate characteristics both species are found in sympatry.

2.3 Gambusia holbrooki and *Aphanius fasciatus* as indicator species

Fig 1: Gambusia holbrooki in a water body of Sant'Erasmo island

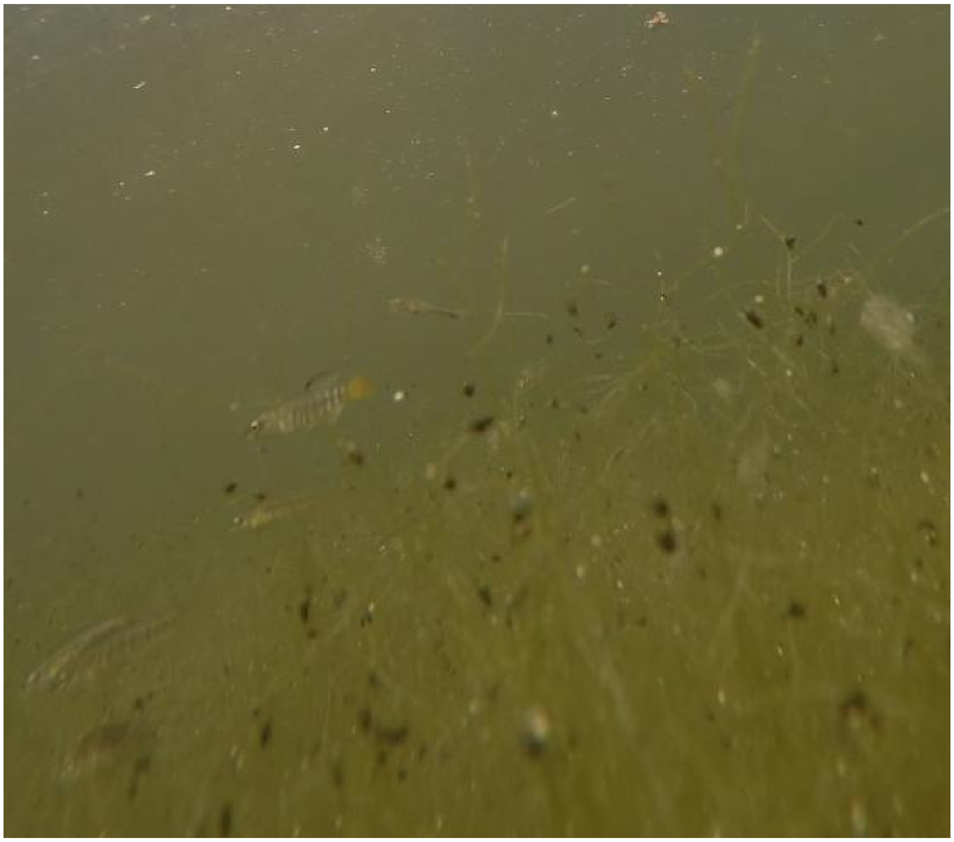


Fig 2: Green algae as one of the main element of Aphanius fasciatus

The scientific literature regarding *A. fasciatus* and *G. holbrooki* allows us to identify their preferences in terms of vegetation, salinity and temperature, and therefore to detect their habitat through the use of specific tools (salinometer, termometer, GoPro Camera and visual analysis) in Sant'Erasmo island.

Both species have a wide range of adaptation and although they are accepting a similar type of habitat, finding both species in the same site is usually very rare.

Knowing the preferences of *A. fasciatus* and of *G. holbrooki*, the presence of one of the two allows to understand the characteristic of the environment (e.g. algae presence, temperature and salinity).

Previous studies confirm that salinity limits the invasive success of mosquitofish and it may mediate behavioural and competitive interactions between fish species. Therefore, although the range of salinity tolerance of *G. holbrooki* is wider, *A. fasciatus* tolerates better higher salinity.
As regard the termal niche, since they are both considered killifish, they both can survive in brackish watercourses characterized by shallow waters and with high thermal excursions along the seasons. *A. fasciatus* is Active over a wide temperature range of 2 – 30 °C while *G. holbrooki* between 18 and 27°C and this makes clear that the two species belong to two different environment and at the end of the project it will be possible to confirm what are the preferences of *A. fasciatus* and *G. holbrooki*.

2.4 Sampling design and measurements

The abandonment of the management of the floodgates on the artificial creeks, determine a change on the type of habitats present on the island, and the use of these species as indicators can help to identify the environmental condition in every watercourse that has been analyzed
Samplings design and measurements
The Venice lagoon is one of the largest ones along the coasts of the Mediterranean
Sea, with a surface of about 540 km2. It is a microtidal transitional water ecosystem, where tides can reach 1 m of excursion, characterised by wide extensions of shallow
brackish water interrupted by a network of deeper channels and salt marsh habitats.
The island of Sant'Erasmo was chosen among other islands of the Venice lagoon for its big amount of artificial creeks. It's about 4km long and between 500m and 1km wide and almost entirely covered by small canals.
During each sampling event, two main chemico-physical water parameters were recorded: temperature (digital thermometer, ±0.1 °C) and salinity (optical refractometer, ±1). To assess the presence/absence of the two species, visual observations were conducted from the shoreline and a video shooting with a digital GoPro Camera.
Most of the watercourses of the island have been studied, although in many cases the turbidity of the water didn't allow the camera to detect any fish, thus the video recording in these cases

has been substituted with photo shooting or a simple visual analysis that could determine the presence or absence of the two fish species we have considered. Few others water bodies haven't been explored because they were included in areas too difficult to reach by foot where the only possible access was by boat.

Although it's a scarcely inhabited island, most of its land belongs to private owners, and the artificial creeks flow on these lands. Therefore in many situations, exploring the canals implied asking the land owner to access to his field and maybe taking advantage on it asking the owner a few questions regarding the management of the artificial creeks.

For each site the presence/absence of *G. holbrooki* and *A. fasciatus* was assessed, in order to obtain a complete map of the island which represents the spread of the two species.

For each sampling analyzed, it has been considered the probable communication of the single creek with other canals in the surroundings. Often, the communication with other watercourses can happen through gates or small pipes in the underground built to facilitate the flow of the water during the tidal movements.

Afterwards, a code has been assigned for every group of canals communicating to each other, in order to assemble them.

Another parameter taken into account during the study is the direct connection of a canal with the lagoon. Since these watercourses are used for navigation of small boats, they undergo a periodical maintenance, such as reshaping of the embankment or dredging.

These canals have a higher age of water, since the gates stay open most of the times and get closed only when high tide goes beyond the 80cm, and the rate of vegetation is lower compared to the closed systems.

It has to be taken into account that the variability of data along the year can be very high as regard the values of temperature, salinity, vegetation rates and precipitations and seasonality can affect them.

In detecting *G. holbrooki* holbrooki and *A. fasciatus*, the purpose of dividing the artificial creeks in groups, aims to consider the possible presence of a species in the canals connected to the site where a fish has been found. In other words, if the presence of an *A. fasciatus* has been detected at site number 5, the same fish will be able to move from the artificial creeks where it has been found, to other canals connected to it. This has also been done to sustain the thesis that the presence is always certain, the absence is not, therefore, the margin of error is reduced by considering the whole group. Considering the connections between the creeks, sites were pooled into 38 stations.

Therefore, when analyzing these data we must consider that they are referring to a specific period going from April to June, corresponding to the spawning season of both species. In particular, as regards the closed system, heavy rains can change the salinity dramatically from one day to another, because the water flow coming from the open lagoon can be very scarce or even absent.

Along the research, also some interviews to the inhabitants have been made, regarding the historical aspect of the artificial creeks and the management of the watercourses of the island of Sant' Erasmo.

group	Average temperature	Standard deviation of temperature	Average salinity %	Standard deviation of salinity %	Min of temperature	Max of temperature	Min of salinity %	Max of salinity%
1	19,6		27,0		19,6	19,6	27,0	27,0
2	22,8	2,7	32,8	2,8	19,1	27,2	29,0	36,0
3	23,5		25,0		23,5	23,5	25,0	25,0
4	20,6	1,8	32,2	3,5	17,3	23,5	24,0	36,0
5	21,2	1,6	32,9	2,7	18,1	24,0	27,0	36,0
6	19,3		36,0		19,3	19,3	36,0	36,0
7	23,2	0,2	33,3	0,6	23,0	23,3	33,0	34,0
8	21,8	0,1	28,5	0,7	21,7	21,8	28,0	29,0
9	26,0		25,0		26,0	26,0	25,0	25,0
10	22,8		38,0		22,8	22,8	38,0	38,0
11	19,4		35,0		19,4	19,4	35,0	35,0

12	20,3	0,7	34,7	2,3	19,7	21,0	32,0	36,0
13	19,2	2,2	7,0	4,6	15,4	20,6	4,0	15,0
14	20,9	0,4	9,0	1,7	20,5	21,3	8,0	11,0
15	22,1	2,6	5,7	4,3	18,2	24,2	1,0	13,0
16	18,9	0,1	20,5	0,7	18,8	18,9	20,0	21,0
17	20,9	0,1	4,5	0,7	20,8	21,0	4,0	5,0
18	18,9		1,0		18,9	18,9	1,0	1,0
19	24,8		2,0		24,8	24,8	2,0	2,0
20	25,2	0,6	9,5	0,7	24,8	25,6	9,0	10,0
21	24,0		4,0		24,0	24,0	4,0	4,0
22	18,6		0,0		18,6	18,6	0,0	0,0
23	23,3		14,0		23,3	23,3	14,0	14,0
24	21,3		6,0		21,3	21,3	6,0	6,0
25	23,0	1,3	30,0	0,0	22,0	24,8	30,0	30,0
26	25,8	1,8	22,0	4,2	24,5	27,1	19,0	25,0
27	23,3	1,7	19,5	3,8	21,8	25,0	17,0	25,0
28	20,9		12,0		20,9	20,9	12,0	12,0
29	25,9	4,0	19,0	3,2	21,7	31,2	14,0	24,0
30	28,7	1,0	29,0	1,4	27,8	30,0	28,0	31,0
31	29,0		14,0		29,0	29,0	14,0	14,0
32	29,3	0,4	15,0	4,2	29,0	29,5	12,0	18,0
33	28,5		5,0		28,5	28,5	5,0	5,0
34	28,3	0,1	10,5	0,7	28,2	28,4	10,0	11,0
35	26,4	0,6	30,0	0,0	26,0	26,8	30,0	30,0
36	28,1	0,2	14,0	1,0	27,9	28,3	13,0	15,0
37	22,6		30,0		22,6	22,6	30,0	30,0
38	22,0	0,1	19,5	2,6	21,8	22,1	16,0	22,0

Tab 2: Data collected during the study regarding the 38 groups of canals

The summary table, shows the data of the canals system collected during the projects.

The columns related to temperature show the average temperature detected during the study.

The variability of this data is very high since the same watercourse can change its temperature dramatically, especially when measuring shallow water creeks and not communicating directly with the open lagoon.

Another value that manifests high variability is salinity. In artificial creeks where water gates have been permanently closed, and after strong precipitations, the salinity can vary by more than 50%. For instance, the site number 50 which is directly communicating with the open lagoon has a water gate at its mouth. The day after a strong rain and a high tide phenomenon, when the gate was still closed, the salinity of the water was 15ppt, while the salinity of the open lagoon can reach 36ppt.

The following columns, show the presence of *Aphanius fasciatus, Gambusia holbrooki* or none of them, for each site analyzed. In the column P/A, a number has been given for every site to express the presence of the species we have considered: 1 for the Aphanius, 2 for the Gambusia, 3 for the coexistence of the two, 0 for the absence of the two.

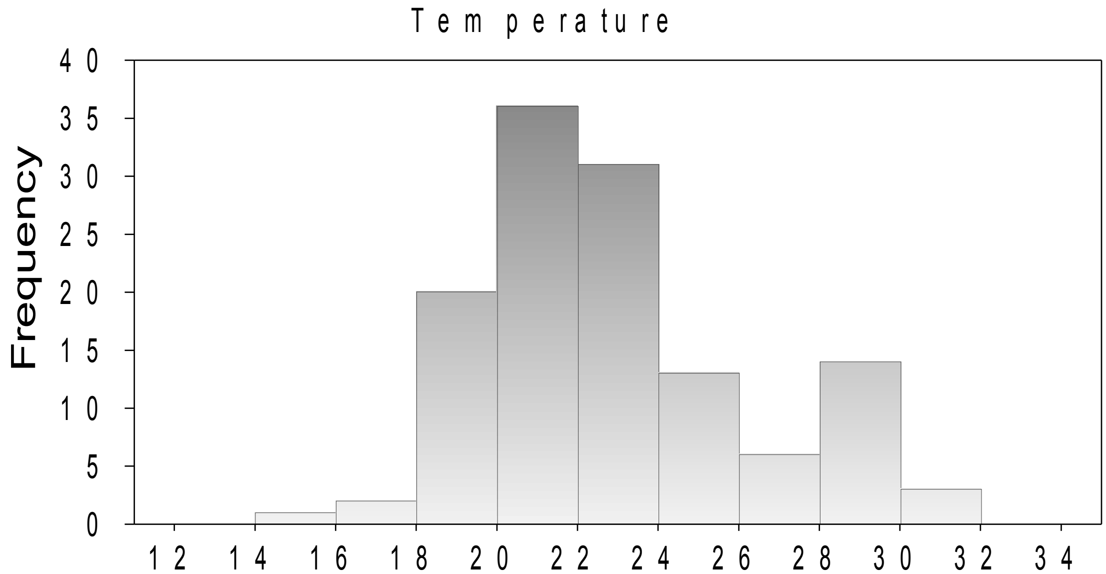
The same values have been developed for the following columns referring to the presence/absence of fishes, temperature, salinity within the whole group of artificial creeks.

At last, also the parameter of presence/absence of algae has been taken into account in order to understand better the fishes preferences where 1 indicates the presence of algae within the group of creeks, and 0 the absence.

3 Results

3.1 Relationships between indicator species and habitat characteristics

In total 128 sites have been measured, meaning that the great part of the artificial creeks of Sant'Erasmo have been studied. Only a few shallow drainage ditches haven't been considered since the water was too turbid and muddy to detect any species through the use of the GoPro camera or Photo camera. The map shows the island of Sant'Erasmo, divided in two parts in order to illustrate better the artificial creeks where all the data of this work come from


Temperature
Frequency
0
5
10
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12
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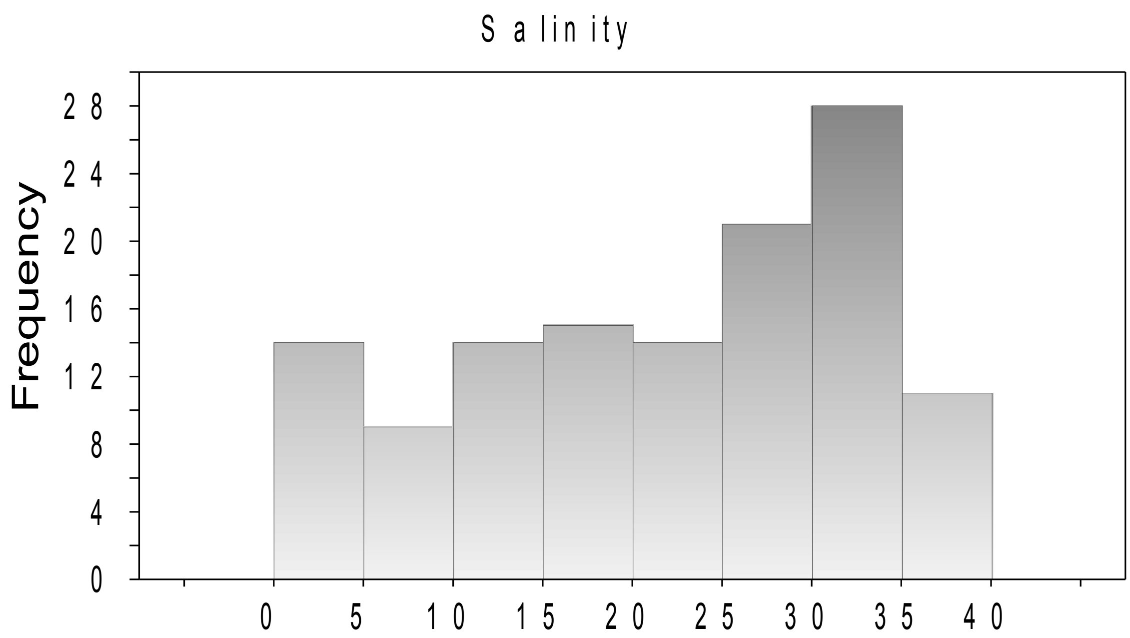
34

Fig 3


Salinity
Frequency
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8
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Fig 4

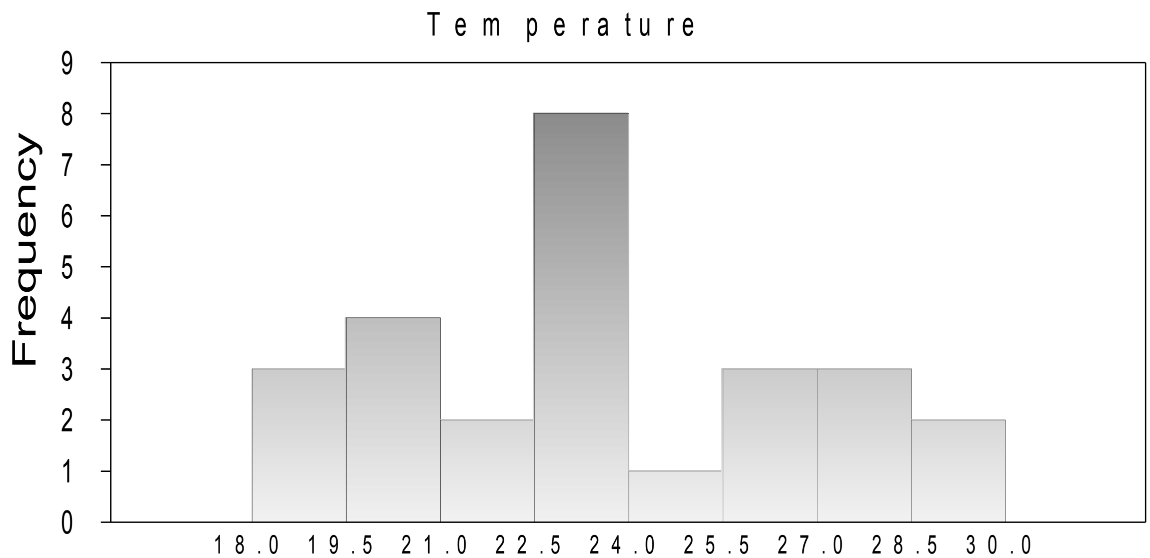

Fig 5

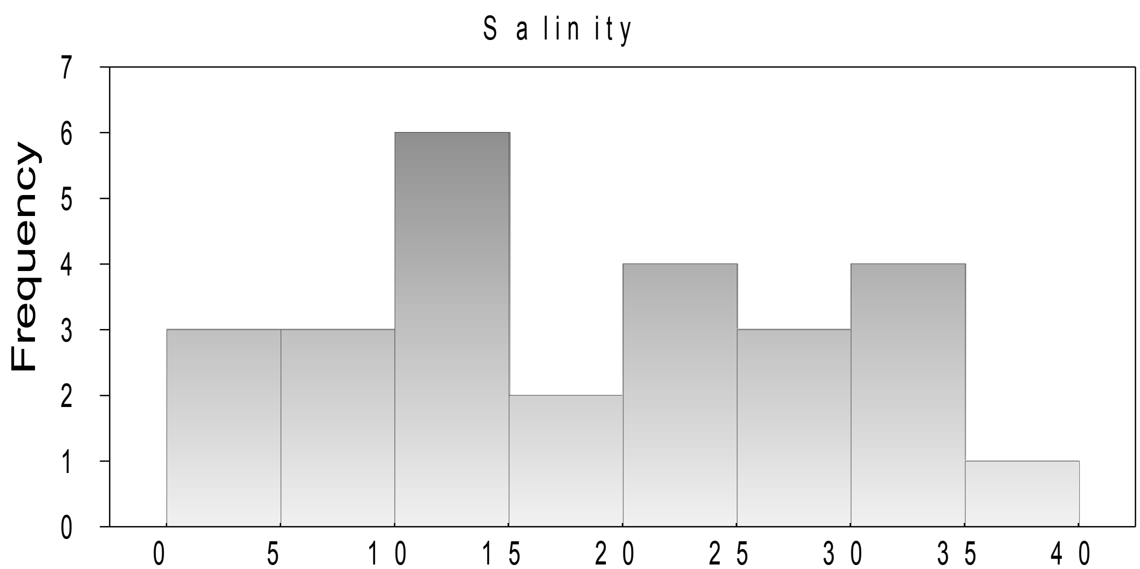

Fig 6

Fig 3/Fig 4/Fig 5/Fig 6 : The frequency of temperature and salinity observed in the artificial creeks of Sant'Erasmo

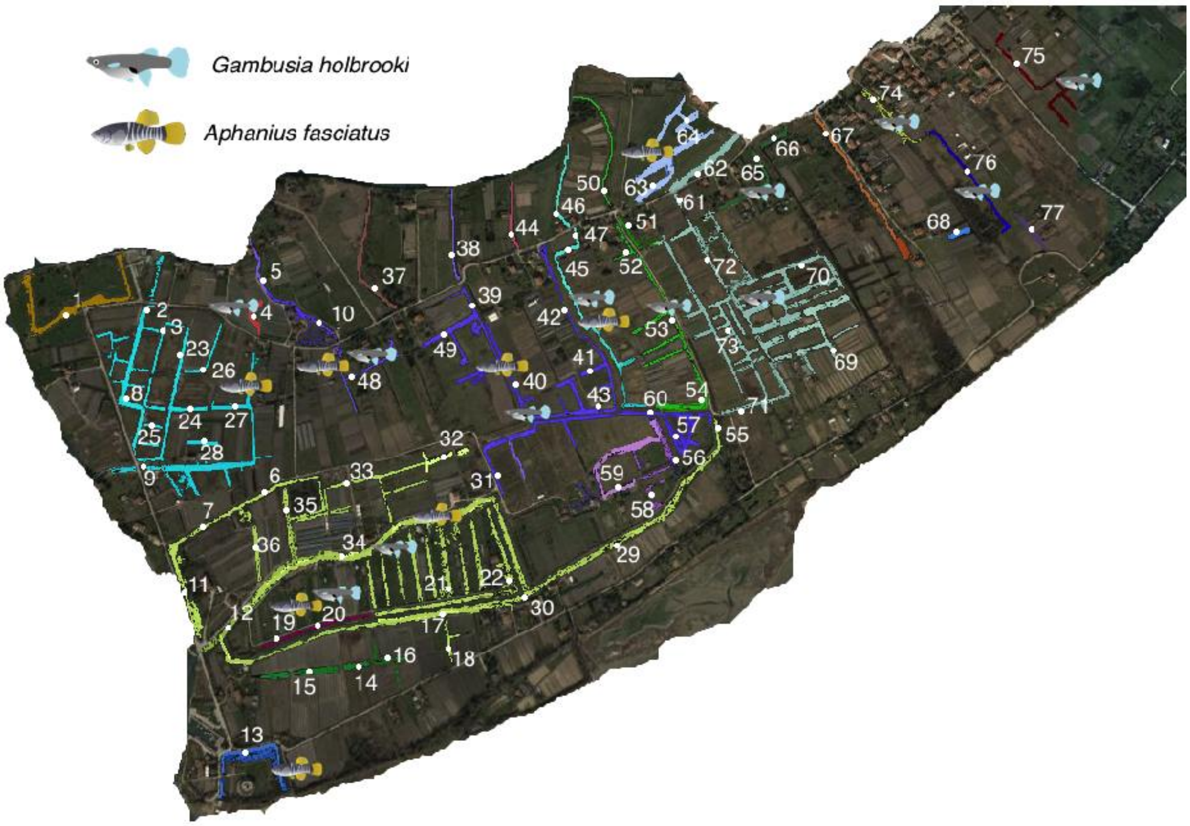

Fig 7/Fig 8 : The maps show the 38 groups of canals and the presence/absence of the species.

The “temperature” data are showing the temperature detected in a certain point at a certain time. The variability of this data is very high since the same watercourse can change its temperature dramatically, especially when measuring shallow water creeks and not communicating directly with the open lagoon.

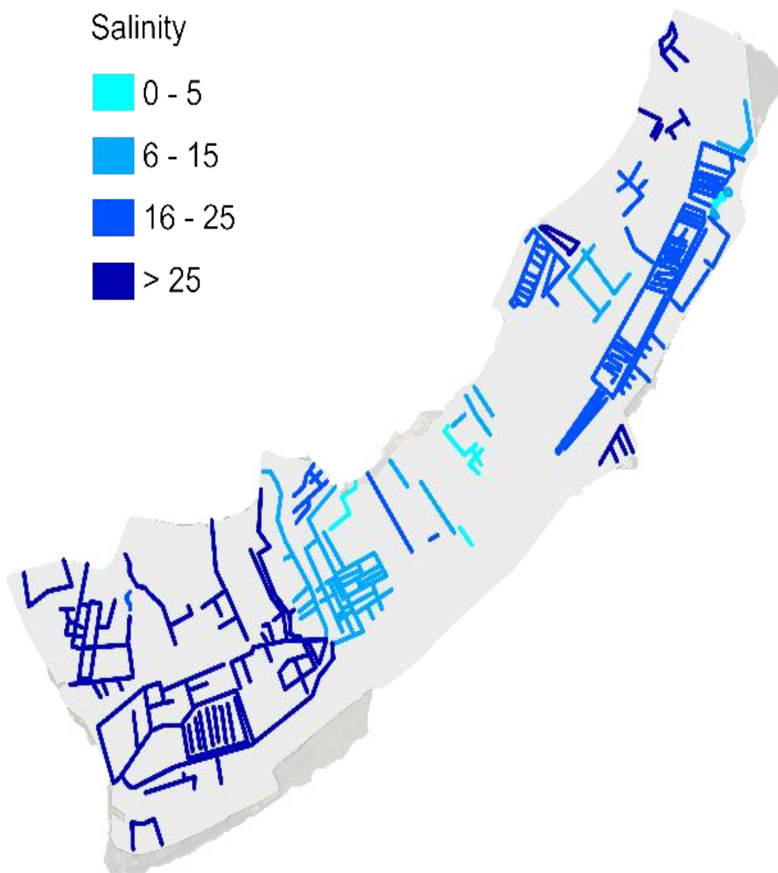

Fig 9 : Distribution of salinity in Sant'Erasmo island

According to the data that have been collected, we can say that considering salinity, Sant'Erasmo is split in two. One side, the south western one, is more saltier than the north eastern one, and therefore, also the aquatic fauna is quite different. As a matter of fact, the southern part hosts more *A. fasciatus*, in some cases even crabs or jellyfishes and the northern part more *G. holbrooki*.

Another value that manifests high variability is salinity. In artificial creeks where water gates have been permanently closed, and after strong precipitations, the salinity can vary by more than 50%. For instance, the site number 50 which is directly communicating with the open lagoon has a water gate at its mouth. The day after a strong rain and a high tide phenomenon, when the gate was still closed, the salinity of the water was 15ppt, while the salinity of the open lagoon can reach 36.

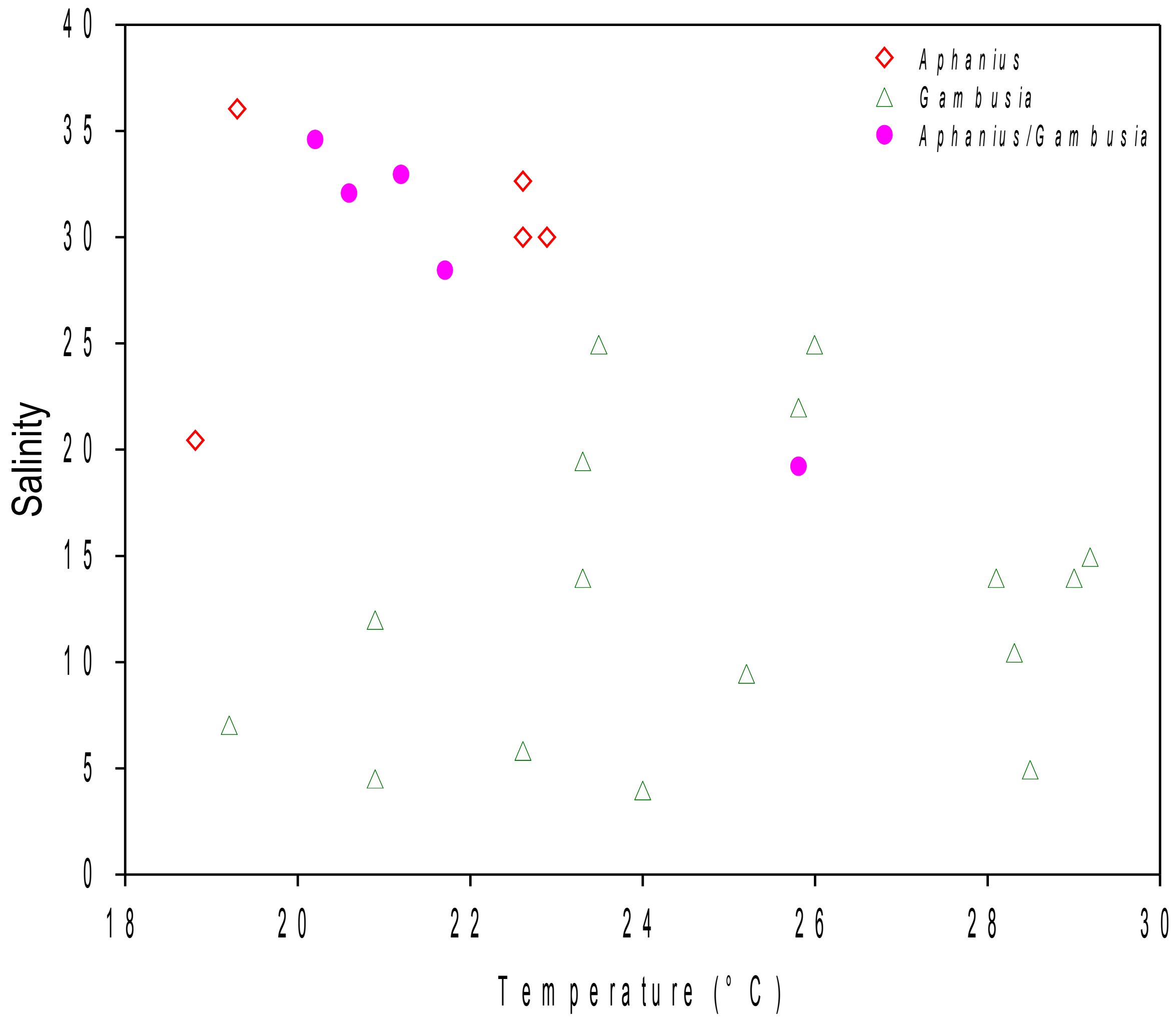

Fig 10 : Distribution of A. fasciatus, G. holbrooki and compresence of the two on the basis of temperature and salinity

The results of this study, shown on the image above, let us understand better how the presence of the mosquitofish is spread in the watercourses of Sant'Erasmo.

According to the experienced data, in a total of 38 groups on the island, 16 have been colonized exclusively by *G. holbrooki*. Meaning that in 16 groups of canals *A. fasciatus* hasn't been found. This data speaks by himself and it's telling us that in a competition between *A. fasciatus* and *G. holbrooki*, it is very likely that *A. fasciatus* will disappear.

The ecological niche of *G. holbrooki* is very wide. Some specimens have been found at salinities going from 4ppt to 35ppt. In a total of 38 watercourses analyzed, only 5 of them were exclusively inhabited by *A. fasciatus*, where the environmental conditions have a narrower range compared to the mosquitofish's niche: according to the data revealed by the research in Sant'Erasmo, *A. fasciatus* lives in habitats between 19°C and 23°C and between 20ppt and 36ppt of salinity.

As regards to the compresence of the two species, the data indicate that *G. holbrooki* reached all the sites in which *A. fasciatus* used to find favorable conditions, except for a group with the average salinity above 35ppt and another group below 19°C.

Apparently, it seems that *G. holbrooki* can potentially dominate most part of the environmental conditions and even oust the autochthonous species, with the exceptions of the colder and higher salinities conditions.

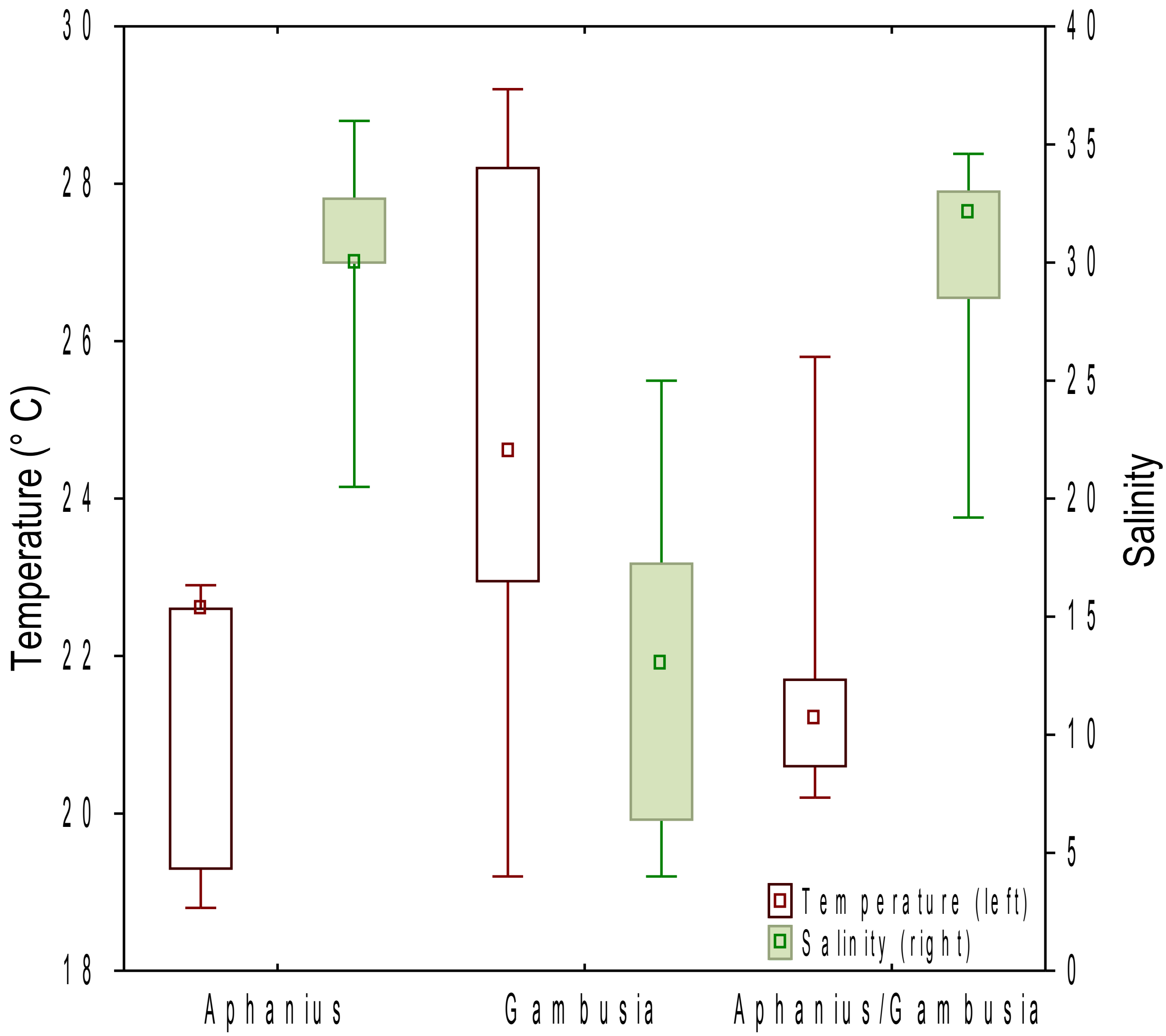

Fig 11 : Ranges of temperature and salinity in which the two species have been found

The results of the study showed above, confirm the great capacity of these two species to survive under a very wide range of environmental conditions.

A. fasciatus range is wide, but *G. holbrooki* one is even wider. In this image, it gets easy to intend how *A. fasciatus* seems to prefer an ecological niche that is narrow compared to the one

of the mosquitofish. Mean salinity in the sites colonized by only *Aphanius* or *Aphanius/Gambusia* is significantly higher than that measured in the sites with only *Gambusia*.
As showed in the figure, both for the temperature and for salinity, *G. holbrooki* has conquered those areas where *A. fasciatus* likely once used to live at, and the stretched quartiles explain why the *A. fasciatus* ecological niche turned to be so concentrated.
Accordingly, the coexistence conditions are almost the same ones in which the major part of *A. fasciatus* live, with the exception of the coldest and highest salinity conditions.

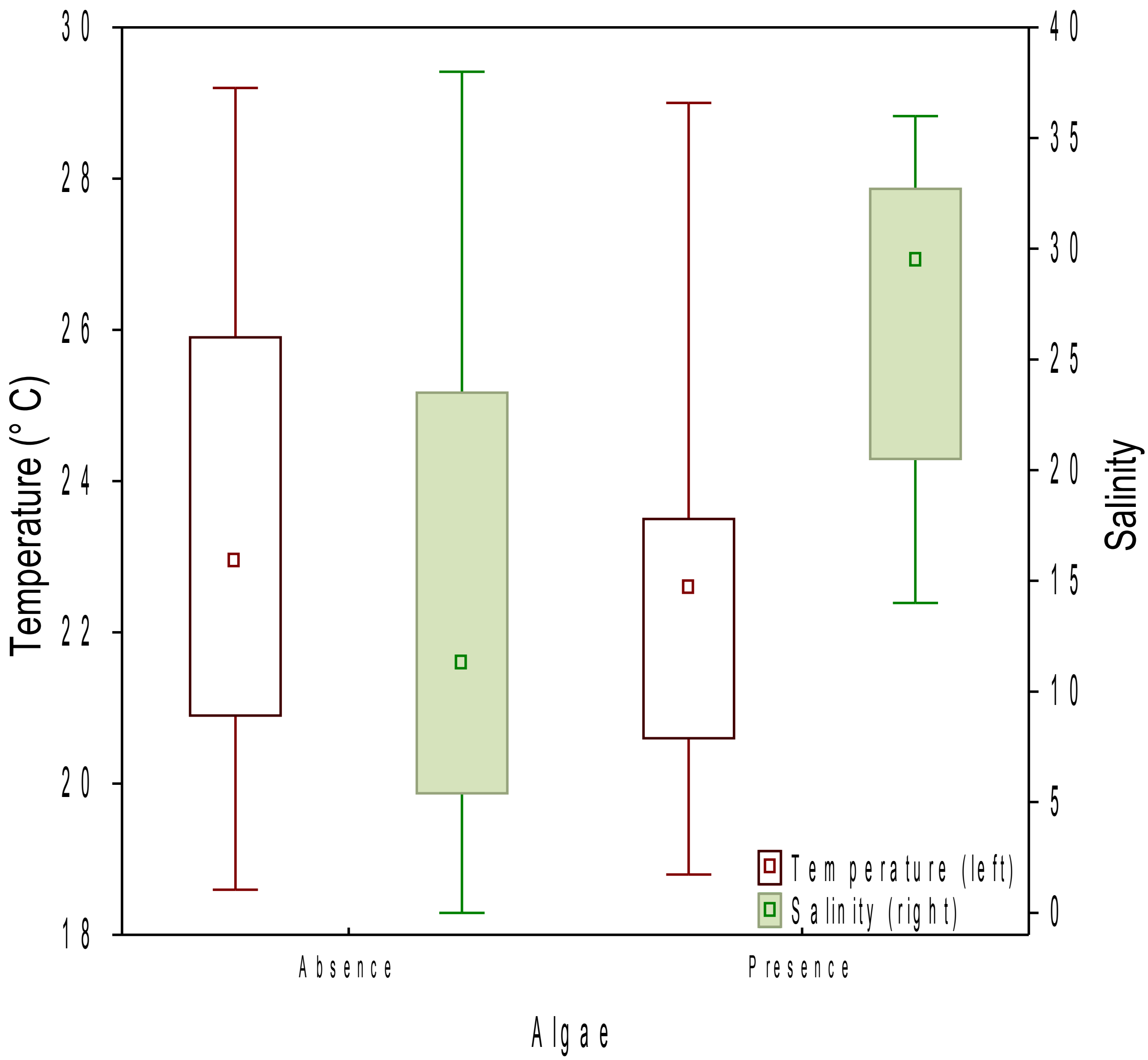

Fig 12 : Ranges of temperature and salinity in which the presence algae has been detected

The algae (particularly diatoms, green algae, and cyanobacteria) provide a vital element for *A. fasciatus* (Alcaraz et al., 2015), and they are present at a very wide range of temperatures.

The data in the figure indicate that mean salinity is higher in the sites with algae than in the sites with no algal coverage.

The mosquitofish, instead, can easily adapt even in habitat with no algal growth.

The results show that between 20° and 24° there is the highest concentration of algae with salinity mainly concentrated between 20 and 25 ppt.

Therefore, it has to be taken into account the level of water flow in the artificial creeks.

In canals where the water flow is scarce, pollution can feed the proliferation of some type of algae that compose the favourire habitat of *A. fasciatus*.

Fig 13 : Green algae in artificial creeks

3.2 The use of artificial creeks: historical perspective

The open systems, which have a direct connection with the open lagoon, are the only canals which are maintaining a specific use, allowing the navigation to the small boats.
Water in these canals, is usually subjected to much more drainage compared to the water in the closed systems, due to the water gates that stay open most of the time.
According to many inhabitants though, navigation appears much more difficult lately, due to a poor maintenance activity from the the Provveditorato Interregionale per le Opere Pubbliche di Veneto Trentino Alto Adige Friuli Venezia Giulia.
The unprotected embankments collapse, storing mud and sand on the bottom of the watercourse, diminishing the depth of the canal and making the the navigation impossible during low tide.
On the border of the island, but also along the navigable channel, there used to be the “cavane” (nowadays there are only two of them left), used as docking areas for the boats that used to come to collect the products from the agriculture fields and the fish. These products were then brought to the venetian market places to be sold.
The closed systems, where the abandonment gave birth to a “renaturalization” of the habitat, are watercourses without any type of use and the people living in the island only use them as drainage ditches of the cultivated fields.
The exploitation of the canals for fishery purposes is nowadays reduced to a few cases such as the case of the farmhouse “Lato Azzurro”, which is dedicating to a very sporadic fishing of mullets, and exclusively for tourism purposes.

Fig 14 : Agriculture and fishery activity in Sant'Erasmo

The fish population decline in the artificial creeks, according to the inhabitants, coincide with the beginning of the use of chemical composts and fertilizer on agriculture that led some of thees creeks to an eutrophic status. Before this time, mullets, solens and sea breams used to live in these watercourses, but nowadays they are disappeared from the island of Sant'Erasmo.

The fishery activity in the island, although less important than the agriculture, started to decrease from the 60s, after the exceptional high tide event of the 1966 which damaged the valley fishing of the island shattering the existing activities.

Others eel farming have been shut down by the end of the 70s.

Some popular beliefs, state that the decline of fish population in the island creeks is due to an increase of predators, such as the great cormorant.

The eutrophication in the drainage ditches, increased especially from the 2000s, not because the use of chemicals but due to a malfunctioning of some watergates.

During the first years of 2000s, an important work maintenance has been done to the floodgates of the island from the Magistrato alle Acque di Venezia.

Most part of the old floodgates, built with a "V" shape in order to let the flow drain away easier, have been substituted with another type of watergates, with "flat" ones with the same width of the channel they are belonging to.

After a few years, many of the watergates started to have problems, since the fluctuations generating against the wall of the new type of floodgates were causing an erosion on the bottom of the creek, opening small leaks between the wall and the bottom. Therefore even when closed, the watergates, are not efficient and allow the water during the high tide to come in.

The inhabitants, despite complaining and requesting assistance, they only received negative feedbacks from the Magistrato alla Acque, so they had to implement the new floodgates with other artisanal permanent barriers made of wood in order to stop the high tide and saving the lands in the nearby from floods.

The issue of this case, is related to the bad management of the floodgates, not only of a lack of maintenance from the charged entity, but also, opening and closing the watergate for the elders of the island can be a hard task.

Nowadays many of these creeks suffer from a poor circulation of waters, and fed by rainwater they become the perfect habitat for *G. holbrooki* holbrooki.

The management of the internal waters and of the floodgates themselves, seems to be now in stall after the abolition from the Renzi Government of the Magistrato alle Acque in June 2014. After years of omitted controls and in some cases of connivance with the interests of the controlled, now the situation is stuck.

The authorities of the Magistrato alle Acque have been transferred to the Provveditorato alle Opere pubbliche and in part had to be assigned to the Nuova città metropolitana.

But the decree had to be issued by 31 March 2015 never came (Alberto Vitucci, 2016).

The water from the artificial creeks, has never been used to irrigate the fields.

However, although, the salt can be very harmful for the cultivated fields, the nearby creeks of

brackish water, if kept inside the embarkments, they don't create any problems to agriculture.
In fact, the local people say that in summertime, the wooden barriers and the closed watergates don't let the water circulate along the channels, so that during the hot season they are completely dried up, making the irrigation process much more difficult. In fact the brackish water in the creeks allows the adjoining land to be imbued of water and the fresh water for irrigation doesn't drain down to the bottom.
Therefore, the whole island would agree with restoring the flow of brackish water inside the islands artificial creeks, not only for the conservation of the autochthonous species but also to facilitate the irrigation of the soil and improve the efficiency in agriculture.
The irrigation was once possible thanks to waterhole, nowadays not in use anymore, collecting fresh water from the aquifers in the depth of the island.
But since the level of the Venice lagoon is lowering, the local authorities are thinking of limiting the use of water from the aquifers in order to not engrave on the subsidence issue (Orsola Casagrande 2010) relying on the water system of the city.

USES OF THE ARTIFICIAL CREEKS

	Fish farming	**Irrigation**	**Drainage**	**Navigation**
Today	Poor	Null	Intense	Poor
Past	Intense	Null	Intense	Intense

-Intense **-Poor** **-Null**

4 Discussion

Our data suggest that *A. fasciatus* occurs at higher salinities and slightly colder temperatures than *G. holbrooki* and that the two species may coexist at these conditions, with *G. holbrooki* showing a wider niche than *A. fasciatus*. The two species may coexist in some of the sites with these characteristics, while *G. holbrooki* occurs mostly in habitats at low salinities where *A. fasciatus* was not found.

The results show that the *A. fasciatus* is an indicator of lagoon and brackish habitats and communities belonging to this type of environment, while *G. holbrooki* indicates warmer and freshwater waters. In a global warming scenario, therefore, the mosquitofish would be the species that can be favoured.

A. fasciatus population are then restricted to saline environments, although it could lives inhabitats that have been invaded by *G. holbrooki*.

The fish population decline in the artificial creeks, according to the inhabitants, coincide with the beginning of the use of chemical composts and fertilizer on agriculture that led some of these creeks to an eutrophic status. Before this time, mullets, solens and sea breams used to live in these watercourses, but nowadays they are disappeared from the island of Sant'Erasmo.

Regarding *A. fasciatus* decreasing population, an hypothesis is that *G. holbrooki* is the predator. As a matter of fact, recent studies, mainly based on use of DNA extracted from stomach content to identify the prey species, reveal the predation of critically endangered *A. fasciatus* transgrediens by world-wide invasive *G. holbrooki* affinis (Keskin & Emre, 2016)

Saline environments, although allow *A. fasciatus* to live without the competition of the mosquitofish, can lead to face other risks such as predation from marine species that didn't use to coexist together with *A. fasciatus*. Apparently this is not the case of Sant'Erasmo island, but it could be a problem that other marginal habitats could possibly deal with.

A. fasciatus is included in Annex II of the Habitats Directive, Annex II of the Protocol SPA / BIO of the Barcelona Convention and Annex II of the Bern Convention. It is included in the general plan of action for the conservation of the Italian freshwater fishes. In IUCN Red List (2006) is in a Least Concern (Relini & Tunesi, 2009).

The reason why some parts of the island show higher salinities, could be due to many reasons: the construction and the activity made to enlarge the width of some canals, in order to allow the

navigation, surely lets the saline water of the lagoon coming in much more easier.
Another reason why some parts of the island show higher salinities and others are more fresh, is the scarce maintenance activity on the watergates. Once they are damaged, most of the times these watergates remain closed allowing rain water to fulfill the canals.
The presence of algae is one of the main element that compose the ideal habitat of *A. fasciatus*. It serves as protection, spawning area and even a food resource (Alcaraz et al, 2015).
Green algae are very common in the Venice lagoon, often fed by pollution such as phosphorous. In 1989, there has been an invasion of Ulva lactuca, causing important cases of massive fish deaths and the rotting algae caused anoxia phenomenon.
Therefore, it has to be taken into account the level of water flow in the artificial creeks.
In canals where the water flow is scarce, pollution can feed the proliferation of some type of algae that compose the favourire habitat of *A. fasciatus*.

5 Conclusions

Visiting Sant'Erasmo, it's easy to perceive that this island, one of the biggest of the lagoon of Venice, holds a very important role in conservation of animal species.
It's not uncommon to find rare species of birds that used to inhabit the islands of the lagoon which now due to the anthropization are finding in Sant'Erasmo a habitat that suits their requirements.
The role of this island as a biological reservoir is given not only by the amount of fish and bird species that Sant'Erasmo holds, but also by an environmental and climate change point of view of which the Lagoon of Venice could suffer.
As clear emerged from the recent IPCC report (IPCC 2014), the Earth's climate is warming at an unprecedented rate, bringing in the near future a rapid rise of sea levels. Areas that face the sea of course they will be affected and rich areas of great biodiversity as the salt marshes, heavily compromised.
The reduction of salt marshes, already in act due mainly to the erosion process, should bring the competent authorities to consider the island of Sant'Erasmo as a real biological reservoir, in

which species living in salt marshes such as *A. fasciatus* and many bird species, could find favorable conditions.

This could be a reachable and viable goal, that would imply though a protection of the autochthonous species, and in this case, focusing on the competition of the two species considered in this project, the protection of *A. fasciatus*.

In order to favour the autochthonous species over the mosquitofish, seems that salinity could be the turning point.

Indeed as showed by the research, the only *A. fasciatus* populations left, are restricted to high salinities while *G. holbrooki* remains at lower salinities.

Moreover, high salinities are encountered also in salt marshes ecosystems and therefore these conditions would favour also other species from the venice lagoon.

The easiest way to restore a higher salinity in the artificial creeks is to establish a proper functioning of the watergates, which can be obtained through investments to the damaged systems that don't regulate the incoming water of the lagoon in the island of Sant'Erasmo.

According to the island inhabitants, there would still be a problem by doing this. During the interviews it was easy to understand that the mean age of the population of Sant'Erasmo is very elevated, and even a simple mansion such as opening and closing a floodgate can be difficult.

Most of young people of the island move to the cities and considering that the only activity of Sant'Erasmo is agriculture, many of them look for other employment on the mainland or in Venice. The are so few inhabitants that the island doesn't get the minimum threshold to have a pharmacy on it.

If, therefore, a work activity may encourage young people to stabilize in the island of Sant'Erasmo, it could be considered the model of Lato Azzurro, farm and cultural association in the Capannone area, which offers an active tourism and valorizing the landscape and the bucolic island life, or the Association Amateur Lagunare Kayaking Sant'Erasmo that comes in the homonymous island with the aim to promote and enhance the sport while respecting the lagoon environment.

The area of the former fish farms, now abandoned, was taken into consideration by an outside company that tried to reactivate an activity of aquaculture, but then it went bankrupt and left everything uncompleted. The fish farms today, almost entirely inhabited by *G. holbrooki*, could be a great opportunity for sustainable tourism, the rediscovery of an activity that constitutes the history of the lagoon.

The option to reopen a new farm in a former farm is a possibility that seems to be very successful in other areas. For example the farm Pestrofa in San Giovanni al Natisone, which reopened and invested on the trout farm, after being closed for years, with a restaurant business linked to their own fish farming (Treppo, 2016).

The realities of rural houses, linked to agricultural activities could then re-establish a presence in the island of a larger population and at the same time, manage the opening and closing of the floodgates of the artificial creeks.

Obviously an efficiency of the closed system is of fundamental importance and must be ensured since those who manage the gates must rely on a proper functioning and constant maintenance by the Provveditorato Interregionale per le Opere Pubbliche di Veneto Trentino Alto Adige Friuli-Venezia Giulia.

Water circulation in the lagoon, would probably be a viable system to vanquish *G. holbrooki* holbrooki from Sant'Erasmo channels, where could consequently stimulated a new type of a sustainable rural tourism in an island that is a biological reservoir of the Venice lagoon.

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