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The management dilemma in the *valli da pesca* of the Venice lagoon

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Contents

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ABSTRACT

In the Venice lagoon, north-eastern Italy, there are some confined areas called in Italian *valli da pesca*, which were built centuries ago to maximize some ecosystem services, such as fishing and hunting. The *valli da pesca* are managed by private owners, who must constantly provide for their conservation which requires incurring demanding expenses. While in the past the main revenue-generating ecosystem service was aquaculture, hunting plays currently a key role in the management of these areas. However, maintaining the *valli da pesca* based on waterfowl hunting, on the one hand, allows for the preservation of the ideal habitats for waterfowl, but on the other hand, means the killing of about 13% of the ducks that are attracted in these places during the hunting season. Such a situation leads to a multifaceted dilemma that will be rattled off in this thesis: the private/public management dilemma, the ecological dilemma, and the ethical dilemma. As for the first dilemma, the thesis analyses the contrast between private management, which requires restricted access for people but funds the interventions devoted to the conservation of habitats, versus hypothetical public management, which ensures enjoyment by people but carries the likely risk of losing lagoon habitats, and thus also Ecosystem Services, due to lack of funding. For the ecological dilemma, a habitat suitability analysis provides evidence that, considering the effect of climate change, it could be risky to base the sole source of income for the *valli* management on waterfowl, because they are likely to change their wintering areas in the future. Finally, the ethical dilemma, a perspective is provided through the environmental humanities' approach, taking into account non-human animals' rights. The last section analyses whether there are feasible alternatives to be applied for the *valli da pesca* management.

THE *VALLI DA PESCA*

Venice, also called the Queen of the Adriatic, is one of the most famous and fascinating cities in the whole world. Its distinctiveness lies not only in its canals and monuments but also in its lagoon.
Indeed, the Venice lagoon is not only the most extended Italian lagoon but also the most extended lagoon of the Mediterranean Sea.
The surface area of the Venice lagoon measures 552 km², 8 percent of which is occupied the islands, 25 percent by saltmarshes, and 67 percent covered by water.
It has an average depth of 10 meters (with a maximum of 21.5 meters), a salinity in the range between 28 and 32 PSU (Zirino et al., 2014), and a width of 13 kilometers. It communicates with the open sea (the Adriatic) through three inlets: Lido, Malamocco, and Chioggia.
The interactions between Nature and culture in the Venice lagoon led to the achievement of archaeological, architectural, natural and cultural preciousness, therefore, Venice lagoon represents an area of extreme importance. The incommensurable value of this ecosystem is not only related to cultural, historical, and artistic evidences, but also to its landscapes and naturalistic significance. Indeed, the lagoon was listed as a UNESCO World Heritage Site in 1987 (Micotti, 2021).
As testified by the importance the UNESCO gave to the whole site, the Venice lagoon is therefore to be considered a multifaceted system, indicated in the scientific literature under the nomenclature of "Ecosystem Services".
However, up to now, several studies recognized the lagoon fragility due both to anthropogenic factors and climate change (Paknazar, 2021).

This thesis will have as its main protagonists *valli da pesca* (literary meaning "fishing farms" in English) which are closed areas of the lagoon, occupying 19 percent of the total area of the Venice lagoon. To date, there are 31 of these territories.
The thesis is organized as follows.
To begin with, in this first chapter the historical context of the *valli da pesca* is presented, describing when and why they came into existence and how they functioned to perform aquaculture ecosystem service. The historical context will be helpful not only to understand how these portions of the closed lagoon developed, but also to provide insight into the change that has taken place in the management, both public and private, of the *valli da pesca*.
As for the second chapter, this thesis analyzes the dilemma of private or public property of the *valli da pesca*. As of today, the *valli da pesca* are considered to all effects as public property belonging to the maritime state domain. This is a legal question that has been debated for years, and in 2011, the *Corte di Cassazione* ruled on this issue. Eventually, the Italian judge of last resort defined the

valli da pesca as public goods. However, in academic circles and beyond, the issue seems to be still open. There are conflicting positions on what the State asserts, while case law has given a meaning that will tend to apply until the legislature expressly takes a position on the matter.

The third chapter will focus on the ecological role of the *valli da pesca*. Different ecosystem services will be taken into account, considering the different management strategies, highlighting how hunting activity has taken a primary role in the conservation of these territories. It will be reported that, even if in the present the hunting management strategy can provide sufficient incomes to ensure the conservation of the *valli da pesca*, this system can be at risk in facing climate change threats. Indeed, a comparison between present and future Species Distribution Models provides evidence that, considering the effect of climate change, it may be risky to base the sole source of income for *valli* management on waterfowl because their wintering areas are likely to change in the future.

The fourth chapter will be used to develop an ethical dilemma, according to the Environmental Humanities' methods. Indeed, it is fair to face the hunting problem considering the ethical and moral aspects. The perspective of the non-human animals will be applied, leading towards a vision of total liberation from all types of dominion and oppression - in which either hunting is enclosed.

Connecting to that, the last section analyses whether feasible alternatives can be applied for the *valli da pesca* management.

The interdisciplinary nature of this thesis asked for different methods to be applied.

To find legal references and judicial decisions, information was retrieved from bibliographic review by academics, rulings of the *Corte di Cassazione (*Court of Cassation*)*, bill of laws (*disegni di legge),* and cases before European Court of Human Rights. Provisions from the Italian Civil Code and the Italian Code of Navigation was also used.

The ecological part was firstly contextualized through a literature review, including both reports and literature sources of the past and recent scientific papers dwelling on the *valli da pesca*. Since ecology takes into careful account the resilience of the ecosystems and the populations they host, the ecological point of view has required to consider if the climate change is going to affect the conditions at which waterfowl find them ideal distribution range. A number of simulations were made regarding the possible effects of climate change on the distribution of the population of huntable birds, and the possible effects on their migratory routes. These data are available in their entirety in the final Appendix.

For the ethical section, an accurate literature review was performed. Information was taken from books and papers by ethologists, philosophers, academics and activists for the rights of animals and the marginalised classes.

The *valli da pesca* are “anthropogenic ecosystems”, artificially isolated from the rest of the lagoon by terrain banks or continuous boundaries and constituted by regulated lakes. They were built centuries ago; their initial scope was to maximize some ecosystem services such as fishing and hunting (Stocco et al., *in press*; Stocco & Pranovi, *accepted for publication*). They are run by private subjects in different ways depending on the ecosystem services they provide. The *valli* can be used for fish production, for hunting, both for hunting and fishing, for recreational activities, even if four of them in the Venice lagoon are in a state of disrepair. This is why these territories are called anthropogenic ecosystems, as they are natural environments, but their preservation is only possible through human care regarding water inputs regulation and maintenance efforts. The ecosystem services offered will also be diverse depending on the activities performed.

This thesis will mainly consider the *valli da pesca* that use hunting, or both hunting and fishing, as a source of income (which are the majority). Conservation of these areas requires the incurrence of demanding expenses. Unlike in the past, when the main income-generating ecosystem service was almost exclusively aquaculture today is waterflow hunting which plays a crucial role in the management of these places. Indeed, a peculiar hunting activity is performed in the *valli da pesca*, with quite luxurious accommodations and services made available. Hunters pay a very high fee for such privileges, largely contributing to the financial budget of the *valli da pesca* management. Consequently, in the *valli da pesca* devoted to hunting, the revenue that makes possible the preservation of excellent conditions of habitats is precisely hunting activity.

A peculiar feature of these places, when they are well managed, is that they become a cradle for biodiversity and a refuge for many wintering birds, mainly ducks, and geese. Most of the species that inhabit these *valli* only spend winters in the *valli da pesca*, but others also nest here or are resident species.

Biodiversity plays a crucial role in supporting the supply of ecosystem services, not only for the ecological functioning of the entire planet itself, but also because it improves human health and wellbeing.

Following up on the above, since it is of paramount importance to conserve the *valli da pesca*, the question underlying this thesis is the following one: to what extent is it ethically, legally, and ecologically acceptable that for the preservation of these important territories, it is necessary to sacrifice about 50,000 waterflow (due to hunting activity) each year?

To understand the context of the *valli da pesca*, it is necessary to trace their history and understand the peculiarities of the aquaculture practiced in the Venice lagoon, before focusing on the *valli* that use hunting as a source of income.

Vallicultura is an Italic practice, whose origin is difficult to identify. This activity is the result of the ability of fishermen to observe and learn the water motion and the behavior of lagoon fish over the centuries.

Fish cultivation was already practiced by Phoenicians, then handed down to the Etruscans and the Romans that coined the term "Piscariae aquae" and then "Clausura vallium" in order to describe the spaces used for this type of farming (Verza, 2019). We can refer to this practice as an evolution of traditional fishing activity.

The construction of the *valli da pesca* intensified during the Renaissance. It is an activity compatible with the features of the lagoon ecosystem, and it follows the tendencies of Nature without impacting too much on this type of environment.

Their origin derives from a desire to intensify the fishing activity. It consists of exploiting the natural presence of fish in the lagoon's brackish waters, enhancing this natural production through hydraulic works, fish sowing, and finally implementing capture methods (Brunelli & Brunelli, 1937). Indeed, between the shoreline pond and the open sea, migratory phenomena of fish naturally occur: they find refuge in shallow waters and, once adults, return to the sea to reproduce. By observing this particular behavior, fishermen understood how to exploit it by trapping the fish along the migratory routes (Brunelli & Brunelli, 1937). They became able to learn which periods are more suitable for fishing, to the point that in the Veneto region there are specific words indicating them, for example the *fraima* period and *notti da bisatti* (which refers to the descent of eels).

Moreover, fishermen also observed how fish lifecycle and behaviour are strongly influenced by water salinity and temperature; therefore, they learned to regulate the irrigation of the *valli* with fresh and saltwater to take advantage of environmental variables in facilitating both fish recruitment and fishing activity. This way, they became able to prevent the suffering of fish, separate them in the fish ponds and select the fish through the opening and the closure of the sewers. Therefore, fishing in the lagoon requires specific knowledge of the biology of the species fished, spawning periods, seasonal migrations, daily movements due to tides, and meteorological conditions (Granzotto et al., 2001). It is also for this professionality required that usually this fishing activity is passed down from generation to generation, almost like a precious secret.

Over the centuries, therefore, men could observe the functioning of this type of ecosystem, intensifying the effectiveness that traditional fishing could provide, and thus creating extensive fish farming. By extensive aquaculture we mean an activity that uses a load of fish not superior to that

supplied in nature, without artificiality in the process of nutrition and reproduction of these animals. There are mainly three phases: the first one is whipping and sowing. The people of the *valli,* over time, have known the migratory behaviors of fish, exploiting it for their gains. In fact, from spring until late summer, the fish fry (known in vernacular as *pesciatelli* or *pesce novello*, as they are born in autumn) enter the lagoon attracted, by fresh water. The fish takes advantage of the abundant amount of food and the appropriate temperature to spend this time in the lagoon's water. Moreover, fry massively colonize shallow water and seagrass beds where predation pressure on these organisms is less than in a marine environment (Granzotto et al., 2001). This spontaneous phenomenon is called "whipped" ("*montata*" or "*rimontata*" in Italian). During the spring months, mostly fry of sea bass, bream, and mugilids enter the lagoon, which are commonly called *pesce novello* or *novellame* ("juvenile fish" in English).

After the winter, the sewers are opened without the risk of the fish moving away thanks to a series of graticules and structures that allows for fry to enter, but prevent larger fish to exit. Nevertheless, due to different conditions like pollution (Bullo, 1940), whipping is nowadays no more sufficient to satisfy the amount needed for the *valli da pesca* and is accompanied by artificial sowing.

The second phase is breeding and growth, in which the juveniles feed and develop until adulthood.

The last phase is the descent and gathering. The fish naturally strive to return to the sea (from September to January), and it is helped by a drainage action. The main drain is opened to let lagoon water flow in, and these animals, attracted by the salt water, are trapped in the fishing channel. Individuals that are too small are sent to overwinter in fish ponds, while the fish ready to be placed on the market are caught.

Structurally speaking, originally there were three types of *valli da pesca* with different features: *valli arginate* (embanked *valli*), *valli semi-arginate* (the semi-margined *valli),* and the *valli aperte* (the open *valli*) (Bullo, 1940).

The *valli aperte* were constituted by large bodies of water and are free from any closure. Initially, only these types of *valli* existed in the Venice lagoon as integral parts of the lagoon system where only fishing was practiced (Granzotto et al., 2001). Most of them nowadays are in abandoned states, where only private fishing is allowed (Brunelli & Brunelli, 1937).

The *valli semi-arginate* are constituted by interrupted embankments and completed by trellises of marsh reeds (*grisole* in vernacular) (Verza, 2019). These temporary enclosed areas were initially called *"acque chiuse*" or "*piscariae*", then from the 15th-century "*valli*" or "*valli da pesca*" (Granzotto et al., 2001). The function of the trellises is to avoid the fish to escape during high tides,

and allow the entrance and exit of the water without resisting the waters and avoiding the creation of strong differences in height (Brunelli & Brunelli, 1937).

Historically, in these *valli* the circulation of water was completely natural. It allowed the natural mounting of the fry while preventing the fish from leaving once they grew up. However, this type of barrage was very fragile and of low height, and it could break under conditions of strong tides and gales, provoking the loss of all the fish, which could return naturally to the sea. Therefore, the "*valli semi-arginate*" were developed, where the upwind part was enclosed by terrain embankments while the leeward part was still bounded by reed fences or trellises (Granzotto et al). From this point, the *valli* became an area to be managed: in winter the undersized fish are kept in wintering fishponds (narrow and deep canals), and in spring they are returned to the *valli* basins. Therefore, the productivity of the *valli da pesca* did not rely on natural mounding anymore, but started to depend also by the caught of fry in the lagoon by the so-called *pescenovellanti* (fishermen who are qualified in catching, transporting, and keeping alive the juvenile fish until they are released) (Granzotto et al., 2001).

Most *valli da pesca* in Venice lagoon belong to this category. Considering the fish farming activity, the *valli semi-arginate* are the most profitable, yet they ensure a lower exchange of water in the streams, evading the tide (Brunelli & Brunelli, 1937). Although the *valli semi-arginate* require increased maintenance, when compared with the *valli arginate,* it allows more easily overturning through natural whipping.

The *valli arginate* are completely surrounded by earth embankments or continuous boulders. They are equipped with one or more sewers through which the *valli* communicate with the open lagoon's waters. The entrance and exit of the water are completely controlled by men, therefore, are considered to be more efficient than the other ones (Verza, 2019).

Since the birth of the *valli semi-arginate* and the *valli arginate*, the *valli da pesca* are no longer areas where a regulated fishery is conducted.

Since the Renaissance in these *valli*, together with fishing activities, also wildlife-hunting activities were practiced. If, in the past, fishing was the main engine for maintaining the economy in these areas, today it has become duck hunting. Indeed, there have been many changes that have made fishing less productive than it used to be and this caused a crisis in the fishing sector. If this was of an extensive type, it has recently been flanked by modern techniques attributable to intensive farming. For example, today both farmed and wild fry are sown in spring, and the quantity of the latter varies according to market demand (Verza, 2019).

Furthermore, in the past, eel was the most produced species, while now it is scarce. The fish species

that are farmed nowadays are sea bream (*Sparus aurata),* sea bass *(Dicentrarchus labrax),* grey mullet *(Mugil cephalus),* thinlip grey mullet *(Chelon ramada),* leaping mullet *(Chelon saliens*), golden grey mullet *(Chelon aurata),* and Lesser grey mullet *(Chelon labrosus)*. Moreover, some *valli* exploit also the big-scale sand smelt (*Atherina boyeri).* The decline in fish productivity is attributable to various factors, such as the increase in predation by piscivore birds, and the decline in market prices of local fish (Verza, 2019). Since hunting, according to the managers, has become the main source of survival in many *valli*, it has led to a change in the management of the latter, with a greater presence of fresh water, lower water levels, and a large number of bare surfaces and sandbanks (Stocco & Pranovi, *accepted for publication*). Hunting begins around the third week of September and lasts until the end of January of each year and is commonly regarded not only as a commercial operation, but also as a traditional activity, a typical festival that unites men.

It is important to highlight that this is possible because the *valli da pesca* are managed by private subjects, granted a concession by the State.

The records of the 17th and 18th centuries show a change in the modes of exploitation of the lagoon: the *valli da pesca* activities underwent an increase, which, according to Rivoal, (2022) was considered detrimental to the fishing communities as it limited their use of the lagoon. Indeed, Rivoal reported that the extension of private properties of *valli da pesca* affected the collective use of the resources of the lagoon, depriving fishermen of fish and fishing grounds and therefore compromising their activities. In that period, the changes that occurred are remarkable for three reasons: in the first place, during the 17th and 18th centuries, the most practiced activity in the lagoon was fishing. Secondly, until that moment, fishing communities were able to negotiate the access to these resources under the Serenissima Republic rules (Fortibuoni et al., 2014); the growth in the number of *valli da pesca,* however, brought fishermen to denounce the exclusive use of ponds and the extension of those areas (Rivoal, 2022). Thirdly, authorities played a central role in this shift from the commons to the private property regime. Indeed, until the 17th century, all the fisheries territories were defined *valli da pesca*, and it comprehended both fish farms and ponds where fishermen were fishing (Caniato et al., 2009). In 1535, there were listed 62 *valli da pesca* in the Venice lagoon, and five years later 61 were listed, of which 27 were closed and 34 were open. This changed at the end of the 17th century when the term *valli da pesca* was attributed only to fish farms, while the other activities were defined *pesca vangativa* (*vagran fishing*) (Rivoal, 2022). As a matter of fact, in 1664 and again in 1772 only 33 *valli da pesca* were classified (Rivoal, 2022).

As it was mentioned above, the custodians of the *valli da pesca* use different activities for allowing their management. In fact, in addition to practices such as hunting and fishing, some of the 31 *valli*

present in the Venice lagoon offer recreational activities such as eco-tourism, bird watching, and hiking.

In addition to offering services, the management of the *valli da pesca* requires a lot of work on the part of the custodian. These management practices are useful not only because they allow fishing and hunting activities, but also because they allow the very existence of the great biodiversity present in the lagoon and the morphology of the *valli* (Verza, 2019). First of all, the water flows are completely controlled by man. The fish and duck species that live here survive in a context of brackish water whose salinity varies from area to area. The freshwater comes from the surrounding canals, while the salt water comes from the lagoon. Before entering the lakes of the *valli*, the water is oxygenated and cleaned of sediments - for this reason, the water that comes out of the *valli* is much cleaner than that which enters. The *valli* custodians must always ensure that the water is in motion to avoid the state of anoxia.

The year is subdivided between periods in which maintenance works of canals, embankments, emerged islands, and the pruning of the vegetation that allows the survival of the fish and ducks are carried out; periods in which the hunting activity is practiced, and periods in which fishing activity is practiced.

Therefore, on the one hand, the *valli da pesca* represent an ecologically important ecosystem that allows the survival of a lot of biodiversities, whereas, on the other, it needs the constant human workforce to be efficient in its purposes.

In essence, in the *valli* availing themselves of hunting as a source of income, the efforts of the *vallesani* (the valli custodians) are made to concentrate large quantities of ducks in autumn and winter. All the care taken in managing the lakes is needed to allow many birds to winter, many of which are migratory species arriving from Russia, Eastern Europe, and Northern Europe, but also from Siberia. These areas are not only ideal because of the natural and "man-made" features arranged by the *valli* custodians, but also for the tranquillity that characterizes them due to the lack of natural predators and the scarce human presence, as well as for a large amount of food arranged, of course, by the *vallesani* to attract ducks. These features allow many other species to take advantage of these environments, such as many odonates and herpetofauna. These *valli* are managed in such an efficient way that they imitate the natural lagoon and irresistibly attract water birds for nesting or wintering.

To summarize the above, the reproductive success of these birds is greater in the *valli* than in the lagoon, and this is mainly due to three factors: the first one is the maintenance factor, every year hydraulic work is carried out for hunting and fishing that creates suitable areas for nesting; the

second one is the scarce presence of predators, always kept under control by wildlife management; and the third one is the scarce presence of human beings (Verza, 2019).
As already mentioned, a part of the ducks and geese frequenting these areas are sedentary, while most are migratory. From around September to January, the species of ducks and geese increase more and more, while from February to April, we see the departure of migratory groups that go to nesting elsewhere. Not all the animal species in these areas are huntable: some are protected because they are at risk, while non-endangered species can be killed according to the law. An example is the Mute swan (*Cygnus olor*), subjected to protection when the species was very scarce, today the individuals of this species have increased considerably (from a few hundred individuals in the 1990s to over 40,000 in the last three years) (Verza, 2019).

This historical and descriptive excursus serves to frame the complexity of the *valli da pesca*, aware that they are artificial areas, but retain the typical structure of the Venice lagoon. The following chapter will be entirely dedicated to the diatribe of public or private management that has involved the *valli da pesca* for years.

DILEMMA

Over the last decades, there has been much of a debate around the nature of the *valli da pesca* – as private or public goods.
In fact, whereas during the Serenissima Republic, it could be stated that they were perceived as private goods since they were assigned to private individuals or subjects (most nobles and monasteries), under the control of the Austro-Hungarian Empire a regulation was adopted, stating that the lagoon was to be considered as part of the public domain. Therefore, evident doubts started to arise on the private or public nature of such *valli da pesca*. Ultimately, despite the entry into force of the Italian Navigation Code and the Italian Civil Code, both adopted in 1942, the *valli da pesca* were not expressly mentioned as public goods, and no legislative act has ever intervened so far in expressly clarifying the matter. This issue has, however, been the object of several lawsuits before Italian judges, and some of them also ended up being examined by the *Corte di Cassazione* (the Italian judge of last resort). Moreover, it also happened that a case on this matter has been heard before the European Court of Human Rights. This case, which will be reported below, concerns the Valle Pierimpiè società Agricola S.p.A. which brought an action against the Italian Republic claiming that it has been deprived of its property, the *valle da pesca Pierimpiè*, after the *Intendenza di Finanza* of Padua (local financial administration body), ordered on 24 June 1989,

then again on 10 June 1991 and 27 April 1994, to vacate the land occupied on the ground that it was part of the public domain.

Access to the *valli da pesca* is strongly restricted; thanks to the managers and the activities they offer and provide, the *valli da pesca* are successfully preserved, but these anthropogenic ecosystems, are not shared with the community. Nevertheless, under the law perspective, the *valli da pesca* are considered public goods.

The administration of public goods usually is in the hands of the State, and the funds for managing them are derived from taxes paid by citizens. However, it is to be noted that if the *valli da pesca* were directly and practically managed by the State, it would be much more complicated to maintain them since, as described above, they require annual upkeep, prompt maintenance interventions, and, as a consequence thereof, a lot of money.

However, the status of the *valli da pesca* deserves attention, and a dilemma about their private management and/or their ownership by public entities remains, although the nature of said ownership has not been expressly clarified yet by the Italian legislator.

As mentioned above, this is a legal question that has been debated for decades: do the *valli da pesca* really belong to private individuals that manage them, or because of their nature should they be considered public property? According to the Italian State, the *valli da pesca* belong to the maritime state domain. However, in scholarship, the question is partially open, that is, there are conflicting positions as to what the State affirms; while case law has given a meaning that will tend to apply until the legislature takes a position on the matter.

In 2011, the *Corte di Cassazione* ruled on this issue. Eventually, the Italian Judge of last resort defined the *valli da pesca* as public goods. With this ruling, scholars seem to go further, since by means of social reading they theorize the possibility that *valli da pesca* belongs to the category of common goods, which is a deserving good as it contributes to the realization of the welfare state (Laffaille, 2016). Through the conception of the *valli da pesca* as a common good, what matters is no longer the domain, but lies upon the function that the good can play within the community.

This chapter will explore this diatribe in more detail, starting with the ruling of the Court of Cassation and going on to mention opposing opinions, and then further elaborating on the issue by citing the draft law adopted by the Senate and presented in 2013, but not approved yet.

During the Court of Cassation's examination of the nature of the contested goods, it is reported what was ruled by the Court of Appeal of Venice in its judgment of 3 April 2008 (and, even before, by the Court of Venice at the end of the first instance proceedings).

First of all, on the basis of the regulation of 8 October 1841, under the Austrian Empire, the Venice lagoon was considered part of the public domain. The Judges of the Court of Cassation held that also the *valli da pesca,* being integral parts of the lagoon, belonged to the public domain. Being part of the lagoon and belonging to the necessary maritime property of natural origin, therefore, the Court questioned whether the *valli da pesca* are owned by private subjects, and focused on one of their physical-natural characteristics: their functional link with the sea. If the *valli da pesca* are part of the sea, then they necessarily belong to the State. Public property, according to Articles 822-831[1] of the Civil Code[2], is divided into State domain (*beni demaniali*), non-disposable State-owned assets, and disposable State-owned assets. According to the Court, the lagoon, being part of the sea, and the *valli da pesca*, being part of the lagoon and being connected to the sea, are part of the State domain. The State domain is made up of those real assets that necessarily belong to the State or sub-State entities due to their intrinsic quality, such as the maritime State domain. These properties, belonging to the State (in the sense of collectivity) cannot be subject to trade and/or transfer lawfully. Although the *valli* are also managed through the construction of dykes, these never interrupt their communication with the sea, so they are part of the maritime domain, also offering some maritime services, such as fishing and (although limited) navigation. This applies despite the

[1] Codice Civile - Art. 822. *Demanio pubblico. "Appartengono allo Stato e fanno parte del demanio pubblico il lido del mare, la spiaggia, le rade e i porti; i fiumi,i torrenti, i laghi e le altre acque definite pubbliche dalle leggi in materia; le opere destinate alla difesa nazionale.*
Fanno parimenti parte del demanio pubblico, se appartengono allo Stato, le strade, le autostrade e le strade ferrate; gli aerodromi; gli acquedotti; gli immobili riconosciuti d'interesse storico, archeologico e artistico a norma delle leggi in materia; le raccolte dei musei, delle pinacoteche, degli archivi, delle biblioteche; e infine gli altri beni che sono dalla legge assoggettati al regime proprio del demanio pubblico".
(Courtesy translation. Civil Code – Art. 822. State domain. "The seashore, beaches, roadsteads and harbours belong to the State and form part of the State domain; as well as rivers, streams, lakes and other waters defined as public by the relevant laws and works intended for national defence.
The following, if they belong to the State, are also part of the public domain: roads, motorways and railroads; airfields; aqueducts; buildings recognised as being of historical, archaeological and artistic interest in accordance with the relevant laws; museum collections, picture galleries, archives and libraries; and other property that is subject by law to the regime of the State").
Art. 823: *"I beni che fanno parte del demanio pubblico sono inalienabili e non possono formare oggetto di diritti a favore di terzi, se non nei modi e nei limiti stabiliti dalle leggi che li riguardano.*
Spetta all'autorità amministrativa la tutela dei beni che fanno parte del demanio pubblico. Essa ha facoltà sia di procedere in via amministrativa, sia di valersi dei mezzi ordinari a difesa della proprietà e del possesso regolati dal presente codice".
(Courtesy translation: Art. 823. "Property that forms part of the State domain is inalienable and cannot be the subject of rights in favour of third parties, except in the manner and within the limits established by the laws that concern it.
It is up to the administrative authority to protect the property that forms part of the State domain. It has the power both to proceed administratively and to avail itself of the ordinary means to defend property and possession regulated by this Code").
Art. 824: *"I beni della specie di quelli indicati dal secondo comma dell'articolo 822, se appartengono alle province o ai comuni, sono soggetti al regime del demanio pubblico.*
Allo stesso regime sono soggetti i cimiteri e i mercati comunali".
(Courtesy translation: Art. 824. "Property of the kind mentioned in the second paragraph of Article 822, if it belongs to the provinces or municipalities, is subject to the regime of public property.
Cemeteries and municipal markets are subject to the same regime").

[2] Royal Decree of 16 March 1942, No. 262, Codice civile (*Civil Code*).

actions of the administration and State authorities. According to the Court of Cassation, in fact, by law, the *valli da pesca* remain part of the public domain, regardless of any or no past actions by the public administration expressly or implicitly recognizing its ownership. In fact, even according to the Judges, given their natural composition, the *valli da pesca* cannot be private property. Should any public official have transferred the *valli da pesca* to private subjects, these would amount to illegal acts because they would be unlawful (Laffaille, 2016).

Indeed, the Administration should have adopted a formal act to modify the public nature of the *valli*, if this was the purpose. The Judge of the Court of Cassation, in fact, required in such a potential case a formal act adopted by the public authorities, amounting to a deed transferring a good from private property to the State domain. In the absence of such an act, the maritime State property cannot lose its status as public good; possession by a private subject of such property cannot, therefore, produce legal effects in relations with the administration, in particular, with reference to any 'acquisition of ownership by *usucapione* (prescription)'. This has become a legal dispute.

The Court of Cassation also took into account the Constitution to solve this legal dispute, stating that it does not contain a proper definition of private and public property. Namely, the Court focused on three articles of the Italian Constitution: Article 2, which states "*The Republic recognises and guarantees the inviolable rights of the person, both as an individual and in the social groups where human personality is expressed. The Republic expects that the fundamental duties of political, economic and social solidarity be fulfilled*[3]"; Article 9, which states: "*The Republic promotes the development of culture and of scientific and technical research. It safeguards natural landscape and the historical and artistic heritage of the Nation*"[4]; and article 42 which states: "*Property is public or private. Economic assets may belong to the State, to public bodies or to private persons. Private property is recognised and guaranteed by the law, which prescribes the ways it is acquired, enjoyed and its limitations so as to ensure its social function and make it accessible to all. In the cases provided for by the law and with provisions for compensation, private property may be expropriated for reasons of general interest. The law establishes the regulations and limits of legitimate and testamentary inheritance and the rights of the State in matters of inheritance*"[5] (Laffaille, 2016). The Court also refers to Constitutional Law No. 3 of 18

[3] Courtesy translation of "*La Repubblica riconosce e garantisce i diritti inviolabili dell'uomo, sia come singolo sia nelle formazioni sociali ove si svolge la sua personalità, e richiede l'adempimento dei doveri inderogabili di solidarietà politica, economica e sociale*".

[4]Courtesy translation of "*La Repubblica promuove lo sviluppo della cultura e la ricerca scientifica e tecnica. Tutela il paesaggio e il patrimonio storico e artistico della Nazione*".

[5]Courtesy translation of: "*La proprietà è pubblica o privata. I beni economici appartengono allo Stato, ad enti o a privati. La proprietà privata è riconosciuta e garantita dalla legge, che ne determina i modi di acquisto, di godimento e*

October 2001[6], stating that the protection of the environment, ecosystem, and cultural heritage falls within the State exclusive competence.

From this point onward, the Court of Cassation decided to overcome the purely patrimonial view of public property, that is a personal-collectivist view. The Court goes beyond the public property/private property dichotomy, dwelling on the interests that derive from such ownership. Therefore, according to the Judge's view, when a property contributes to the realization of the welfare State, it falls into the category of public property, being a source of benefit to the community. According to the *Cassazione*, the *valli da pesca* are functionally bounded to the interests of the State/community (regardless of their ownership title), and contribute to the development of people and the protection of the landscape. The State has thus a responsibility to protect these areas.

The Judges availed themselves of the concept of "common goods", previously deeply analyzed by several scholars. The purpose was to qualify some goods as common goods, in order to differentiate them from public and private goods in view of their function and the needs they are supposed to eventually meet. It is a measure for the protection of some goods that the public property has failed to maintain. According to Laffaille, this would allow to overcome the division between public law and private law and some of the dilemma of the *valli da pesca*: these assets would belong to no one, they would belong to the community.

However, there have been scholars supporting opinions against the position adopted by the Court of Cassation, which will be briefly mentioned below. They essentially dispute the public nature of the *valli da pesca* of the Venice lagoon for several reasons. First of all, as already mentioned, there are dams that separate the *valli* from the lagoon, with the ability to adjust water inlet and outlet and salinity. Hence, the man-made modifications have led objectors to assess the *valli* as private property. Moreover, the Court of Cassation in 2011 confers a uniform status of all the *valli*, characterizing them as identical, whereas they are not since they could be categorized into different types (*valli arginate*[7], *valli semi-arginate*[8], and *valli aperte*[9]). In the past, only the *valli aperte* (open *valli*) were considered part of the public domain, since they directly communicate with the open sea. According to Laffaille, 2016, the Court has ignored the issue of dyshomogeneity.

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i limiti allo scopo di assicurarne la funzione sociale e di renderla accessibile a tutti. La proprietà privata può essere, nei casi preveduti dalla legge, e salvo indennizzo, espropriata per motivi d'interesse generale.
La legge stabilisce le norme ed i limiti della successione legittima e testamentaria e i diritti dello Stato sulle eredità".

[6] Legge Costituzionale 18 ottobre 2001, n. 3, *Modifiche al titolo V della parte seconda della Costituzione* (Constitutional Law of 18 October 2001, No. 3, Amendments to Title V of the second part of the Italian Constitution).

[7] Embanked valli*: valli da pesca* that are completely surrounded by earth embankments or continuous boulders.

[8] Semi-margined valli*: valli da pesca* that are are constituted by interrupted embankments and completed by trellises of marsh reeds (*grisole* in Italian).

[9] Open valli*: valli da pesca* that are constituted by large bodies of water and are free from any closure.

Other issues provoke objections among scholars: in fact, the Court of Cassation (evoking the previous judgment of the Court of Appeal of Venice) refers to the 1841 Austrian Regulation, which established the public nature of the lagoon. This argument was disputed because the Regulation confirmed the public nature of the *valli* at that time (*status quo ante*), but left the nature of the *valli* themselves unclear.

The Court of Cassation also argues that the *valli da pesca* can be used for maritime uses, such as fishing and navigation. According to the opposing scholars, it forgets to mention hunting, which is very important for these places. Then, as for navigation, this Court does not specify that only small boats can be used in these places, due to the conformation of the *valli* and the dams. Finally, considering fishing, according to opposing opinions, we must remember that it is extremely different from the activity practiced in the open lagoon. Fishing practiced in the *valli* is anthropogenic, and fish cannot move from one *valle* to another. According to Laffaille, 2016, there is no public use for fishing.

Some *valli* holders claim to have ownership titles dating back to the Serenissima period. Indeed, some holders have already pointed out the ambiguous conduct of the State authorities. In time, holders have been asked to pay taxes on properties. In 1988, the State started to act legally, when it sought (in vain) the conviction of the owners of the *valli* for encroaching occupation of the maritime domain. An example of such a situation is the Società Agricola Pierimpiè S.p.A., which manages *Valle Pierimpiè*, whose context will be reported below.

Therefore, according to the 2011 judgment of the Court of Cassation, the *valli da pesca* have to be treated as part of the public maritime domain, belonging to the sphere of the public assets, since public authorities have never privatized them through legal acts, making them *de facto* private property. Moreover, the *valli* are part of the public good, belonging to the collectivity, because they are functionally related to the interests of the community. Among scholars, also concerning this topic, the concept of common goods was introduced. In fact, according to them, this condition would remove the supreme control of the State and the domination of the owner. The use of the common good would in fact be open to all, so the division between public and private law would be overcome (Rodotà, 2013).

The contrasting opinions maintain that the private status of the *valli* would be lawful. According to them, the Court of Cassation would have been very vague for the reasons already mentioned above, in addition to the fact that it vaguely considered the concept of public good since it merely defined them as a source of benefit for society. Yet it does not clarify the type of benefit (economic, social, environmental?). Eventually, according to Laffaille and some of the authors mentioned by the latter,

raising up the concept of common goods, an ideologic and romanticized aspect would be introduced, -which however could be put into practice for the time being.

In order to better understand the issue, it is necessary to underline that the Italian legislator made a first attempt to legislate on the *valli da pesca*, but such an attempt never saw the light as it remained a draft law[10] (which was notified to the Presidency of the Senate of the Italian Republic, on 20 June 2013, and drafted on the initiative of Senators Dalla Tor, Marin, Conte, Bonfrisco, Zanettin, and Piccoli). Since 2013, said draft law has not been subject to the vote of the Senate, nor of the Chamber of Deputies, yet. Therefore, said draft law still remains a mere project.

It is however useful to recall some of its suggested provisions as it comprehensively addressed the issue of ownership and management of the *valli da pesca* in the Venice lagoon. In particular, reference was made to Law no. 366 of 5 March 1963[11], art. 28[12] of the Italian Navigation Code[13], and article 822 of the Italian Civil Code. Indeed, article 822 of the Civil Code does not expressly include the *valli da pesca* among the assets belonging to the State domain (*beni demaniali*). Conversely, article 28 of the Navigation Code, entered into force in 1942, established that also the bodies of salt or brackish water that, at least for a part of the year are in free communication with the sea are part of the State domain, thus the *valli da pesca* would fall under this description.

The above draft law also stresses that Article 9 of Law No. 366/1963[14], on the other hand, provides for the possibility of expropriating the *valli da pesca*, by the Venice water magistrate, in the event

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[10] Disegno di legge n. 854 del 20 giugno 2013, *Regime giuridico e valorizzazione delle valli da pesca della laguna di Venezia* (Draft Law No. 854 of 20 June 2013 on the legal regime and valorization of the *valli da pesca* of the Venetian lagoon)

[11] Law of 5 March 1963, No. 366, *Nuove norme relative alle lagune di Venezia e di Marano-Grado* (New provisions on the lagoons of Venice and Marano-Grado).

[12] *"Fanno parte del demanio marittimo: a) il lido, la spiaggia, i porti, le rade; b) le lagune, le foci dei fiumi che sboccano in mare, i bacini di acqua salsa salmastra che almeno durante una parte dell'anno comunicano liberamente col mare; c) i canali utilizzabili ad uso pubblico marittimo".* Courtesy translation. *"The maritime state domain includes: a) the lido, the beach, the ports, the roadsteads; b) lagoons, the mouths of rivers flowing into the sea, basins of brackish salt water which, for at least part of the year, freely communicate with the sea; c) canals usable for public maritime use*".

[13] Royal Decree of 30 March 1942, No. 327, *Codice della Navigazione* (Navigation Code).

[14] "*La laguna di Venezia è costituita dal bacino demaniale marittimo di acqua salsa che si estende dalla foce del Sile (conca del Cavallino) alla foce del Brenta (conca di Brondolo) ed è compreso fra il mare e la terraferma.*

Essa è separata dal mare da una lingua naturale di terra fortificata per lunghi tratti artificialmente, in cui sono aperte tre bocche o porti, ed è limitata verso terraferma da una linea di confine marcata da appositi cippi o pilastri di muro segnati con numeri progressivi.

Tale linea delimita il territorio lagunare nel quale debbono essere osservate le norme e prescrizioni contenute nella presente legge a salvaguardia della laguna".

Courtesy translation. "*The Venice lagoon consists of the state-owned maritime basin of salt water that extends from the mouth of the Sile (Cavallino basin) to the mouth of the Brenta (Brondolo basin) and lies between the sea and the mainland.*

It is separated from the sea by a natural tongue of land fortified for long stretches artificially, in which three mouths or ports are open, and is limited towards the mainland by a boundary line marked by stones or wall pillars marked with progressive numbers. This line delimits the lagoon territory in which the regulations and prescriptions contained in this law must be observed to safeguard the lagoon".

that this administration, which is in charge of managing the entire lagoon, deemed it necessary to allocate these areas for tidal expansion. Concerning the latter aspect, the Venice Water Authority, a peripheral branch of the Ministry of Infrastructure and Transport, in recent years has developed initiatives aimed at verifying the impact of the opening of the *valli da pesca* on the high-water phenomenon, intended to improve the lagoon environment. The activities developed were mainly studies, projects, and experiments, implemented in Valle Figheri (*Regime Giuridico e Valorizzazione Delle Valli Da Pesca Della Laguna Di Venezia*, 2013). The outcome of the studies ruled out that the opening of the *valli da pesca* could actively contribute to mitigating the high-water phenomenon or to improving the status of the lagoon ecosystem.

As pointed out earlier, Article 822 deals with public domain, owned by the State. The *valli da pesca* are not expressly mentioned in Article 822 of the Civil Code, so the question that arises is whether the *valli da pesca* are considered part of the sea, in which case by law they belong to the maritime State domain.

On the other hand, as in the aforementioned Article 28 of the Navigation Code, the basins of salt or brackish water that at least during part of the year freely communicate with the sea belong to State property, therefore, by interpretation the *valli da pesca* are also included.

In view of the above, we must therefore consider that there still is around the nature of the property whether it be private or public between scholars and judges, in the absence of clear legislation on them. However, such a dilemma seemed to be solved, for the time being, by the Joint Chambers of the Court of cassation which classified them as public goods, particularly falling within the category of public domain.

Nevertheless, this being said, all the assets added by men for the maintenance of the *valli da pesca* appear to be private property, including the stretches of water determined by man's flooding of the pre-existing land. Therefore, there is still a need to verify the ownership of the brackish water stretches.

At this point, it is necessary to check which *valli* were already completely dammed before the entry into force of the Navigation Code, in order to verify to which *valle* Article 28 cannot be applied. Such *valli* therefore cannot be considered State property, because at the time, being closed, they were not open to the free expansion of the sea.

The consequence of adopting this draft law and approving it as law would be to trace a distinction between privately owned stretches of water (as they were dammed before Article 28 of the Navigation Code came into force), and stretches of water owned by the State.

However, the importance of maintaining these places by human hands is emphasized, in order to preserve not only the landscape nature of the *valli*, but also the birdlife. Therefore, in this bill, it is

specified that the State-owned parts of the *valli* should be granted to private owners in order to exploit and maintain these *valli*. Hence the evidence of making the public good (brackish water) ancillary to the private good (the rest of the valley) on concession.

The bill is divided into four articles. The first article is divided into four paragraphs. They recall what has already been mentioned before, i.e., that the *valli* compendiums consist of the banks, margins, dry land, stretches of water determined by man-made flooding of dry land, and stretches of water (second paragraph). Only the banks, margins, dry land, and bodies of water determined by man-made flooding of dry land are private property (third paragraph). Those *valli* that were closed before the entry into force of Article 28 of the Navigation Code would be privately owned (fourth paragraph), should this draft law be approved in the future.

The second article is divided into six paragraphs. The first paragraph emphasises that the holders of the *valli* may take the watery parts belonging to the maritime State domain as concessions. The second paragraph says that the annual fee is commensurate with the parameters applied for lagoon concessions and is doubled if fish farming is not practised in the *valle*. The third paragraph emphasises that owners are obliged to maintain in an ordinary and extraordinary manner, as well as to enhance the landscape, the stretches of water granted by the State property. The fourth paragraph presents the applicant's need to submit a five-year plan containing ordinary and extraordinary maintenance activities, an environmental conservation and enhancement program, and any program for the productive enhancement of the *valli da pesca*, to be carried out at their own care and expense. Failure to implement the programme may imply the revocation of the concession. The fifth paragraph states that the concession has a duration of thirty years. The sixth paragraph provides that the conformations of the Venice lagoon constitute criteria for the granting of concessions (Regime Giuridico e Valorizzazione Delle Valli Da Pesca Della Laguna Di Venezia, 2013). The third article stipulates that a water fee, updated periodically, commensurate with the surface area of the waters shall be applied to all *valli* compendiums.

The fourth article emphasises that the State-owned stretches of water of *the valli da pesca* must be used, also for the purposes of production activities, in compliance with the regulations in force to safeguard Venice and its lagoon.

It is also specified that Article 9 of Law 366 of 5 March 1963 would be repealed.

Although this bill is full of food for thought, since it has not been approved yet, we should refer only to the 2011 ruling of the Court of Cassation, which considers the *valli da pesca* as State property. The issue is very controversial, and despite the Court ruling, the holders of the *valli da*

pesca continue to claim their right to ownership. Referring to Article 28 of the Navigation Code, there should be no doubt that these places belong to the State.

However, in order to understand the legal complexity of this issue, we can report the case of one of the *valli da pesca* in the Venice lagoon, Valle Pierimpiè. The State (namely *the Intendenza di Finanza* of Padova) in 1989, 1991, and 1994 ordered the holder of said *valle* to vacate the land it was occupying, as it belonged to the public domain, demanding the payment of an indemnity that could amount to several million euros. In 1994, the holder owner sued the Ministries of Finance, Finance, Tourism, Navigation, and Public transports, stating that the *valli da pesca* had been handed down through sale between individuals since time immemorial (there are titles dating back to the 15th century), that in 1886 it had been put up for sale by the Civil Court of Venice, and that it has always been privately owned as evidenced by Austrian legislation.

However, in May 2004, the Court of Venice declared that Valle Pierimpiè belongs to the State maritime domain, bringing as grounds article 28 of the Navigation Code. In order for *valli da pesca* to fall within the State domain, they must meet the following parameters: physically be part of the lagoon and thus communicate with it and lend themselves to one of the public uses of the sea (bathing, fishing, and navigation). In fact, the *valle* was communicating with the sea when article 28 came into force in 1942, and although navigation and bathing were difficult, if not impossible, fishing was practiced. Legally then, Valle Pierimpiè was part of the public domain, and the holder according to the Government, was condemned to pay compensation to the State for the illegal occupation of the area. Such an amount, however, was quite high and could have led to the bankruptcy of the company.

After having unsuccessfully filed lawsuits before every instance of Italian jurisdiction, the holder of *Valle* Pierimpiè decided to seize the European Court of Human Rights.

Therefore, the company relied on Article 41 of the European Convention of Human Rights[15], requesting that the State was ordered to recognize its right of ownership over the *valle da pesca* Pierimpiè, and consequently not to demand compensation for its occupation. If its requests were not

[15] Article 41 - *Right to good administration*.
"1. Every person has the right to have his or her affairs handled impartially, fairly and within a reasonable time by the institutions, bodies, offices and agencies of the Union.
2. This right includes:
(a) the right of every person to be heard, before any individual measure which would affect him or her adversely is taken;
(b) the right of every person to have access to his or her file, while respecting the legitimate interests of confidentiality and of professional and business secrecy;
(c) the obligation of the administration to give reasons for its decisions.
3. Every person has the right to have the Union make good any damage caused by its institutions or by its servants in the performance of their duties, in accordance with the general principles common to the laws of the Member States.
4. Every person may write to the institutions of the Union in one of the languages of the Treaties and must have an answer in the same language".

upheld by the Court, the holder would have demanded compensation for the suffered damages affecting its property and business.

The Court held that, although the State was right and the aforementioned *valle* Pierimpiè belonged to the public maritime domain, and therefore was to be considered as public property, the amount to be paid was definitely excessive, violating Article 1 of Protocol No. 1[16].

In 2016, the Court received amicable statements from the Government and the holder of the *valle* in question, in which the Government authorized the Valle Pierimpiè Società Agricola S.p.A. to continue operations within the *valle* for another 20 years, despite it being publicly owned, having to pay a lower compensation (186.129,94 euros) due to the unlawful occupation of State property (*Sentenza Della Corte Europea Dei Diritti Dell'Uomo Del 1° Settembre 2016 - Ricorso n. 46154/11 - Valle Pierimpiè Società Agricola S.P.A. c. Italia,* 2016).

As it can be noticed, the dilemma over the public or private nature of the *valli* is a delicate one. By now, most of the *valli da pesca* of the Venice lagoon are managed by private subjects. What happens is the concession to private parties through tenders called by the municipality, which grants the area under management against payment of a fee, similarly to what happens with beach management. The holders of these *valli* make use of activities such as hunting and fishing or recreational activities to maintain them, and thanks to the income they earn, they are able to do the hydraulic and maintenance work that is needed every year or two. However, besides the workers, the holders, and the hunters, nobody can experience the beauty of these territories.

ECOLOGICAL ROLE OF THE *VALLI DA PESCA*

The *valli da pesca* nowadays represent an artificial ecosystem that depend on men's efforts to survive and to maintain the distinctive elements of a transitional water ecosystem, such as saltmarshes presence, salinity gradients, the maintenance of water fluxes, landscape elements, and the preservation of the process of the lagoon that hosts them (Stocco & Pranovi, *in press*).

The *valli da pesca* usually receive lagoon water that enters from a dam, flows into a brackish lake, and finally flows to the land. On the other side, freshwater from inland rivers is stored in some basins, creating a freshwater wetland area, from which the water overflows and reaches the major

[16] Article 1 of Protocol No. 1 – Right to property: *1. Every natural or legal person is entitled to the peaceful enjoyment of his possessions. No one shall be deprived of his possessions except in the public interest and subject to the conditions provided for by law and by the general principles of international law.*
2. The preceding provisions shall not, however, in any way impair the right of a State to enforce such laws as it deems necessary to control the use of property in accordance with the general interest or to secure the payment of taxes or other contributions or penalties".

brackish basin. Finally, the mixed water circulates in different sectors of the *valli* and eventually flows out into the lagoon.

Besides being important wintering and nesting sites, they make a great contribution, in terms of Ecosystem Services, to the lagoon ecosystem. In fact, the managed *valli da pesca*, despite representing only 19% of the Venice lagoon, account for 38% of the total potential ecosystem service provision, securing 24% of the total amount of Ecosystem Services that flows to society, thus contributing to the provision of Ecosystem Services in the lagoon (Stocco & Pranovi, in press). Moreover, the abandoned *valli da pesca* still show a higher capacity to provide Ecosystem Services, testifying for the persistence of the influence of the human interventions on the landscape aimed at maximizing some peculiar characteristics.

As mentioned above, there are 31 *valli da pesca* in the Venice lagoon, managed with different strategies, which provide various regulation, provisioning, and cultural Ecosystem Services. According to a recent Ecosystem Services assessment, the *valli da pesca* today can be divided into five groups with different management strategy used: one group use the strategy to maximize fish production from aquaculture; another group of nine *valli* that prioritize hunting activity as strategy management; a third group of eight *valli* that manage both hunting and aquaculture (and sometimes also tourism); a fourth group is represented by *valli* that allows for cultural activities such tourism and environmental education trips as management strategy; and finally, there is a group of abounded *valli da pesca* that are not managed anymore.

At a first sight, it may seem that the *valli da pesca* are able to provide only the provisioning Ecosystem Services they manage in order to maximize them, as often happens for intensive agricultural ecosystems, intensive aquaculture cages, or similar productive areas. On the contrary, a recent analysis found that the *valli da pesca* devoted to aquaculture and hunting maximization have higher values for regulating & maintenance ecosystem services.

In addition, when considering the cultural Ecosystem Services, the abandoned *valli da pesca*, despite being the only *valli* where a public and free access is granted, have a cultural and touristic attractiveness lower than that of the managed *valli*.

Such a pattern is dependent on the effect of the management strategy, which modify the landscape characteristics. For example, the *valli* that use fishing as the main source of income have the highest portion of the area covered by water, followed by *valli* that use both fishing and hunting, while those that use mostly hunting and those that are abandoned show different characteristics. In the latter group, there is a preponderance of saltwater, unlike in the managed *valli* in which there are more freshwater pools and saltmarshes, ensuring higher landscape heterogeneity. *Valli* that use

recreational activities (such as tourism activities) have the largest portion of land not covered by water compared to the others.

Therefore, there is a particular difference between abandoned and managed *valli*. In fact, the authors found that ensuring the management of fishing *valli* also allows for a higher capacity of Ecosystem Services than the abandoned *valli*. This could result from the fact that the structure of the *valli da pesca* donates more resilience in slowing down the loss of environmental heterogeneity, and preventing excessive anthropogenic pressure. However, it has been shown that, although unmanaged *valli* show lower ecosystem service provision than the managed *valli*, it is still 3.77 times higher than the capacity per unit area of the open lagoon. Therefore, the *valli da pesca*, even if unmanaged, provide more ecosystem services than the open lagoon. For instance, about 12% of the carbon dioxide sequestered each year in the Venice lagoon, is owed to saltmarshes and seagrasses meadows which are located in the *valli da pesca*.

The cited study also found a negative correlation between the ability to provide ecosystem services and the flow of cultural ecosystem services: in fact, the *valli da pesca* are closed-regime areas that do not encounter a large human presence, with the exception of the *valli da pesca* that use recreation as a source of income. This negative correlation can be explained by the fact that maximizing Ecosystem Services hinders tourist access. In fact, unlike activities such as hunting, fishing, and plant and honey harvesting, the *valli da pesca* that offer tourist attractions lose important landscape elements that allow them to mimic the natural functioning of the lagoon; this landscape arrangement does not respect the current ecological role of natural elements.

From an ecological point of view, in order to preserve more Ecosystem Services, the *valli da pesca* should perform the role for which they were born, Ecosystem Services services such as fishing and hunting, maintaining the peculiar features of the landscape and its ecological processes. This result highlights the difficulty of ensuring both the maintenance of Ecosystem Services provided by the *valli da pesca,* through practices such as hunting and fishing, and the provision of cultural Ecosystem Services derived from them.

All these peculiarities in the *valli da pesca* benefit the entire lagoon ecosystem and confirm the importance they have from an ecological point of view. Indeed, if there is a desire to maintain true lagoon spaces, these places are indispensable. The *valli da pesca* represent a real paradox: they are totally man-made, artificially arranged natural spaces, but they are the real lagoon areas that maintain natural conditions.

However, a critical point arises: the majority of these areas are sustained thanks to private managers' investments, which are largely derived by the income earned from the hunting activity.

Hunting is based only on the resource of huntable waterfowl, that migrates and winter in the *valli da pesca*, where they are attracted due to both natural factors and artificial feeding.
But to rely only on one resource can be risky, especially when considering the climate change effects on the ecosystems (Weiskopf et al., 2020).
Indeed, the analyses performed on forecasts provided with the MaxEnt Species Distribution Models revealed that the ideal temperature and bioclimatic conditions are likely to shift more northward in Europe, even if this is not evident for all the considered species.

Before commenting on the projected climatic conditions in Europe and the *valli da pesca* in the future, it is appropriate to know the species of anatids living in these areas, both during the wintering period and the resident ones. The hunting period lasts approximately from the third week of September to January 31.
Here follows a list of some of the species that populate the *valli da pesca* at different times of the year.

Huntable waterfowl species

Anas acuta (northern pintail)

Figure 1: Anas acuta (Northern Pintail)

The Northern pintail (Fig. 1) overwinters in the *valli da pesca* approximately from September (they arrive until November) to April (some start to leave at the end of February).
It is a species distributed worldwide, mainly in the northern hemispheres. These ducks like to live in wetlands (like lagoons, lakes, rice or oat fields, rivers, and ponds) and their breeding season takes place in spring and summer, particularly in early May.
Nevertheless, they are recognized as irregular breeders in Italy, because they occasionally nest here in fresh and slightly brackish water. They are monogamous and they lay 7 to 9 eggs per year.

Nowadays they are not vulnerable, even if the European population is declining (less than 25% in 20.4 years) (BirdLife International (2015), 2015) and still massively hunted.
Therefore, in Italy and particularly in the *valli da pesca*, the northern pintails (*Codone* in Italian) are wintering, irregular nesting, transient, and huntable, while they are non-resident and vulnerable.

Spatula clypeata (northern shoveler)

Figure 2: Spatula clypeata (Northern shoveler)

The Northern shoveler (Fig. 2) overwinters in the *valli da pesca*. The autumn migration begins in August and lasts until December, and the spring migration begins in February until May. The migration peak is between October and November for the autumn migration and between the 15th of March and the 15th of April for the spring migration.
In Italy the Northern shoveler, besides being migratory and wintering, is also partially sedentary and breeding, especially in the Venice lagoon and in the Po valleys. However, there is an extremely small number of pairs because their colonization is fairly recent. They are monogamous and the pairs form before spring migration. The females lay between 8 and 10 eggs starting in April.
The species is huntable, but the conservation status is inadequate, indeed, it is inserted on the red list in Italy, constituting almost 70% of the Anatidae hunted in March.
Therefore, in Italy, particularly in the *valli da pesca*, the northern shovelers (*Mestolone* in Italian*)* are wintering, nesting, resident, transient, vulnerable and huntable.

Anas crecca (Green-winged Teal)

Figure 3: Anas crecca (Green-winged teal)

The Green-winged teal (Fig. 3) overwinters in the *valli da pesca* from August (up to December) to April (leaving starting from February), the migration peak is between October and November for the autumn migration and in March for the spring migration.

In Italy besides being migratory and wintering, this species is nesting (few confirmed cases, 20-50 pairs) and sedentary. The hatching takes place in April and May, they lay 8-10 eggs.

21% of the population lives in the Venice lagoon. In Europe, this species usually nests in the North and East part, and it winters in Western and Southern Europe and Africa, therefore in Italy they are not only wintering but also transient.

It is in a good conservation state, it is huntable, even if hunting represents a disturbance for these animals that have strongly gregarious habits.

Therefore, in Italy, particularly in the *valli da pesca*, the green-winged Teal (*Alzavola* in Italian) is wintering, nesting, resident, transient, vulnerable and huntable.

Anas penelope (Eurasian Wigeon)

Figure 4: Anas penelope (Eurasian wigeon)

The Eurasian Wigeon (Fig. 4) overwinters in the *valli da pesca* from August (up to December), to April (leaving starting from February), the migration peak is between October and December for the autumn migration and in March for the spring migration.

This species occasionally nests in Italy (not in Venice province), but there are few pairs, presumably made up of individuals unable to migrate due to impairments caused by hunting. It is very gregarious and forms numerous flocks. Nesting takes place in the boreal zone and the Russian steppe; they usually lay from 6 to 12 eggs.

The Eurasian wigeon has a positive conservative state and it is huntable.

Therefore, in Italy, particularly in the *valli da pesca*, Eurasian wigeon (*Fischione* in Italian) is wintering, irregularly nesting, transient, and huntable. It is not resident and vulnerable.

Anas platyrhynchos (Mallard)

Figure 5: Anas platyrhynchos (Mallard)

The Mallard (Fig. 5) is the most widespread among the wild duck species and the most numerous. In Italy, this species is sedentary and nesting, but it is also regularly migratory and wintering. Most mallards are widespread in the internal and coastal Po Valley, on the Tyrrhenian side, and in Sardinia. This species has expanded since the 1960s, the reason is not well known yet, probably it is a consequence of an introduction for hunting purposes. The reproduction period varies from February to July, the females usually lay 5 to 15 eggs.

Outside the breeding season, it is gregarious species, that can also be observed in groups of thousands of individuals, especially in the *valli da pesca* of Venice.

Therefore, in Italy, particularly in the *valli da pesca*, the mallard (*Germano reale* in Italian) is wintering, nesting, resident, and huntable. It is not transient and it is not vulnerable.

Spatula querquedula (Garganey)

Figure 6: Spatula querquedula (Garganey)

In Italy, the Garganey (Fig. 6) is a regular migrant, breeder, and irregular winter visitor.
The post-reproductive migration takes place from August to September, while the pre-reproductive migration takes place from mid-February to April. The Garganey's reproduction period comes between the second decade of March and the second decade of August and the females lay 8-9 eggs. In Italy, it is possible to see the Garganey from the end of February - March to the end of July - September, but March is the period in which they are most visible. It is a long-range migrant and has well-defined wintering points, concentrated in the Sahel area (southern belt of the Saharan region), therefore it is also transient.
It is huntable and considered vulnerable because of the reclamation of wetlands, destruction of its habitat, anthropic disturbance, and lead poisoning.
Therefore, in Italy, particularly in the *valli da pesca*, the Garganey (*Marzaiola* in Italian) is irregular wintering, nesting, transient, vulnerable and huntable. It is not resident here.

Mareca Strepera (Gadwall)

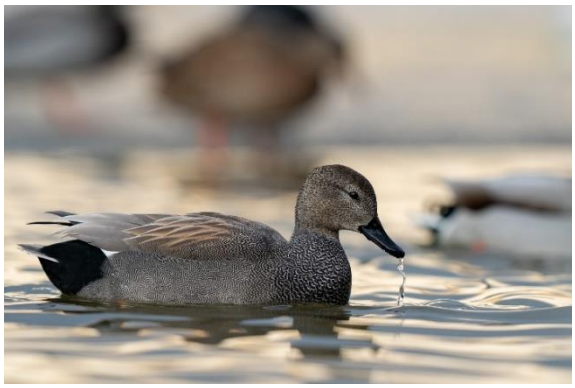

Figure 7: Mareca strepera (Gadwall)

In Italy, the Gadwall (Fig. 7) is a very localized breeder (very few pairs: 50-100), a regular migrant, and a winter visitor. The most important nesting areas consist of the coastal wetlands of the Upper Adriatic and some of the inland areas in the Po Valley (Casale, 2015).

This species migrates between September and December (the migration peak is October - November) and leaves in mid – January until April.
Couples are formed during the migration and remain together until spawning, which takes place between April and June (they lay 8 to 12 eggs). They are not considered at risk and are huntable in the *valli da pesca*.
Therefore, in Italy, particularly in the *valli da pesca*, the Gadwall (*Canapiglia* in Italian) is wintering, nesting, resident, transient, and huntable. It is not a vulnerable species.

Aythya fuligula (Tufted duck)

Figure 8: Aythya fuligula (Tufted duck)

In Italy, the Tufted duck (Fig. 8) is a localized breeder, a migrator, and a winter visitor. Usually, it nests in Nord-East Europe, the British Isles, and Northern Asia, but recently it has started to nest also in Italy (a few dozen of pairs). The reproduction period starts from the first decade of August, and the female lays 5 to 12 eggs.
The pre-reproductive migration movements start at the end of September until November and they leave for the post-reproductive migration in February - March.
It is a huntable species and is currently considered in decline.
Therefore, in Italy, particularly in the *valli da pesca*, the tufted duck (*Moretta* in Italian) is wintering, nesting, resident, in decline, and huntable. It is not transient.

Non huntable waterfowl species

The species just described above are huntable according to the law. It will follow a list of non-huntable species that are present in the *valli da pesca*.

Aythya ferina (Common pochard)

Figure 9: Aythya ferina (Common pochard)

The Common pochard (Fig. 9) is considered a migrator, a winter visitor, and, an irregular nesting species in Italy. The nesting here started in the mid-1970s. The pairs form in Spring (there are currently 300-400 pairs in Italy) and they lay 8 to 10 eggs in May. The post-reproductive migration starts in August until December (the migration peak takes place between mid-October and November) and pre-reproductive migration starts in February and ends in April (the migration peak takes place between mid-February and March). The wintering areas of this species are the Mediterranean area, the Black Sea, and central Europe.

It is currently in decline, threatened by many activities, for this reason, the TAR in 2022 forbade hunting the common pochard, as it is considered a threatened species at the global level (spec1).

Therefore, in Italy, particularly in the *valli da pesca*, the Common pochard (*Moriglione* in Italian) is wintering, irregularly nesting, and vulnerable. It is not resident, transient and huntable.

Anser anser (Greylag goose)

Figure 10: Anser anser (greylag goose)

The Greylag goose (Fig. 10) is historically important since the famous ethologist Konrad Lorenz studied the imprinting phenomenon on a female specimen of greylag goose, Martina.

The reproduction period of this species takes place in spring, between may March and May and the female lays 4 to 6 eggs, the couple is monogamous and extremely close-knit and the male collaborates in the brooding. It is a gregarious species outside the reproductive period.
The greylag gooses usually live in Scotland, Iceland, Scandinavia, Russia, Poland, and Germany, and, in winter, they migrate to Spain, France, the Eastern Mediterranean, and North Africa. They winter also in the *valli da pesca*, and the pre-reproduction migrations start in January and continue until March, while the autumn migration takes place in August /September. Extraordinary is the typical "V" formation that they use for migration, also common in the species of geese that will be described below. They are passing through Italy during migrations, but they do not nest or reside here.
Therefore, in Italy, particularly in the *valli da pesca*, the Greylag goose (*Oca selvatica* in Italian) is wintering, transient, and vulnerable. It is not huntable, resident and nesting.

Anser fabalis (Bean goose)

Figure 11:Anser fabalis (bean goose)

The Bean goose (Fig. 11), nesting from Scandinavia to Russia, reaches Southern Europe to wintering, even if in the last years the number of exemplars that are abounding the Mediterranean areas to winter further north is increasing. The Bean gooses that winter in Italy come mainly from Germany and Holland, they also pass-through Italy when they migrate further south, but they do not nest in Venice. During the year, they lay 4 to 6 eggs between June and July. The migration takes place at the end of August (the migration peak is in October) and they return to the northern areas between March and May.
It emerges that *Anser fabalis* in Italy does not reach a thousand individuals and that often, indeed, it is closer to a hundred. Indeed, in the past, both hunting and the loss of habitat provoked a consistent decline in the species.
Therefore, in Italy, particularly in the *valli da pesca*, the Bean goose (*Oca granaiola* in Italian) is wintering, transient, and vulnerable. It is not huntable, resident and nesting.

Branta canadensis (Canadian goose)

Figure 12: Branta canadensis (Canadian goose)

The Canadian goose (Fig. 12) is a migratory bird originally from Canada, that lives typically in northern environments. It has been introduced in Europe in the 17th century in Great Britain and Ireland and in time it was established also in Norway, Sweden, Finland, and West Germany.

The Canadian gooses are monogamous, the female lays 3 to 9 eggs every year. For the most they are migratory, yet some of them are sedentary.

It is not so much present in Italy. Some pairs of this species have been introduced here illegally in the 1990s. In the Venice lagoon, the Canadian goose is rare, and it has been sighted on a few occasions. Therefore, it is possible to affirm that the Canadian goose (*Oca canadese* in Italian) is a kind of irregular appearance (irregular migrant), irregular breeding, and is rare. The winter stop is temporary and limited to a few individuals. It is not huntable.

Anser albifrons (Specklebelly goose)

Figure 13: Anser albifrons (Specklebelly goose)

The Specklebelly goose (Fig. 13) nests mainly in Russia and it is a regular winter visitor in Italy, in particular in the Adriatic lagoons. They lay 5 to 7 eggs every year and it is a very domesticable and quiet species. The first exemplars in the Adriatic arrive in November, the migratory peak is in January and February. They start to leave at the end of February, until April. This is a protected

species, and the most important limiting factors include illegal killing and collision with power lines.

The Specklebelly goose (*Oca lombardella* in Italian) stays in Italy only for the wintering period, it does not nest here, nor stabilize in Italy or pass through these areas to winter further south. It is not huntable.

Netta rufina (Red-crested pochard)

Figure 14:Netta rufina (Red-crested pochard)

The Red-crested pochard (Fig. 14) in Italy is a migrant, a winter visitor, and a partially sedentary breeder (it nests in Sardinia and some wetlands of northern Italy). The Italian population is very small, limited to just over 20 couples. Here, it appears regularly during migrations, but in small numbers. The individuals observed in the South Lagoon of Venice are most likely the consequence of recent artificial releases.

The post-reproduction migration takes place in October and November, while the pre-reproductive migration takes place between February and April.

Couples start to form in autumn and last until winter, the females in captivity are parasitic because they often lay their eggs in the nests of conspecifics or other water birds, and lay 8 to 10 eggs every year. On the continent level and in the European Union, the Red-crested pochard is considered not at risk, yet in Italy, they are inserted in the Red National List, therefore it has been prohibited hunting this species.

Therefore, in Italy, particularly in the *valli da pesca*, the red-crested pochard (*Fistione turco* in Italian) is wintering and vulnerable. It is not huntable, resident and nesting, or transient.

The question naturally arises: is it possible that, due to climate change, conditions will no longer be favourable for hosting these anatid species in the *valli da pesca*, or that environmental conditions will arise in the future whereby, instead of migrating southwards, these birds will migrate to other latitudes or longitudes, or even no longer migrate at all.

Many migratory birds, as it was described above, during winter, migrate southwards to find better favourable conditions.

In the Appendix at the end, an assessment of the distribution of duckweed species of interest in the time period between 2021 and 2040, and 2081 and 2100 is provided, using Maxent software version 3.4.4., with input data from the WorldClim dataset and species occurrence data retrieved from GBIF database. What emerges is that the ideal areas for ducks are moving northwards overall.

In Figure 15, it is shown the present species distribution. It can be noted that in Europe, and in Italy as well, the conditions are quite favourable for hosting the anatids species. While towards the north-east part of the Eurasian continent, the habitat suitability is quite low. This means that nowadays, by averaging, the ducks that were described above prefer climate conditions and environmental variables that are present in Europe (yellowed coloured territories).

Figure 16 instead, describes the habitat suitability for the anatid species in the future between 2081 and 2100. It can be noted that, compared also Figure 16 with Figure 15, overall, favourable conditions increase towards the north, and decrease, very slightly, in Europe (especially southwards). This model is representative of the fact that, due to climate change, suitable environmental conditions for these species will increasingly improve in areas towards the north. Of course, this model is not sufficient to state the future of migration of these species, yet it gives important insights on the climate change threaten that may affect not only the migratory routes of ducks (and other migratory species as well), but also the future of the *valli da pesca*. Also, climate change is not the only challenge that birds have to face during migrations. They are, still today, threatened by habitat destruction, hunting, chemical pollution and by aircraft collision (Higuchi, 2012).

The main risk emerging from the map in Figure 16 is that, due to favourable conditions in other parts of the Eurasian continent, many duck species will no longer migrate southwards to overwinter, and thus to the *valli da pesca*, but will remain northwards or move to different areas (perhaps to central Europe). This would not only be dangerous for the species itself, but also for the role that migration plays in ecosystems. Indeed, migratory species link ecosystems that are separated by great distances and time (Whelan et al., 2008). Waterfowl, for instance, are seed dispersers, linkers of many distance wetland areas, and aquatic invertebrates' dispersers (Whelan et al., 2008). This shows the ecological importance that migratory birds have. Unfortunately, this change in the migratory species behaviour is already happening. Research conducted by the University of Helsinki shows that migration of some waterfowl from Finland, like ducks and geese, is two weeks to one month later than 30 years ago (Lehikoinen & Jaatinen, 2012). Water of Nordic areas, where aquatic birds used to spend summer, cools more slowly, allowing these animals to stay longer in

their nesting areas, having more food available due to the higher temperatures (Lehikoinen & Jaatinen, 2012).

Another aspect emerges from the figures below (Fig. 15 – 16), namely that it is not far-sighted to base the survival of these indispensable territories on an activity that may no longer be viable in the future: hunting. Changing the waterfowl autumn migration timing may lead to changes in species-specific hunting bags, even if, as it was already mentioned, hunting is itself a phenomenon that alters the migration of birds, as they tend to avoid it and settle in other sites where hunting is prohibited (Lehikoinen & Jaatinen, 2012).

Therefore, from these studies and the maps shown below with present and future projections calculated through the environmental variables that birds physiologically require, it becomes clear that, if these species were not wintering in the *valli da pesca*, hunters would not have the main attraction that leads them to perform this activity (Fig. 15 - 16). Also, for this reason, it is essential to find alternatives that could substitute this source of income.

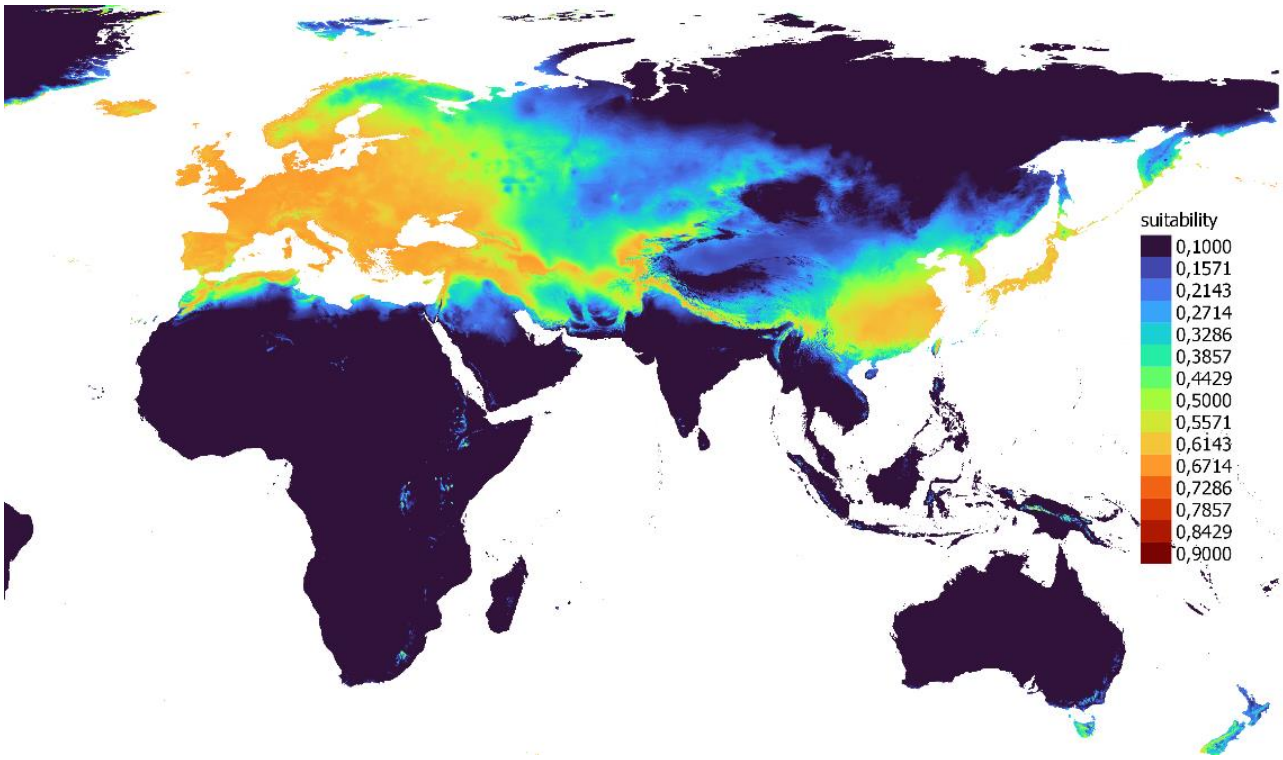

Figure 15: average distribution of present suitable conditions driving the considered species presence

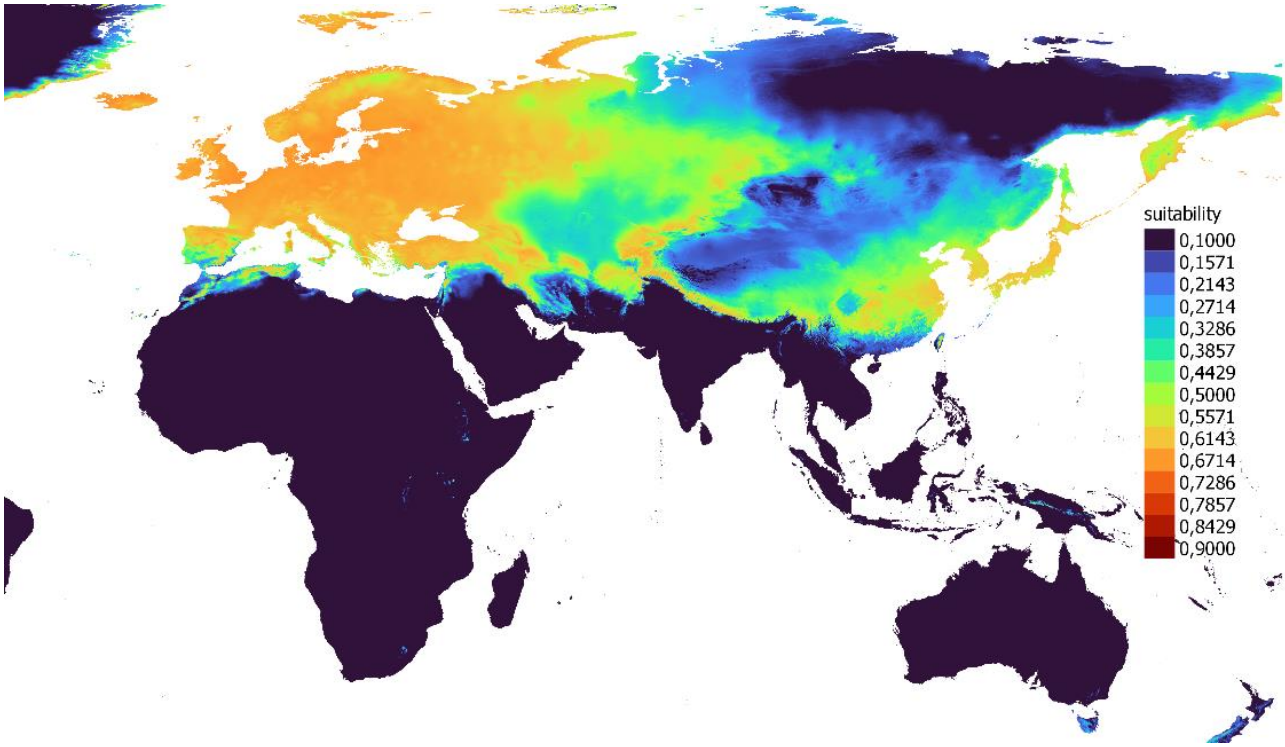

Figure 16: average distribution of predicted suitable conditions for the considered species in the period 2081-2100.

THE ETHICAL PROBLEM

Before discussing the ethical dilemma of hunting, it is necessary to briefly contextualise this activity.

Hunting is the practice of killing or capturing wild animals to obtain food, leather, and other materials or for recreational purposes. In the past, hunting was one of the main sources of livelihood (as well as gathering), used to feed villages, groups, tribes, and families. Our species depended also upon this activity and, presumably, most men learned to hunt from their fathers (Duda & Criscione, 2014). It is believed that people used to practice hunting out of exhaustion, where they were able to kill the prey by chasing it for hours until it would have been so tired that men could hit it.

Nowadays, hunting - and even more fishing - is still used as a sustenance technique in some indigenous tribes around the world; however, in the western areas, it has a different purpose, which is mainly recreational.

It is classified as an outside activity, during which people, supported by the law, are surrounded by nature and are in close contact with free and wild animals. It is a very ancient practice that has been continued until now (Tickle, 2016). Contrarily, the term poaching refers to the practice of killing an animal that is protected according to the law, or killing more animals than allowed; therefore, this is

an illegal activity. If a species is protected or it can be hunted in a particular country depends on different factors, such as its distribution, laws, and local traditions. In Europe, as far as birds are concerned, one has to consider the nature of the species classification in Annex II of Directive 2009/147/EC[17] (which determines the conditions under which 82 species of birds may be hunted or not in specific countries), which is divided into two parts: part A lists 24 species that can be hunted in all countries of the European Union (always if the local laws, in the implementation of such a Directive, allow it); part B decides which European countries can open the hunting season for the 58 remaining species. EU national authorities have the right to decide whether to allow a hunting season or not for a particular species (Hirschfeld et al., 2019).

Hunting is an activity that has evolved with society; therefore, nowadays there are conflicting opinions about it. Every year a new debate arises over the morality of hunting practice.

There are three types of hunting according to the Environmental philosopher Gary Varner: therapeutic, subsistence, and sport (Duclos, 2017).

Therapeutic hunting means killing free animals for conservation purposes. Subsistence hunting means killing free animals for human nourishment. Sport hunting means killing free animals for enjoyment or fulfilment (Duclos, 2017). These categories are not mutually exclusive. Many people, even those who do not fight for animals' rights, consider hunting wrong because it provokes unnecessary harm and death to innocent beings. Many believe that hunting is acceptable only if it is necessary for the hunter (for nutritional needs). Many are also opposers to sport hunting, believing that it is repugnant to feel pleasure by killing an animal. Contrarily, indigenous hunting is more supported, probably because it is perceived as a subsistence activity.

In this debate, hunters usually respond that hunting is a natural practice and the pleasure is not in the killing gesture but in doing an action that awakens our animal side. They seem to have a strong connection with the animal that they kill. Many of them feel to give contribute to the conservation of wildlife. They sustain to care about wildlife and have a deep sense of respect for them, contrary to the reality of farms and the urban citizens, alienated from the ways to produce food. For this reason, according to hunters, the killing must be done quickly and professionally.

A reflection on the meaning of 'care for wildlife' might arise: does it only mean not causing suffering during the killing? Or perhaps the meaning lies in allowing the animal to fulfil their physiological and biological needs, allowing them to grow and experience the life they deserve? The hunter feels to establish a relationship with the prey that is completely different from that in slaughterhouses. In slaughterhouses, the killing is cynical, repetitive, and regulated by precise

[17] [17] Directive 2009/147/Ec of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds.

instructions. In the hunt, there are no walls, no boundaries that limit the animal's escape (not always), and there is no repetitiveness.

Moreover, hunting does not refer only to the connection with nature: it is itself regarded as a cultural activity. Indeed, most of the time it is traditionally transmitted from one family member (usually a male, like the father or the grandfather) to another one (like the son, or sometimes the daughter). Usually, it is an activity that starts before 20 years of age, unless one is initiated by a friend and in that case, it can be possible to start at an older age.

As mentioned before, the ethicality of hunting is much debated. Very often, the lion-gazelle binomial and the excuse of traditions are used to justify hunting by hunter supporters. Because the lion eats the gazelle, it is thought that man is also justified in carrying out this predatory act; similarly, as we have always hunted, we are justified in pursuing this activity because 'it has always been done'. However, this is not a fair comparison according to some scholars: the lion and the gazelle are phylogenetic architects for each other, the speed of the lion has been calibrated to that of the gazelle, and their prey-predator relationship keeps an ecosystem in balance, also considering that most predation sessions fail, and most predators struggle to feed and starve, so prey and predator are in a state of equilibrium (Marchesini, 2017; Dawkins & Krebs, 1979).

From the human point of view, interestingly, the sight of a gazelle being captured by a lion is considered a violent act. In fact, we tend to empathize with the prey, and this can make us reflect on our nature, that of prey and not of the predator. This feeling of ours is a result of our fears, because, in every empathic feeling, there is an identification, and human beings tend much more easily to empathize with the gazelle that dies as prey than with the lion that dies of starvation and hunger (Marchesini, 2017).

Considering also the use of weapons for hunting, which many compare to lion tusks, it is worth reflecting on. On the one hand, it is believed that the use of weapons is the exercise of human ingenuity put into practice to hunt, therefore the real weapon of humans is intellect; on the other hand, opponents consider that there is a disconnection between the creation of tools created for the purpose of killing and the handling of them. The weapon creates a dystopia in the rituals of its use, in the times of understanding its power, unlike a claw or a fang that grows coherently with the body. Thus, one cannot possess a weapon and appeal to one's instinct, because in our ethographic inheritance there are no innate structures of gun management. Having a weapon entails a violation of the primal state of nature and in fact, who owns one has a different and higher level of responsibility (Marchesini, 2017).

Next, the consequences of hunting migratory birds in Europe will be described in order to understand the impact this activity has on these species.

The hunting of birds is a traditional activity practiced by millions of people all around Europe, and, as mentioned earlier, the EU Member States must comply with the Birds Directive 2009/147/EC and its national implementation laws, which determined the conditions under which hunting is legally permitted in each country (Hirschfeld et al., 2019). In the 1980s, in Europe and in the Mediterranean basin, around 10-15 million ducks and geese by 3.2 million hunters were annually shot (Madsen & Fox, 1995; Scott, 1982).

Rattling off the dilemma of hunting in the *valli da pesca*, both the consequences of hunting and the problem of poaching should be mentioned to have a more complete overview. Indeed, more than 200 species of the 500 that migrate over Europe are in an unfavorable state of conservation (BirdLife International, 2004). Migration species suffer not only from hunting traps (and poaching) along the route, but also from the destruction and changes of wetland areas, or the use of pesticides. Although this is a commonly discussed subject, few species have been studied to understand the effect of hunting, and this is also because these anatids go through different countries with different hunting rules and structures (Hirschfeld & Heyd, 2005). When this topic was brought to life, the European hunting organizations affirmed that the practice of hunting migratory birds respects the sustainable use of natural resources and that it has no effects on the populations.

It is, therefore, necessary to differentiate between legal hunting activities, and the application of illegal hunting techniques and poaching. The latter two are considered “bird crime” (Durst & Mikuška, 2014).

Waterbird hunting affects the population dynamics as a direct consequence of the harvest kill (Madsen & Fox, 1995). Yet, there are some controversies considering the indirect results of the disturbance of this activity, even if the bird is not killed.

It has been observed that hunting, along with other disturbing factors, can accelerate the decline of waterfowl species, including some of those following the Black Sea-Mediterranean Flyway (Hirschfeld & Heyd, 2005). This decline hits particularly wintering ducks and ducks that stage in the wetlands during spring migration. For instance, as highlighted by (Sackl et al., 2020) because of unsustainable hunting and poaching the average number of Garganeys during spring migration (a species that populate also the *valli da pesca*) has remarkably dropped in some selected sites in the past 20 years.

Considering the legal hunting activities, one of the problems that cause the decline of some bird species is that it doesn’t follow their phenology. In many countries, the beginning of the hunting season starts in late August or early September, this may have a negative impact on those late-

breeding species that have not completed their annual breeding cycle by that time (Durst & Mikuška, 2014). For instance, in Serbia, hunting is permitted until late February, and this may impact spring migration for some species.

Shooting activity may affect the distribution and the behavior of waterbirds, yet because most birds are migratory, the long-term impacts and consequences of hunting for a population are difficult to demonstrate.

Among the methods used to study the state of disturbance caused by hunting is the "escape flight distance," which is the distance at which a bird, or flock of birds, soars in response to a disturbance. There are few studies, most of which have been done on geese, while there is little information regarding ducks. It has been seen that the escape flight distance of geese is doubled during the hunting season, and this is indicative of the disturbance caused by this activity, increasing the birds' responses to other forms of human activity in the absence of hunting (Madsen & Fox, 1995). It has also been reported an increase in mistrust towards humans and lower use of resources during hunting periods, which can be disadvantageous for birds that need a lot of nourishment to migrate. Despite this, very little is still known about the degree of impact that can cause hunting disturbance.

As mentioned before, another issue could be the side effects provoked by this legal activity. For instance, in Slovenia Mallard is the only huntable duck species. Yet, it was observed that the reproductive cycle of another species, the Ferruginous Duck, suffered from disturbance by Mallard hunting.

Another encounterable issue is the similarity between some protected species and some huntable ones. These last could be confused and killed. For instance, the Red-crested pochard could be potentially confused (and killed) with the Eurasian Wigeon by novice hunters in the *valli da pesca*, being remarkably alike. These examples demonstrate that sometimes the legal hunting regulations are not suitable to protect the threatened species.

Considering the so-called “bird crimes”, it should be mentioned illegal hunting techniques and poaching. Some illegal hunting techniques practiced in the Adriatic Flyway are the use of voice records to attract birds. Illegal hunting techniques may provoke disturbance or deterioration of entire species groups.

Lastly, it should be mentioned the illegal practice of poaching. Unfortunately, there are not much data to rely on as this is not an ordinary activity. For instance, in January 2017 in *Valle Grassabò* were killed and sequestered by the police 28 geese, 5 of them were Specklebelly geese and 23 were Greylag geese (Roccaforte, 2017). Moreover, on the same day, 150 birds killed more than the permitted number were seized.

These premises are useful to better face the dilemma of the use of hunting to preserve the *valli da pesca.*

It is necessary to consider also how times are changing and how this might affect hunting and, consequently, how the management of the *valli da pesca* would be compromised if there were to be major social changes in the future.

As mentioned before, society is changing at an unprecedented rate. Associations against hunting are increasing and more and more young people have a negative opinion about it (Berati, 2004).

Indeed, during the 1990s three referendums were proposed to tighten hunting regulations, and even if none of them reached the quorum, they are a signal of a change in progress.

On June 3, 1990, in Italy people were asked to vote in two referendums: the first one was on the tightening of the rules governing hunting. The turnout was 43.4% with 92.3% in favor and 7.8% against; the second one was on the prohibition of access for hunters to private funds (denying them the possibility of hunting on private properties without permission). The turnout was 42,9% with 92,3% in favor and 7,7% against (Berati, 2004b). For the first time in Italy, the referendums did not reach the quorum, therefore, the result was declared invalid. Many politicians of that time largely spread the slogan "*go to the seaside instead of the poll*", this probably contributed to the failure to obtain the quorum (Berati, 2004). These referendums were promoted by various parties and institutions like the Radical party, Verdi, the Italian Bird Protection League, Legambiente, WWF, also by some representatives from the world of culture and entertainment.

On June 15, 1997, another referendum on the prohibition of access for hunters to private funds was issued. Once again, the quorum was not reached: the turnout was 30.2% with 80.9% in favor and 19.1% against (Berati, 2004).

In 2021 the Committee "Si Aboliamo la Caccia" (*Yes, let's abolish hunting*) began a collection of signatures aimed at the implementation of a referendum for the complete abolition of hunting activity. The petition collected 520.000 signatures (needed 500.000 valid signatures), yet the Court of Cassation considered null and void 130,000 paper signatures and 47,000 digital signatures, for a total of over 177,000 signatures (Scibilia, 2021). Therefore, the referendum on hunting was not held.

Although these legal actions did not reach the desired results, sooner or later in the future, someone could submit again the proposal to abolish hunting, and the results this time may be different. Hunting is an activity that is finding much less acceptance than once; it is in decline and practiced mainly by the elderly. In 1980, there were about 1,701,853 hunters in Italy, 3 per cent of the

population at the time. In 2002 there were 730,000 hunters, a decrease of 56 per-cent since 1980. In 2016, 579252 hunting licenses were issued (Mazzoni della Stella, 2020).
Returning to the delicate situation of the *valli da pesca*, it can be considered risky and short-sighted to base the survival of an ecosystem, which offers many ecosystem services to the population and shelter to many animal species, on a practice that has been undergoing severe pressure from the Italian animal rights movements. In fact, the 2021 referendum proposal lost the involvement of very important and very influential animal rights groups because they did not agree with the drafting of some proposed points, but this could be different in the future and have opposite results. For this reason, in this thesis, it is shared the need to find effective and short-term solutions that allow owners to manage and maintain the *valli da pesca*.

After these preliminaries, it is useful to elaborate on the concept of the relationship and perception between humans and non-human animals, going on to outline what biases and weaknesses represent this type of relationship, and raising awareness that non-human animals are subjects, bearers of interest. The following philosophical-ethological concepts serve to understand the key topic of this chapter at its best.
First of all, each human's relationship with other animals can be skewed, depending on the path of knowledge each of us takes toward them. When animals of different species are very similar to us, it can provoke two types of distortions. The first type of distortion is the projective tendency, that is, the complete attribution of human characteristics to animals, with difficulty in recognizing when these are really attributable and when they are not; the second is the distancing tendency, which is the opposite effect: in fact, sometimes proximity can be disturbing, making it difficult to recognize characters that are really shared (Marchesini, 2018). When we see non-human animals that are very different from us, such as insects, we tend to manifest other distortions. On the other hand, the perspectival distortion is the tendency to increase the differences between us and them, while zeroing the differences between them, intended as quite homogeneous group of beings all similar to each other, but not sharing the same nature of us; on the other hand, the reductionist distortion is manifested as the propensity not to recognize the character of subjectivity (Marchesini, 2018). These are interpretative biases, which seriously compromise the ability to know thoroughly and in completeness a characteristic, the *animality*, that also represents us as human beings, much more than we are inclined to think.
Human beings tend to put up an emotional barrier with non-human animals. We sometimes perceive animal behaviour as mechanical, repetitive, predictable and fixed. Even hunters, who are great observers of nature, could define animal behaviour as recurrent. This can create an emotional

distancing, identifying them as machines. However, this does not correspond to reality: the animal's need to move in reality constantly poses new challenges to it. Even situations that may appear to be recurring on the surface must actually be considered similar, not identical. The animal individual is always brought to deal with novelties, different situations, and challenges that it could not solve without progressing (Marchesini, 2018). Surrounded in a world full of stimuli, where sensory organs and cognitive capacities of the brain make possible a plethora of interactions that overcome even the most imaginative human mind.

Animal life, like ours, is shaped by learning. Sometimes, the behavior of a species appears repetitive and homogenized among different subjects; anyway, this happens in the presence of an untrained eye, limited to a superficial level of evaluation. Just as in the ancient Greece, other peoples who did not speak Greek were considered barbarians and homogenized within a single category, because they produced so-called verse (bar-bar), so in the present human beings struggle to identify protagonists in animal otherness denying its ownership (Marchesini, 2018).

Animal individuals are subjective protagonists not because they are different from one another (indeed, even rocks are different among other rocks yet they have not their own subjectivity), but rather because the animal in living in the moment is never repetitive, does not respect the species canon. We, as humans, are animals in every respect, physical, biological, and ontological (Marchesini, 2018). We are equals, and as such, other animals like us are moved by desires, which are not material things, but verbal predicates, which change according to the species we belong to (Marchesini, 2018). We are gatherers: children on the beach collect shells, in the woods mushrooms, on the meadow flowers… a cat, differently, will have the desire to chase, it does not desire the ball, it desires to chase it. (Marchesini, 2022).

Besides desiring, the animal dimension is also characterized by the condition of feeling. Sentience and the desiring condition are very important and representative qualities that give the animal a kind of self-ownership. In fact, the animal also belongs to itself under someone else's authority. This condition makes the animal a bearer of interest (Marchesini, 2018). Not only that, wishing involves not only the will to accomplish something, but also the capacity to have emotions.

It is often asserted that animals are sentient creatures, and this characteristic is usually only referred to as the ability to feel pain. Animals are indeed endowed with a body that is sensitive to pain: harassment, coercion, and mistreatment cause discomfort and affect their state of equilibrium. And so do the chasing, hounding, and awareness to be hunted and driven to death. The capacity to suffer, which has had much weight in ethical battles over animal rights, differentiates animality from the rest, even from other vital presences that do not belong to the animal world, such as plants. However, the capacity to feel does not only concern pain, but also an inner dimensional, emotional

life, feelings, attitudes and their momentary condition. This kind of feeling gives rise to an inner world, full of meaning. (Marchesini, 2018). When animals, like humans, experience a negative emotion, their actions and structures will be correlated to the process of "how to avoid". All animal experiences, therefore, create subjectivity, not only in their manifestations and actions but also in the world of the unconscious. The emotional condition, thus, is an essential disposition without which there is no biography because this is recognized within a certain living experience (Marchesini, 2018). Moreover, to consider emotions as mere responses to external stimuli is a great reduction that limits us to understanding the subjectivity and individuality of each animal, just as to say that animals feel only basic emotions, such as fear, anger, joy, and sadness, is misleading and incorrect. In fact, if we think about how shared emotional expressions are among species, such as horripilation, the emission of feces and urine, and the contraction of the body, we realize that the emotional condition has ancient origins, and is not confined to the human dimension, as we often hear (Marchesini, 2018). Our society struggles to recognize subjectivity in animals, especially as a result of Western philosophy stemming from the French philosopher Descartes in the 17th century, who considered animal body to be merely automatons. From this point on, the separation between humans and animals became more and more pronounced. In fact, before the Darwinian revolution, the animal condition was seen as prerogative diversity from humans, and not in a logic of common membership. The human being incorporated the *res cogitans* (the thinking soul) that gave him free will, the animal in contrast had only the *res extensa* (purely somatic condition) that led the animal even to the inability to feel pain. *Res extensa* means something that can be mensurated, and mathematized, but the subjectivity of each individual has no measures, no limits.

It has been easy for humans throughout history to condemn animals to muteness, and to the absence of thought. And although considering nonhuman animals as entities with their own subjectivity is uncomfortable for many humans who have always regarded them as objects to be freely disposed of, modern philosophy and ethology are beginning to recognize their inner world, rich with desires, emotions, and subjectivity. Animals have taught us many different things. Birds, for instance, the animals that are hunted in the *valli*, did not only teach us how to fly, but that flying is possible. They opened new existential dimensions (Marchesini, 2018).

These premises are useful as an introduction to the dilemma of hunting in the *valli da pesca* in the Venice lagoon. This will be the starting point of a reflective chapter on the ethicality of this activity, also considering the new total liberation movements of the last decades.

If we want to dissect and resolve this hunting dilemma, it is necessary to tackle the issue of hunting also on an ethical and philosophical level, using the antispecist, and therefore the intersectional, perspective presented in the studies of Environmental Humanities.

The climate and biodiversity crisis that humanity is experiencing should lead us to tackle problems not in an anthropocentric way, but in a systemic and ecocentric way. Indeed, it would be appropriate to address the issue of hunting not only from the human point of view but also from non-human animals, which in this context represent the victims. According to the antispecist approach, on which this chapter is based, it is time to consider the animal as a being which deserves respect like every man and woman.

Certainly, many scholars agree that the problem of climate change, biodiversity conservation, and ecosystem maintenance needs urgent consideration, but it cannot be solved without starting from the root of the problem, nor can it be solved by always maintaining the same course because we will always have the same results.

What humans have done over the centuries was to create hierarchies, whether they may be of gender, ethnicity, or species. Hierarchies inevitably lead to the exploitation and welfare of some at the expense of the sacrifice of others. Hierarchies also lead to having less compassion for others, defined as being different from us, and not deserving of our rights and empathy. This has happened in the past, considering, for example, slavery in America, where black slaves were completely dominated and exploited because they were considered inferior beings, not equal to white men, and even the struggle that women had to go through to have equal rights with men, that is still happening today.

This little digression serves to get to another major problem caused historically by hierarchies: speciesism. Our relationship with animals has been based since ancient times on violence, predation, and exploitation (Best, 2017). A species hierarchy has been created between humans and animals, leading the dominator to act in ways that he would consider perfidious if enacted against someone of his hierarchical rank, another human being.

Considering hunting, we can see those traps, ambushes, the assault of many against one, the strong against the weak, and the killing of offspring to parents - or vice versa, are all practices defined as wicked and vile if done to a human being, yet it is today's practice carried out by the hunter (Tolstòj, 2020). This hierarchy enacted by man affects not only non-human animals, but also nature itself. Indeed, the behaviour of many human beings has led our species to be almost alienated from nature, assuming our superiority, and losing the awareness that we are an integral part of nature.

Although this is a generalization, unfortunately for a long time this pattern has been dominant, especially in Western culture.

The result of a history built on hunting, pastoralism, and ranching, is the birth of a spread mentality that has matured to domination and subjugation to animals and nature, which has opened the door even to the exploitation of other human beings. This self-granted coronation of man has led to anthropocentrism, which is the cause of all the disastrous times we live in. We live in a period of severe empathy deficiency, where the majority of people has lost contact with nature, and has also lost relational contact with other animals, who used to teach us so much (Best, 2017). In fact, it is not easy to see people having relationships with animals outside of cats and dogs. We should regain a connection, mainly sentimental, with nature (Best, 2017).

It is also interesting to bring up the use of language. Although it may seem secondary, words are a tool used by human beings on a daily basis. For instance, sometimes mild terms are used referring to the suffering and death of animals caused by humans. For example, terms such as "cull," "harvest," "manage," and "thin the herd" are used by hunters, but they always mean to kill.

This is one of the ways used to romanticize this practice, however, there are many others used nearly always by hunters themselves or by hunting associations. Phrases such as "the pivot of hunting activity are conviviality and friendship," or "hunting in the first place is an event of celebration and traditions, a fellowship between men"(Verza, 2019), only make this activity culturally acceptable. But if we change our perspective and consider the point of view of the hunted animal, it does not become easy to romanticize fear, flight, and death. This softened language, of the man immersed in nature who experiences a moment of conviviality, who cares about the good of wildlife and the preservation of biodiversity, is used both among hunters, and frequently also in those contexts in which the hunter has to rehabilitate his image, perhaps in front of an anti-hunting public. This type of approach, however, is seen by anti-hunting communities as a mere attempt to deflect the passion of the hunter - mostly male - to dominate nature.

It can be argued that hunting is relational, involves emotions, involves active management and entails the exercise of situational ethics, and this is also the way hunting is defined, especially in magazines aimed at a non-hunting audience (von Essen & Allen, 2020). It cannot therefore be denied that hunting is emotional and relational. However true, once again, only the hunter's experience is taken into account, and there is no question of whether the animal likes it when a human ends its life, even if quickly and painlessly. And this is asked not because the animal does not have the ability to respond, but rather because man does not have the will to listen. Quoting Tronto, (1993), "care" can be defined as "everything we do to maintain, contain and repair our

‘world’ so that we can live in it as well as possible". As always, seeing the direction our world has taken, 'we' includes only human beings.

According to this philosophy, the dilemma of using hunting for preserving the *valli da pesca* is wrong from the root, because hunting itself is wrong. Steven Best in his book “Total Liberation: Revolution for the 21st Century”, states that only from the eyes of the victims we can imagine a social organization that is completely different and worthy for all human and non-human beings. Indeed, he considers extremely truthful the concept of *total liberation*, not as a utopic goal to be achieved, but as a comprehension of interconnected liberation movements, such as human, animal, and planet liberation, which only faced together can form alliances between topics like democracy, sustainability, ecology, humans and animals’ rights. It is a fight against dominion and hierarchies. Supporting the dominion of humans, more powerful and superior, on non-human animals proves that some qualities can justify the use of violence on someone who has different qualities.

Therefore, only by combining more perspectives, it is possible to have a more truthful overview. For instance, history has always been written from the winner's perspective, the white man's. The new feminist perspective highlighted the dominant patriarchal culture of society, and it permitted the evolution into a more inclusive one. In the same way, trying to see from the animal's point of view could reveal the terrible ecological and social consequences provoked by the alienation from nature. This progressive way of considering society, at least as far as only hunting is concerned, is spreading through the younger generations. Indeed, hunting is an end in itself, it is considered a recreational activity without any benefit for the community, and fewer people are willing to accept it as a morally valid practice, rather they consider it an absolute injustice to be opposed to.

In the hunting season 2014/2015, it was evaluated by a CABS study the number of wild birds legally hunted (including the migratory species) in the European Union: reached more than 52 million. The official statistics were taken from 24 EU countries, only in Italy that year there were registered 689.000 hunters and they killed 3.702.797 birds. (Hirschfeld et al., 2019) . As Steven Beast would say, mass killing appears to be outrageous only when applied to humans.

For instance, in Europe in that season were killed 236.219 specimens of Eurasian Wigeon (*Anas penelope*), a species that is huntable in 21 European countries, yet the data were available only for 12 countries (Hirschfeld & Attard, 2017). In Italy, 11.252 specimens were killed (Hirschfeld & Attard, 2017). To make other two examples, that year in Europe were killed 42.616 specimens of garganeys (3.387 in Italy) and 522.253 specimens of green-winged teals (54.491 in Italy) (Hirschfeld & Attard, 2017). Considering the validity of the data, we should be aware that for Great Britain, Ireland, Greece Netherlands the statistics are missing, therefore a match of "higher real data" is to be expected (Hirschfeld & Attard, 2017).

Again, this section represents only the ethical part of the problem. It leaves out ecological, economic, and political considerations. However, it must make one think about how each number transcribed above does not represent a mere piece, but an individual, with its own characteristics, subjectivity, emotions, fears, and will, as was described in the first part of this chapter. Morality accepts no justifications, there is no such thing as compassionate killing of a being willing to live, just as there is no such thing as other compassionate violence (like rape, or torture), there is no purpose that justifies the means, and there is no tradition that outweighs the importance of life on earth.

In violent situations, as in hunting, it is difficult for a human to remain completely impassive, and this is because, unlike objects, the animal contacts you, looks you in the eyes, and therefore there will be always emotional involvement (Marchesini, 2022).

In conclusion, our society is gaining awareness, and although the process seems slow, it is traveling much faster than all the battles and reforms that have taken place in the past. Humans belong to a, sometimes, violent species, which recognizes it as the wrong action to break windows and damage physical property, rather than to allow the killing of many sentient beings, for sport or fulfillment (in this thesis we are not considering the entire livestock industry). However, we should not be confused by centuries of hierarchies, domination, colonization, wars, and environmental devastation; humanity has much more to offer, and the splendor of which we are capable has manifested itself throughout the centuries with art, music, religion, literature, but also with compassion and progress (Best, 2017).

Therefore, echoing what has been written in this chapter and considering the anti-speciesist philosophy, alternatives to hunting should be found for the survival of the *valli da pesca* in the Venice Lagoon. This is a practice based on violence and death, practiced in an ecosystem that is already fragile and on animals that are already suffering from not indifferent anthropic pressure (due to wetland reclamation, pesticide use, urbanization, and much more). But these are not the only reasons to replace this activity. As it turns out, society is changing, as described below, referendums and petitions may occur, whether in the long or short term and the outcome is unknown, so we need to be prepared to find suitable alternatives if there are hunting bans, bans on hunting some species that are huntable today, or reductions in the hunting season. If we combine this potential problem with ethics and morality, then all doubt disappears.

That is why in the next chapter some solutions will be proposed, focuses on how to give the possibility to *valli* owners to continue to maintain these anthropogenic ecosystems, a treasure of the Venice lagoon, with solutions that, even if only theoretically feasible, are sustainable from legal,

ethical and ecological point of view, to give the possibility to *valli* owners to continue to maintain these anthropogenic ecosystems, a treasure of the Venice lagoon.

FACING THE FUTURE

The *valli da pesca*, like all the wetlands in general, are important environments to evaluate the intensity of climate change. Wetlands, indeed, support many public goods and services, such as providing freshwater and acting as carbon sinks. Unfortunately, these places are some of the most threatened in the world, mainly for the degradation caused by urbanization and industrial pressure (Lefeuvre et al., 2003), and also because their importance, ecologically speaking, has only recently been recognized. Indeed, an evaluation of public environmental policy reported that half of the wetlands have disappeared in the century, and this trend is still happening, despite the higher awareness (Lefeuvre et al., 2003).

Interestingly, these places have been extolled for their richness in biodiversity, even though many species are not able to spend their entire life cycle here but are mostly transient. In this regard, it has been argued that wetlands, lagoons and the *valli da pesca*, are of fundamental importance precisely for waterfowl. The Ramsar Convention (Convention on wetlands of international importance especially as waterfowl habitat., 1971) established that the numeric distribution of waterfowl is used as an assessment of the importance of wetlands, and this is calculated on the basis of the percentage of water birds that use to wintering or breeding in a specific wetland, compared to the total regional, national or worldwide population size (Lefeuvre et al., 2003). In this connection, it is fair not only to underlying the importance of the *valli da pesca* for water birds, but also the importance of water birds for the *valli da pesca* (and the wetlands in general). Indeed, waterflow represents vital components for these places, since during migration from one place to another, they can help establishing or increasing biodiversity. New plant, amphibian, or fish species may be introduced to new places, by being stuck in a feather, on a foot, or through ingestion and excretion. This distribution is important for climate change as well since new species slowly can adapt and colonize different environments, diversifying gene pools. Ducks and geese may be helpful also for the control of invasive species since they feed on pesky insect larvae and weeds. Moreover, ducks and in particular Mallards, being very numerous, contribute to the dispersion of seeds of wetland plants from one place to another, therefore they play an important role in maintaining a connection between different areas contributing to preserve existing patches of healthy plant communities, while wetlands like lagoons are disappearing (Kleyheeg et al., 2017).

In this regard, it is interesting to note that the *valli da pesca*, which serve as refuge areas for waterfowl and thus help maintain healthy biodiversity due in part to ducks, represent a hunting ground where about 13 percent of the ducks that find refreshment here are killed.
For this reason, and for the reasons given in this thesis, it would be consistent to find hypothetical alternative solutions, or ideas, to allow waterfowl, animals that already experience strong anthropogenic pressures, to colonize the *valli* without risking being killed.

Finding alternatives to the management of the *valli* through hunting (or aquaculture) is a difficult task, especially given the fact that to date, this activity, as these places are managed, seems to be very efficient.
Initially adoptable solutions will be proposed, to then proposing more idealistic ones, which are difficult to realise and should be studied in more detail to ensure the maintenance of these areas.
To start, transitional solutions could be adopted. The ethical problem would not be immediately solved, but the proposed ideas would make hunting less impactful.
First of all, it would be appropriate to reduce the number of individuals that can be hunted per hunting season. In fact, about 13% of the specimens that inhabit the *valli da pesca* during the hunting season are currently shot. Although this percentage does not cause an ecological imbalance, it is still a large number of individuals (in the *valli da pesca* during the period 2010-2019, an average of 38404 (±7299) specimens were killed per year, i.e. a maximum of 45703 individuals).While it is true that from an ethical point of view the dilemma would not be solved, from an ecological point of view the impact would certainly be minor, also considering that, as mentioned earlier, the climatic conditions for many species of ducks migrating in the *valli da pesca* will become more favourable towards the north, potentially decreasing the number of individuals migrating to more Mediterranean areas.
A second solution could be to increase the 'rent' price to be allowed to hunt in the *valli da pesca*. Actually, the price for doing this activity is already very high; it is a whim that few hunters can afford. If the cost of this activity grew even higher, it would become a truly elitist practice, practicable by even fewer individuals. As a result, there would be fewer hunters in the *valli*, and fewer anatids would be hunted. On the other hand, increasing too much the quota for access to the privilege of hunting in the valley could increase the likelihood that interest in hunting would totally decline, with the consequent risk that with it the main source of funding for maintaining these areas would also suddenly decline. Therefore, another transitional proposal could be to allow the sale of hunted game and caught fish from aquaculture. By devising a brand to be affixed, a high-value commercial line could be obtained, which would sprout, after appropriate marketing, a higher price

in the market. This would make it possible, at least hypothetically, to keep hunting quotas at the same price, but to reduce the number of hunters, being able to make up for the loss of income, caused by the lack of a few hunters, with the earnings obtained from the sale of appropriately valorised fish and game meat.

Again, the ethical dilemma would not be solved, but at least the net number of victims would decrease. Hunting would be less of an impact considering the potential changes that will take place in the future.

These three solutions could be a start, a transition to begin to address the problem plaguing the *valli da pesca*, without completely revolutionising their suitability for hosting ducks, and the ecological services they offer.

Considering the option of changing completely the activities practised in the *valli da pesca*, a viable option could be aquaponics, a cultivation method that could be suitable in the *valli*. This is a method that uses a combination between plants, bacteria, and fish. Fish provide nourishment to plants through their excretions directly in the water, without the need to use a solid substrate like the soil. Then, the scraps enter a mechanical and biological filter where, before reaching the plants, the water is separated from the solid wastes and the nitrifying bacteria convert fish droppings (ammonium and urea) into nitrates. Thus, the water containing nitrates enters the cultivation tanks, where the plants use the nutrients that they need, carrying out a phytodepuration of water. Finally, the water enters the fish tanks before being purified through a UVC lamp (la Pira, 2022).

In this system, the roots of the plants are directly in contact with the water. Synthetic pesticides and chemicals are not used; therefore, the products are more natural.

This system allows 3-4 times more production than traditional agriculture, and production costs are lower, as there is no need for tools to work the land. Moreover, this so-called circular economy allows to save water savings of 90%, reduces consumption, and has a very low environmental impact (la Pira, 2022). This production is, therefore, safe, healthy, and sustainable.

The conditions in the *valli da pesca* could be suitable for the implementation of aquaponics. Indeed, aquaponics is possible even with saltwater, called marine aquaponics (or Maraponics).

It could be a fair compromise, avoiding systems such as hunting or fish farming, but growing plants with the help of the fish that live in the *valli* at certain times of the year.

Of course, compared to aquaponics, maraponics has less available suitable plants to use, since the vegetables in maraponics need to tolerate salinity (at least 5g/l, indeed halophytes must perform the phytoremediation process) (Sontakke & Haridas, 2020; Ayers & Wescott, 1989).

The halophilous species that can be cultivated could be samphire (*Chrithmum maritimum*), the *agretti* (Salsola soda), some species of the genus Salicornia, and quinoa (Sontakke & Haridas,

2020). In brackish water other vegetables can be cultivated, such as chard (*Beta vulgaris var. Maritima*) and beet (*Beta vulgaris var. Cycles*) (Sontakke & Haridas, 2020). Other resistant species are the common tomato (*Lycopersicon esculentum*), the cherry tomatoes *(Lycopersicon esculentum var. Cerasiformee*) and basil (*Ocimum basilicum*) (Sontakke & Haridas, 2020). There are interesting properties of halophytes that have been studied for years and to date are very useful in several fields, such as food production, animal feed, oil industry, pharmaceutical and nutraceutical sector (Buhmann & Papenbrock, 2013; Koyro et al., 2011; Sontakke & Haridas, 2020).
This can be an interesting solution, not only because it would give alternatives to hunting and fishing, but also because it would make salt water useful while preserving fresh water.

There is another cultivation technique that demonstrates human adaptability and ingenuity. Indeed, there is a cultivation technique that is suitable for the lagoon ecosystems and as a consequence, for the *valli da pesca*. In Tunisia, in the Ghar El Melh lagoon, local people use an indigenous method to cultivate on the sand, called Ramli agricultural system (meaning *on sand*), using sea tides to irrigate crops with fresh rainwater, without using artificial irrigation. This represents an adaptation system to the environmental conditions, the goal is to irrigate the crops naturally from below, thanks to the tidal movements (Samaâli & Tounsi-Guerin, 2019), that bring fresh water floating on the surface of the sea, irrigating crops. Farmers have to continuously adjust the level of the soil, through the addition of sand and manure, keeping it at the exact water level. If the soil is too low, the roots come into contact with the salt water, killing the crops; if it is too high, the roots dry out. These ingenious techniques allow for cultivation all year round, also in periods of drought. The Ramli technique has recently been recognised as a World Ingenious Agricultural Heritage Systems (GIAHS), a program designed by FAO to preserve traditional but innovative agricultural system practices (Semer Des Graines Dans Les Sables Tunisiens, 2020). The most produced vegetables are potatoes, tomatoes, onions, garlic, melons, watermelons, zucchini, and squash, with also some local varieties such as boutebssi squash, local varieties of melons and watermelons, white beans, and some chili pepper seeds (GIAHS, 2020).
Therefore, this cultivation technique could be suitable also for the environment of the *valli da pesca*, opening new avenues and opportunities for the use of these lands.
Another activity that could replace hunting is birdwatching. England, where it originated, boasts 2 million people, both experts, and amateurs, who call themselves birdwatchers. This activity is becoming much more popular and well-known in Italy. This is a passion that allows one to free oneself from daily tension and immerse oneself in nature, as well as having an educational and healthy function. For all these reasons, birdwatching could easily be a substitute activity for hunting

in many *valli da pesca*. For experts, these places could become specific spots where particular types of water birds could be observed. In this way, the owner of the *valle* could continue to charge rent, so as to be able to maintain the maintenance costs. Being a very different activity from hunting, the rental costs would certainly be lower than those paid by hunters nowadays, but this does not preclude an increase in the number of birdwatchers who can exploit the surroundings of these places. For instance, there are already *valli da pesca* where birdwatching is possible along their boundaries, such as in the external perimeter of Valle Grassabò, Val Dogà, Valle Dragojesolo (Stival, 2018). These are *valli* in the northern lagoon devoted to both fishing and hunting.
Birdwatching, in addition to being more ethically correct, would allow at least part of the community to make use of these places, eliminating the option of restricted access only to those who have received the *valli da pesca* by hereditary concession.
These just mentioned are activities that could be suitable in the *valli da pesca*, bringing benefits to the community as well. The transitional proposals are feasible in the short term, the other proposals would require a little more study but would still be feasible in the short to medium term. Indeed, one must consider not only the ecological aspect (favourable areas for ducks further north), but also the ethical and social aspect that has been changing in recent years.

Conversely, the activities proposed below are practically unrealistic nowadays. Indeed, these solutions should be studied longer and in detail. As a matter of fact, it is considerably difficult to find alternatives that are sustainable, ethical, and preserve the conditions of the *valli da pesca* in the Venice lagoon.
For each proposal, the consequences that these activities could have on the *valli da pesca* will be mentioned.
In some *valli*, six to be exact, recreational activities are offered. The first example that is mentioned needs to be evaluated cautiously, as it offers a possible alternative, but it is part of those goods considered luxury, and may therefore be not very inclusive. It can be cited, however, as it is an existing alternative. In Santa Cristina, located in the north-eastern part of the lagoon, one can rent an entire villa (for 16 people), inside the *valle.*
A substitute activity could therefore be sustainable tourism. The hectic life that human beings have been living in recent decades has also led tourism to undergo changes. Over the years, tourism has been defined as relaxation and entertainment without taking into account its environmental impact. For the past few decades, the idea of responsible tourism, called ecotourism, has been gaining ground, in which forms of recreation are nature-friendly, peaceful, and cultural - ecotourism is about getting to know the traditions of the place one chooses to go to. The *valli da pesca* would

become open to an albeit restricted public, allowing tourists to appreciate the untouched nature of the lagoon. If activities such as hunting and fishing would be avoided in this way, however, there are cons that must be mentioned and which raise doubts about the potential of sustainable tourism for all the *valli*. In fact, the income from tourist activities (such as agritourism or renting places to spend time in the *valli*) would probably not be as high as that brought in by hunting. This would cause repercussions for the owners of the *valli*, who might not have enough money to bear all the maintenance costs. The second doubt that arises is whether, with this type of activity, nature would still remain as pristine as it is now. In fact, as already described in the previous chapters, these *valli* are extremely restricted access. Only those who work there, the *valli* owners, and hunters at certain times of the year are allowed access, making it a quiet space for the preservation of waterfowl biodiversity. One can wonder if these places were open for restricted groups, would they still be quiet enough for the birds that live there or are passing through?

Another *valle* that practices a different activity other than hunting and fishing is Valle Averto, a WWF Oasis. Initially, it was a normal *valle da pesca* that exploited the migration of fish to practice aquaculture, since 1985 it has become an Oasis and later a State Nature Reserve. Valle Averto is open to the public at certain times of the year and is an important nesting and wintering site for avifauna. It must be specified that following changes made to the *valle*, it is now different from typical *valli da pesca*, and therefore has a completely different function and conformation from other *valli*. For this reason, as it is structurally and functionally different from other *valli*, we cannot take it as a point of reference, but it is nevertheless correct to mention that this environment has become a protected area, useful for the conservation of local biodiversity.

The lagoon, rightly, being an environment divided between land and sea, has a very particular ecological structure. Of course, it is very difficult to find alternative solutions to hunting that are as profitable as elitary hunting, but one possible solution may lie in the cultivation of high-value foods. One particular idea, for example, would be the cultivation of vines for wine production. On the island of Santa Cristina, there are ancient red grape vineyards. In fact, on this island, it is produced the vine *Ammiana*. It is an important, old wine, ruby red in colour and with a fruity aroma.

Wine is produced on other islands in the Venetian Lagoon: on the islands of Sant'Erasmo, in the Orto dei Carmelitani (Orto degli Scalzi), on the island of Torcello, on the island of Mazzorbo and, as just mentioned, on the island of Santa Cristina (Cavallo & Mastrovito, 2022).

On the Island of Mazzorbo, for example, for some years now the Bisol family has been running the Venissa project: vineyard, inn, starred restaurant, and resort (Colognese, 2019). *Dorona* wine, a wine appreciated and enjoyed by doges since the 15th century, is produced here. In 2002, Bisol

found some plants in a garden on the island of Torcello, which, after some research, were confirmed to be rooted cuttings of the Venetian Dorona (Colognese, 2019). In 2010, the Bisol family began its first year of production. It is a white wine, vinified like a red, which is left to age in the bottle for a few years before being tasted. From the Dorona grapes, they produce the Venissa white wine (while the Venissa red wine is produced on the Island of Santa Cristina as well) (Cavallo & Mastrovito, 2022).

On the island of Torcello, there is an experimental vineyard created in 2014 to safeguard the biodiversity of the lagoon's viticultural heritage. It consists of all the lagoon vine varieties whose DNA has been mapped.

In the Orto dei Carmelitani, on the other hand, there is an old vineyard garden, which underwent a transformation between 2013 and 2016 by planting different varieties of grapes and restoring old ones. It was promoted by *Consorzio Vini Venezia* and *Venezia Wine and Food* and partially financed by the *Venice Chamber of Commerce* (Cavallo & Mastrovito, 2022). Despite its environmental characteristics, Venice has been home to agricultural land within the lagoon for centuries. In fact, it is assumed that grape cultivation for wine has been present in Venice since Roman times, and that the direct and indirect actions of the church were fundamental to the spread and presence of vines in the Venetian lagoon.

It must be said that the soil conditions of the oldest islands, such as Santa Cristina, Torcello and Mazzorbo, make these places quite fertile for growing vines, not only because of the sea mud as in other parts of the lagoon, but also because of the fertile soil and river sand.

We know that these areas can be fertile precisely because of the properties of the sea mud on which they are raised. After it dries, this sea mud contains bitumen, oil, and salts from animal and plant remain. In these soils, unlike dry land, the soil regenerates faster due to the presence of molluscs and other organic remains mixed in with the calcareous earth. The sand of the Venice lagoon, resulting from the desegregation of Alpine granite rock, is rich in potassium carbonate, an important component for viticulture. The sand also benefits the vines against phylloxera. These conditions have protected the vines from exogenous agents, even allowing the preservation of some ancient vine stocks. There were even vines grown on sandbanks and dunes near San Nicolò in the past. Another beneficial condition is characterised by the warmth of the sea, which encourages the growth of trees.

On the other hand, it must be remembered that excessive exposure to brackish water and sea wind can be harmful: for wine, this affects fermentation and thus quality. One technique that was used to repair from the wind was the construction of straw palisades.

The viticulture activities that already take place in the lagoon make it clear that this practice is possible in this environment. However, it is correct to point out that it would become much more challenging for the *valle* owner to use the *valle da pesca* for this purpose, both for a practical factor, because they would have to manage them differently from how they do now, and for an economic factor, as the gain would be significantly less than that received from hunting. Moreover, our planet is undergoing climate change, and this could make it even more difficult to grow these products in a brackish place.

Another possible alternative to hunting, concerning cultivation, is regenerative agriculture. This proposed solution is still very idealistic, as it involves proposing a cultivation technique on land made up of 70% water. However, it could be feasible, perhaps in the future, with a much more in-depth and detailed study.

Regenerative agriculture is a way to collaborate with nature, regenerating soil, without polluting and impoverishing it, while cultivating food. The main intention of this practice is to improve the health of the soil, restore highly degraded land, improve the quality of water, and enhance vegetation and productivity. Regenerative agriculture practices place special emphasis on increasing soil carbon, with the premise of increasing crop yields and mitigating climate change. In order not to damage the organisms in the soil, this practice avoids the use of fertilisers, pesticides, and herbicides (Rhodes, 2017). Indeed, one-quarter of biodiversity lives in the soil (both micro-organisms and macro-organisms, responsible for the biological cycling of nutrients). Therefore, this type of cultivation could not only be a sustainable alternative to hunting, but also it could regenerate the soil, improving its quality.

The human population is constantly increasing, thus the way we farm is essential to preserve human health and the health of the planet. Therefore, some *valli da pesca* that possess within their property area large extension of land behind the lakes and are already carrying out agricultural activities, could be suitable places for preferring this type of agriculture instead of the traditional, intensive methods, considering also that from a socio-economic point of view, regenerative agriculture also improves economic prosperity compared to a traditional type of agriculture (Schreefel et al., 2020). Regenerative agriculture involves easy but special cultivation methods: the first one is cultural diversification. Cultural diversification, meaning avoiding monoculture, widens the number of species in contact with the soil, improving its structure; stimulates the biological activity of soils; improves fertility (Garuti, 2020). The second important point of regenerative agriculture is the reduction of the impact on the soil. Differently from intensive agriculture, this practice does not

involve plowing, nor the deep impact of the soil, favouring also the life of earthworms and other organisms, important for the fertility of the ground.
The third measure is to maintain always the soil covered. This means that during the year there should not be portions of land without plants. This method helps to retain water, fixing nutrients and organic substances. What is interesting is that animals could graze freely on this cultivated land, increasing the fertility of the soil, and improving soil structure.
Therefore, this alternative, although it would require a fairly long transformation process, could be possible and would anticipate a change of attitude that should be adopted towards nature. Indeed, regenerative agriculture protects the soil and the water reserves, increases biodiversity, and improves climate resilience.

The above ideas are only meant to be hints to show that there are alternatives to hunting and fishing, even if this means revolutionising the work of many years, traditions and habits.
These ideas, even if many of them are idealistic and not practicable in this moment, are perhaps more inclusive in so far as more people can benefit from the products and services that the *valli da pesca* can provide.

CONCLUSION

The *valli da pesca* are pictures of a bygone past, remained intact thanks to the constant work of men, bound to traditions that they wish to preserve. Born as places of aquaculture, today these are mainly hunting places. The main goal of *valli* owners is, indeed, to be able to attract as many ducks and geese as possible, to allow hunters to benefit from large numbers of prey. This allows, thanks to the money obtained, the preservation of these closed areas of lagoon. To attract ducks, *valli* owners work persistently, maintaining these places, providing many ecological services to the community, as described in the previous chapters, and preserving the biodiversity and morphology of these territories.
As mentioned at the beginning of this work, one of the main purposes of this master thesis was to answer the question of whether we are willing to accept or not hunting for the management of the *valli da pesca*, and possibly to propose alternatives to replace hunting with activities that still allow the survival of the places.
To recapitulate, it is appropriate to mention that although this activity nowadays works well for these purposes, there are three reasons why we need to look for alternatives that will ensure the preservation of the *valli* in the same way as hunting activity does.

The first reason is that society is changing at an unprecedented speed. Indeed, as it was described above, in the past 30 years there have been three referendums to tighten hunting regulations and a petition to abolish hunting completely. Although the referendums did not reach the required quorum and the petition did not receive a sufficient number of signatures to initiate the referendum, their presence alone is a symptom of a social movement that is gaining momentum in our country, so one cannot rely on an activity that is standing still in an advancing society.

The second reason concerns climate change and the challenges that our planet will face in the next future. Indeed, as it was already described, favorable conditions probably will be distributed also in the northern part of the Eurasian continent. This situation leaves many questions open: will the duck species that migrate from the north to the *valli da pesca* still make this journey if conditions are favorable even further north? This hypothesis becomes very concrete knowing that, today, migratory timing of many aquatic birds has changed: the departure of some duck and geese species from Finland has been delayed compared to 30 years ago due to more favorable conditions in the Nordic countries (Lehikoinen & Jaatinen, 2012). This process is very serious because, in addition to all the ecological imbalances and species-specific problems that this situation could cause, it is evident that the survival of an ecosystem cannot be based on only one activity - hunting, which apart from being unethical from the antispeciesist point of view, could undergo serious changes in the future, if waterfowl were to be missing. Even if the individuals who migrate to the *valli* today will decrease in number in the future, changes would still have to be made as the percentage of animals killed could be too high and compromise the ecological balance in force today. So, where would the *valli* owners get their upkeep money from without hunting?

The last reason concerns a purely ethical-philosophical approach. Starting from the anti-speciesist point of view, addressed in the discipline of Environmental Humanities, the change must be radical and total if we want to witness a change. Human beings must recognize the animal as a subject, bearer of interests, sentient being in the meaning of being able to feel pain, and emotions. For this reason, when in this thesis it is highlighted the willing to substitute hunting and fishing with other alternatives, it is because it is recognized, thanks also the interdisciplinary discipline of the Environmental Humanities, the value of each non-human animal.

In this thesis, the dilemma of private and public ownership of the *valli da pesca* has been addressed. It was clarified that the *valli da pesca* are territories belonging to the State, managed by private "custodians", that decide how to exploit these areas. These private managers have been very important for the preservation of these territories, allowing them to survive in the most natural conditions possible of how the lagoon should be.

Yet, is interesting to ask what would happen if the State started to actually claim the complete ownership of all the *valli da pesca*. How would the management of *valli da pesca* be dealt with? Would there be enough funds for their effective maintenance? Would activities such as hunting and fishing still be used for their preservation? Would the State, managing these territories, make them accessible to the whole community, and opened to the public? And how? Although this possibility would represent a right for the citizen, it could entail a risk to the nature of these places. Indeed, the *valli da pesca* serve as a refuge for many water birds, undisturbed by humans and surrounded by silent nature. This condition would probably change, posing maybe another problem for the preservation of biodiversity. Indeed, about 350/450000 euro per year are needed for the preservation of each *valle*. Multiplying this number by the *valli* still under management, we arrive at a figure of around 10-12 million per year. To date, they are employed in a way that no public system can deliver. If a bank breaks, for example, there is a need for immediate repair. The private owner today can manage it, the public would probably not be able to.

However, it should be wondered if we were represented by an ethical State, whether it would enhance these places for a purely ecological purpose and anthropic well-being. Indeed, we should think about the meaning of the public good and, in particular, we could consider the notion of common good conceived by scholars: a good that is shared by the community and that brings benefits. Yet, the benefits are not only economic, there could be ecological benefits, psychological benefits, and emotional benefits. If hypothetically, the State claimed its right not only to own, but also to manage the *valli da pesca* by itself, and it would be able to maintain these territories through the funds, they could hypothetically become giant reserves, placed between the land and the water, where humans, fish, and migratory birds coexist in an encounter of species. But again, which trade-offs should face men and women for the fruition of these places, in order to achieve a responsible attendance that is capable even to accept that in some seasons the access could be forbidden, to lower the pressures due to human presence?

It is as difficult to find alternatives to the systems used today for preserving the *valli da pesca*, that it might suggest that as of today, there are none. However, starting with transitional processes, or by matching different activities alternative to hunting, might be the right choice for a future that is more ethical, socially accepted and forward-looking than it is now.

ANNEX

Anas acuta predictions between 2021 and 2040

Below is a forecast analysis of the distribution of *Anas acuta* species in the future period between 2021 and 2040.

Subsequently, it will be reported a forecast analysis of the distribution of *Anas acuta* in the period between 2081 and 2100.

The plot in Figure 17 verifies how much the model analysis is accurate. In the graph, it can be noticed that the training data is AUC=0.582, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would.

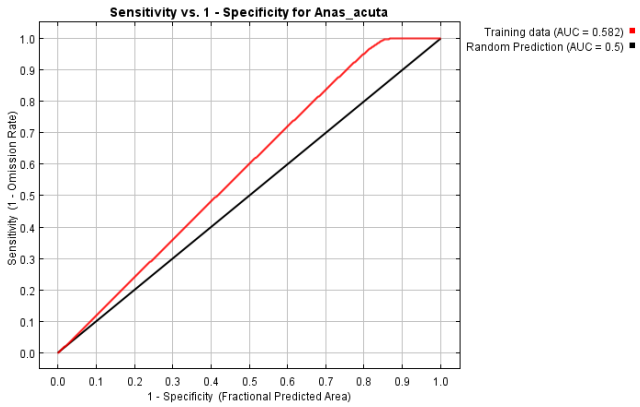

Figure 17: receiver operating characteristic (ROC) curve for the same data

Figure 18 is a Maxent representation model for *Anas acuta*. Warmer colours (green and yellow) show more favourable predicted conditions for this species. White dots show the presence locations used for training (areas where the data were taken). As can be observed, the presence locations used for training are North America, Europe, Japan, and some spots in the central area of the Asian continent. The areas just mentioned have warmer colours, with green shades tending to yellow, meaning that these areas show favourable conditions. Italy as well is a location used for training. As can be seen, parts of China, Russia, the southernmost part of South America, and the Scandinavian European countries also show favourable conditions for this species.

This depiction may make it apparent that *Anas acuta* prefers northernmost latitudes presumably cold-temperate climates. Afterward, the climatic variables used to form the model will be reported. The climatic variables played a role in predicting the distribution of this species in the near future,

and will be useful in understanding the climatic conditions this species physiologically requires.

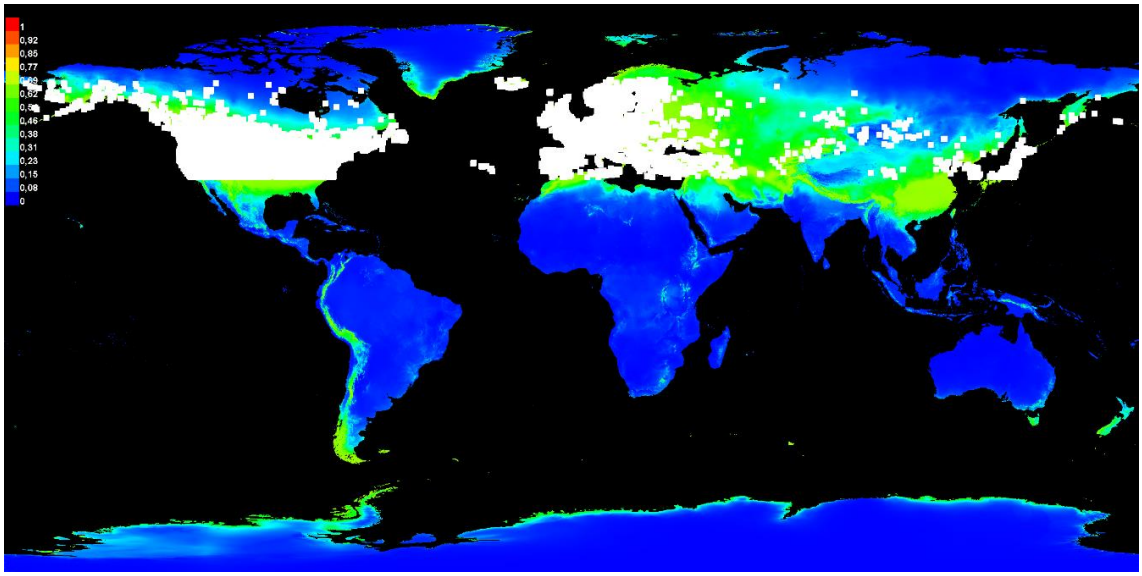

Figure 18: Representation of the model for Anas acuta 2021-2040

Figure 19 shows the projections of the model for the *Anas acuta* onto the environmental variables used for the prediction (bio.11: mean temperature of Coldest quarter, bio.12: annual precipitation, bio.15: Precipitation Seasonality (Coefficient of Variation), bio.19: precipitation of the coldest quarter, bio.6: min temperature of the coldest month, tmax.1, tmax.2, tmax.3 (maximum temperature). The results shown in this map (Fig. 19) show that the areas with favourable conditions will be almost similar to the previous map (Fig.18). However, an improvement in the favourable conditions can be seen in the eastern and north-eastern part of the Eurasian continent, and slightly in Northern America.

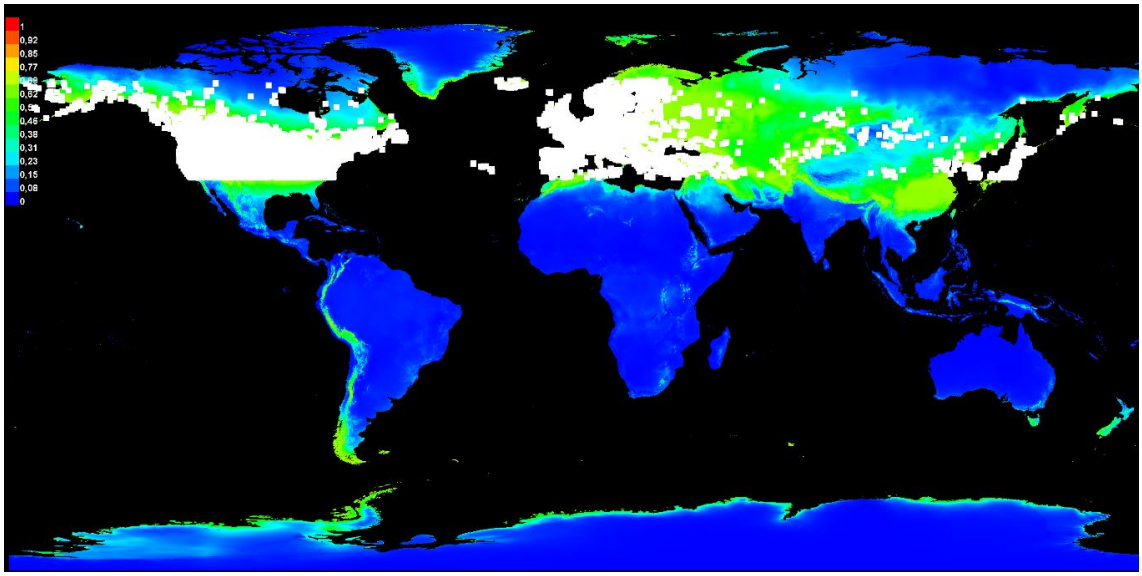

Figure 19: projection of the Maxent model for Anas acuta onto the environmental variables (2021-2040)

The following picture compares the environmental similarity of variables in the projection 2021-2040 to the environmental data used for training the model (Fig. 20).

Figure 20 shows how novel each point is in the hotlayers climate conditions. Indeed, there are problems called “novel climate conditions”: during the projections, prediction variables can assume values outside the training range. In Figure 20, negative values indicate novel climate (there are no red points, therefore there are not hotlayer values outside the range); while the positive values are blues, and the more they are close to 100, the more they equal to the median values in layers. In the interested area of this thesis, the Venice lagoon, the value is 28,9. It means that the values in this point are not novels, yet they are not extremely equals to the median values in layers.

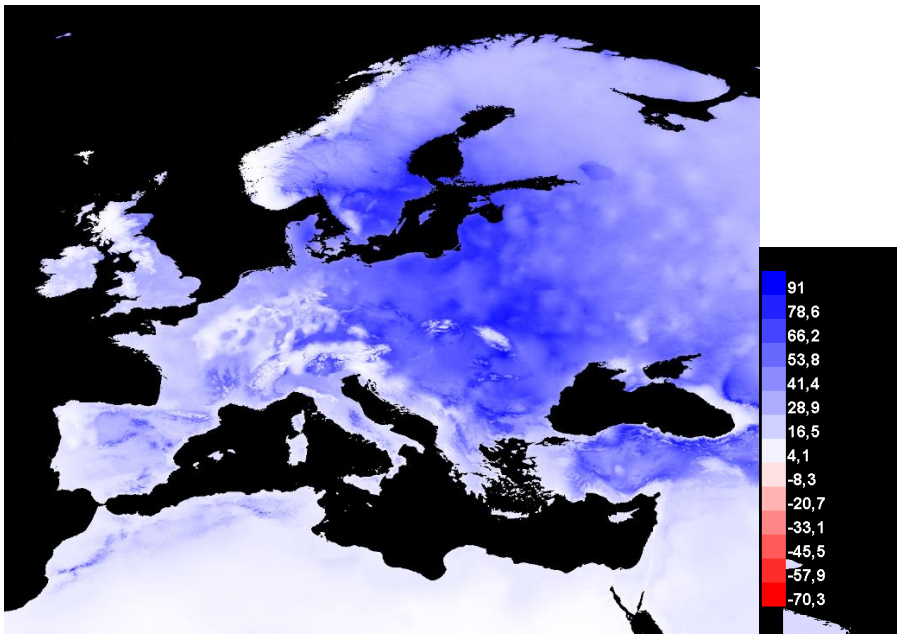

Figure 20: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance (Fig.21). As can be noticed, the single most efficient variable for the distribution prediction is tmax.2, it means that this variable contains useful information to estimate the distribution of *Anas acuta*. Other efficient variables are bio.11 (mean temperature of the coldest quarter), and tmax.12. While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)) and bio.19 (Precipitation of the coldest quarter). On the other hand, the light blue lines show that none of the environmental variables used contain really useful information that is not included in other variables, a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is tmax.2, which therefore appears to have the most information that isn't present in the other variables (light blue line).

Hypothetically, therefore, if seasonal temperatures were to change in the sites occupied by *Anas*

acuta, as well as the minimum temperature in the coldest months (bio.6) this species would be affected.

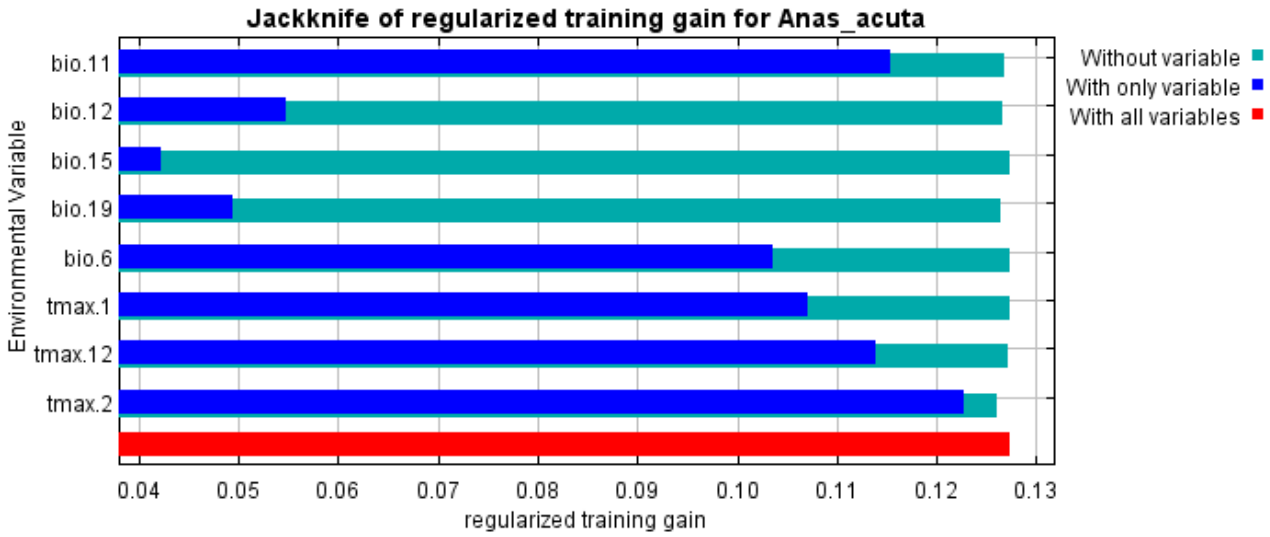

Figure 21: Jackknife of regularized training gain for Anas acuta

Maxent prediction uses different environmental variables, that affect the predicted distribution of this species. The following response curves show how the probability predicted for the presence of the species changes as each environmental variable varies, keeping all variables at the mean value. The y-axis shows the expected probability of the suitable condition. On the x-axis is defined the 'cloglolg output', which indicates the estimated probability of presence (of the species) between 0 and 1.

For instance, the following figures show the response curves that use only the corresponding variable, leaving out the other variables (Figs. 22-23). Figure 22 shows the response curve of *Anas acuta* to tmax.2 (maximum temperature). As can be noticed, the temperature range in which the probability of finding *Anas acuta* is highest is between -5°C and 18°C. However, this species tolerates temperatures below -5°C quite well, as the probability of finding *Anas acuta* lies also between -5°C and -15°C, just as it tolerates temperatures up to 20°C. While Figure 23 shows the response of *Anas acuta* to bio.11, (mean the coldest quarter (bio.11), the average temperature range in which the chance of finding *Spatula clypeata* is higher is between – 10°C and 10°C (Fig.23).

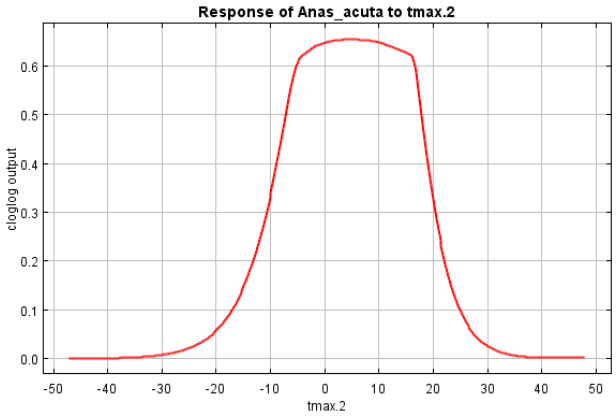

Figure 22: Response of Anas acuta to tmax.2

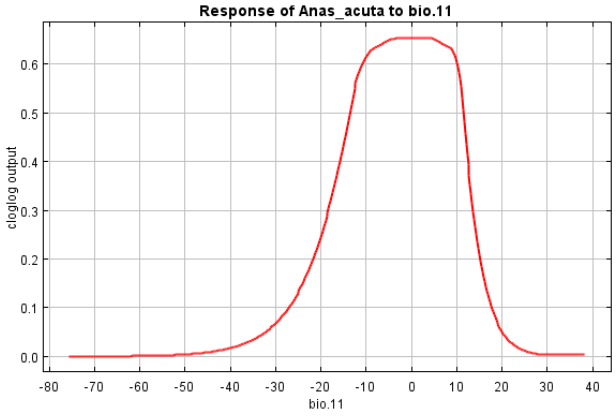

Figure 23: Response of Anas acuta to bio.11

Anas acuta predictions between 2081-2100

As for the 2081-2100 predictions for *Anas acuta*, the graph in Figure 24 shows that the training data is AUC=0.582, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would.

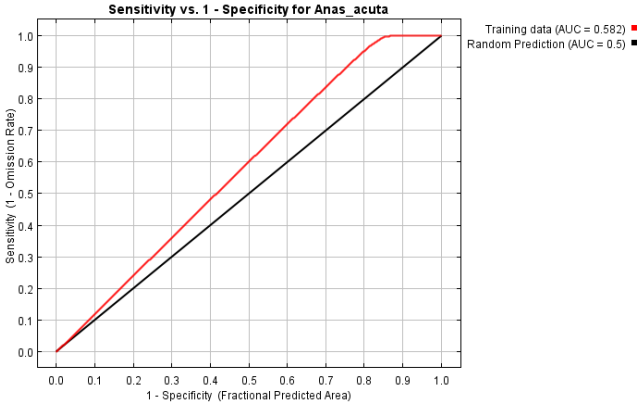

Figure 24: receiver operating characteristic (ROC) curve for the same data

As far as concerns the map showing the predicted future conditions (Fig. 25), it seems that it is not very dissimilar to the one in Figure 18. The warmer zones, precisely the green ones (that indicate

conditions typical of areas where this species is found) are Europe, North America, southernmost part of South America, and central and south-eastern areas of Asia. Italy is an area used for training hosting favourable conditions.

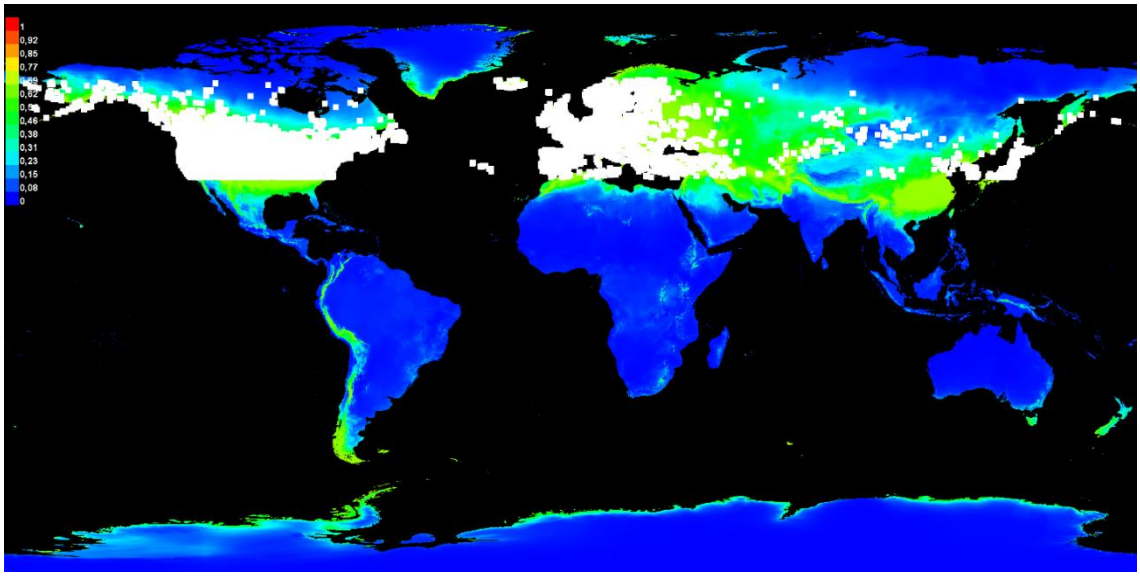

Figure 25: Representation of the model for Anas acuta 2081-2100

As far as concerns the map showing the projections of the model for the *Anas acuta* onto the environmental variables used for the prediction between 2081-2100, it can be noticed that the conditions in Asia probably will be more favourable for hosting this species, mostly in Russia, therefore towards a north-eastern longitude. Also, in America, the northern area shows more distributed favourable conditions.

Although conditions still seem favourable in Italy, the increase of green areas in Asia and the north can be perceived as the rise of places that will have favourable conditions to host this species, probably because the climatic variable will reach values more suitable for these birds than they are now (Fig. 26). If conditions at these locations become more favourable for *Anas acuta*, this species could hypothetically change its migratory behaviour, causing changes not only to the species itself, but also ecologically.

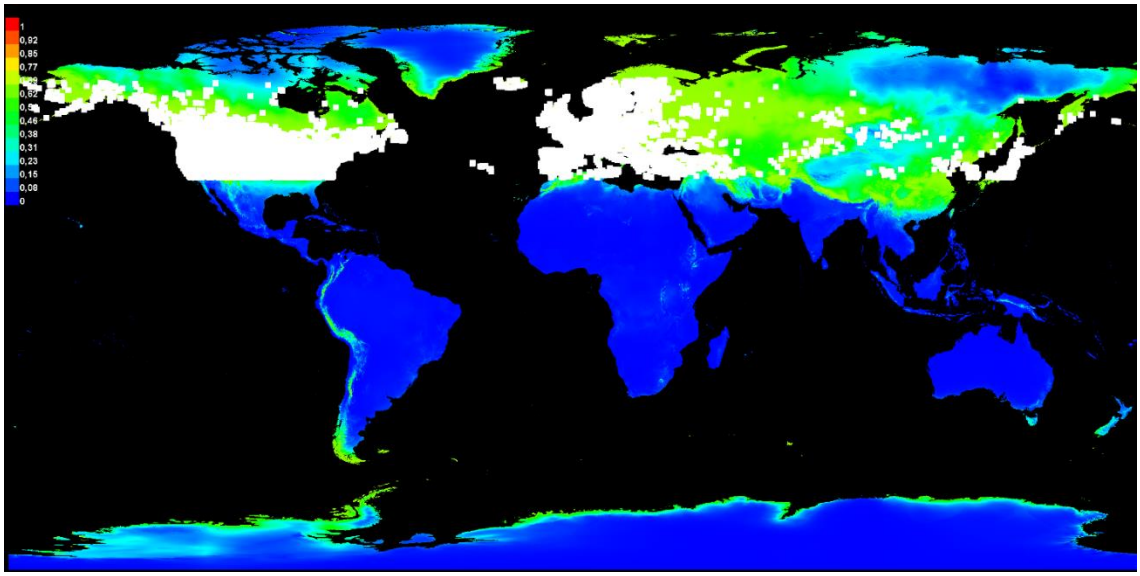

Figure 26: projection of the Maxent model for Anas acuta onto the environmental variables (2081-2100)

In Figure 27, it can be noticed a difference from Figure 20. Here, as well as Figure 20, there are no negative points (red ones) that indicate novel climate ("novel climate conditions"); while the positive values (blue shades), change in Figure 27. In this case, the value in north-east Italy has decreased, it is between 8.9 and 20.5, meaning that the value is approaching negative, it is not equal to the median values in layers.

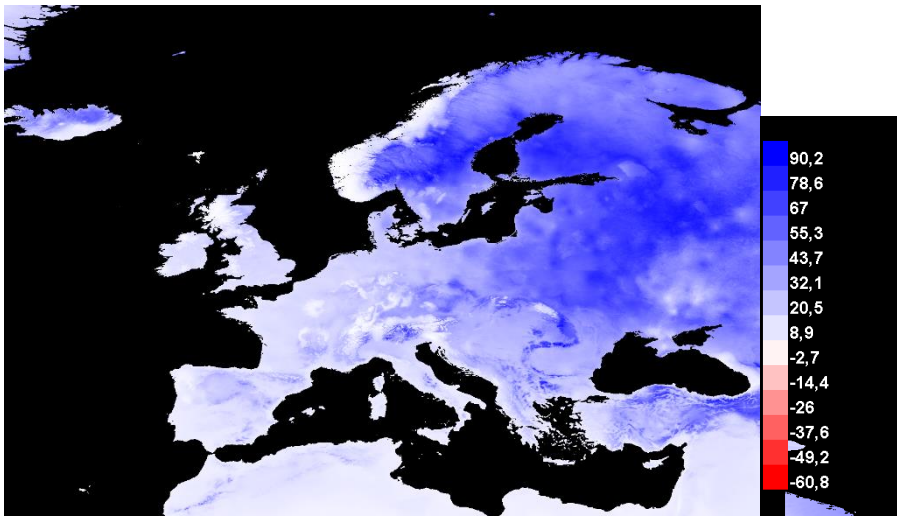

Figure 27: how novel each point is in the hotlayers climate conditions

The following picture shows Jackknife of regularized training gain for *Anas acuta* (Fig. 28), and, similarly to Figure 21, the single most efficient variable for the distribution prediction is tmax.2, it means that this variable contains useful information to estimate the distribution of *Anas acuta*. Other useful information as well is bio.11 (mean temperature of coldest quarter). While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)) and bio.19

(precipitation of coldest quarter). On the other hand, the light blue lines show that none of the environmental variables used contain useful information that is not included in other variables, a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is tmax.2, which therefore appears to have the most information that isn't present in the other variables. Once again, the variables that impact more on *Anas acuta* is the temperature (bio.11 as well is important and represents the mean temperature of the coldest quarter).

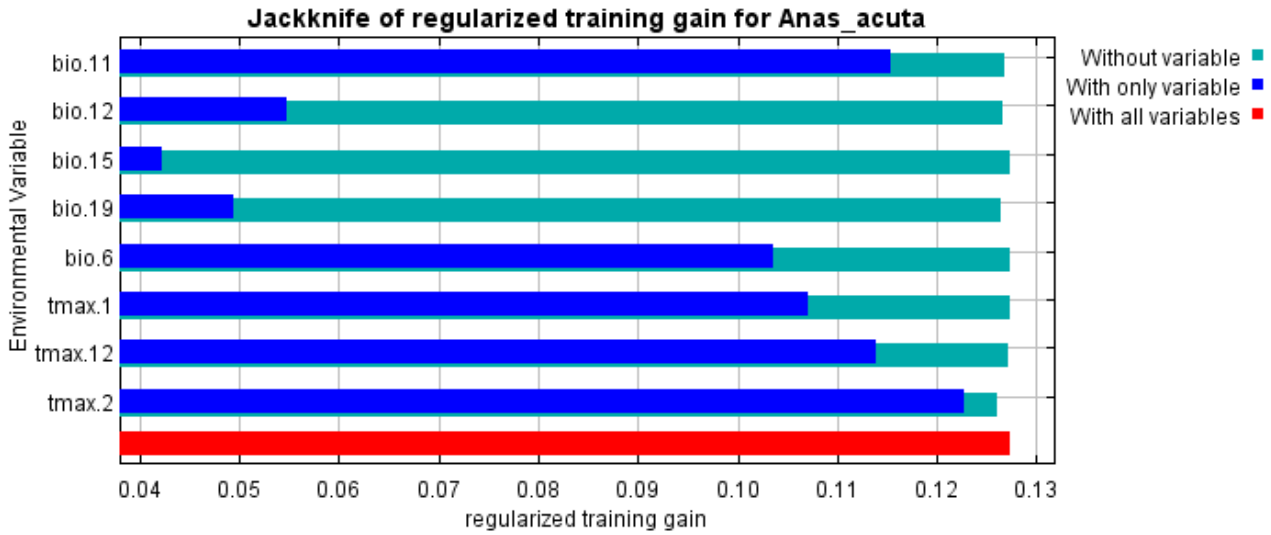

Figure 28: Jackknife of regularized training gain for Anas acuta

As it was mentioned, temperature plays an important role for *Anas acuta*, as it can be noticed from the following response curves. In Figure 29, it can be seen that the temperature range in which the probability of finding *Anas acuta* is highest is between -5°C and 18°C, while it is noticeable that the mean temperature of the coldest quarter that they tolerate, therefore the range in which the chance of finding *Anas acuta* is higher, is between – 10°C and 10°C (Fig.30).

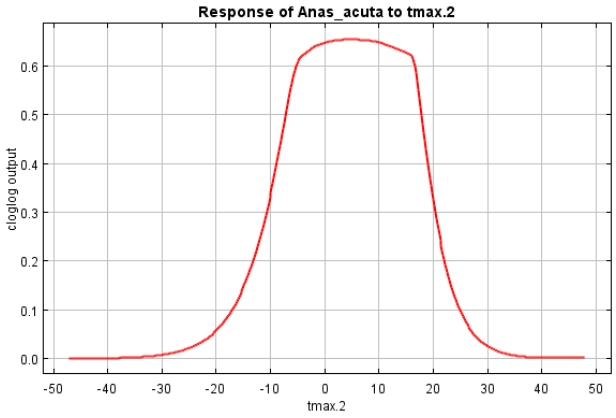

Figure 29: Response of Anas acuta to tmax.2

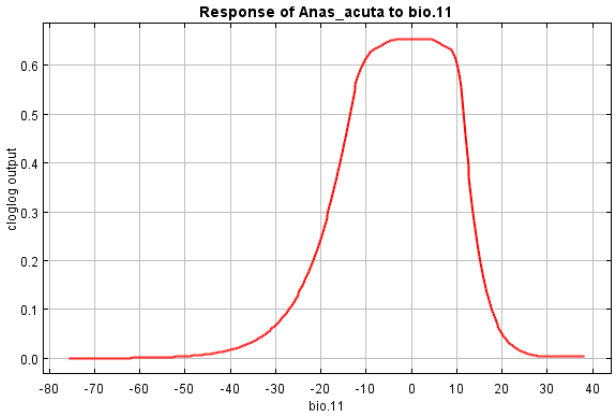

Figure 30: Response of Anas acuta to bio.11

Anas crecca predictions between 2021 and 2040

As it has been done for *Anas acuta*, and as will be done for other anatid species that inhabit the *valli da pesca*, forecasts of *Anas crecca* distribution both in the short future between 2021 and 2040, and in the more distant future between 2081 and 2100, will be presented next.

As mentioned before, the plot represented in Figure 31 verifies how much the model analysis is accurate. In this case, the training data in the graph below of Figure 15 is AUC = 0.560, thus higher than AUC = 0.5 (random prediction). It means that the model performs better than a random model would.

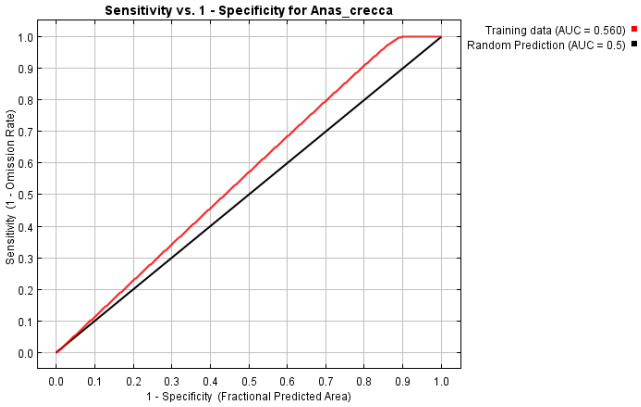

Figure 31: receiver operating characteristic (ROC) curve for the same data

Focusing on the Maxent representation model for *Anas crecca* (2021-2040), the presence locations used for training are in Europe, North America, parts of Russia and Japan. The warmer areas, green spots tending to yellow, similarly to those for *Ana acuta*, are found in North America, Europe, China, Patagonia and part of Russia. These areas show favourable predicted conditions. Distributed in central Asia the conditions are not favourable, yet they could become so.

It would seem that *Anas crecca* prefers temperate areas tending towards cold as opposed to very warm and dry areas. Italy, as well as for *Anas acuta*, represents a presence location used for training, with favourable conditions (green coloured) (Fig.32).

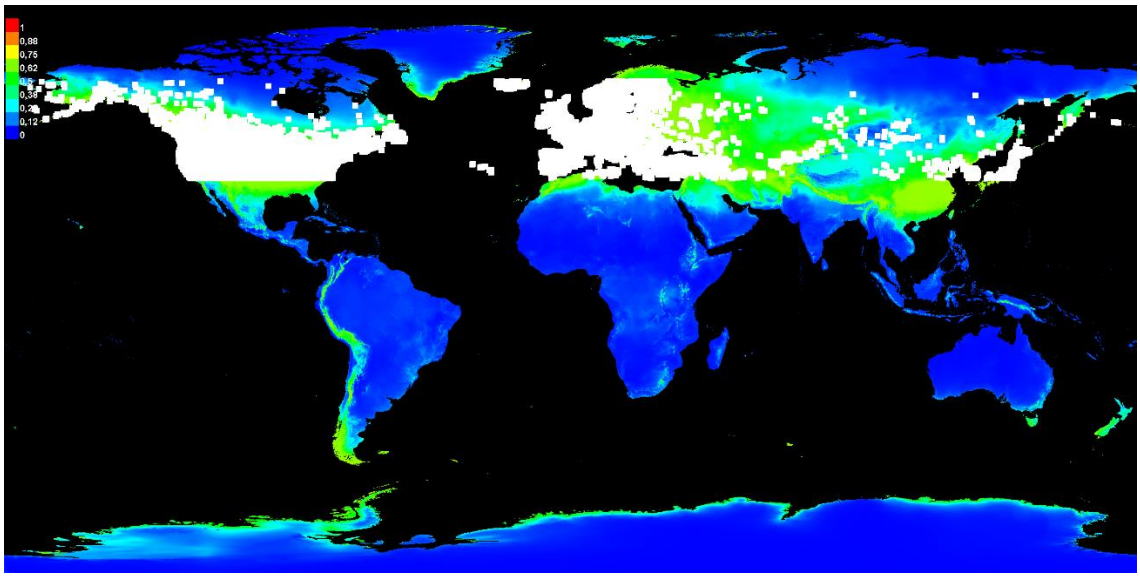

Figure 32: Maxent representation model for Anas crecca (2021-2040)

Figure 33 shows the projections of the model for the *Anas crecca* onto the environmental variables used for the prediction (bio.11: mean temperature of Coldest quarter, bio.12: annual precipitation, bio.15: Precipitation Seasonality (Coefficient of Variation), bio.19: precipitation of the coldest quarter, bio.6: min temperature of the coldest month, tmax.1, tmax.2, tmax.3 (maximum temperature)). Areas with favourable conditions in the central eastern part of the Eurasian continent slightly increase. As for the previous map (Fig. 32), the presence locations used for training are in Europe, North America, Japan, Russia, and Italy as well. The areas with favourable conditions for *Anas crecca* are the same as those found in the map with the predicted projections of *Anas acuta* (Fig. 19).

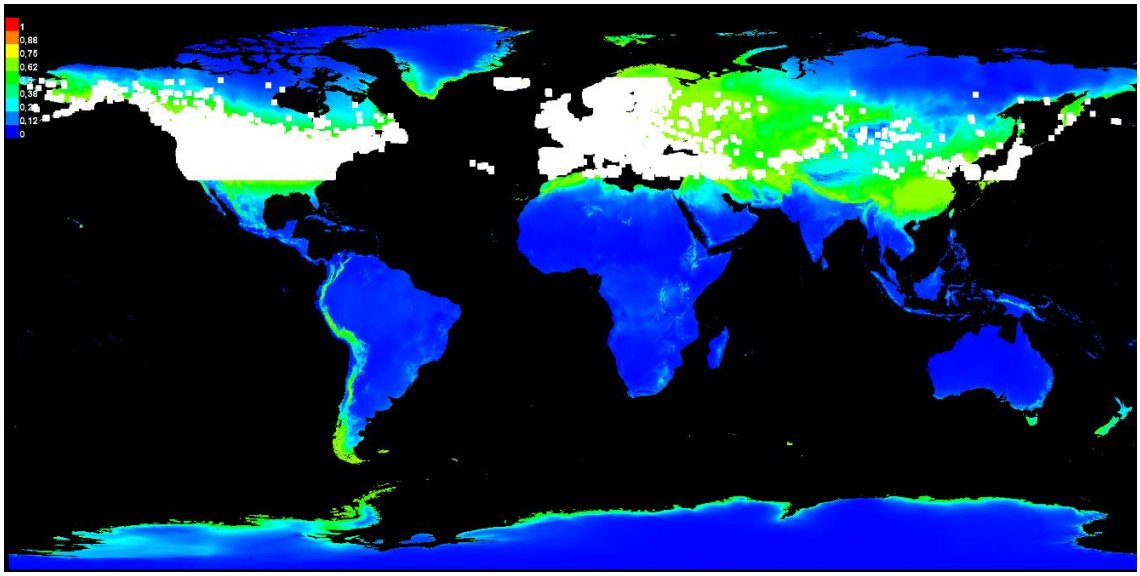

Figure 33: projection of the Maxent model for Anas crecca onto the environmental variables (2021-2040)

The following picture compares the environmental similarity of variables in the projection 2021-2040 to the environmental data used for training the model (Fig. 34). In Figure 34, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while the positive values are blues, and the more they are close to 100, the more equals to the median values in layers. In the interested area of this thesis, the Venice lagoon, the value tends to 31. It means that the values in this point are not novels, yet they are not extremely equal to the median values in layers.

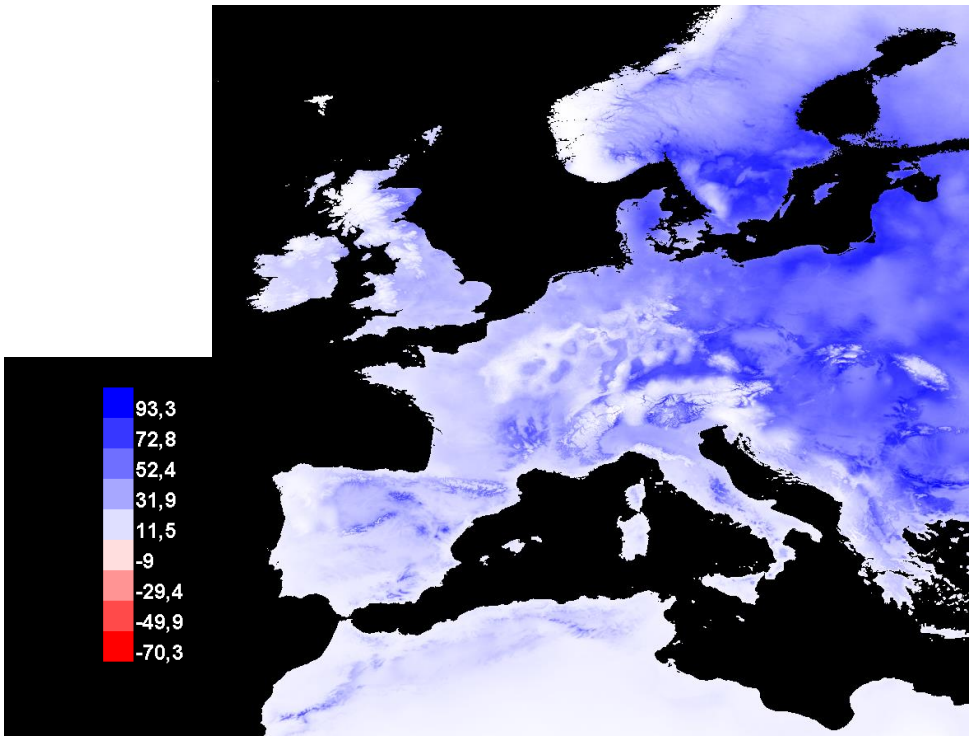

Figure 34: how novel each point is in the hotlayers climate conditions (Anas crecca 2021-2040)

The following picture shows the results of the jackknife test of variable importance for *Anas crecca* for the future predictions 2021-2040 (Fig.35). As can be noticed, the single most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Anas crecca*. Another variable that contains useful information for the prediction of the distribution of this species in the future is bio.11 (mean temperature of the coldest quarter). While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.19 (precipitation of the coldest quarter) is not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, among all, the environmental variable that decreases the gain the most when it is omitted is tmax.2, which therefore appears to have the most information that isn't present in the other variables.

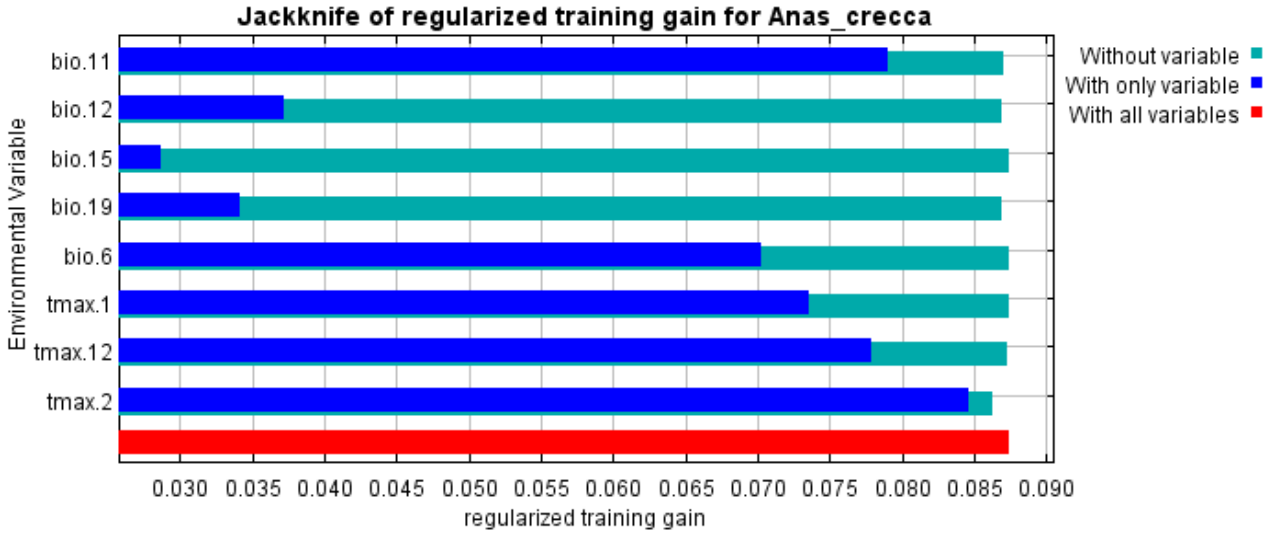

Figure 35: Jackknife of regularized training gain for Anas crecca (2021-2040)

As for *Anas acuta*, temperature plays an important role for *Anas crecca* as well, and this can be noticed from the following response curves. In Figure 36, it can be seen that the temperature range in which the probability of finding *Anas crecca* is highest is between -5°C and 18°C, while it is noticeable that the mean temperature of the coldest quarter that they tolerate, therefore the range in which the chance of finding *Anas crecca* is higher, is between – 10°C and 10°C (Fig.37).

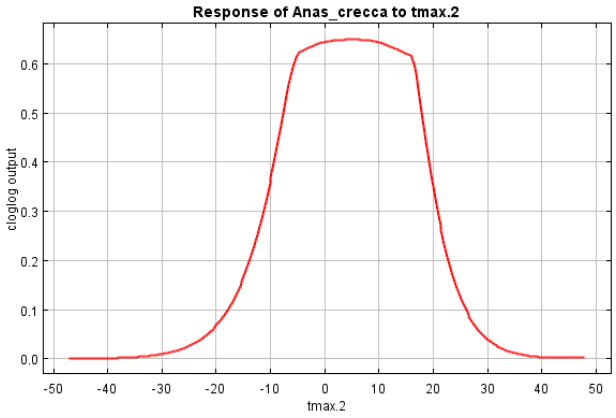

Figure 36: Response of Anas crecca to tmax.2

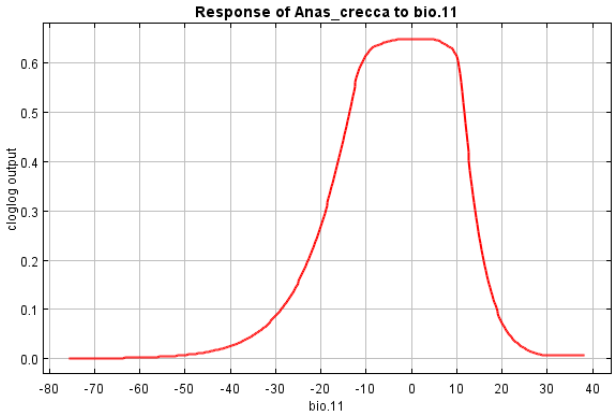

Figure 37: Response of Anas crecca to bio.11

Anas crecca prediction between 2081-2100

As for the 2081-2100 predictions for *Anas crecca*, the plot in Figure 38, showing the receiver operating characteristic (ROC) curve for the same data, shows that the training data is AUC=0.560, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would.

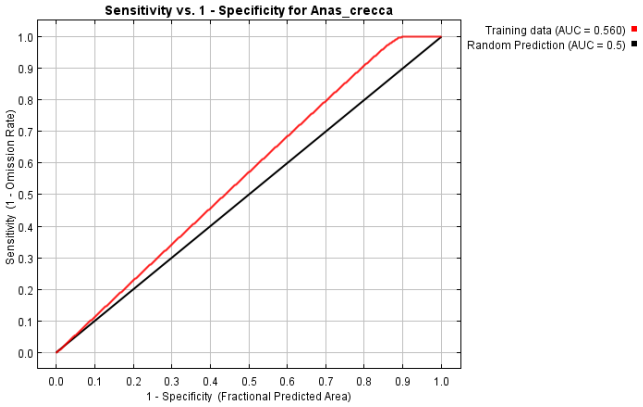

Figure 38: receiver operating characteristic (ROC) curve for the same data

Commenting the next map (the representation of model for *Anas crecca*), it can be seen that the locations used for training are Europe, parts of China and Russia, Japan and North America (Fig.

39). Approximately, North America, China, Europe, the southernmost part of South America, and parts of Asia correspond to the green parts, those areas where the conditions are typical of places where the species is found. The representation model of *Anas crecca* is similar to the representation model of *Anas acuta*, meaning that they need similar environmental conditions for their wellbeing and survival (Fig. 25 - 39).

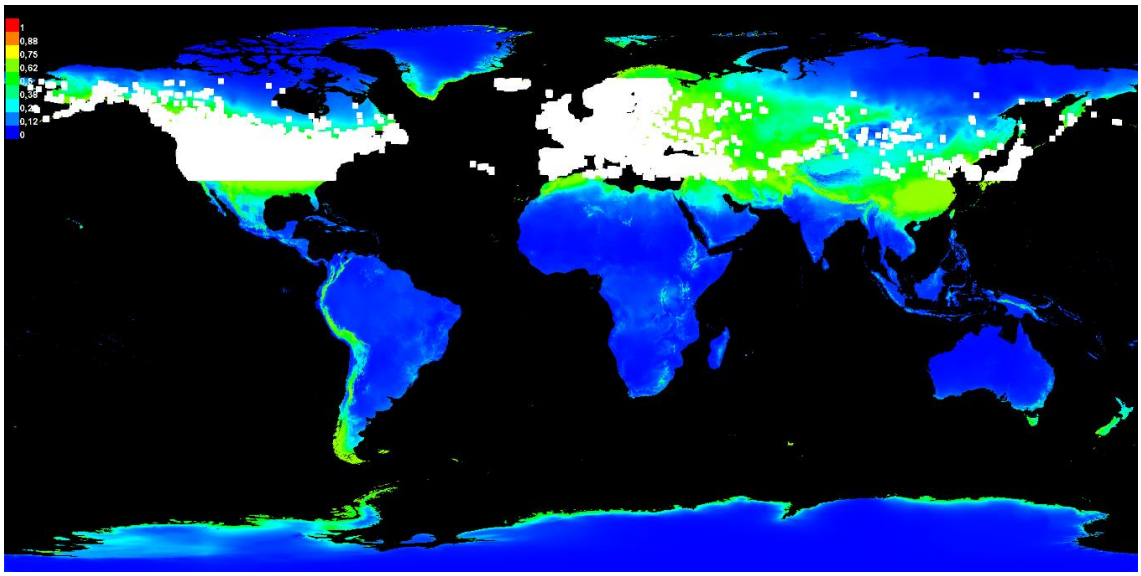

Figure 39: Representation of the model for Anas crecca 2081-2100

As far as concerns the map showing the projections of the model for the *Anas crecca* onto the environmental variables used for the prediction between 2081-2100, it can be seen that favourable conditions slightly increase even in the northernmost areas, like Siberia, and in throughout the north-eastern part of the Asian continent. Conditions still remain favourable in Italy and Europe, yet the increase of green areas in Asia and in the north can be perceived as the rise of places that will have favourable conditions to host this species, probably because the climatic variable will reach values more suitable for these birds than they are now (Fig. 40), as it was for the map showing projections of the model for *Anas acuta* (Fig. 26).

This may raise questions about the future need for these waterbirds to migrate to areas further south, or to stay further north, as these areas will potentially have favourable environmental conditions for this species. A change in migratory behaviour may have important consequences for the survival of the species itself, also causing potential ecological changes.

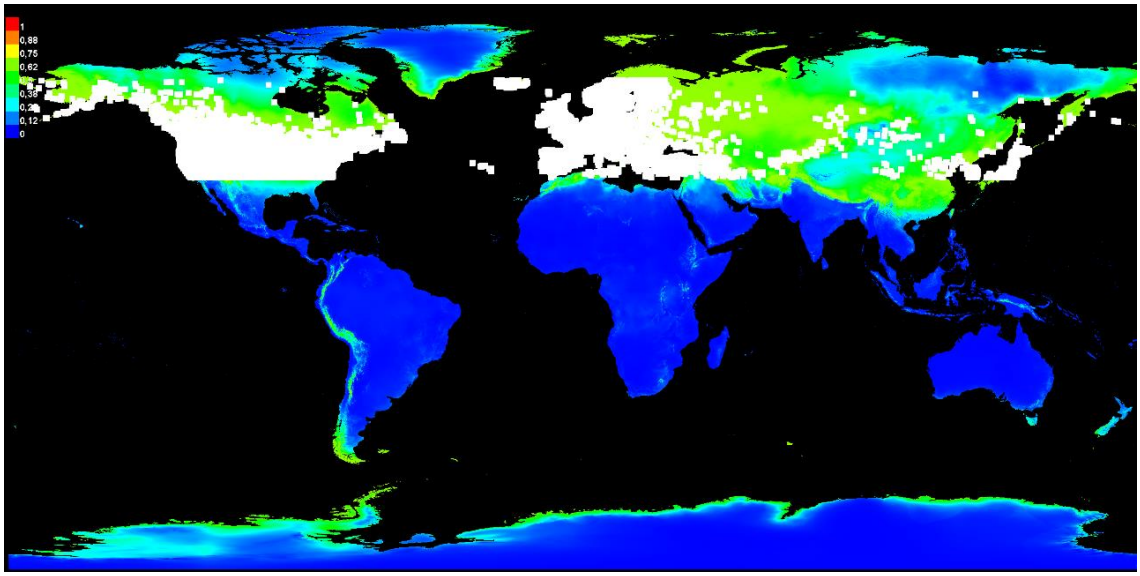

Figure 40: projection of the Maxent model for Anas crecca onto the environmental variables (2081-2100)

The following picture compares the environmental similarity of variables in the projection 2081-2100 to the environmental data used for training the model (Fig. 41). Figure 41 - as well as Figure 27 - shows a change in the Venice lagoon area, the value has decreased compared to the model for 2021-2040 (Fig. 34), it is around 15.2, meaning that the value is approaching negative. Negative values mean "novel climate", as so during projections, predicted variables can assume values outside the training range.

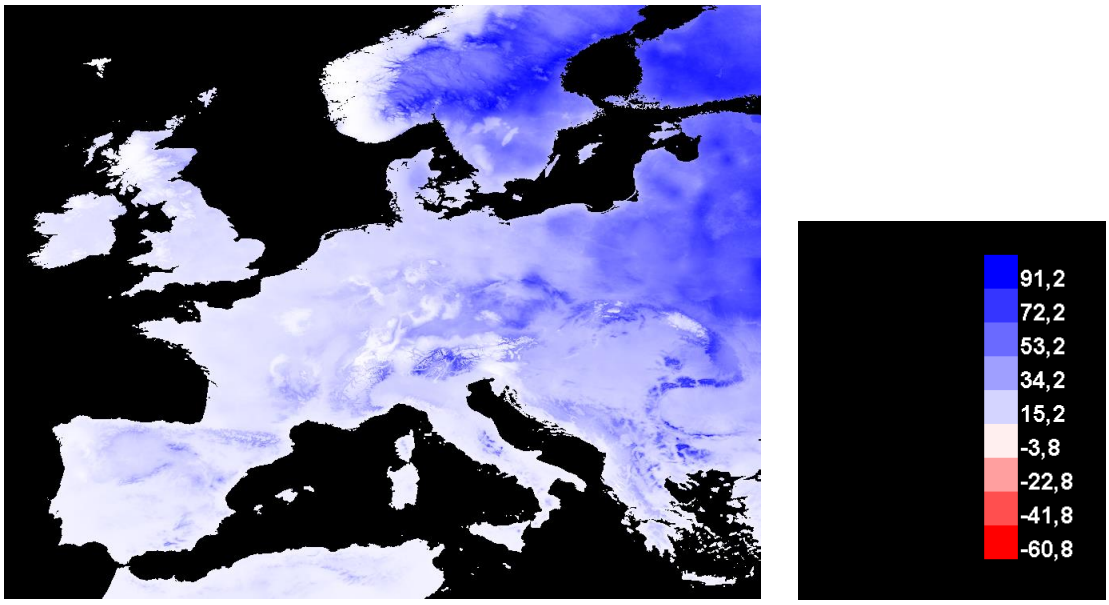

Figure 41: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Anas crecca* for the future predictions 2081-2100 (Fig.42). As can be noticed, the single most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Anas crecca*. Another variable that contains useful

information for the prediction of the distribution of this species in the future is bio.11 (minimum temperature of the coldest quarter). While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.19 (precipitation of the coldest quarter) is not a very useful information for this species, as well as variable bio.12 (annual precipitation). On the other hand, the light blue lines show that none of the environmental variables used contain useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is tmax.2, which therefore appears to have the most information that isn't present in the other variables.

These values are very important for predicting how much the wellbeing of this species might be affected, and thus how much their behaviour might change, should values such as temperature change, especially in the *valli da pesca*. If temperatures were to rise too much in the Mediterranean part of Europe, this would potentially create an unfavourable condition for *Anas crecca*, as the temperature it prefers is between -5°C and around 17°C (Fig. 43), while it is noticeable that the mean temperature of the coldest quarter that they tolerate, therefore the range in which the chance of finding *Anas crecca* is higher, is between – 10°C and 10°C (Fig.44).

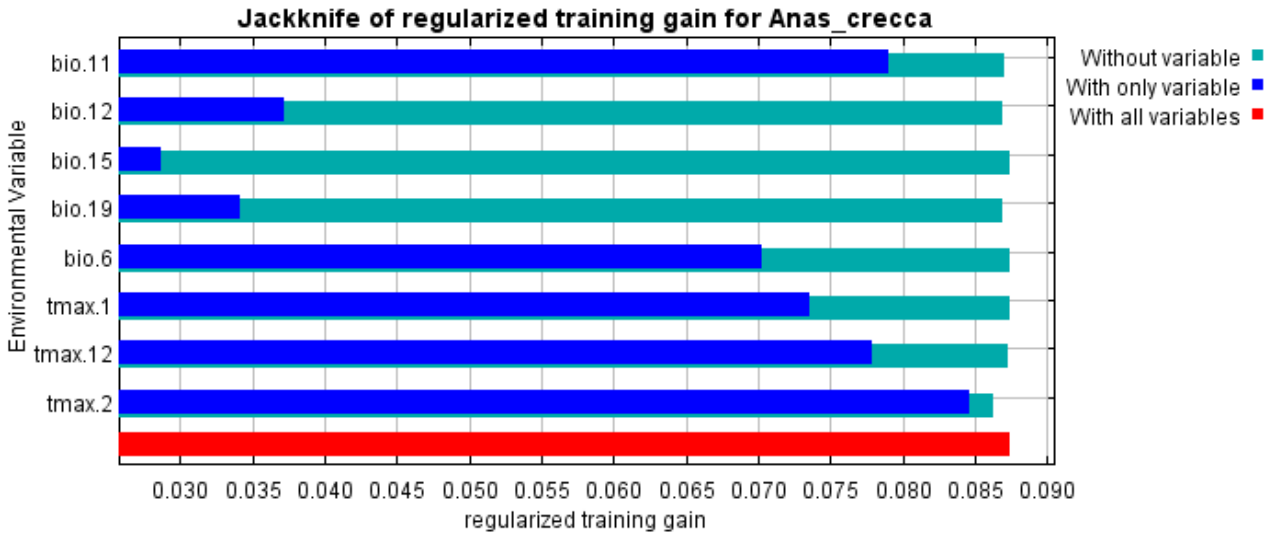

Figure 42: Jackknife of regularized training gain for Anas crecca (2081-2100)

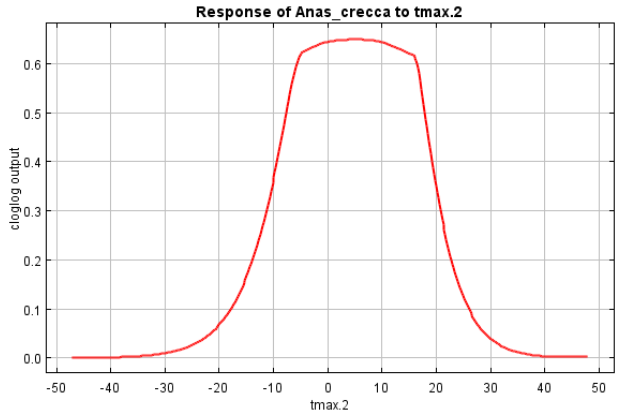

Figure 43: response curve of Anas crecca to tmax.2

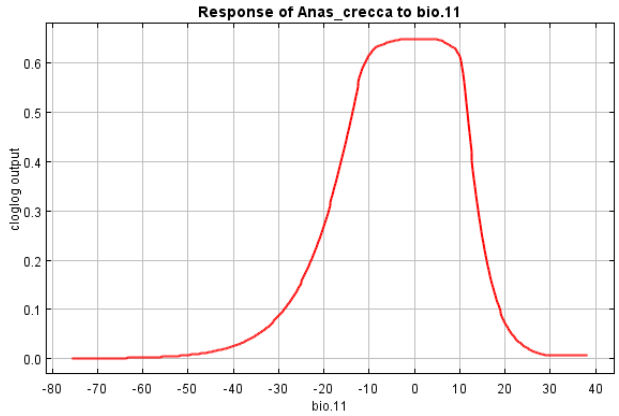

Figure 44: Response curve of Anas crecca to bio.11

Anas penelope prediction between 2021-2040

As it was done for *Anas acuta* and *Anas crecca*, now it will be described the predicted distribution analysis of *Anas penelope* both in the short future (2021-2040) and in the more distant future (2081-2100).

Verifying how much the model is accurate, Figure 45 shows that the training data is AUC=0.619, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would.

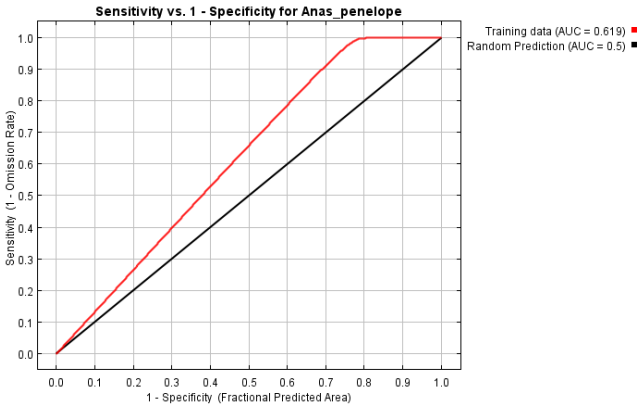

Figure 45: receiver operating characteristic (ROC) curve for the same data

Figure 46 is a Maxent representation model that shows areas with better predicted conditions for *Anas penelope* (2021-2040). It is similar to Maxent representation models of *Anas acuta* and *Anas crecca* (Fig. 18 – 32), yet there are some differences in the presence locations used for training, which are in Nord-Centre-South Europe, North America with a higher concentration along the coasts, some spots in Russia and Japan. The warmer areas, green spots tending to yellow, are found in North America, Europe, China, southernmost part of South America. These areas, that show favourable conditions, are somewhat less extensive than previous species.

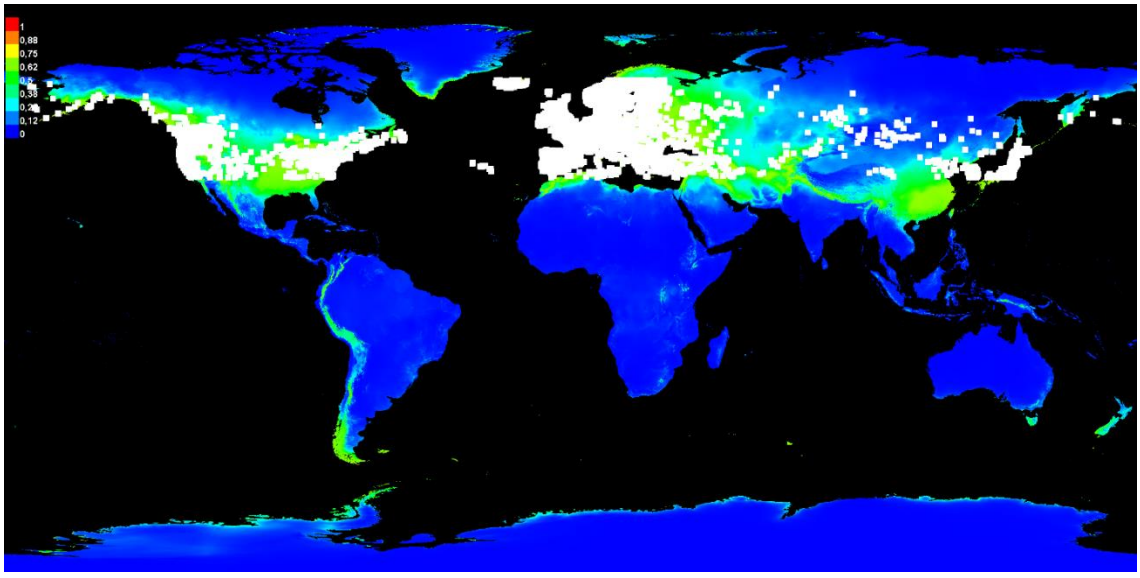

Figure 46: Representation of the model for Anas penelope (2021-2040)

As far as concerns the map in Figure 47 showing the projections of the model for the *Anas penelope* onto the environmental variables used for the prediction between 2021-2040 (prediction (bio.11: mean temperature of Coldest quarter, bio.12: annual precipitation, bio.15: Precipitation Seasonality (Coefficient of Variation), bio.19: precipitation of the coldest quarter, bio.6: min temperature of the coldest month, tmax.1, tmax.2, tmax.3 (maximum temperature)), it can be seen that conditions

slightly increase longitudinally towards the east, without, however, reaching perfect favourable conditions for *Anas penelope*. The same can be seen in North America, where the conditions improve in the norther without reaching the green colour, namely the favourable conditions. Hypothetically, this map may indicate that this species is slightly less adaptable than *Anas acuta* and *Anas crecca*.

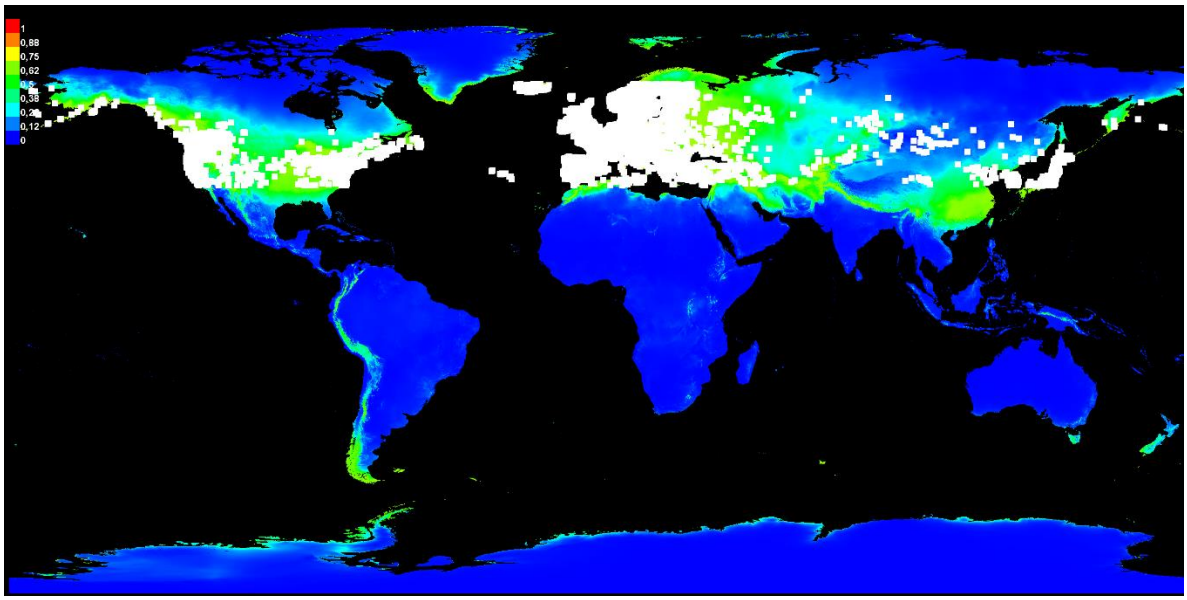

Figure 47: projection of the Maxent model for Anas penelope onto the environmental variables (2021-2040)

The following picture compares the environmental similarity of variables in the projection 2021-2040 to the environmental data used for training the model (Fig. 48).

In Figure 48 there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while the positive values are blues, (the more they are close to 100, the more equals to the median values in layers). In the Venice lagoon (North-East Italy), the value tends to 31. It means that the values in this point are not novels, yet they are not extremely equal to the median values in layers.

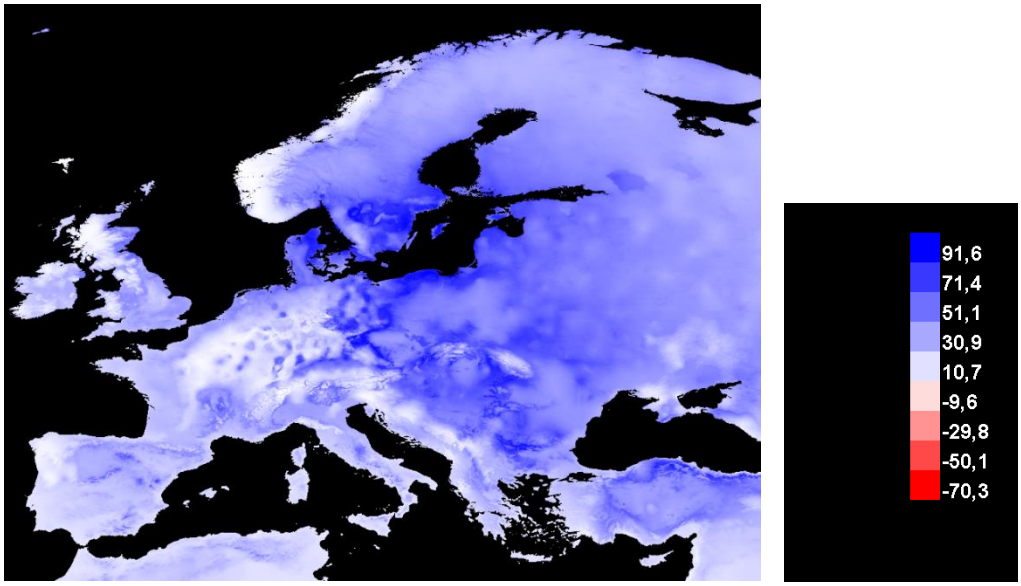

Figure 48: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Anas penelope* for the future predictions 2021-2040 (Fig.49). As it can be noticed, the single most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Anas penelope*. Other variables that contain useful information for the prediction of the distribution of this species in the future are tmax.12 and bio.11 (mean temperature of the coldest quarter). While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.12 (annual precipitation) is not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line; however, the environmental variable that decreases the gain the most when it is omitted is bio.19 (precipitation of the coldest quarter), which therefore appears to have the most information that isn't present in the other variables.

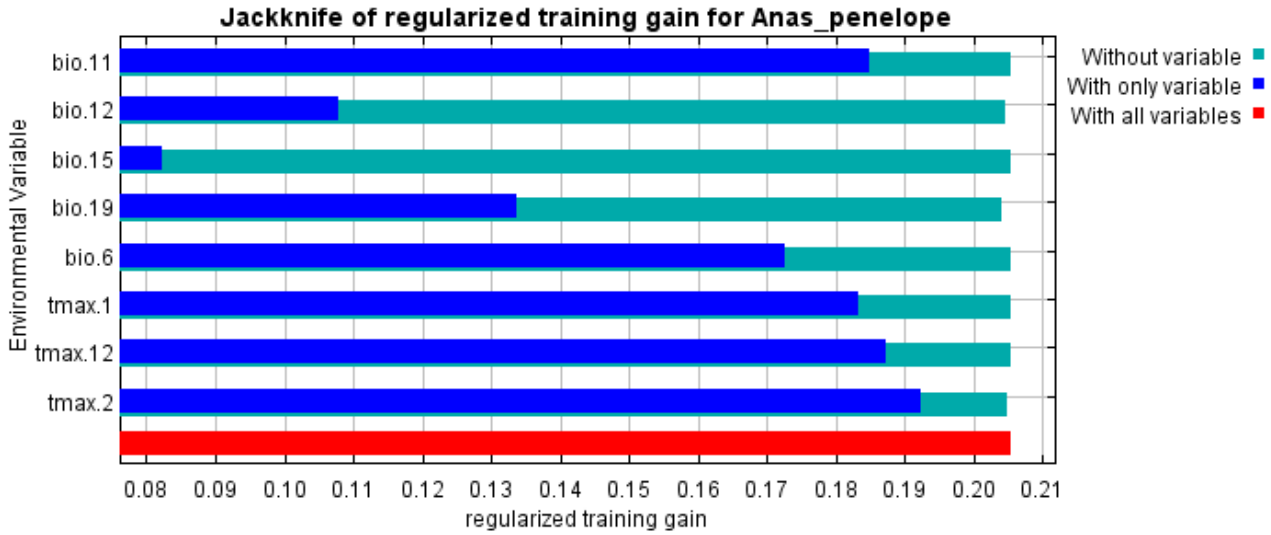

Figure 49: Jackknife of regularized training gain for Anas penelope (2021-2040)

As it can be seen, precipitation does not strongly impact *Anas penelope*. It can be deduced also by the following responses curves. Indeed, the response of *Anas penelope* to bio.19 and bio.12, after a certain value remains nearly constant (Fig. 50-51). Instead, this species is impacted by temperature. As it can be noticed, the temperature range in which the probability of finding *Anas penelope* is highest is between -5°C and 15°C (Fig. 52).

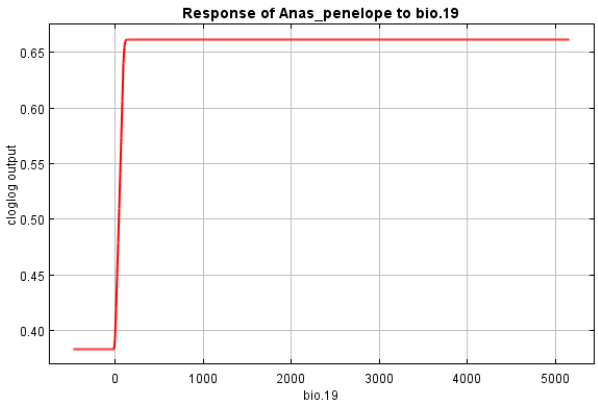

Figure 50: Response curve of Anas penelope to bio.19

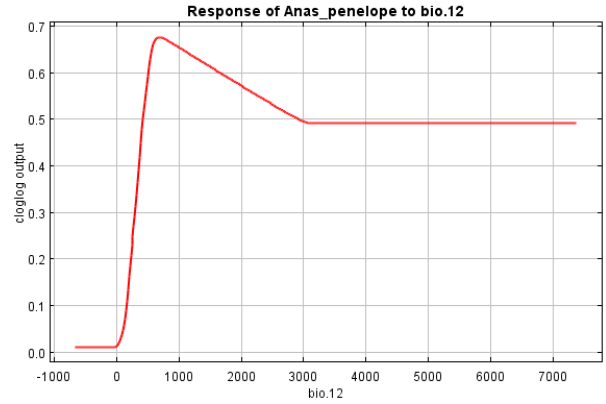

Figure 51: Response of Anas penelope to bio.12

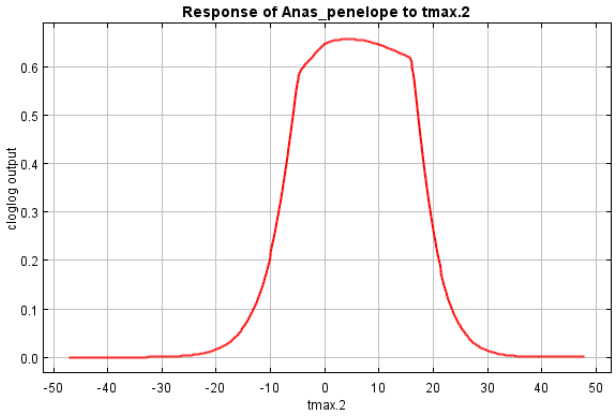

Figure 52: Response of Anas penelope to tmax.2

Anas penelope predictions between 2081-2100

As for the 2081-2100 predictions for *Anas penelope*, the graph in Figure 53, which shows the receiver operating characteristic (ROC) curve for the same data, the training data is AUC=0.619, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would.

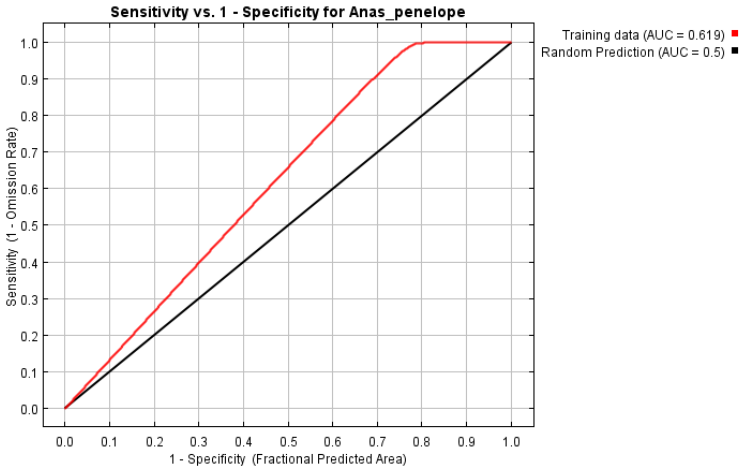

Figure 53: receiver operating characteristic (ROC) curve for the same data

Figure 54 shows a representation of Maxent model for *Anas penelope*, highlighting areas with favourable predicted conditions. The locations used for training are in all Europe (as for *Anas acuta* and *Anas crecca*), yet in North America locations used for training are more towards the coasts, unlike in Figure 25 - 39, in which the locations training was concentrated throughout North America. Green areas are as well in Europe, parts of China (south-eastern part of Asia), part of Patagonia (southernmost part of South America), and part of North America. There are no favourable conditions in Russia, differently from the representation of *Anas acuta* and *Anas crecca* (Fig. 25 - 39).

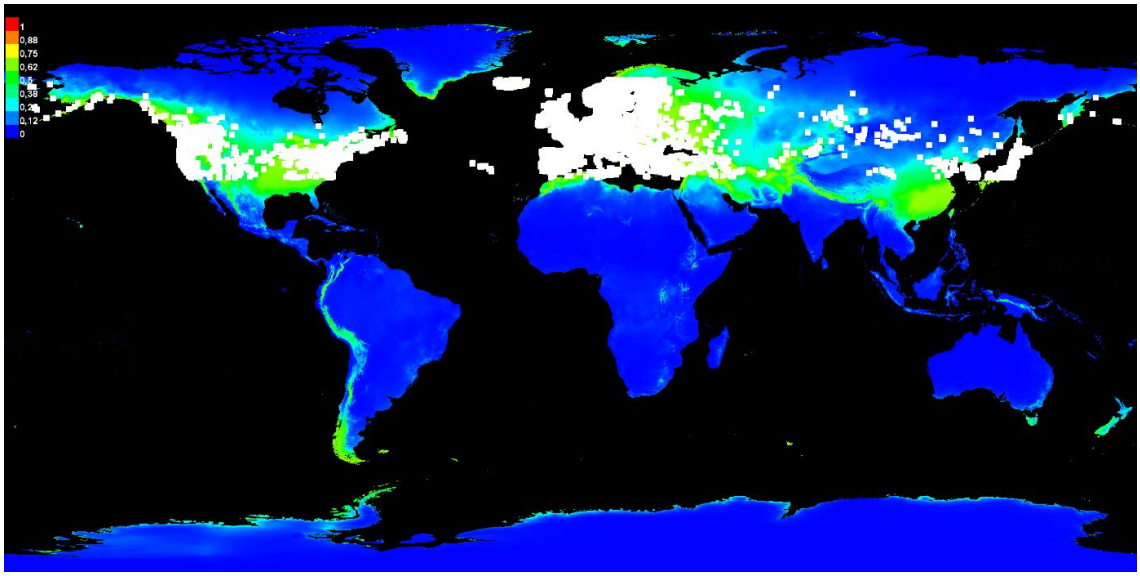

Figure 54: Representation of the model for Anas penelope (2081-2100)

As far as concerns the map showing the projections of the model for the *Anas penelope* onto the environmental variables used for the prediction between 2081-2100, it can be seen that favourable conditions increase in the central and northern parts of the Asian continent, although many areas in the north still do not reach the green colouring that is typical of the places where this species resides. Conditions also improve in the Scandinavian countries, i.e., north of the European continent, and in North America, becoming a more hospitable environment for *Anas penelope*. Conditions still remain favourable in Italy and Europe. However, comparing Figure 55 with *Anas acuta* and *Anas crecca* map projections onto the environmental variables (Fig. 26 - 40), it seems that Asia presents less favourable conditions for *Anas penelope*. This might suggest that this species needs different environmental conditions than the others seen previously. The places with the most favourable conditions remain Europe and North America.

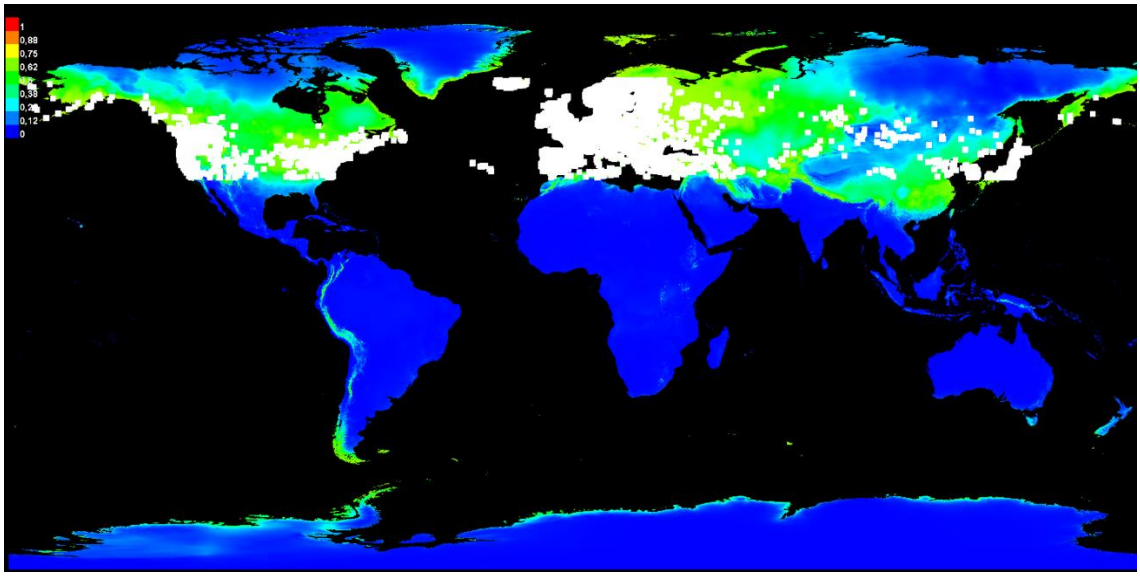

Figure 55: projection of the Maxent model for Anas penelope onto the environmental variables (2081-2100)

The following picture compares the environmental similarity of variables in the projection 2021-2040 to the environmental data used for training the model (Fig. 48).

In Figure 56, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while the positive values are blues, (the more they are close to 100, the more equals to the median values in layers). Figure 56 shows a change in the Venice lagoon area, the value has decreased compared to the model for 2021-2040, it is around 17, meaning that the value is approaching negative. Negative values mean "novel climate", as so during projections, predicted variables can assume values outside the training range.

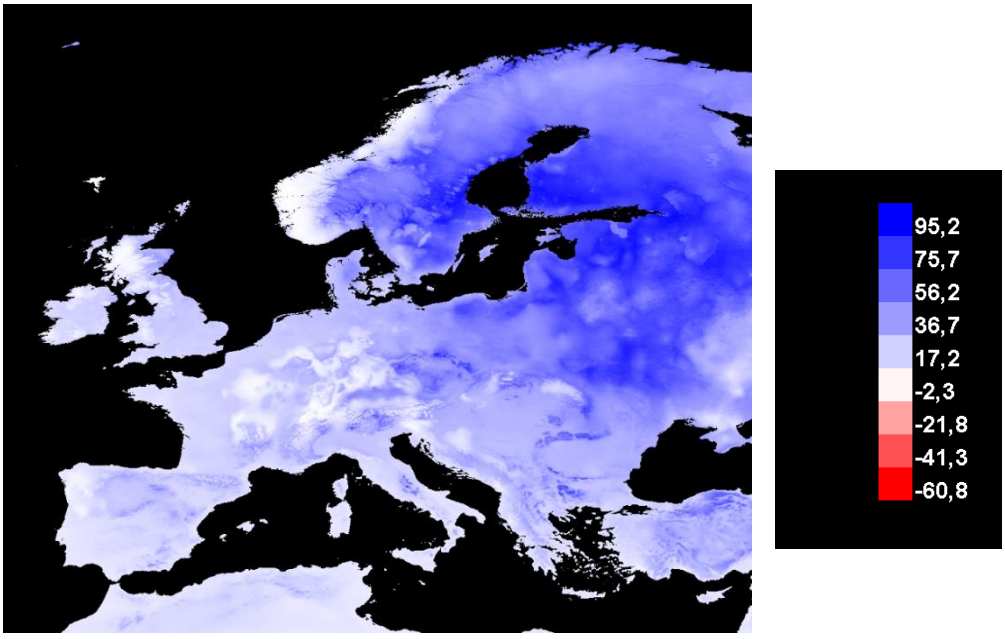

Figure 56: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Anas penelope* for the future predictions 2081-2100 (Fig.57). As it can be noticed, the single most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Anas penelope*. Another variable that contains useful information for the prediction of the distribution of this species in the future is bio.11 (mean temperature of the coldest quarter). While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.12 (annual precipitation) is not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is bio.19 (precipitation of the coldest quarter), which therefore appears to have the most information that isn't present in the other variables.

Therefore, as mentioned before, precipitation does not strongly impact this species, while temperature plays a major role in the physiological well-being of *Anas penelope*.

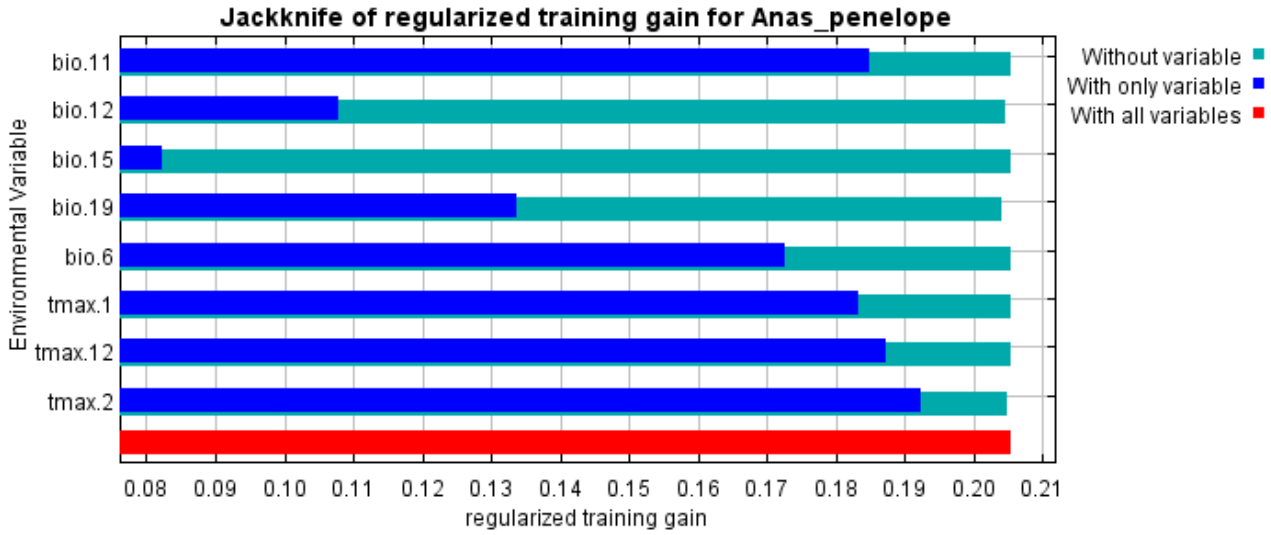

Figure 57: Jackknife of regularized training gain for Anas penelope (2081-2100)

Figure 58 shows the response curve of *Anas penelope* to tmax.2, as can be seen, the range in which the probability to find *Anas penelope* is highest is between -5°C and around 16°C.

In Figure 59 instead it is shown the response curve of *Anas penelope* to bio.11 (mean temperature of the coldest quarter). The range in which the probability to find *Anas penelope* is highest in the coldest quarter is between -8°C and 10°C.

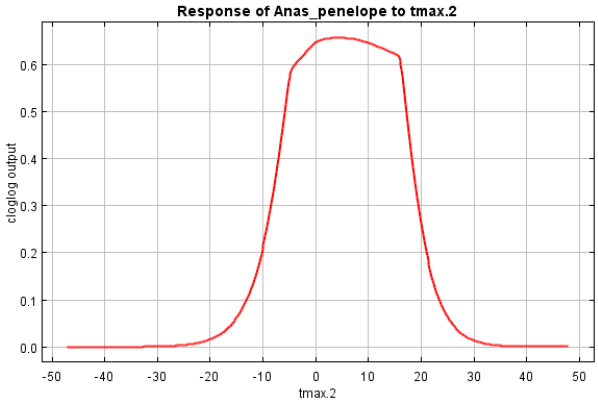

Figure 58: Response curve of Anas Penelope to tmax.2

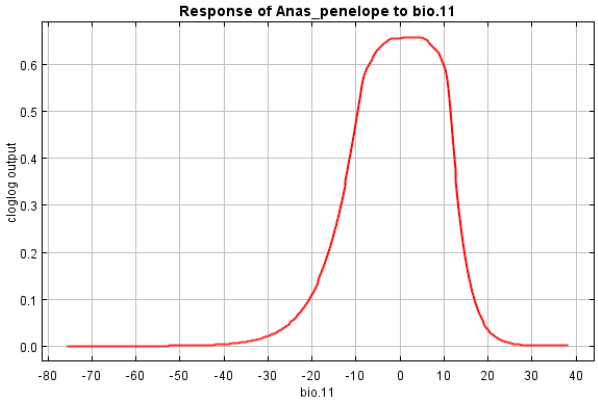

Figure 59: Response curve of Anas Penelope to bio.11

Anas platyrhynchos prediction between 2021-2040

Below it is presented a predicted distribution analysis of *Anas platyrhynchos*, commonly known as Mallard, present in the *valli da pesca* all year round. As for the other species, first the predicted distribution between 2021 and 2040 will be seen, followed by an analysis of the predicted distribution between 2081 and 2100.

The plot in Figure 60 - the receiver operating characteristic (ROC) curve for the same data – shows that the training data is AUC=0.542, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would.

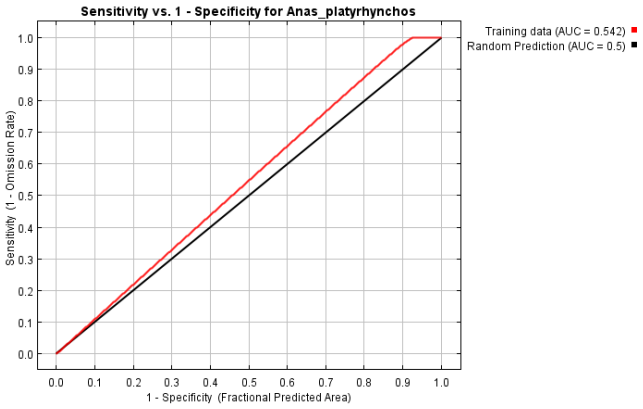

Figure 60: receiver operating characteristic (ROC) curve for the same

The map in Figure 61 shows the favourable conditions for the distribution of *Anas platyrhynchos*. The locations used for training (white dots) are in Europe, Japan, North America, and parts of Asia. The green areas, those with predicted favourable conditions for *Anas platyrhynchos* are in North America, Europe, parts of China (southeast Asia), parts of Russia (northeast Asia), and differently from *Anas acuta*, *Anas crecca*, and *Anas penelope*, for mallards also the west coast of South America presents more favourable conditions.

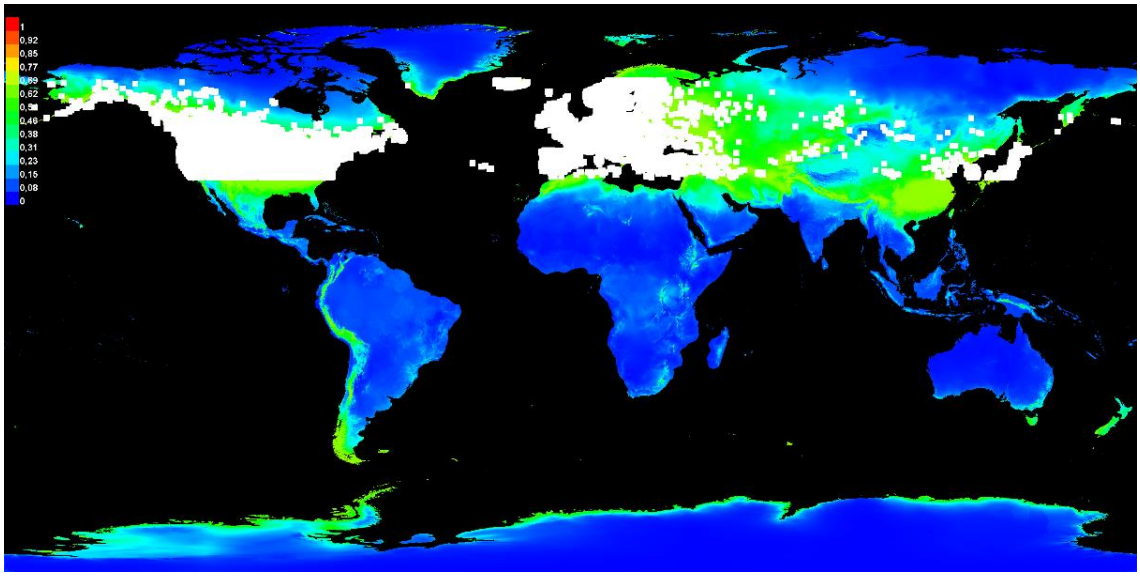

Figure 61: Representation of the model for Anas platyrhynchos (2021-2040)

The map represented in Figure 62 – namely the projection of the Maxent model for *Anas platyrhynchos* onto the environmental variables in the period between 2021-2040 – is quite similar to the representation model for *Anas platyrhynchos* (Fig. 61). Favourable predicted conditions are

still in Europe, North America, west coast of South America. Conditions become slightly more favourable towards the central-eastern part of the Eurasian continent, as well as along the eastern coasts of Asia. They also improve slightly in North America. This representation is not very dissimilar from the maps of *Anas acuta*, *Anas crecca* and *Anas penelope* (Fig. 18 – 32 - 47), meaning that they require similar environmental variables for living well.

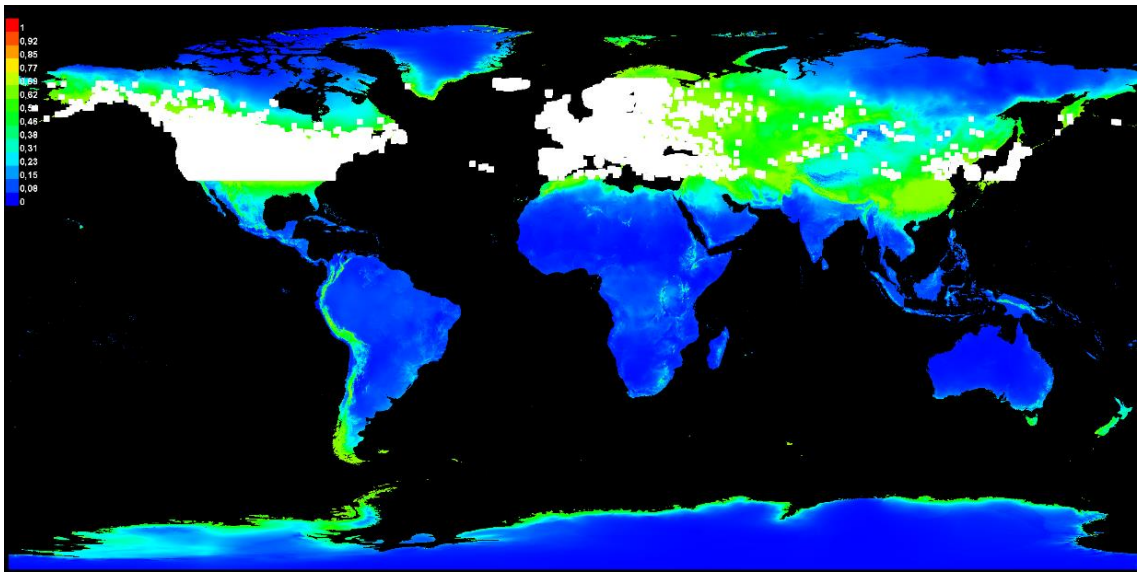

Figure 62: projection of the Maxent model for Anas platyrhynchos onto the environmental variables (2021-2040)

The following picture compares the environmental similarity of variables in the projection 2021-2040 to the environmental data used for training the model (Figure 63).

In Figure 63, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while there are blue positive values. In the Venice lagoon (North-East Italy), the value tends to 29.9. It means that the values in this point are not novels, yet they are not extremely equal to the median values in layers.

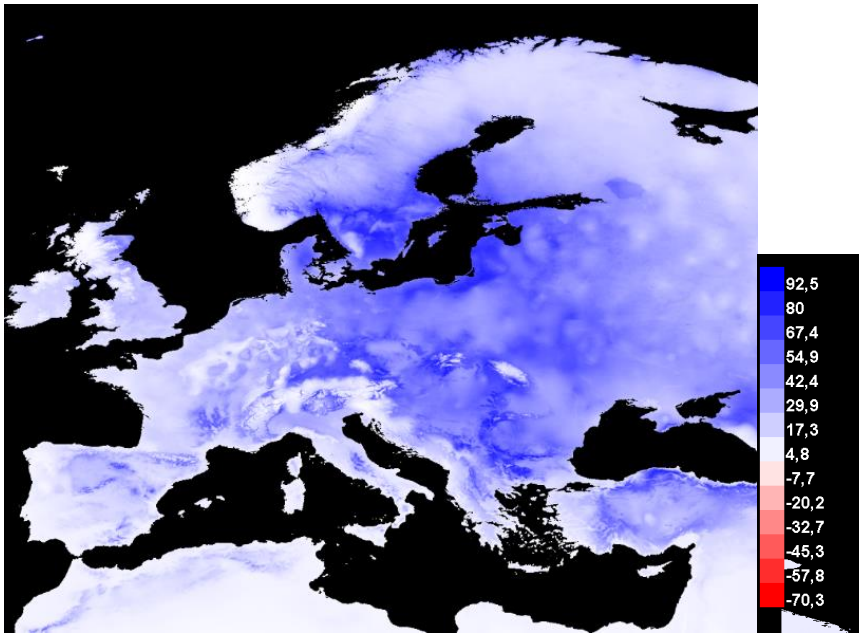

Figure 63: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Anas platyrhynchos* for the future predictions 2021-2040 (Fig.64). As it was done for the other species above, the single most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Anas platyrhynchos*. Another variable that contains useful information for the prediction of the distribution of this species in the future is bio.11 (mean temperature of the coldest quarter). While, also for this species, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.19 (precipitation of the coldest quarter) is not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is tmax.2, which therefore appears to have the most information that isn't present in the other variables.

This graph shows that *Anas platyrhynchos*, as well as for *Anas penelope*, precipitation does not strongly impact its physiological well-being. It can be deduced also by the following responses curves. Indeed, the response of *Anas platyrhynchos* to bio.19 and bio.12, after a certain value remains nearly constant (Fig. 65-66).

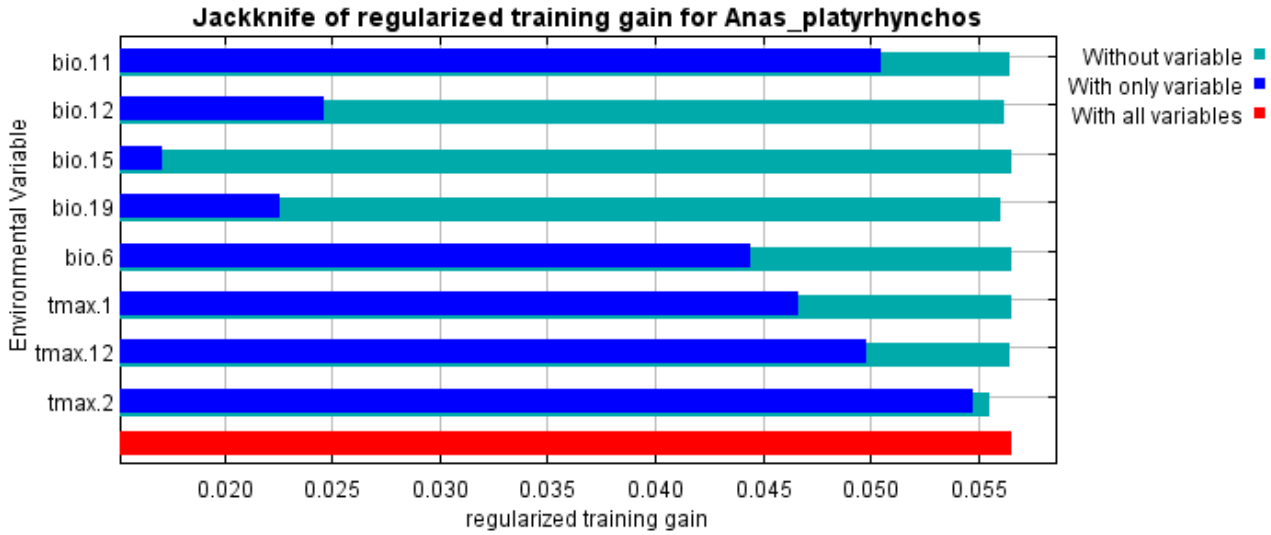

Figure 64: Jackknife of regularized training gain for Anas platyrhynchos (2021-2040)

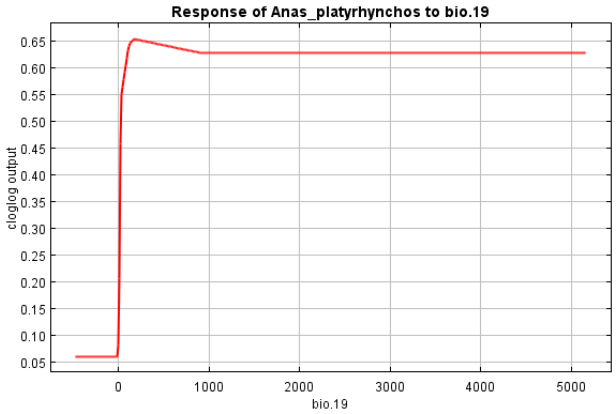

Figure 65: Response of Anas platyrhynchos to bio.19

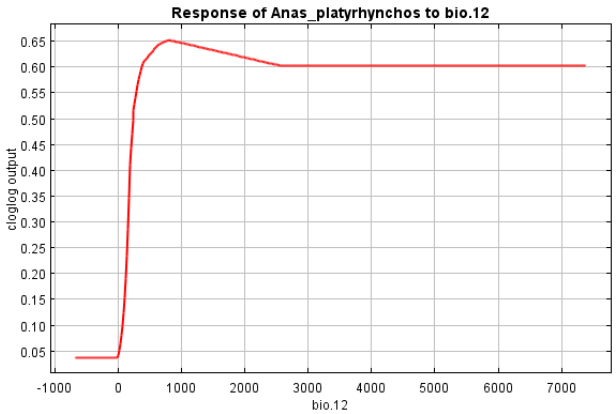

Figure 66: Response of Anas platyrhynchos to bio.12

Following, it is presented the response curve of tmax.2, which shows how the predicted probability of presence of *Anas platyrhynchos* changes as this environmental variable is varied. As it can be seen, the temperature values corresponding to a higher estimated probability of occurrence of this species (cloglog output) range from -5°C to 15°C (Figure 67). Therefore, temperature is indeed an important value for this species.

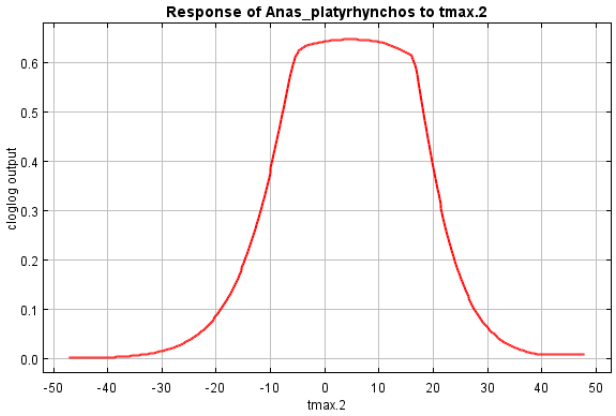

Figure 67: response of Anas platyrhynchos to tmax.2

Anas platyrhynchos prediction between 2081-2100

The plot in Figure 68 - receiver operating characteristic (ROC) curve for the same data- shows that the training data is AUC=0.542, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would.

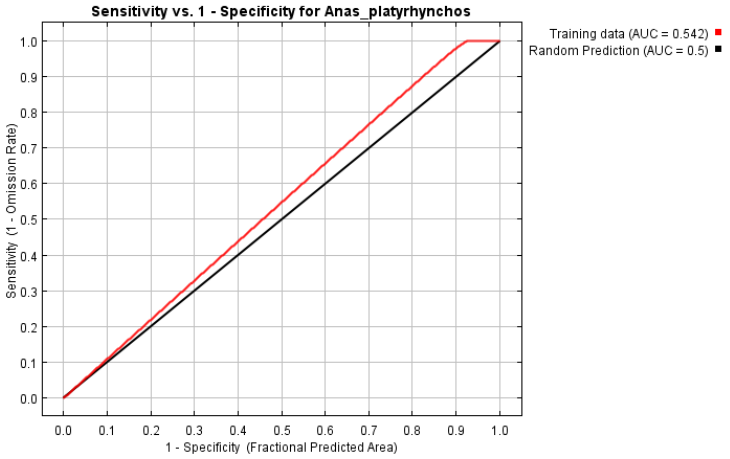

Figure 68: receiver operating characteristic (ROC) curve for the same data

The map in Figure 69 shows that the favourable conditions for *Anas platyrhynchos* are quite similar to the predicted distribution of *Anas acuta*, *Anas crecca* and *Anas penelope* for the same period. White dots – locations used for training – are in Europe, North America, Japan and some spots in Asia. Green areas are in Europe, North America, parts of China, parts of Russia, and the west coast of South America.

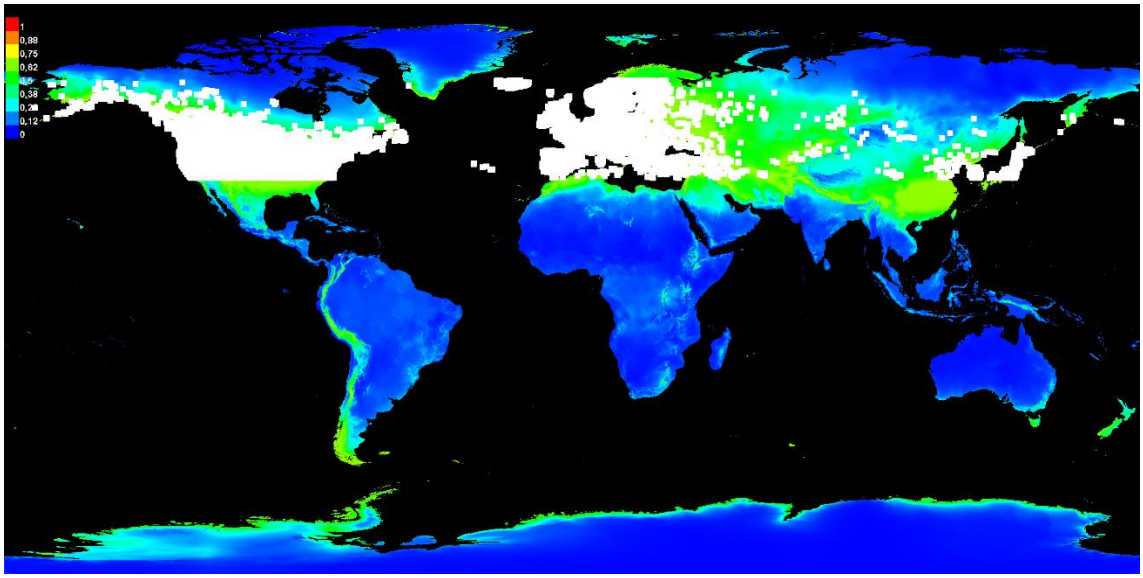

Figure 69: Representation of the model for Anas platyrhynchos (2081-2100)

The map in Figure 70 shows the projection of the model for *Anas platyrhynchos* onto the environental variables (2081-2100). What is different, also comparing the maps of *Anas acuta*, *Anas crecca* and *Anas penelope* (Fig. 26 - 40 - 55) is that in the eastern part of the Eurasian continent, from north to south, favourable conditions for this species will increase greatly. Many of these areas will not yet be suitable for hosting this species, but they are well on their way. North of the American continent, favourable conditions for *Anas platyrhynchos* will also improve, becoming more suitable for hosting this species. Also north America will become more favourable for hosting *Anas platyrhynchos*. This species lives in the *valli da pesca* all year round, is very common.

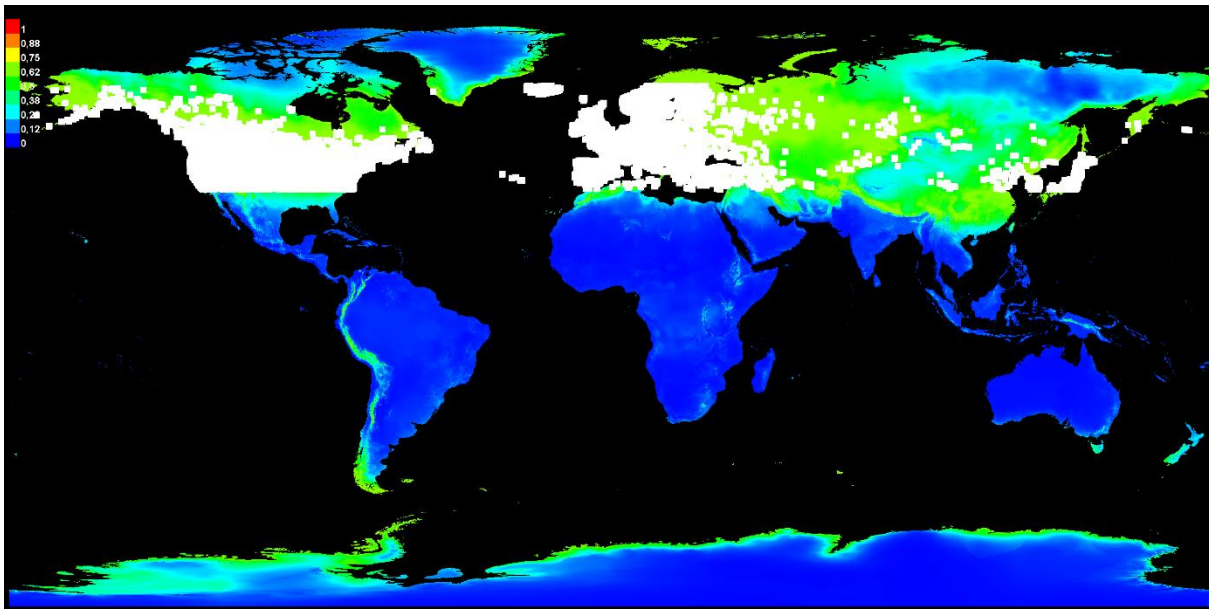

Figure 70: projection of the Maxent model for Anas platyrhynchos onto the environmental variables (2081-2100)

The following picture compares the environmental similarity of variables in the projection 2081-2100 to the environmental data used for training the model (Figure 71).

Figure 71 - as well as Figures 27 - 41 – 56, shows a change in the Venice lagoon area, the value has decreased compared to the model for 2021-2040 (Fig. 63), it is around 15.6, meaning that the value is approaching negative. Negative values mean “novel climate”, as so during projections, predicted variables can assume values outside the training range.

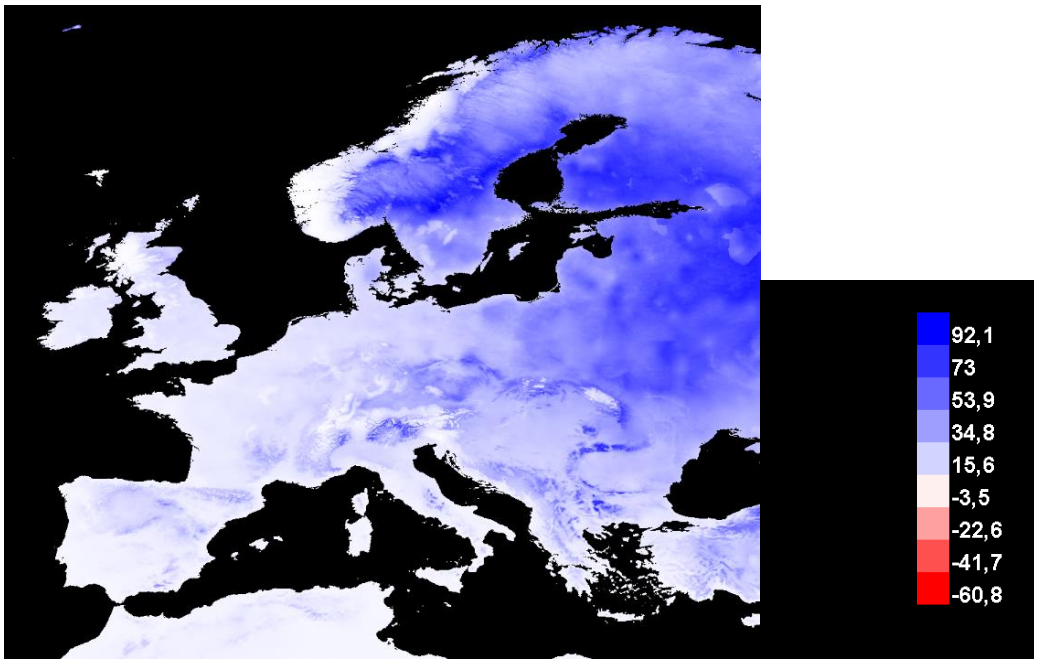

Figure 71: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Anas platyrhynchos* for the future predictions 2081-2100 (Fig.72). It can be noticed it is not dissimilar from the jackknife tests of *Anas acuta*, *Anas crecca*, and *Anas penelope* (Fig. 28 – 42 – 57): the single most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Anas platyrhynchos*. Another variable that contains useful information for the prediction of the distribution of this species in the future is bio.11 (mean temperature of the coldest quarter). While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.12 (annual precipitation) is not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is tmax.2, which therefore appears to have the most information that isn't present in the other variables. Therefore, as mentioned before, precipitation does not strongly impact this species, while temperature plays a major role in the physiological well-being of *Anas platyrhynchos.*

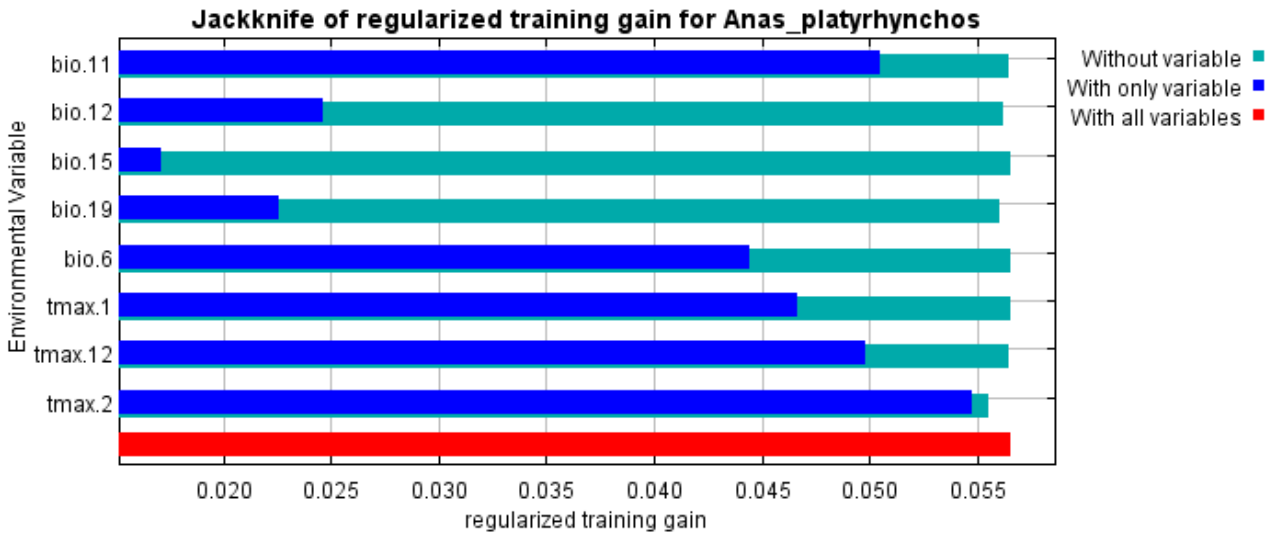

Figure 72: Jackknife of regularized training gain for Anas platyrhynchos (2081-2100)

The response curve of tmax.2 shows how the predicted probability of presence of *Anas platyrhynchos* changes as this environmental variable is varied. As it can be seen, similar to the response curve of *Anas platyrhynchos* in the future 2021-2040 (Fig. 67), the temperature values corresponding to a highest estimated probability of occurrence of this species (cloglog output) range from -5°C to 18°C (Fig. 73).

In Figure 74 instead it is shown the response curve of *Anas platyrhynchos* to bio.11 (mean temperature of the coldest quarter). The range in which the probability to find *Anas platyrhynchos* is highest in the coldest quarter is between -10°C and 10°C.

Figure 73: response curve of Anas platyrhynchos to tmax.2

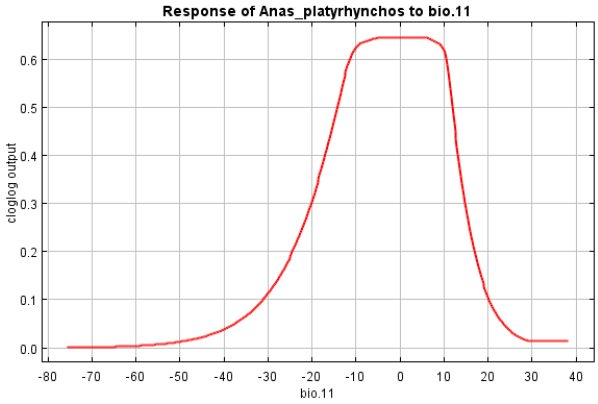

Figure 74: response curve of Anas platyrhynchos to bio.11

Anas querquedula prediction between 2021-2040

Below is a forecast analysis of the distribution of the *Anas querquedula* species in the future period between 2021 and 2040. Subsequently, it will be reported a forecast analysis of the distribution of *Anas acuta* in the period between 2081 and 2100.

The plot in Figure 75 verifies how much the model analysis is accurate. In the graph, it can be noticed that the training data is AUC=0.780, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would. Therefore, the model is accurate.

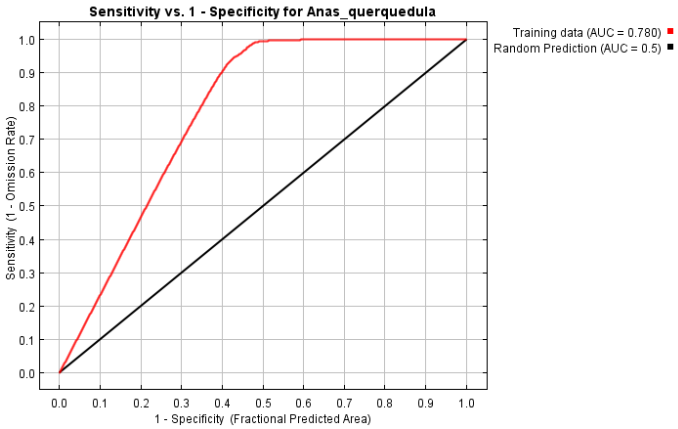

Figure 75: receiver operating characteristic (ROC) curve for the same data

The map in Figure 76 shows the favourable conditions of *Anas querquedula*. The locations used for training (white dots) are placed in Europe, on the east and west coast of North America, scarcely in North Africa, in Japan, and some spots are present also in central Asia. The favourable conditions shown by the maps are fewer compared to those of the other Anatids (*Anas acuta*, *Anas crecca*, *Anas penelope*, and *Anas platyrhynchos*) (Fig. 18 – 32 – 46 - 61). These favourable conditions are on the east and west coasts of North America, in Europa, and slightly in China (south-east part of Asia).

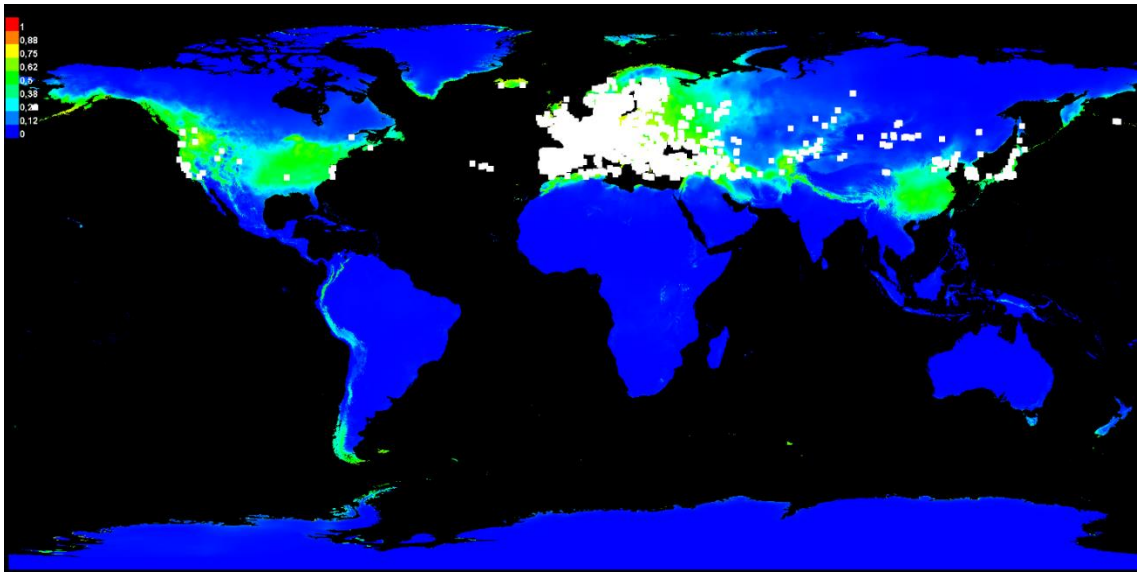

Figure 76: Representation of the model for Anas querquedula (2021-2040)

The map in Figure 77 shows the projection of the model for *Anas querquedula* onto the environental variables (2021-2040). It is not very dissimilar from map in Figure 75, indeed the locantions used for training are approximately in the same spots (little on the North America coasts, in Europe, in Japan, and little in central Asia), and the favourable predicted conditions are on the west and east coast of North America, in Europa and in part of China on south-east of Asia.

Compared to other anadits (Fig. 19 – 33 – 47 - 62), it seems from this map that *Anas querquedula* prefers milder climatic conditions and areas along the coasts.

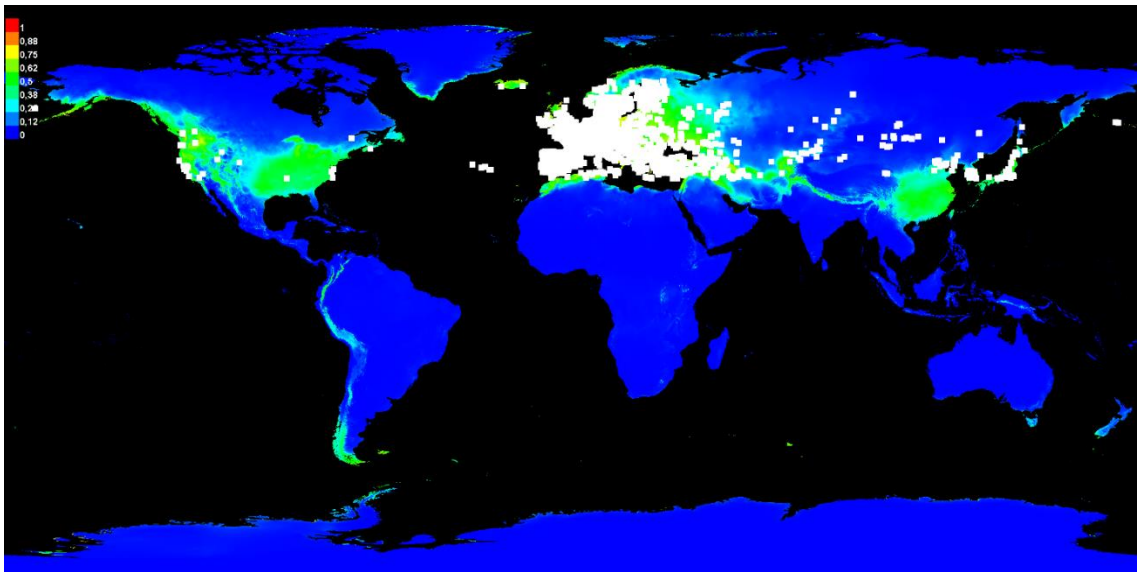

Figure 77: projection of the Maxent model for Anas querquedula onto the environmental variables (2021-2040)

The following picture compares the environmental similarity of variables in the projection 2021-2040 to the environmental data used for training the model (Figure 78).

In Figure 78, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while there are blue positive values. In the Venice

lagoon (North-East Italy), the value tends to 32,3. It means that the values in this point are not novels, yet they are not extremely equal to the median values in layers

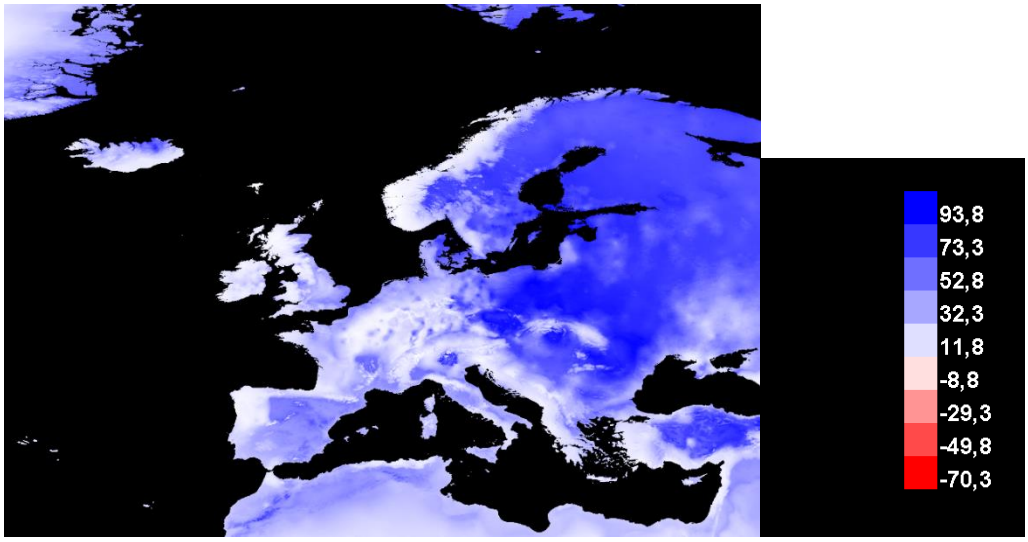

Figure 78: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Anas querquedula* for the future predictions 2021-2040 (Fig.79). It can be noticed that this time it is slightly different from the jackknife tests of *Anas acuta*, *Anas crecca*, *Anas penelope*, and *Anas platyrhynchos* (Fig.21 – 35 – 49 - 64): the single most efficient variable for the distribution prediction is tmax.12 (blue line), it means that this variable contains useful information to estimate the distribution of *Anas querquedula*, contrary to other anatids, wherein their single most efficient variable for the distribution prediction was tmax.2. Another variable that contains useful information for the prediction of the distribution of this species in the future is bio.11 (mean temperature of the coldest quarter), and tmax.2. While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.12 (annual precipitation) is not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is bio.12 (annual precipitation), which therefore appears to have the most information that isn't present in the other variables.

Therefore, also for *Anas querquedula*, temperature plays a major role in the physiological well-being of this species.

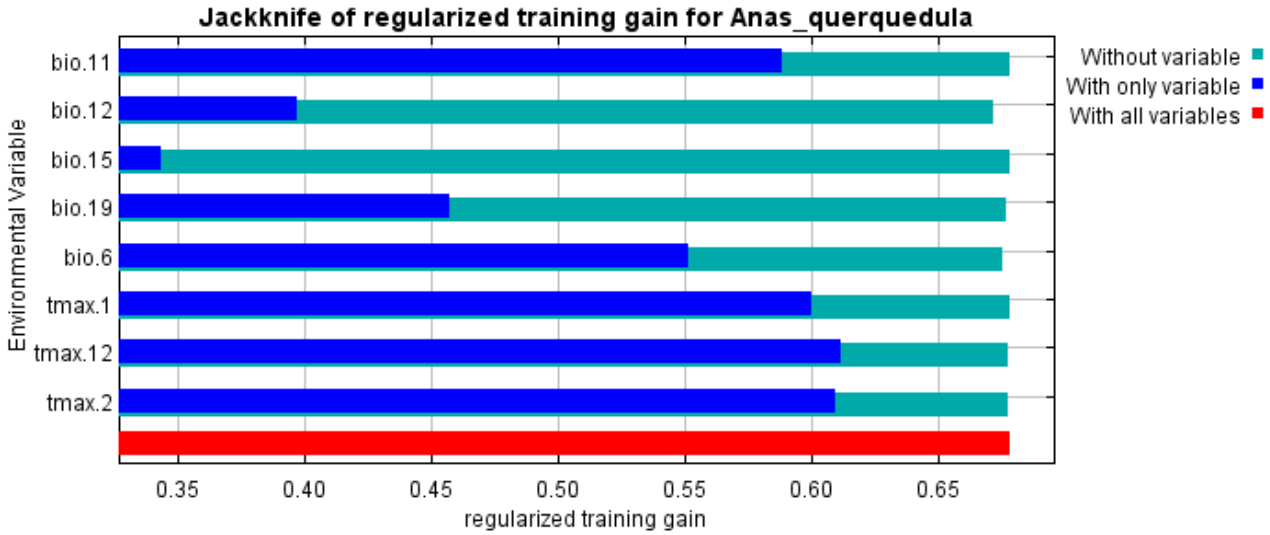

Figure 79: Jackknife of regularized training gain for Anas querquedula (2021-2040)

It can be seen that *Anas querquedula* prefers milder climate conditions also from the following responses curves (Fig. 80 – 81). As it can be noticed, the temperature range in which the probability of finding *Anas querquedula* is highest is between 0°C and 18°C (Fig. 80 - 81), therefore the temperature range has slightly increased compared to the response curves of the other anatids (Fig. 22 – 36 – 52 - 67).

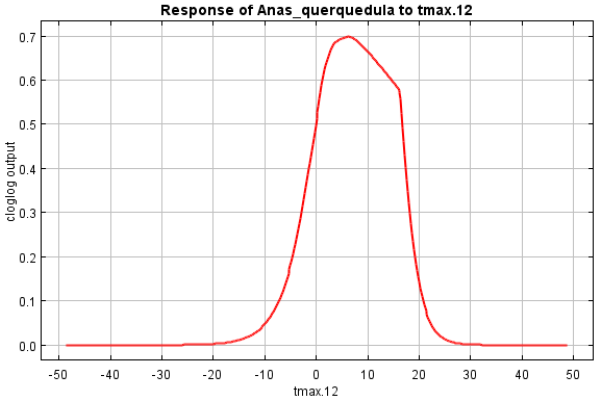

Figure 80: Response of Anas querquedula to tmax.12

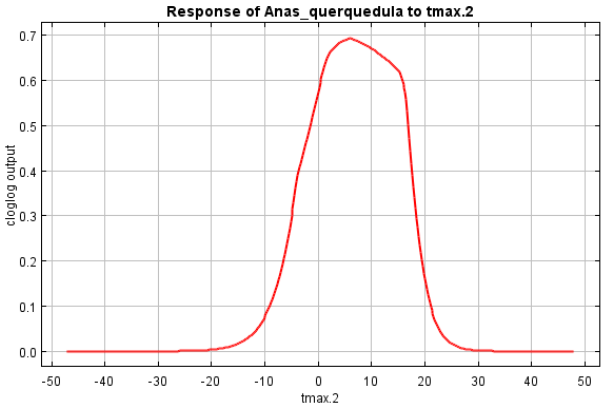

Figure 81: Response of Anas querquedula to tmax.2

Anas querquedula prediction between 2081-2100

The plot in Figure 82 - the receiver operating characteristic (ROC) curve for the same data – shows that the training data is AUC=0.780, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would, therefore the model is accurate.

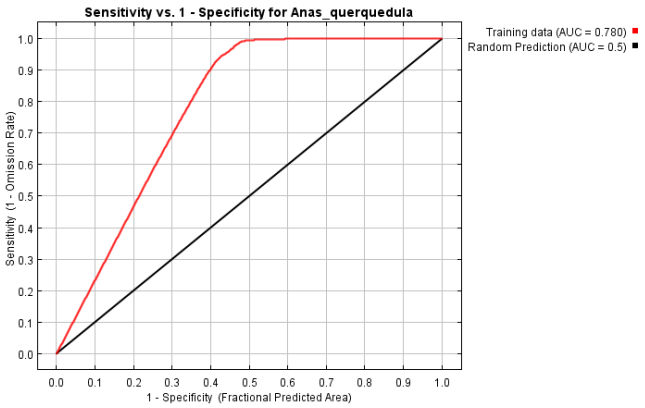

Figure 82: receiver operating characteristic (ROC) curve for the same data

The map in Figure 83 shows the favourable conditions of *Anas querquedula*. The locations used for training (white dots) are placed in Europe, on the west and (slightly) on the east coast of North America, some spots on the northwest coast of the African continent, in Japan, and some spots are present also in central Asia. The favourable conditions shown by the maps are fewer compared to those of the other Anatids (*Anas acuta*, *Anas crecca*, *Anas penelope*, and *Anas platyrhynchos*) (Fig. 25 – 39 – 54 – 69). These favourable conditions are on the east and west coasts of North America, in Europa, on the northwest coast of the African continent, and slightly in China (south-east part of Asia).

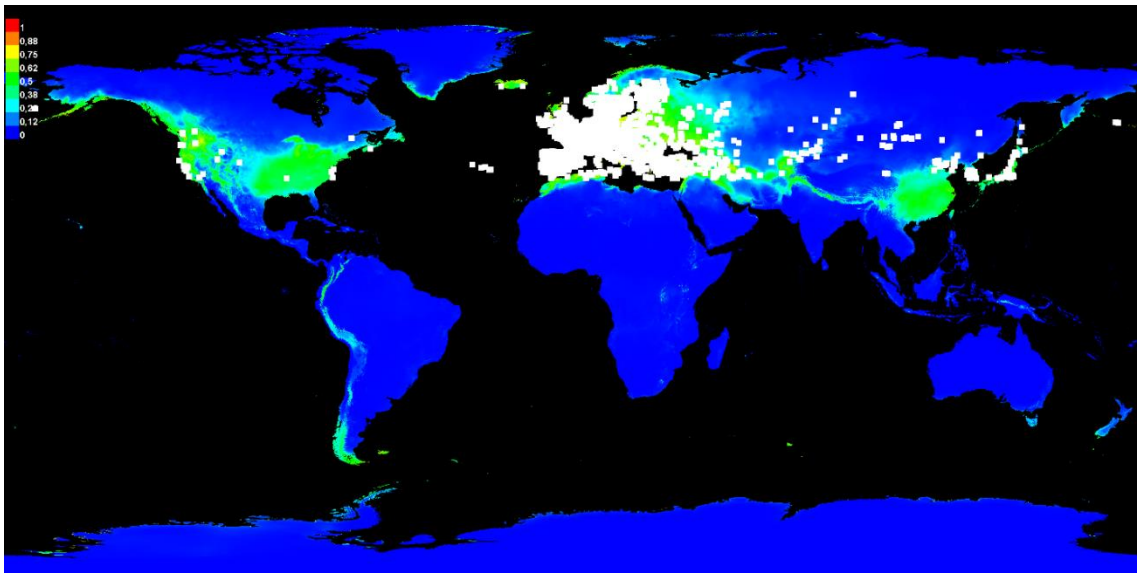

Figure 83: Representation of the model for Anas querquedula (2081-2100)

The map in Figure 84 shows the projection of the model for *Anas querquedula* onto the environental variables (2081-2100). The locantions used for training are approximately in the same spots of Figure 83 (on the west and (slightly) on the east coast of North America, in Europe, in Japan, and little in central Asia). The favourable predicted conditions have increased compare to map in Figure 83 sligthly on the North American coasts, becoming greener on the borders and light blues in the centre (not showing proper favourable conditions); greener areas are visible also in the North-east part of Europe, and longitudinally to the west the conditions are slightly increased (light blue) without becoming properly favourable.

Compared to other anadits, it seems from this map that *Anas querquedula* prefers milder climatic conditions and areas along the coasts.

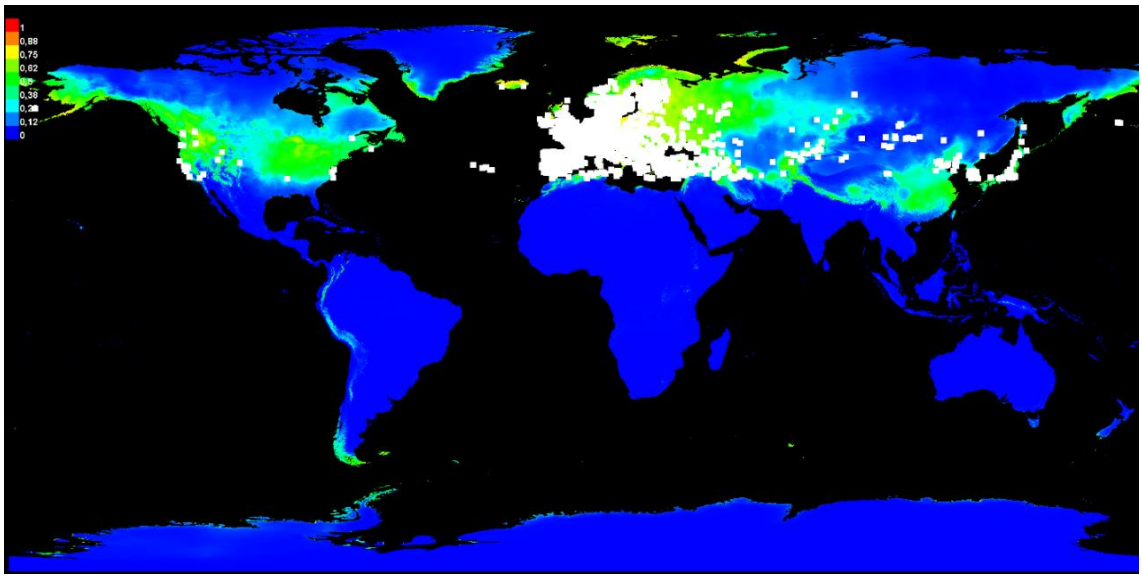

Figure 84: projection of the Maxent model for Anas querquedula onto the environmental variables (2081-2100)

The following picture compares the environmental similarity of variables in the projection 2081-2100 to the environmental data used for training the model (Fig. 85).

Figure 85- contrary to the projections of other anatids –in the Venice lagoon area, the value has increased compared to the model for 2021-2040 (Fig. 78), it is around 33.8. The value is approaching positive (in blue), positive values are similar to BIOCLIM values, the closer they are to 100, the more the values are extremely equal to the median value in the layers.

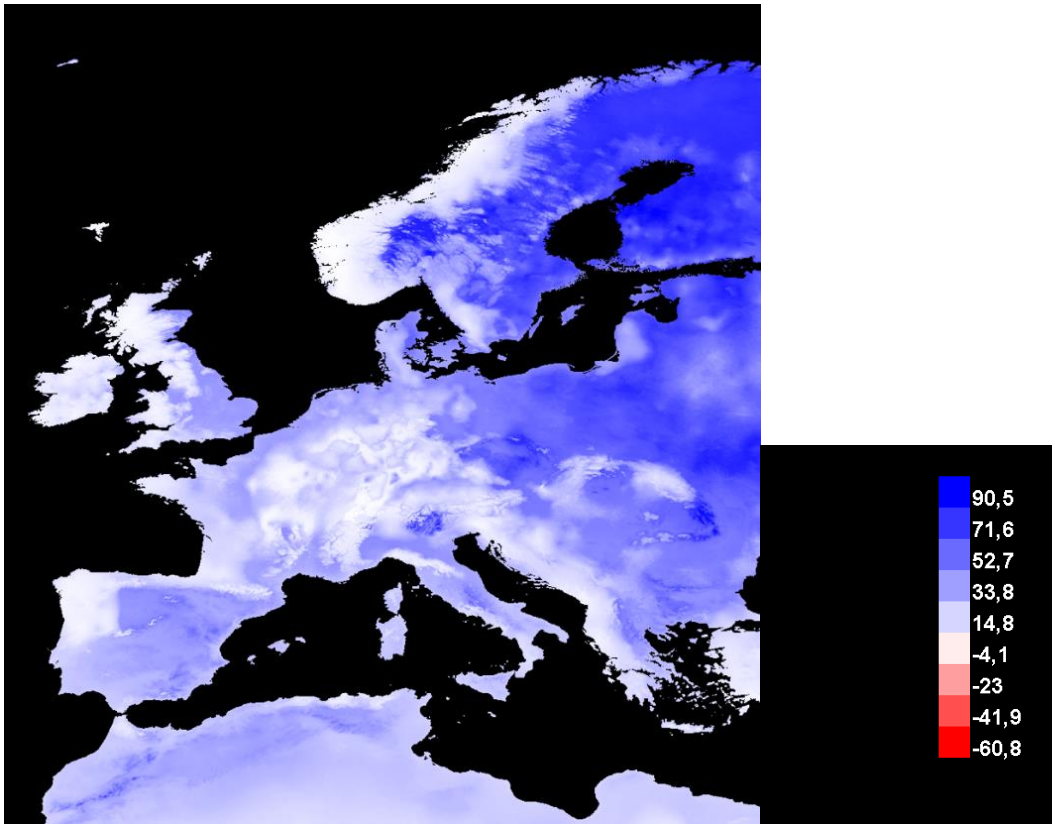

Figure 85: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Anas querquedula* for the future predictions 2081-2100 (Fig.86). It can be noticed that this time it is slightly different from the jackknife tests of A*nas acuta, Anas crecca, Anas penelope*, and *Anas platyrhynchos* (28 – 42 – 57 – 72): the single most efficient variable for the distribution prediction is tmax.12 (blue line), it means that this variable contains useful information to estimate the distribution of *Anas querquedula*, contrary to other anatids, wherein their single most efficient variable for the distribution prediction was tmax.2. Another variable that contains useful information for the prediction of the distribution of this species in the future is bio.11 (mean temperature of the coldest quarter), and tmax.2. While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.12 (annual precipitation) is not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is bio.12 (annual precipitation), which therefore appears to have the most information that isn't present in the other variables.

Therefore, also for *Anas querquedula*, temperature plays a major role in the physiological well-being of this species.

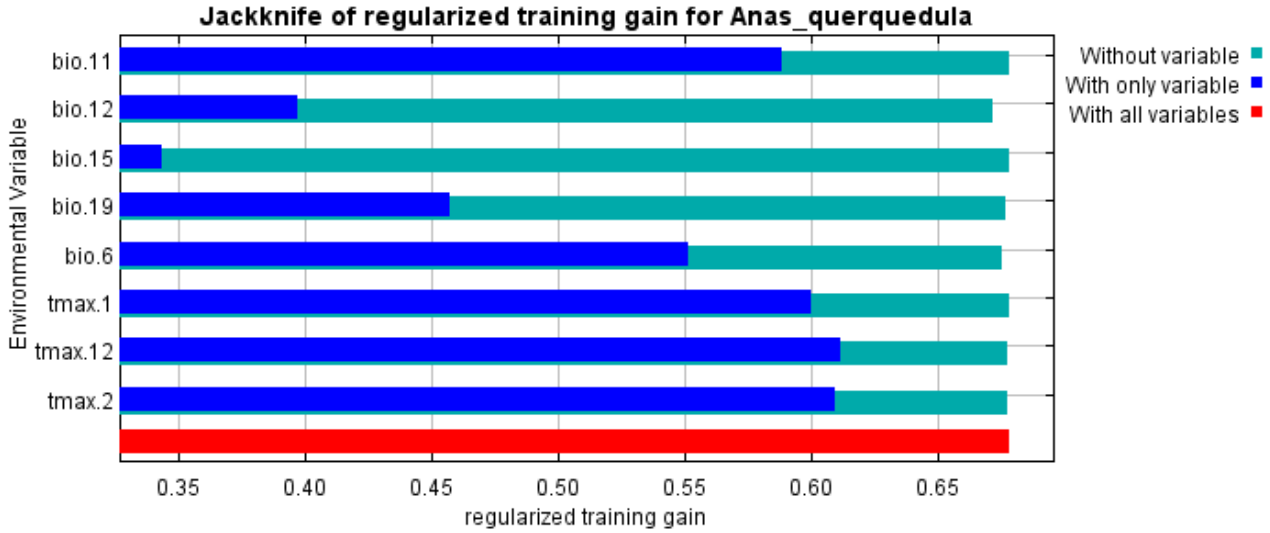

Figure 86: jackknife of regularized training gain for Anas querquedula (2081-2100)

It can be seen that *Anas querquedula* prefers milder climate conditions also from the following responses curves (Fig. 87 - 88). As it can be noticed, the temperature range in which the probability of finding *Anas querquedula* is highest is between 1°C and 18°C for tmax.12, and between 0°C and 15°C for tmax.2, therefore the temperature range has slightly increased compared to the other anatids.

Therefore, the conditions in the northernmost areas of the world will remain probably too cold for hosting this species, that prefers mildest climate, continuing to favour Mediterranean and coastal areas.

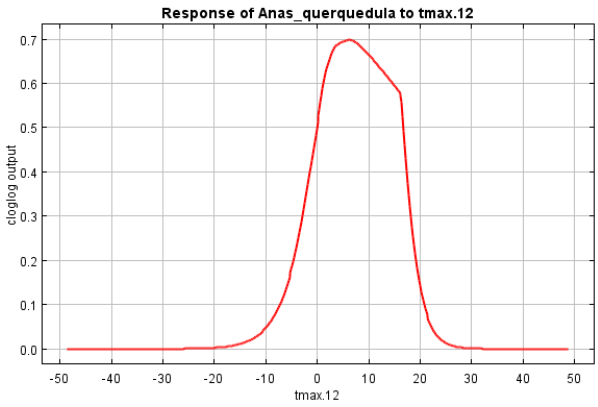

Figure 87: Response of Anas querquedula to tmax.12

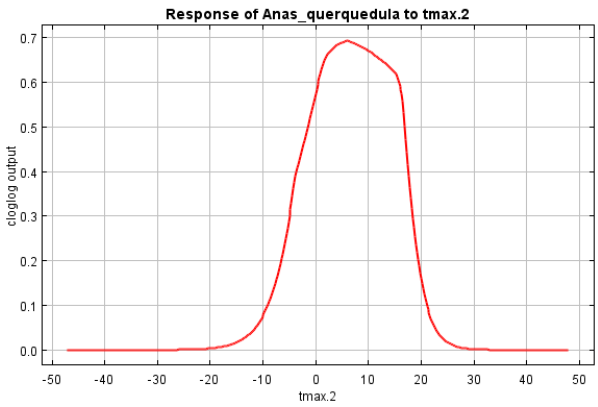

Figure 88: Response of Anas querquedula to tmax.2

Anas strepera prediction between 2021-2040

Below is a forecast analysis of the distribution of the *Anas strepera* species in the future period between 2021 and 2040. Subsequently, it will be reported a forecast analysis of the distribution of *Anas strepera* in the period between 2081 and 2100.

The plot in Figure 89 - the receiver operating characteristic (ROC) curve for the same data – shows that the training data is AUC=0.577, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would.

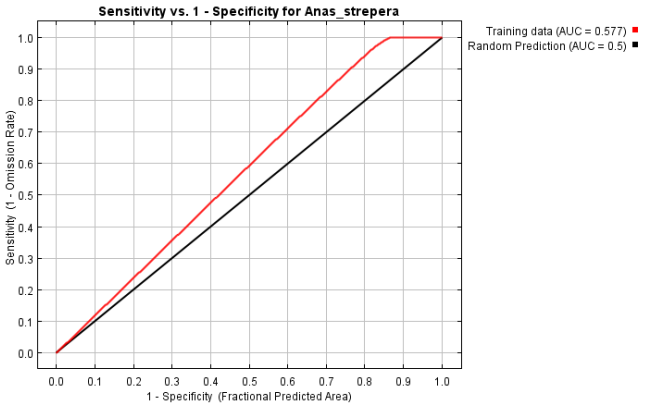

Figure 89: receiver operating characteristic (ROC) curve for the same

Figure 90 is a map that shows the favourable conditions for *Anas strepera*. The locations used for training (white dots) are in North America, in Europe, in Japan, and some spots are distributed also in central Asia. The conditions typical of places where this species is found (the green areas) are placed in North America, Europe, central Asia and China (Southeast Asia). Longitudinally further east, in Asia, the conditions are light blue, meaning conditions that are not favourable but could become.

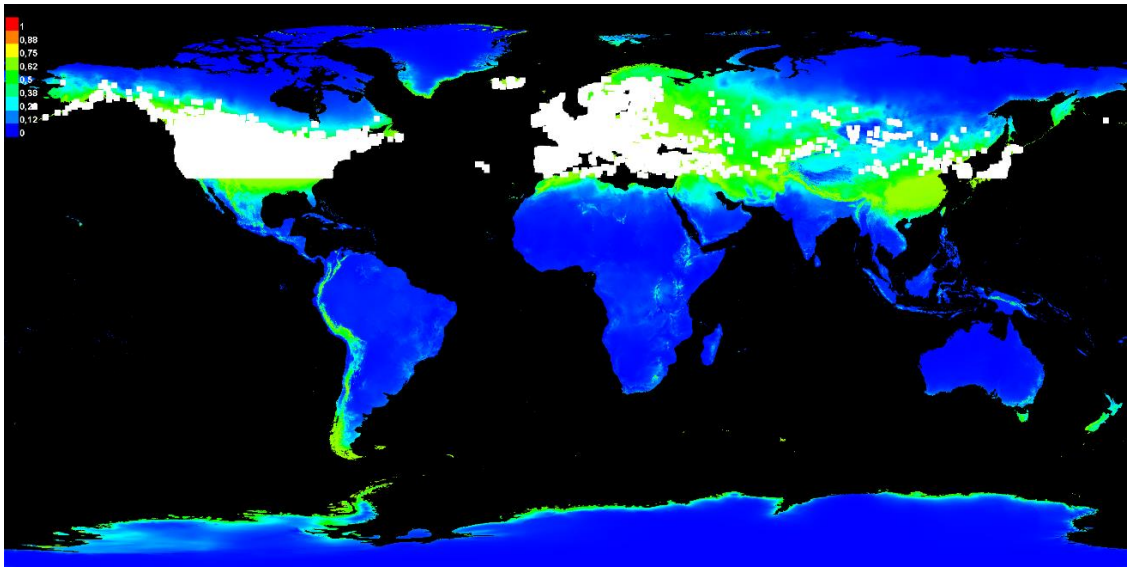

Figure 90: Representation of the model for Anas strepera (2021-2040)

The map in Figure 91 shows the projection of the model for *Anas strepera* onto the environental variables (2021-2040). The locantions used for training are approximately in the same spots of Figure 90 (white dots are distributed in North America, Europe, Japan and more dispersedly in the Asian contintent). The favorable conditions compared to Figure 90 have increased: in North America the favorable conditions have slightly increased northwards and southwards; in Europe favourable conditions have increased eastwards, becoming more distributed in central Asia. As for *Anas acuta*, *Anas crecca*, *Anas penelope*, and *Anas platyrhynchos* (Fig. 19 – 33 – 47 – 62), this species seem to be able to tolerate colder climate conditions, hypothetically being able to adapt to climatic conditions further north.

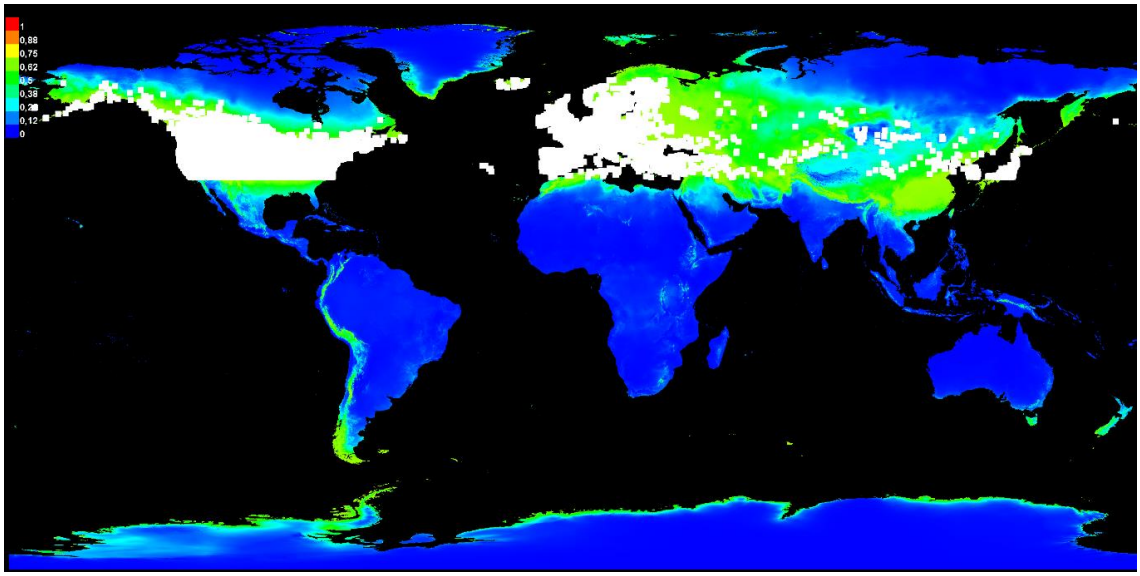

Figure 91: projection of the Maxent model for Anas strepera onto the environmental variables (2021-2040)

The following picture compares the environmental similarity of variables in the projection 2021-2040 to the environmental data used for training the model (Fig. 92).

In Figure 92, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while there are blue positive values. In the Venice lagoon (North-East Italy), the value tends between 30.4 and 50.6. It means that the values in this point are not novels, yet they are not extremely equal to the median values in layers

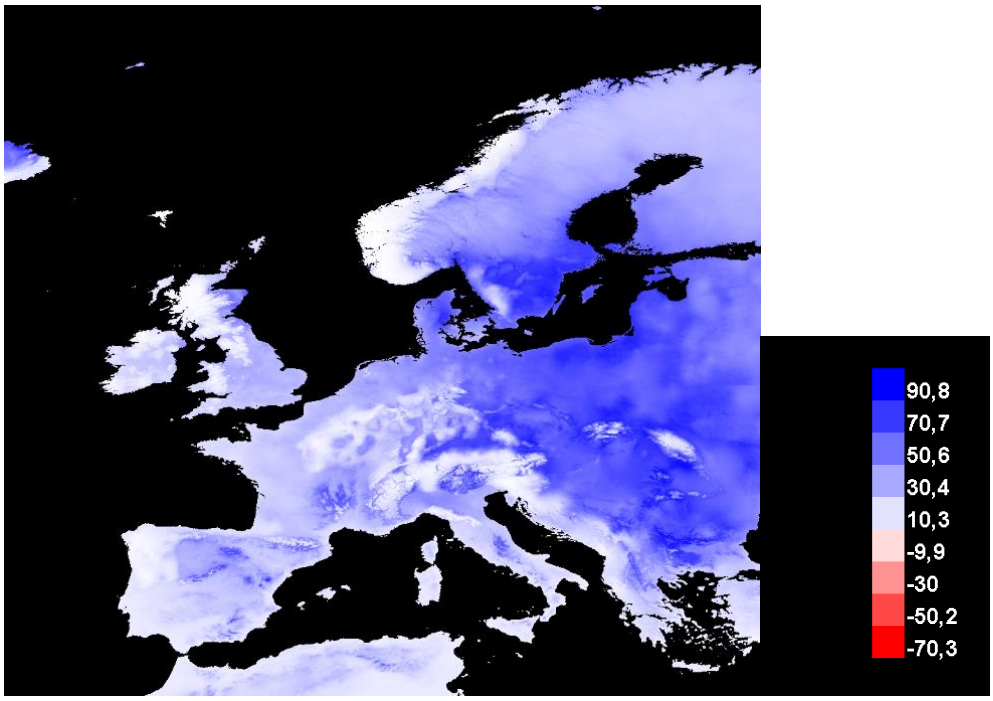

Figure 92: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Anas strepera* for the future predictions 2021-2040 (Fig.93). It can be noticed that it is similar to the jackknife tests of *Anas acuta*, *Anas crecca*, *Anas penelope*, and *Anas platyrhynchos* (Fig. 21 – 35 - 49 – 64): the single most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Anas strepera*, contrary to *Anas querquedula*, wherein its single most efficient variable for the distribution prediction was tmax.12 (Fig. 79). Another variable that contains useful information for the prediction of the distribution of this species in the future is bio.11 (mean temperature of the coldest quarter), and tmax.12. While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.19 (precipitation of coldest quarter) is not a very useful information for this species. On the other hand, the environmental variable that decreases the gain the most when it is omitted is tmax.2 which therefore appears to have the most information that isn't present in the other variables (light blue line). Therefore, also for *Anas strepera*, temperature plays a major role in the physiological well-being of this species, unlike rainfall, which does not impact this species very much.

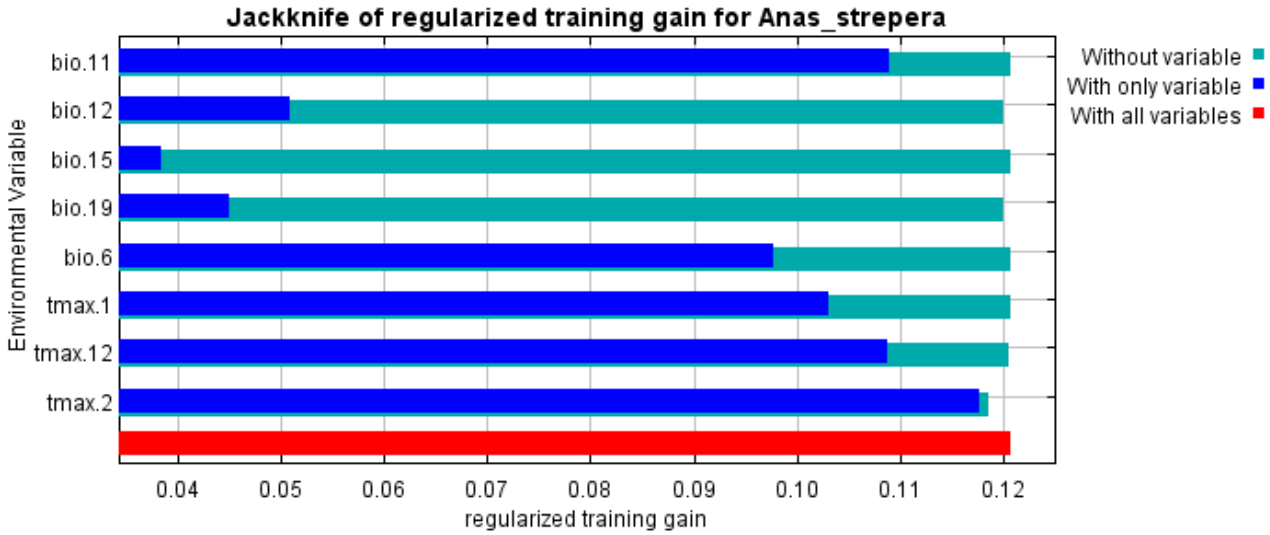

Figure 93: Jackknife of regularized training gain for Anas strepera (2021-2040)

As it was mentioned, temperature plays an important role for *Anas strepera*, as can be noticed from the following response curves. In Figure 94, it can be seen that the temperature range in which the probability of finding *Anas strepera* is highest is between -5°C and 19°C, while it is noticeable that in the coldest quarter, the average temperature range in which the chance of finding *Anas strepera* is higher is between – 10°C and 10°C (Fig.95).

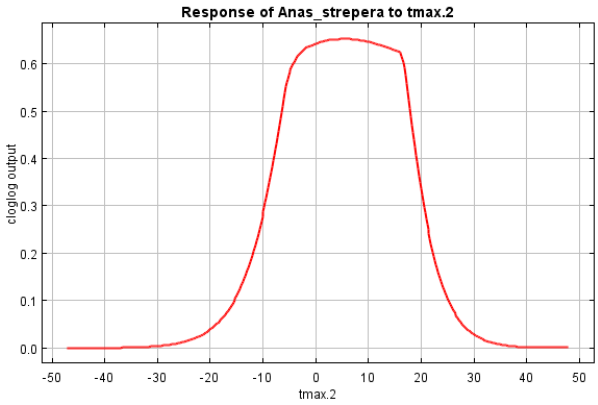

Figure 94: Response of Anas strepera to tmax.2

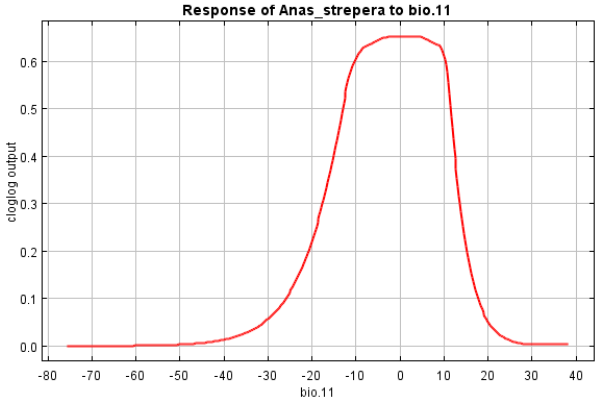

Figure 95: Response of Anas strepera to bio.11

Anas strepera prediction between 2081-2100

The plot in Figure 96 - the receiver operating characteristic (ROC) curve for the same data – shows that the training data is AUC=0.577, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would.

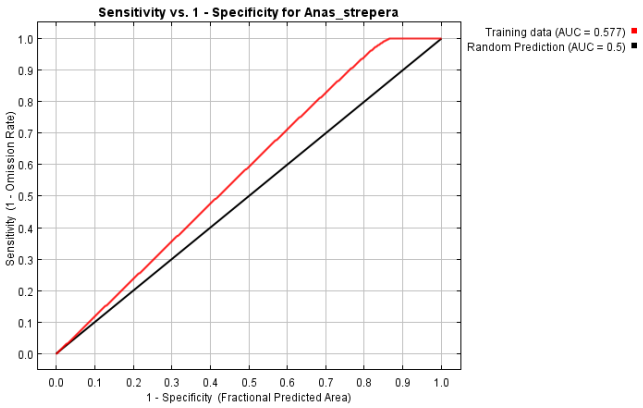

Figure 96: receiver operating characteristic (ROC) curve for the same

The map in Figure 97 shows the favourable conditions of *Anas strepera*. The locations used for training (white dots) are concentrated in North America, Europe, and moving towards east there are some spots used for training distributed also in Asia. Green areas are conditions typical to places where the species is found. In the map, favourable conditions are found in North America, Europe, southernmost part of South America (Patagonia) and slightly the west coast of South America. Conditions are favourable also in the south-east of the Asian continent (China). The map in Figure 97 is similar to the representation model of *Anas acuta*, *Anas crecca*, *Anas penelope*, and *Anas platyrhynchos* (Fig. 25 – 39 – 54 – 69).

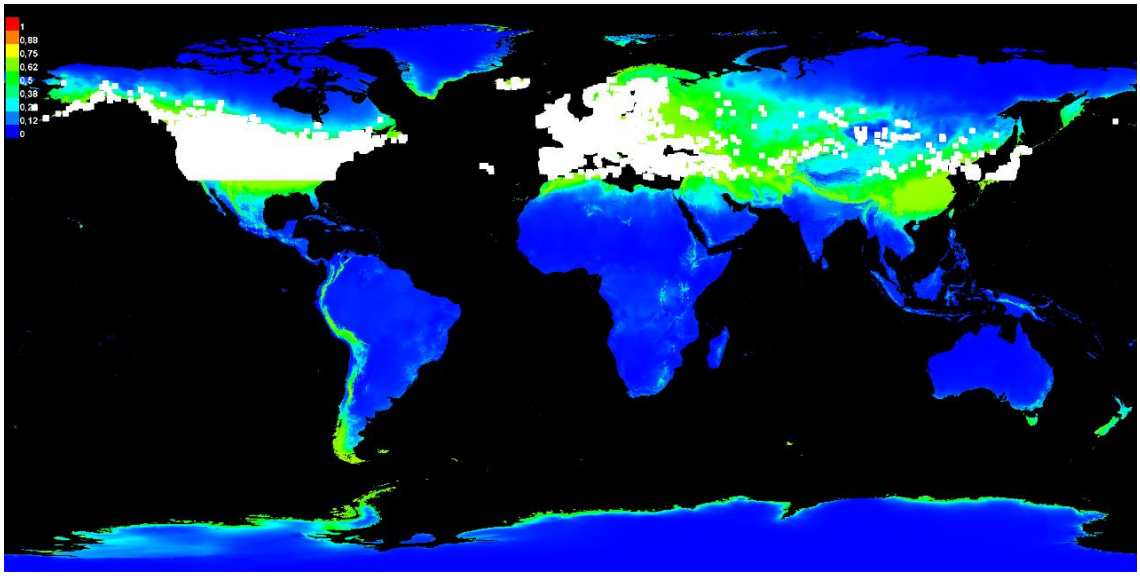

Figure 97: Representation of the model for Anas strepera (2081-2100)

The following map shows projection of the model for *Anas strepera* onto the environental variables (2081-2100) (Fig.98). As can benoticed, compared to map in Figure 97, favourable conditions for

this species have shifted northwards. For instance, the southest part of North America has shifted to light blue, indicating that the conditions will not be favourable anymore for *Anas strepera* in those areas, while the northernmost territories indicate that conditions are favourable.

In the Eurasian continent it can be seen a similar situation: the southernmost territories witness a change from green (favourable conditions) to light blue (no longer favourable conditions). Whereas, further north and towards the central-eastern part there is a clear improvement in conditions for *Anas strepera*.

This could mean that, in the future, suitable conditions for this species will be found further north, hypothetically affecting the migratory route of this species, thus causing potential damage not only to the species but also to the ecological balances that migration ensures.

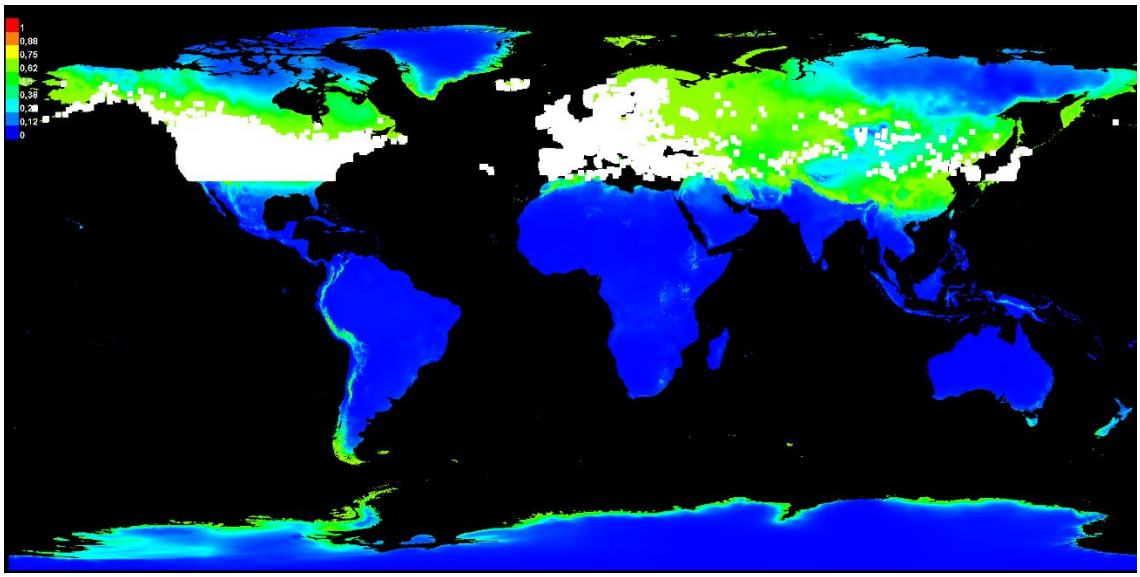

Figure 98: projection of the Maxent model for Anas strepera onto the environmental variables (2081-2100)

The following picture compares the environmental similarity of variables in the projection 2081-2100 to the environmental data used for training the model (Fig. 99).

In Figure 99, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while there are blue positive values. The map shows a change in the Venice lagoon area, the value has decreased compared to the model for 2021-2040 (Fig. 92) it is between 13,3 and 31,8, meaning that the value is approaching negative. Negative values mean “novel climate”, as so during projections, predicted variables can assume values outside the training range.

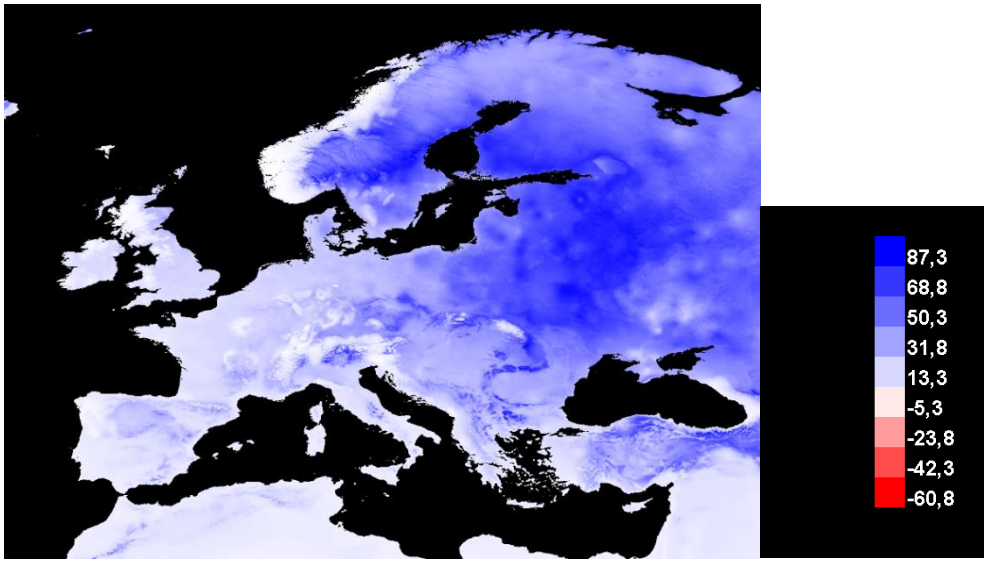

Figure 99: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Anas strepera* for the future predictions 2081-2100 (Fig.100). It can be noticed that it is similar to the jackknife tests of *Anas acuta*, *Anas crecca*, *Anas penelope*, and *Anas platyrhynchos*, and also to the jackknife test of *Anas strepera* for the future predictions 2021-2040 (Fig. 28 – 42 – 57 – 72 – 93): the single most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Anas strepera*, contrary to *Anas querquedula* (Fig. 86), wherein its single most efficient variable for the distribution prediction was tmax.12. Another variable that contains useful information for the prediction of the distribution of this species in the future is bio.11 (mean temperature of the coldest quarter), and tmax.12. While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.19 (precipitation of coldest quarter) is not a very useful information for this species. On the other hand, the environmental variable that decreases the gain the most when it is omitted is tmax.2 which therefore appears to have the most information that isn't present in the other variables (light blue line).
Therefore, also for *Anas strepera*, temperature plays a major role in the physiological well-being of this species, unlike rainfall, which does not impact this species very much.

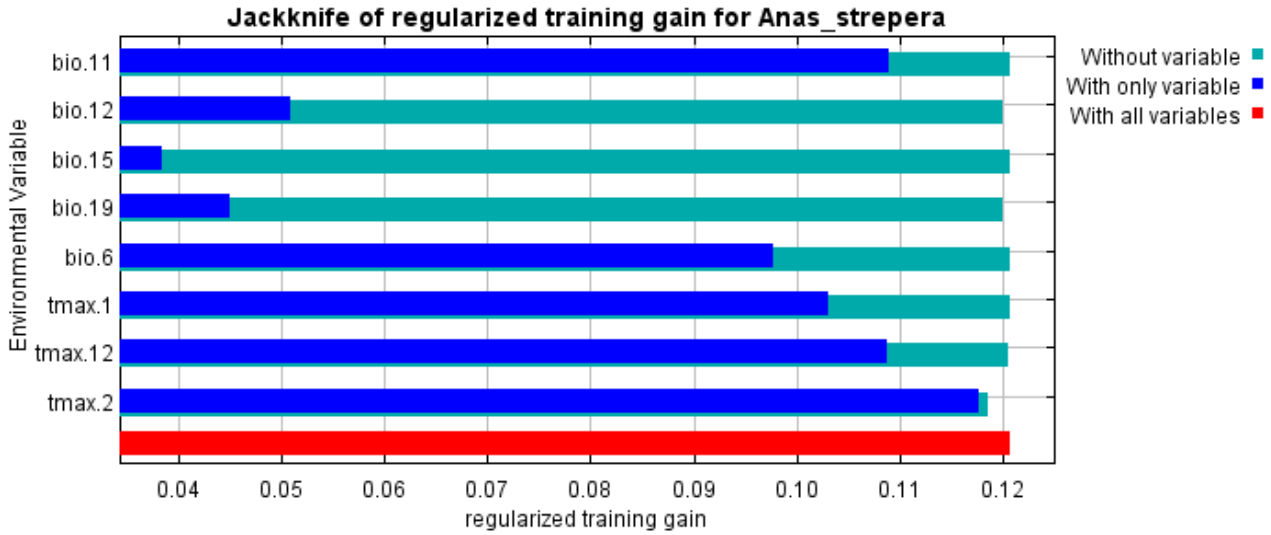

Figure 100: Jackknife of regularized training gain for Anas strepera (2081-2100)

As it was mentioned, temperature plays an important role for *Anas strepera*, as can be noticed from the following response curves. In Figure 101, it can be seen that the temperature range in which the probability of finding *Anas strepera* is highest is between -5°C and 18°C, while it is noticeable that in the coldest quarter (bio.11), the average temperature range in which the chance of finding *Anas strepera* is higher is between – 10°C and 10°C (Fig.102). As can be seen from the graph in Figure 103, on the other hand, rainfall plays an important but secondary role in the well-being of this species: the range in which the probability of finding *Anas strepera* is greatest goes from 200 to 2800, after which the line becomes constant.

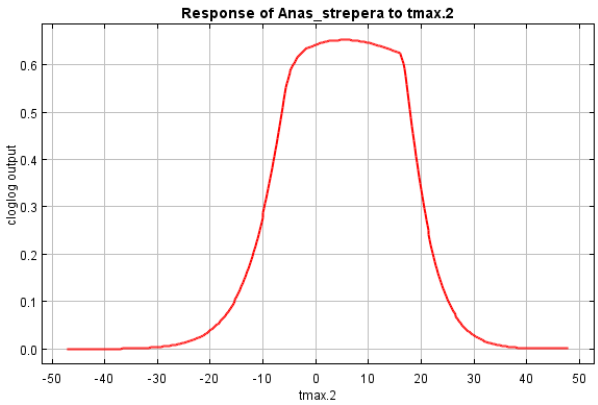

Figure 101: Response of Anas strepera to tmax.2

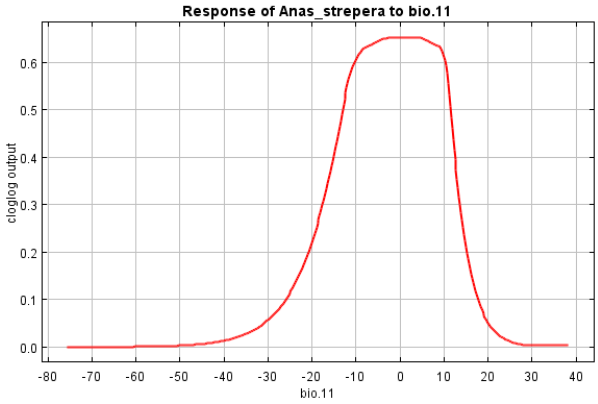

Figure 102: Response of Anas strepera to bio.11

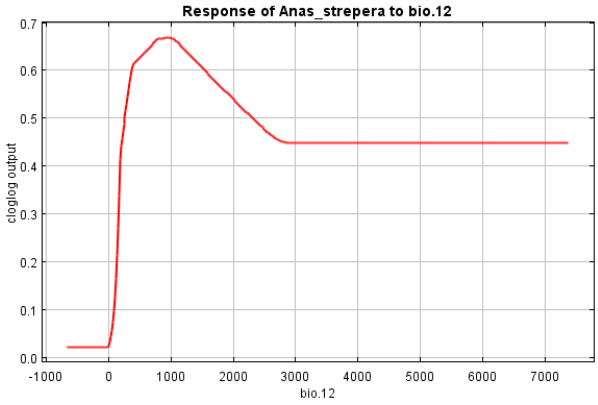

Figure 103: Response of Anas strepera to bio.12

Aythya ferina prediction between 2021-2040

Below is a forecast analysis of the distribution of the *Aythya ferina* species in the future period between 2021 and 2040. Subsequently, it will be reported a forecast analysis of the distribution of *Aythya ferina* in the period between 2081 and 2100.

The plot in Figure 104 - the receiver operating characteristic (ROC) curve for the same data – shows that the training data is AUC=0.664, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would.

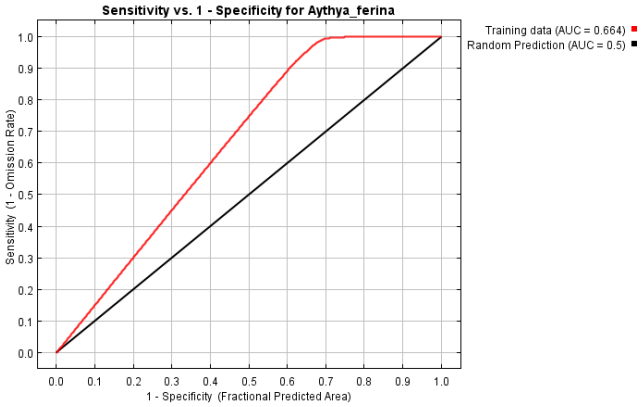

Figure 104: receiver operating characteristic (ROC) curve for the same

Figure 105 shows the representation of the model for *Aythya ferina*. Differently from the other representation models (Fig. 18 – 32 – 46 – 61 – 76 - 90), white dots (locations used for training) are scarcely present in North America, while in Europe, Japan and partly in central Asia there are locations used for training. Green areas, namely conditions typical where *Aythya ferina* is found, can be seen in North America mainly on the east and west coast (in the centre instead the conditions are favourable tending to light blue), in Europe, in China in the south-easternmost part of the Asian continent, and in the southernmost area of South America.

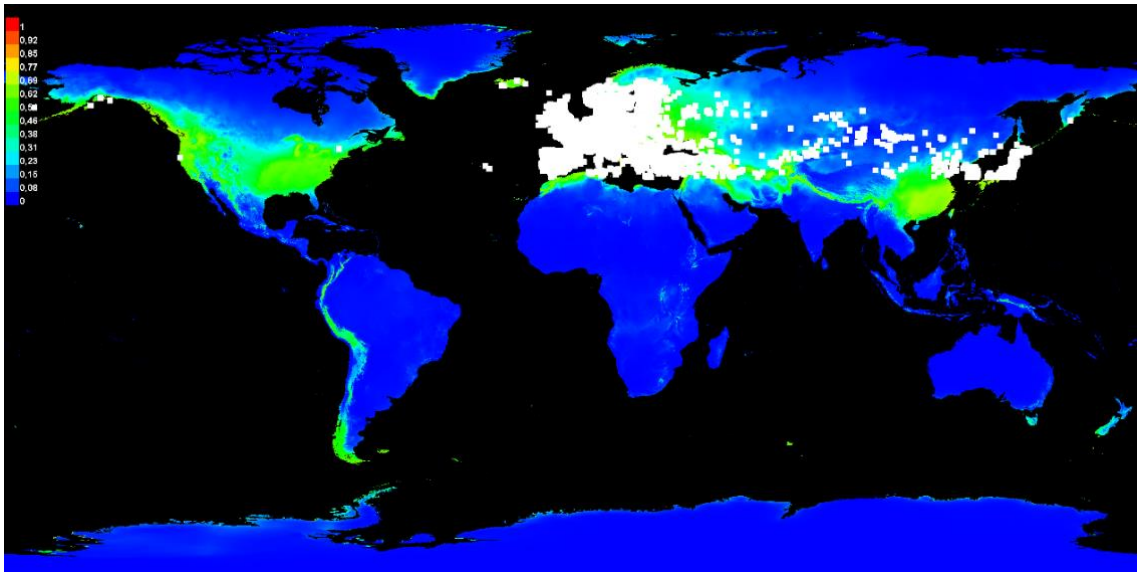

Figure 105: Representation of the model for Aythya ferina (2021-2040)

Figure 106 (projection of the Maxent model for *Aythya ferina* onto environmental variables) is quite similar to Figure 105: favourable conditions for this species are found on the east and west coast of North America, in Europe and in the south-easternmost part of the Asian continent, although they are slightly worse than in the previous map (Fig. 105). Green areas are found also in the southernmost part of South America. Conditions in the north-eastern part of Europe become more favourable, without however reaching optimal conditions for this species.

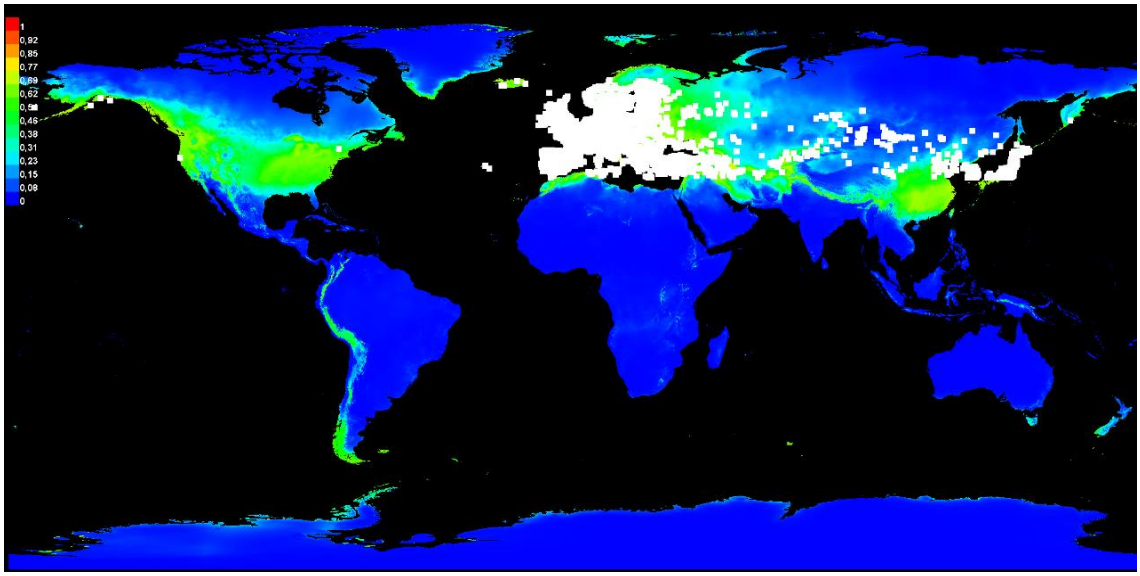

Figure 106: projection of the Maxent model for Aythya ferina onto the environmental variables (2021-2040)

The following picture compares the environmental similarity of variables in the projection 2021-2040 to the environmental data used for training the model (Fig. 107).

In Figure 107, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while there are blue positive values. In the Venice lagoon (North-East Italy), the value tends to 42,7. It means that the values in this point are not novels, yet they are not extremely equal to the median values in layers.

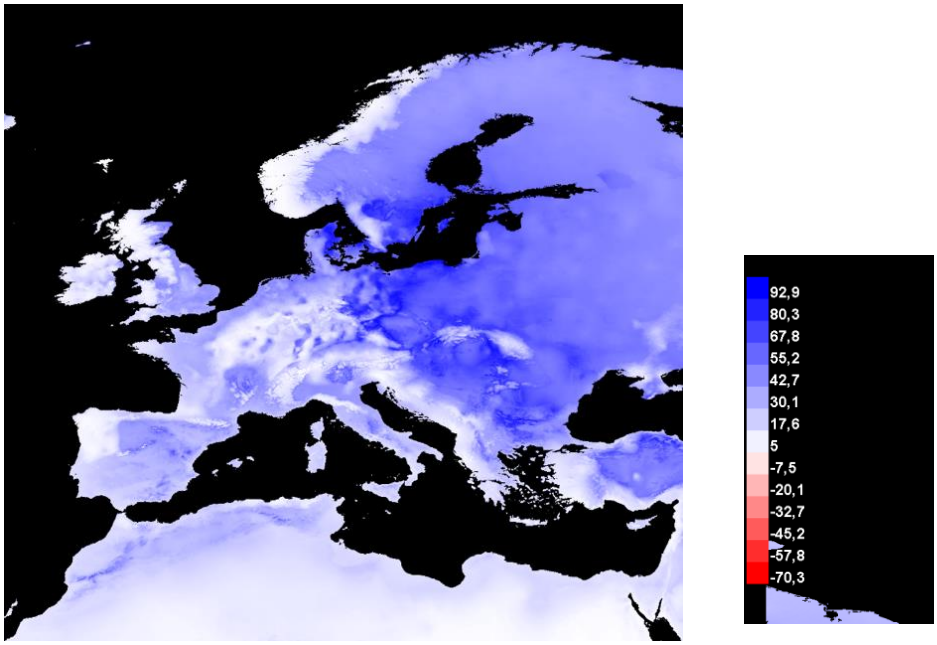

Figure 107: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Aythya ferina* for the future predictions 2021-2040 (Fig.108). It can be noticed that this time it is slightly different from the jackknife tests of *Anas acuta*, *Anas crecca*, *Anas penelope*, and *Anas*

platyrhynchos, (wherein their single most efficient variable for the distribution prediction was tmax.2.) (Fig. 21 – 35 – 48 – 64), indeed, as the jackknife test of *Anas querquedula* (Fig. 79), the single most efficient variable for the distribution prediction is tmax.12 (blue line), it means that this variable contains useful information to estimate the distribution of *Aythya ferina*. However, other variables that contain useful information for the prediction of the distribution of this species in the future are tmax.2 and bio.11 (mean temperature of the coldest quarter). While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.12 (annual precipitation) is not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain really useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is bio.12 (annual precipitation), which therefore appears to have the most information that isn't present in the other variables. Therefore, also for *Aythya ferina*, temperature plays a major role in the physiological well-being of this species.

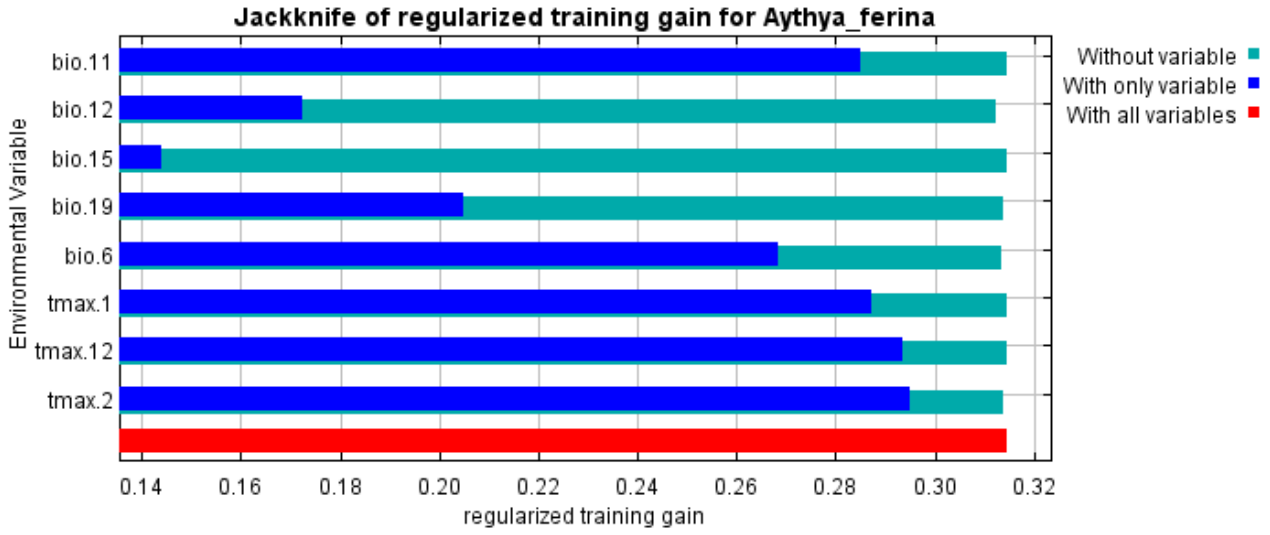

Figure 108: Jackknife of regularized training for Aythya ferina (2021-2040)

As was mentioned, temperature plays an important role for *Aythya ferina*, as can be noticed from the following response curves. In Figure 109, it can be seen that the temperature range in which the probability of finding *Aythya ferina* is highest is between 0°C and 15°C, while it is noticeable that in the coldest quarter (bio.11), the average temperature range in which the chance of finding *Aythya ferina* is higher is between – 5°C and 15°C (Fig.110). Therefore, compared to other species, *Aythya ferina* favours milder temperatures, tolerating the cold less.

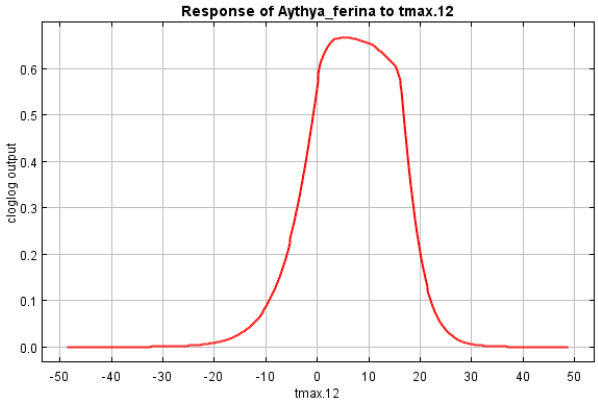

Figure 109: Response of Aythya ferina to tmax.12

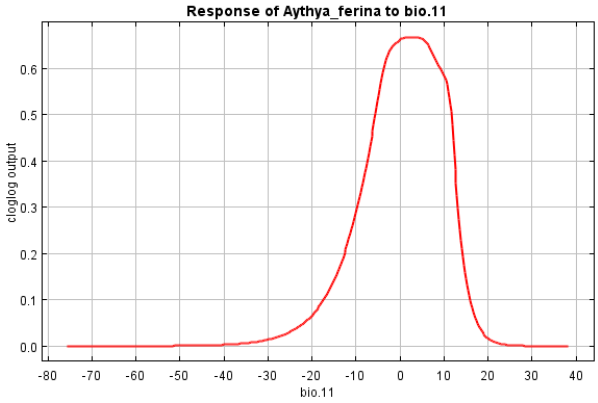

Figure 110: Response of Aythya ferina to bio.11

Aythya ferina prediction between 2081-2100

As for the 2081-2100 predictions for *Aythya ferina*, the graph in Figure 111 shows that the training data is AUC=0.664, thus higher than AUC=0.5 (random prediction). It means that the model performs better than a random model would.

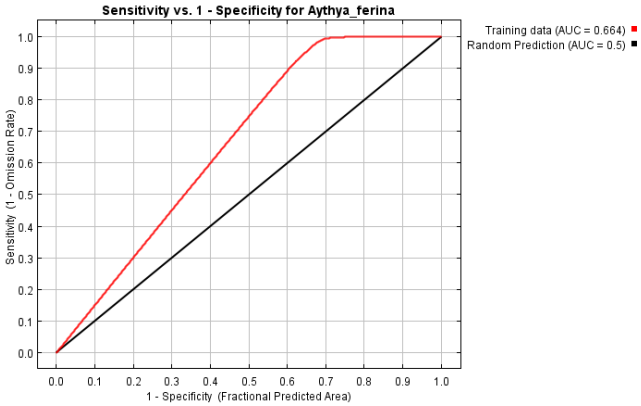

Figure 111: receiver operating characteristic (ROC) curve for the same

The map in Figure 112 shows the favourable conditions of *Aythya ferina*. The locations used for training (white dots) are concentrated in Europe, and moving towards east there are some spots used for training distributed also in central Asia and Japan. Green areas are conditions typical to places where the species is found. In the following map, favourable conditions are found in North America

yet mainly on the east and west coasts, in Europe, in Patagonia (southernmost area of South America) and slightly in the west coast of South America. Conditions are favourable also in the south-east of the Asian continent (China).

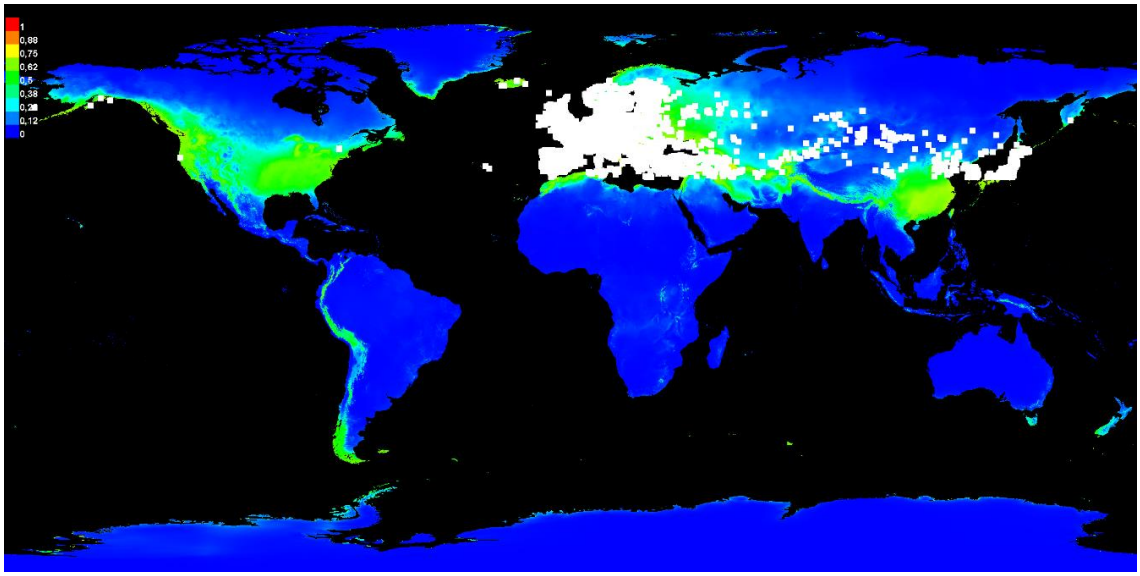

Figure 112: Representation of the model for Aythya ferina (2081-2100)

The following map shows projection of the model for *Aythya ferina* onto the environental variables (2081-2100) (Fig.113). As it can be noticed, compared to map in Figure 96, more favourable conditions for this species have shifted northwards. For instance, in North America green favourable conditions have increas and these are more distributed on the territory, more than just that, moving northwards, it can be seen that conditions increase even if they do not reach favourable conditions (gree ones).

In the Eurasian continent it can be seen a similar situation: further north between Europe and Asia the conditions increease considerably becoming favourable, and towards the central-eastern part of Asia there is a clear improvement in conditions for *Aythya ferina*, the map in fact takes on a light blue colouring, compared to before, when it was blue.

This could mean that, in the future, suitable conditions for this species will be found further north, hypothetically affecting the migratory route of this species, thus causing potential damage not only to the species itself but also to the ecological balances that migration ensures.

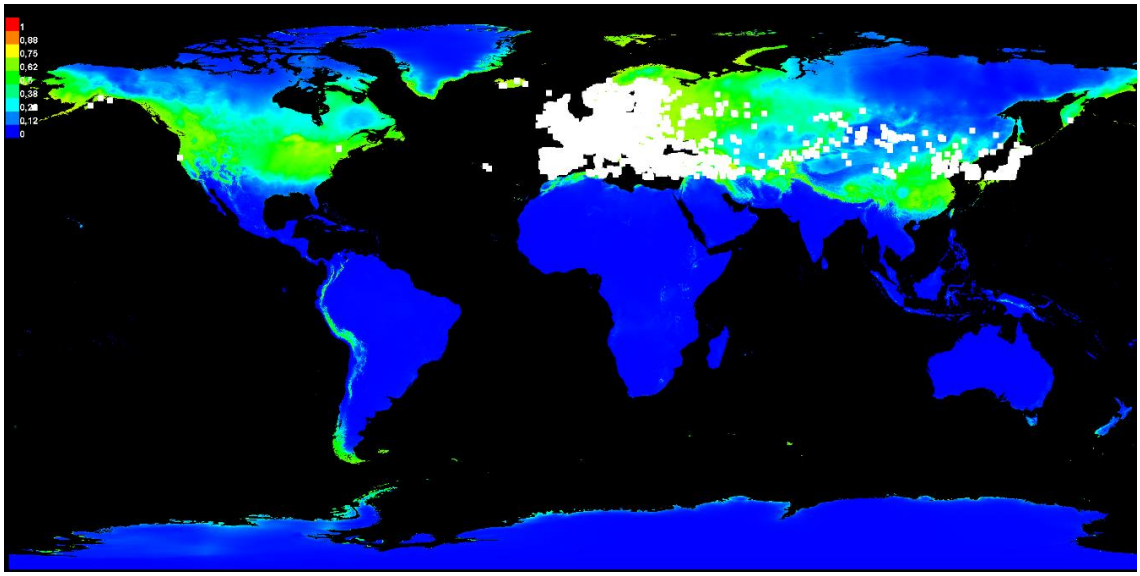

Figure 113: projection of the Maxent model for Aythya ferina onto the environmental variables (2081-2100)

The following picture compares the environmental similarity of variables in the projection 2081-2100 to the environmental data used for training the model (Fig. 114).

In Figure 114, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while there are blue positive values. The map shows a change in the Venice lagoon area, the value has decreased compared to the model for 2021-2040 (Fig. 107), it is around 35,8, meaning that the value is approaching negative. Negative values mean "novel climate", as so during projections, predicted variables can assume values outside the training range.

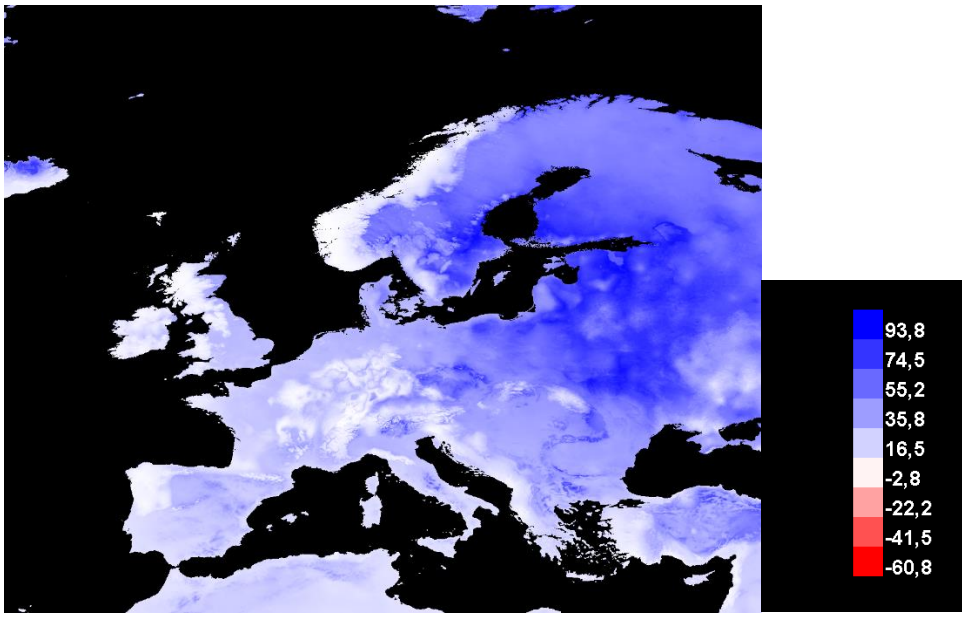

Figure 114: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Aythya ferina* for the future predictions 2081-2100 (Fig.115). It can be noticed that it is similar to the

jackknife tests of *Anas acuta*, *Anas crecca*, *Anas penelope*, *Anas platyrhynchos* and *Anas strepera*, (Fig. 28 – 42 – 57 – 72 – 100) the most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Aythya ferina*. Other variables that contain useful information for the prediction of the distribution of this species in the future are tmax.2 and bio.11 (mean temperature of the coldest quarter). While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.12 (annual precipitation) is not a very useful information for this species. On the other hand, the environmental variable that decreases the gain the most when it is omitted is bio.12 which therefore appears to have the most information that isn't present in the other variables (light blue line).

Therefore, also for *Aythya ferina*, temperature plays a major role in the physiological well-being of this species, unlike rainfall, which does not impact this species very much

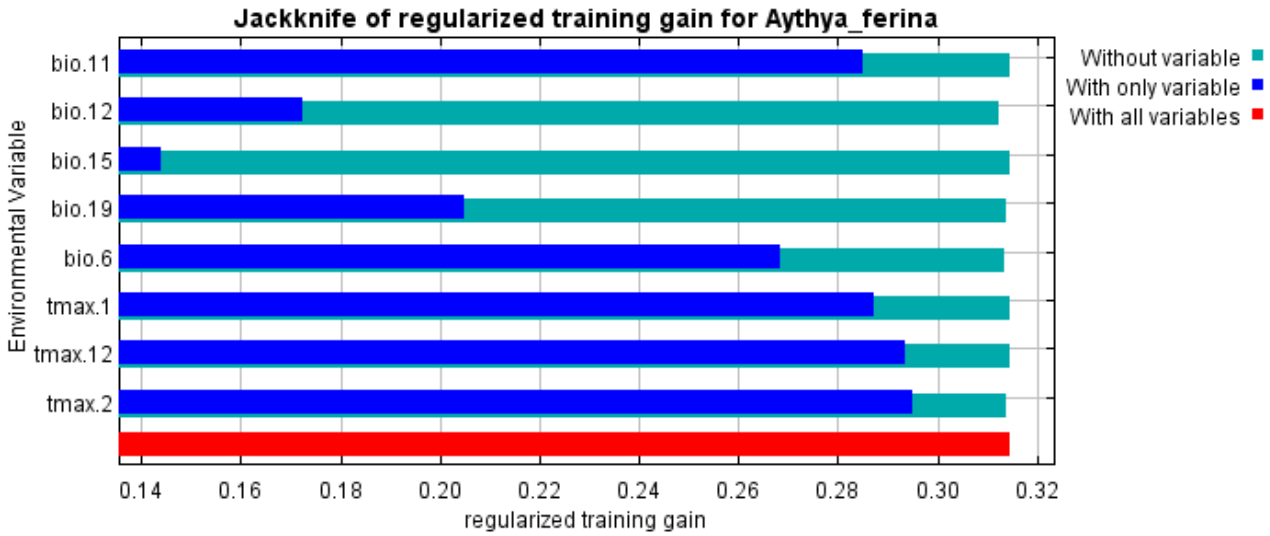

Figure 115: Jackknife of regularized training gain for Aythya ferina (2081-2100)

As was mentioned, temperature plays an important role for *Aythya ferina*, as can be noticed from the following response curves. In Figure 116, it can be seen that the temperature range in which the probability of finding *Aythya ferina* is highest is between 0°C and 15°C, while it is noticeable that in the coldest quarter (bio.11), the average temperature range in which the chance of finding *Aythya ferina* is higher is between – 5°C and 10°C (Fig.117).

As can be seen from the graph in Figure 118, on the other hand, rainfall plays an important but secondary role in the well-being of this species: the range in which the probability of finding *Aythya ferina* is greatest goes from 600 to 3000, after which the line becomes constant.

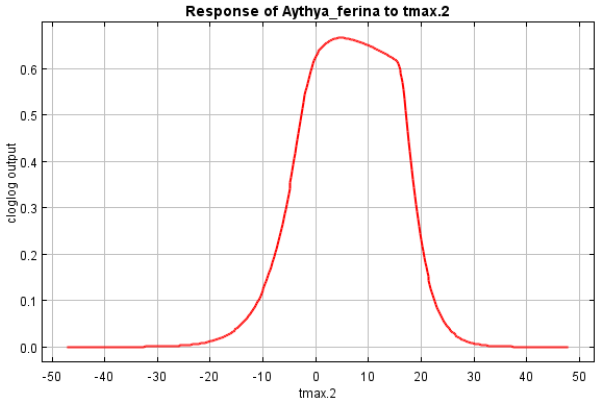

Figure 116: Response of Aythya ferina to tmax.2

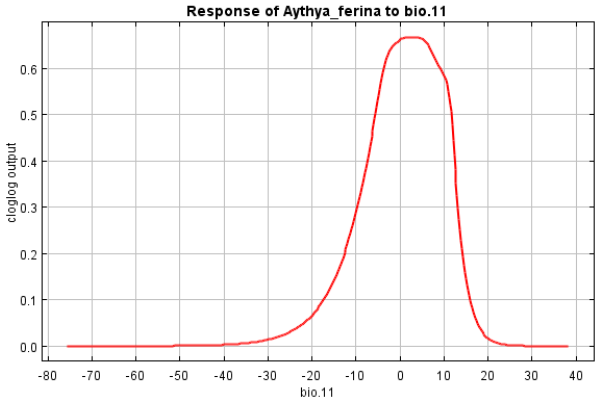

Figure 117: Response of Aythya ferina to bio.11

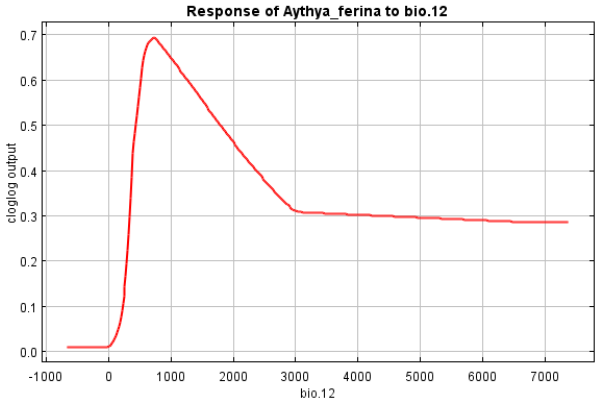

Figure 118: Response of Aythya ferina to bio.12

Aythya fuligula prediction between 2021-2040

Below is a forecast analysis of the distribution of the *Aythya fuligula* species in the future period between 2021 and 2040. Subsequently, it will be reported a forecast analysis of the distribution of *Aythya fuligula* in the period between 2081 and 2100.

The plot represented in figure 119 verifies how much the model analysis is accurate. In this case, the training data in the graph below of Figure 119 is AUC = 0.630, thus higher than AUC = 0.5 (random prediction). It means that the model performs better than a random model would.

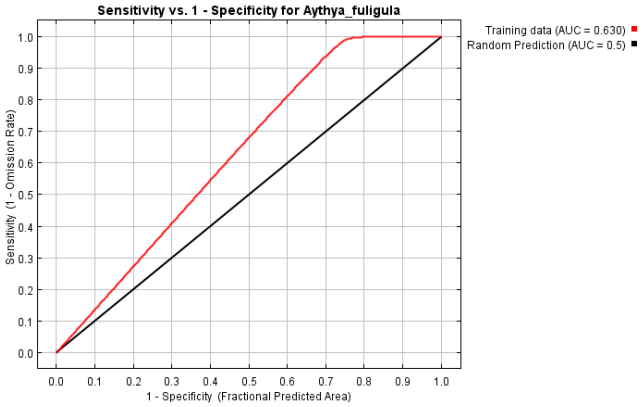

Figure 119: receiver operating characteristic (ROC) curve for the same data

The map on figure 120 is a representation of the model for *Aythya fuligula*. The locations used for training (white dots) are located in Europe, Japan and partly in Asia, while in North America there are fewer locations used for training, mainly on the western and eastern coasts. Favourable conditions are located on the west coast of North America and more distributed on the east coast of North America, in Europe and in southeaster part of Asia. Also, in the southernmost part of South America the conditions seem to be favourable.

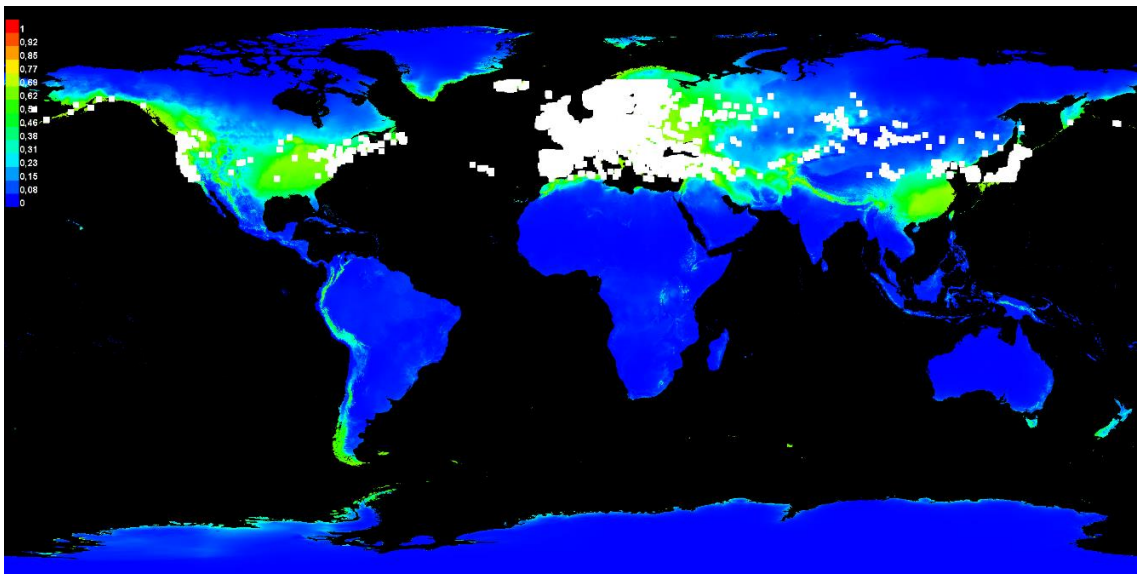

Figure 120: Representation of the model for Aythya fuligula (2021-2040)

Figure 121 (projection of the Maxent model for *Aythya fuligula* onto environmental variables) is quite similar to Figure 120: favourable conditions for this species are found on the east and west coast of North America (light blue colours are more distributed, therefore, the conditions for this specie have improved without becoming favourable), in Europe and in the south-easternmost part of the Asian continent, although they are slightly worse than in the previous map (Fig. 120).

The map in Figure 121 is similar to the predicted favourable conditions of *Anas querquedula* (Fig. 77). Green areas are found also in the southernmost part of South America. Conditions in the north-eastern part of Europe become more favourable, without however reaching optimal conditions for this species.

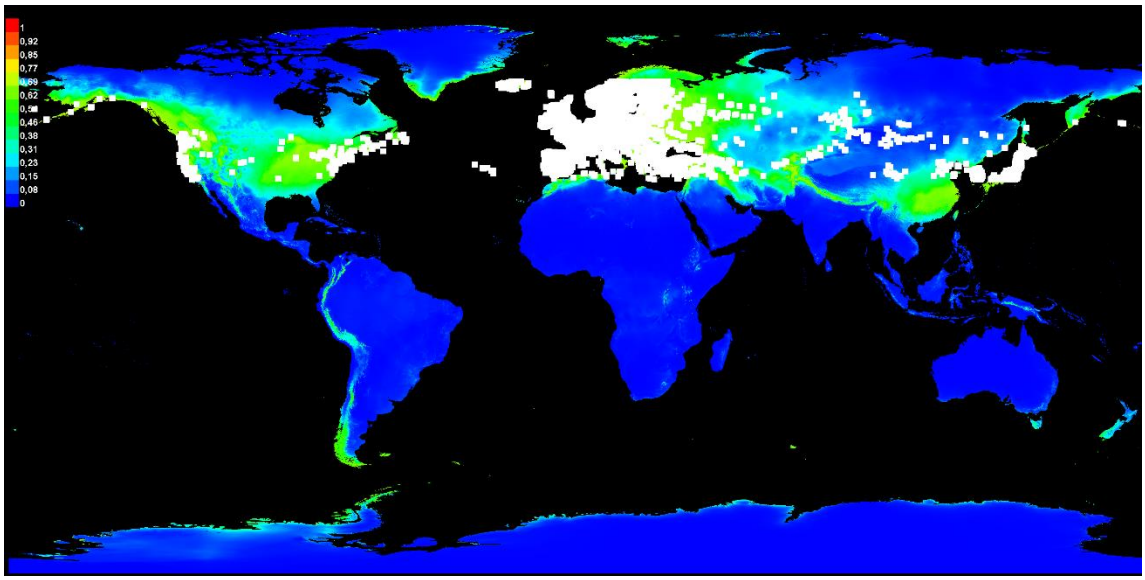

Figure 121: projection of the Maxent model for Aythya fuligula onto the environmental variables (2021-2040)

The following picture compares the environmental similarity of variables in the projection 2021-2040 to the environmental data used for training the model (Fig.122).

In Figure 122, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while there are blue positive values. In the Venice lagoon (North-East Italy), the value tends to 30,2. It means that the values in this point are not novels, yet they are not extremely equal to the median values in layers.

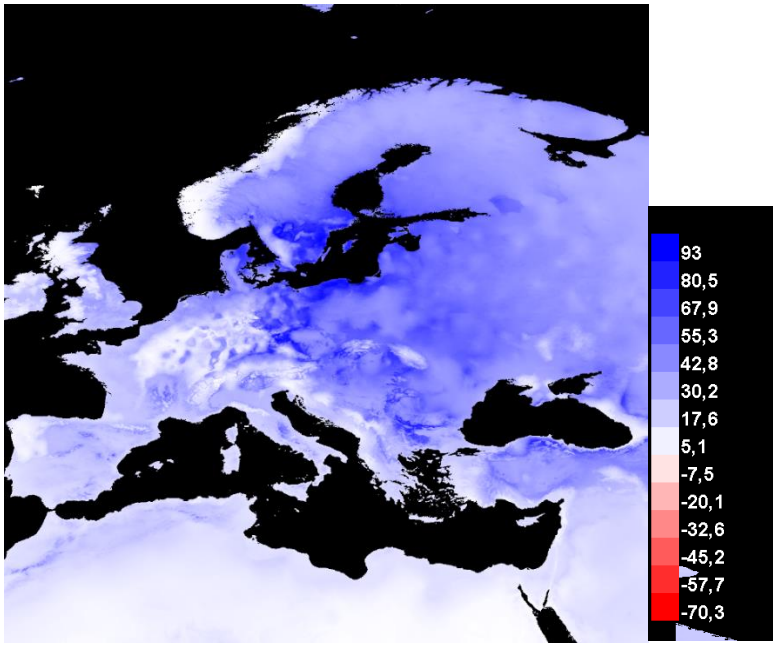

Figure 122: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Aythya fuligula* for the future predictions 2021-2040 (Fig.123). It can be noticed that plot time shows that the single most efficient variable for the distribution prediction, as for *Anas acuta*, *Anas crecca*, *Anas penelope*, *Anas platyrhynchos*, and *Anas strepera*, is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Aythya fuligula.* (Fig. 21 – 35 – 49 – 64 – 93). However, other variables that contain useful information for the prediction of the distribution of this species in the future are and bio.11 (mean temperature of the coldest quarter), and tmax.2. While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.12 (annual precipitation) is not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain really useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is bio.19 (precipitation of the coldest quarter), which therefore appears to have the most information that isn't present in the other variables. Therefore, also for *Aythya fuligula*, temperature plays a major role in the physiological well-being of this species.

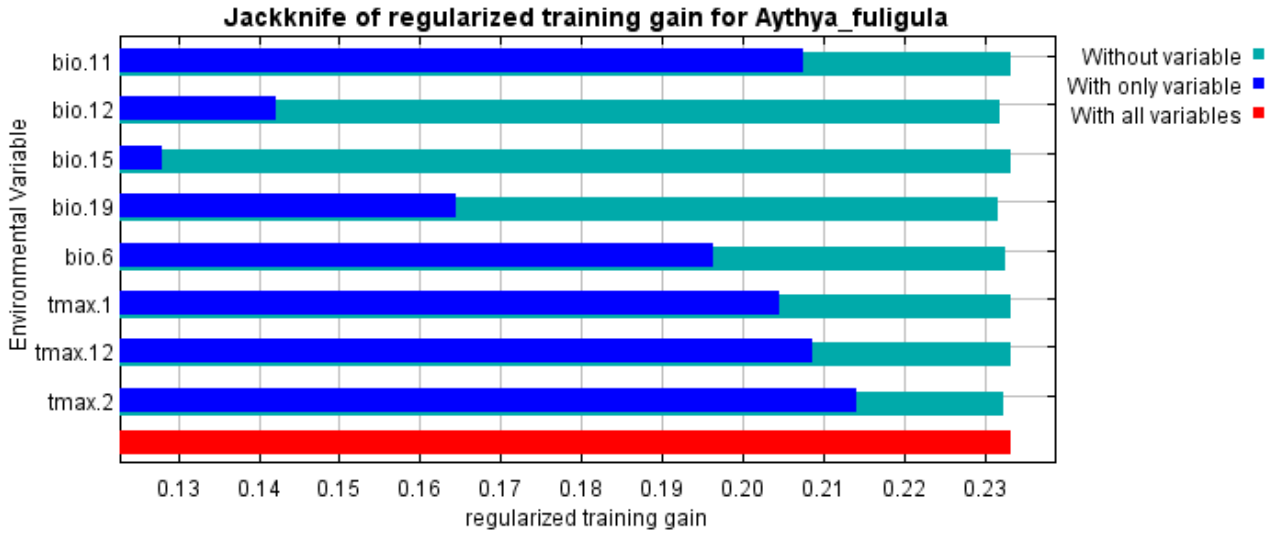

Figure 123: Jackknife regularized training gain for Aythya fuligula (2021-2040)

As was mentioned, temperature plays an important role for *Aythya fuligula*, as can be noticed from the following response curves. In Figure 124, it can be seen that the temperature range in which the probability of finding *Aythya fuligula* is highest is between -5°C and 15°C, while it is noticeable that in the coldest quarter (bio.11), the average temperature range in which the chance of finding *Aythya fuligula* is higher is between – 10°C and 10°C (Fig.125).

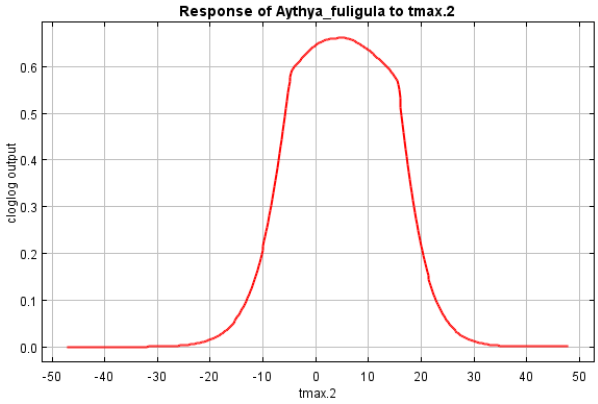

Figure 124: Response of Aythya fuligula to tmax.2

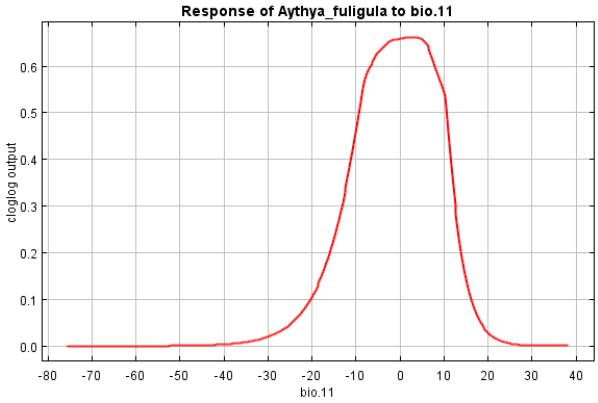

Figure 125: Response of Aythya fuligula to bio.11

Aythya fuligula prediction between 2081-2100

The plot represented in Figure 126 verifies how much the model analysis is accurate. In this case, the training data in the graph below of Figure 126 is AUC = 0.630, thus higher than AUC = 0.5 (random prediction). It means that the model performs better than a random model would.

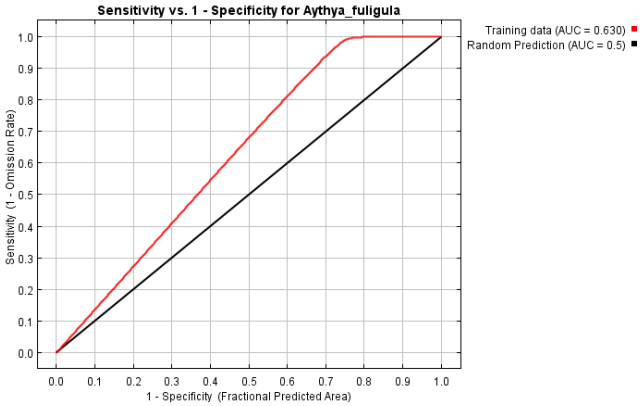

Figure 126: receiver operating characteristic (ROC) curve for the same

The map in Figure 127 shows the favourable conditions of *Aythya fuligula*. The locations used for training (white dots) are placed in Europe, scarcely on the east and west coast of North America, in Japan, and some spots are present also in the central and eastern part of the Asian continent. The favourable conditions shown by the maps in North America are fewer compared to those of the

other Anatids (*Anas acuta, Anas crecca, Anas penelope, Anas platyrhynchos, Anas strepera*, and *Aythya ferina*) (Fig. 25 – 39 – 54 – 69 – 97 - 112). In Europe instead, there are evidences of favourable conditions, as well as (slightly) in China (south-east part of Asia).

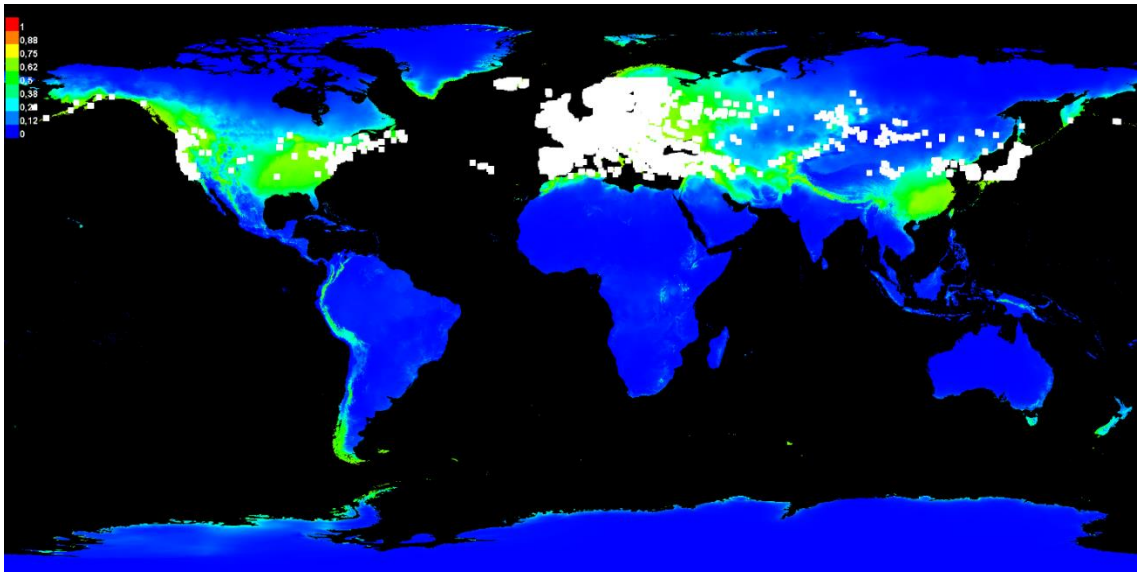

Figure 127: Representation of the model for Aythya fuligula (2081-2100)

The map in Figure 128 shows the projection of the Maxent model for *Aythya fuligula* on the environmental variables. The first difference from Figure 127 is In North America, where favourable conditions increase northwards. Also, in the Eurasian continent the conditions improve, becoming favourable (green) in the northern central area, while towards east, conditions improve for this species, without becoming completely favourable. In south-east Asia, towards China, conditions in the projection map worsen slightly.
As for other species, conditions seem to improve in the time period from 2081 to 2100 northwards, leading to hypothetical changes in migratory routes that may affect the survival of the species and ecosystem balances.

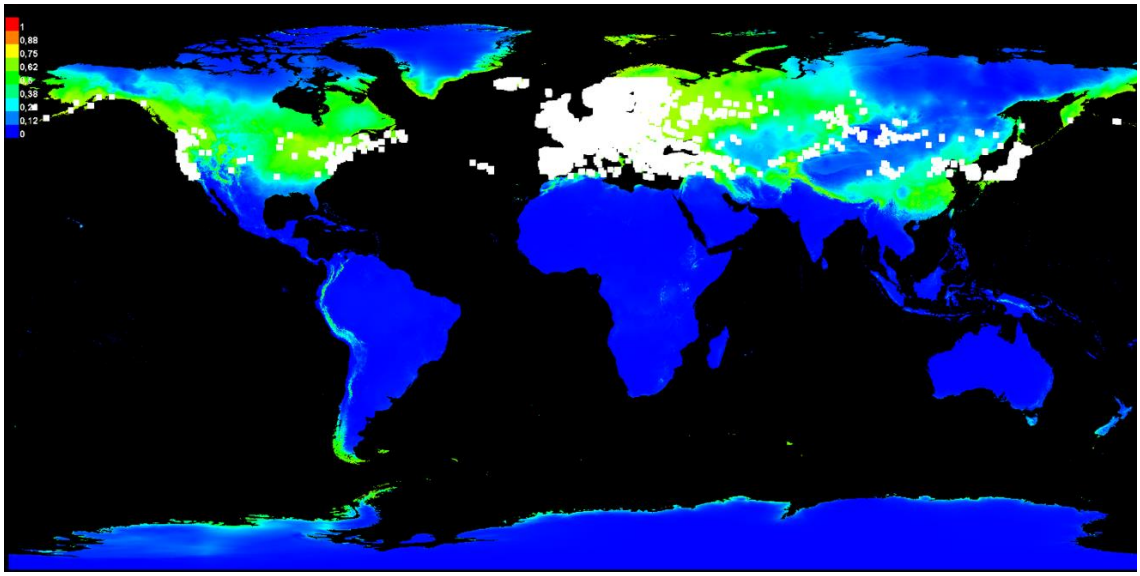

Figure 128: projection of the Maxent model for Aythya fuligula onto the environmental variables (2081-2100)

The following picture compares the environmental similarity of variables in the projection 2081-2100 to the environmental data used for training the model (Figure 129).

In Figure 129, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while there are blue positive values. The map shows a change in the Venice lagoon area, the value has decreased compared to the model for 2021-2040 (Fig. 122), it is around 16,3, meaning that the value is approaching negative. Negative values mean "novel climate", as so during projections, predicted variables can assume values outside the training range.

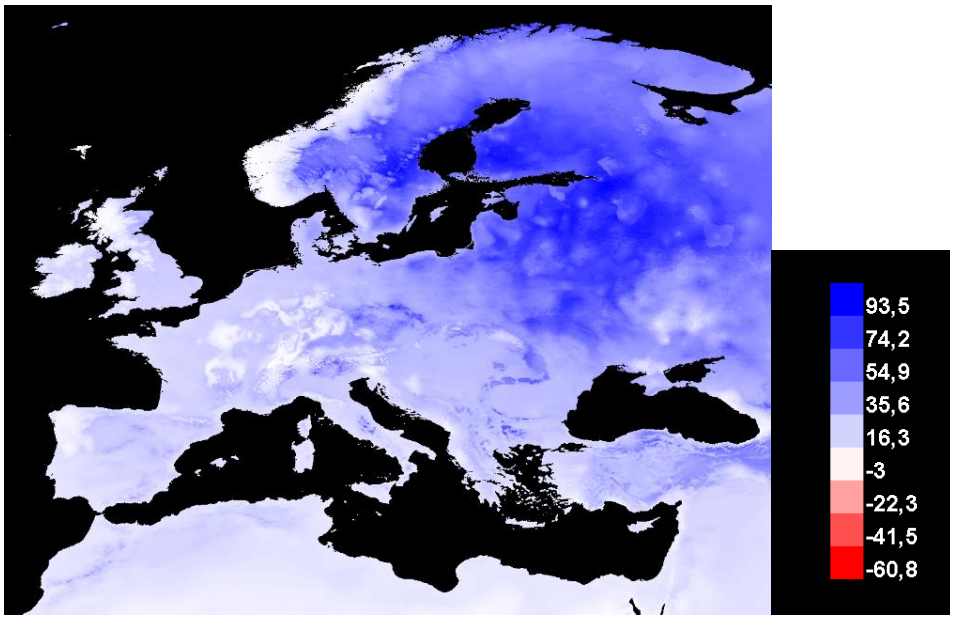

Figure 129: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Aythya fuligula* for the future predictions 2081-2100 (Fig.130). It can be noticed that plot time shows that

the single most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Aythya fuligula*. However, other variables that contain useful information for the prediction of the distribution of this species in the future are and bio.11 (mean temperature of the coldest quarter), and tmax.12. While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.12 (annual precipitation) is not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain really useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is bio.19 (precipitation of the coldest quarter), which therefore appears to have the most information that isn't present in the other variables. Therefore, also for *Aythya fuligula*, temperature plays a major role in the physiological well-being of this species.

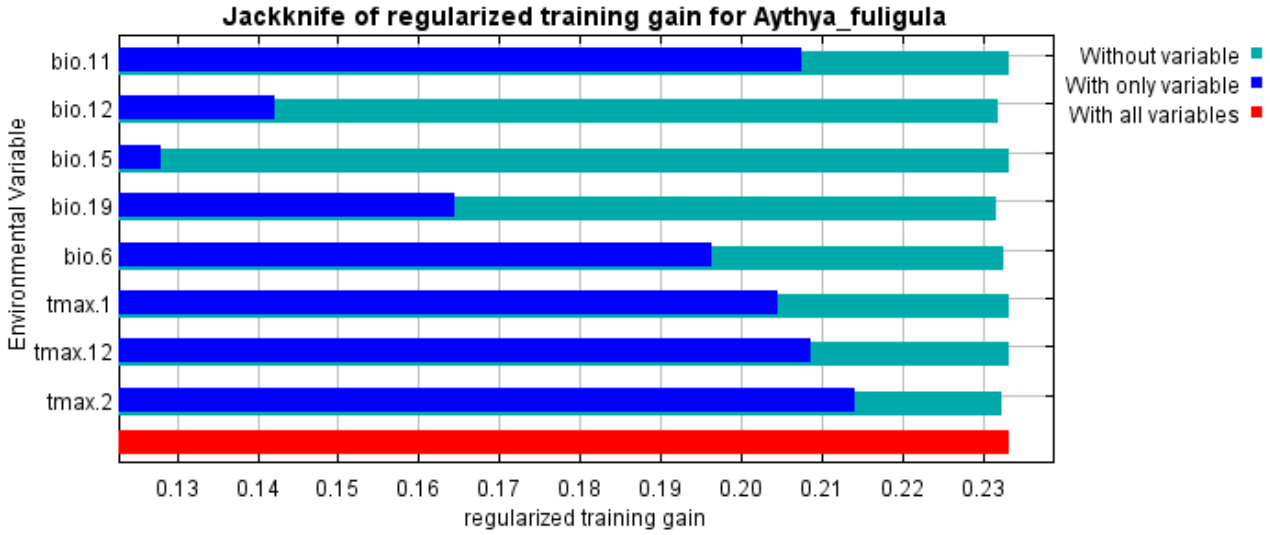

Figure 130: Jackknife of regularized training gain for Aythya fuligula (2081-2100)

As was mentioned, temperature plays an important role for *Aythya fuligula*, as can be noticed from the following response curves. In Figure 131, it can be seen that the temperature range in which the probability of finding *Aythya fuligula* is highest is between -5°C and 15°C, while it is noticeable that in the coldest quarter (bio.11), the average temperature range in which the chance of finding *Aythya fuligula* is higher is between – 10°C and 10°C (Fig.132). As can be seen from the graph in Figure 133, on the other hand, rainfall plays an important but secondary role in the well-being of this species: the range in which the probability of finding *Aythya fuligula* is greatest goes from 500 to 3000, after which the line becomes constant.

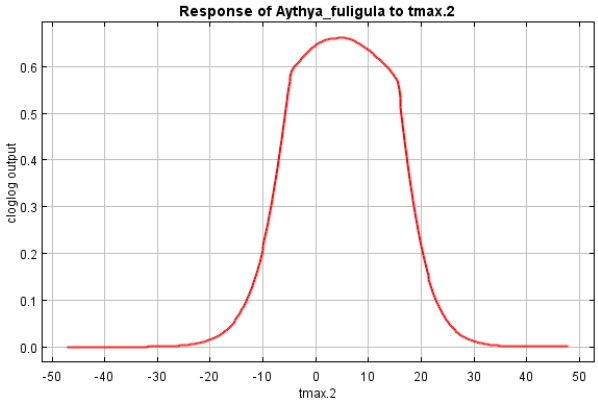

Figure 131: Response of Aythya fuligula to tmax.2

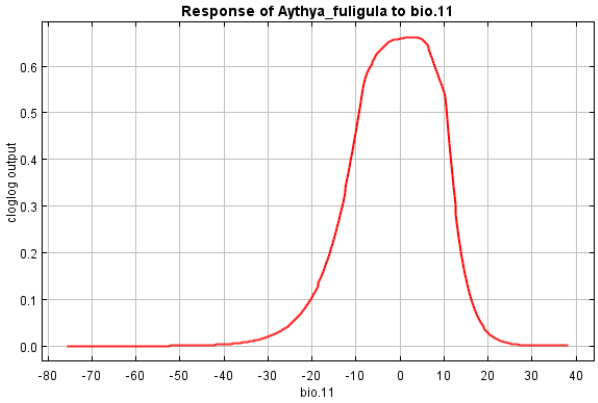

Figure 132: Response of Aythya fuligula to bio.11

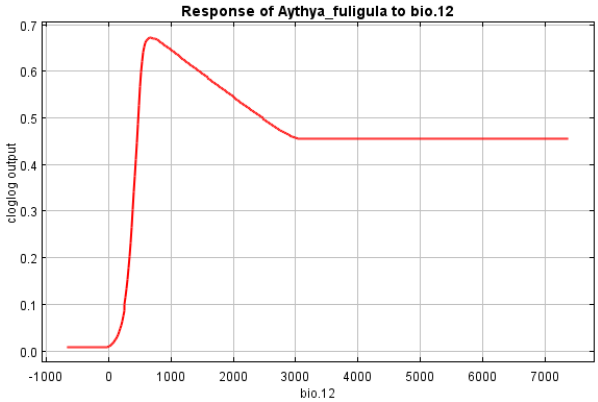

Figure 133: Response of Aythya fuligula to bio.12

Spatula clypeata prediction between 2021-2040

Below is a forecast analysis of the distribution of the *Spatula clypeata (*or *Anas clypeata)* species in the future period between 2021 and 2040. Subsequently, it will be reported a forecast analysis of the distribution of *Spatula clypeata* in the period between 2081 and 2100.

The plot represented in Figure 134 verifies how much the model analysis is accurate. In this case, the training data in the graph below of Figure 134 is AUC = 0.586, thus higher than AUC = 0.5 (random prediction). It means that the model performs better than a random model would.

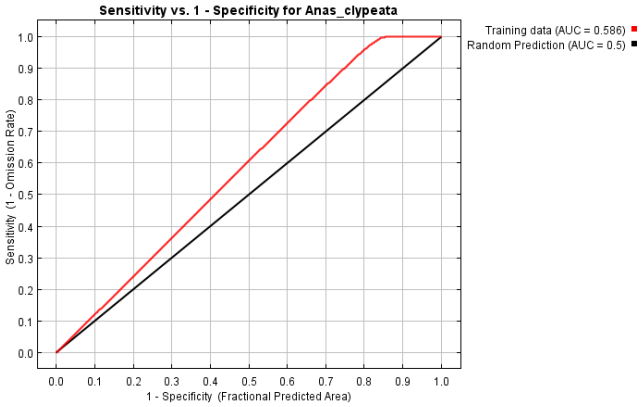

Figure 134: receiver operating characteristic (ROC) curve for the same data

The map in Figure 135 shows the favourable conditions of the distribution of *Spatula clypeata*. The locations used for training (white dots) are concentrated in North America, Europe, Japan, partly in central Asia and some dots are present also in northwest area of Africa. Green areas (places typical where Spatula clypeata is found) are in North America, partly in southernmost and on the west coast of South America, in Europe, in the northwest part of Africa, and in south-eastern part of Asia. In the central area of Eurasian continent, the conditions vary from green to light blue, meaning from favourable to quite unfavourable.

The representation model for Spatula clypeata is similar to the representation models of *Anas acuta*, *Anas crecca*, *Anas penelope*, *Anas platyrhynchos* and *Anas strepera* (Fig. 18 – 32 – 46 – 61 – 90).

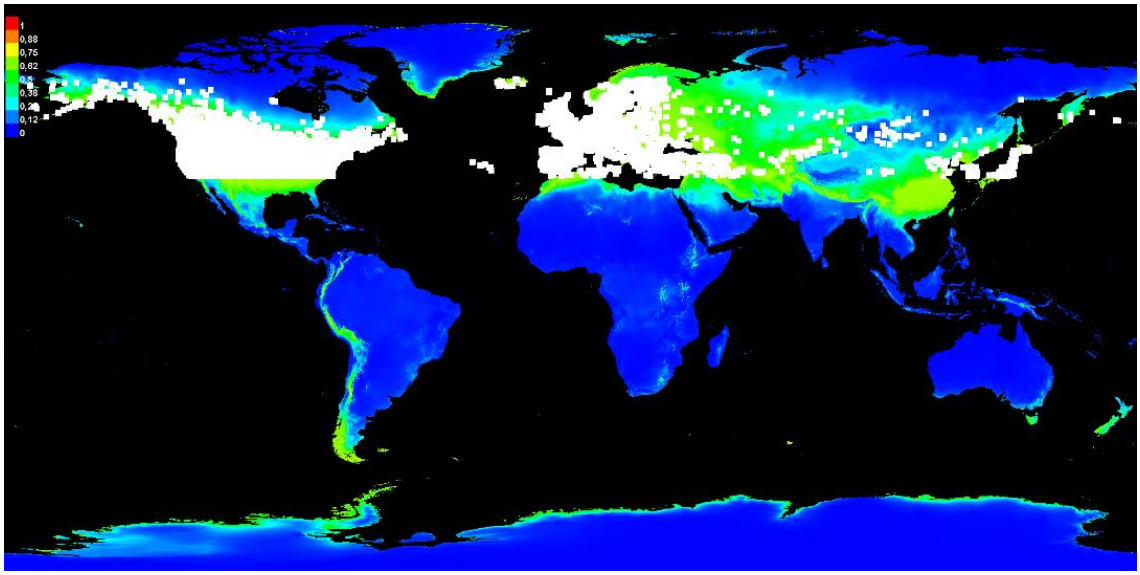

Figure 135: Representation of the model for Spatula clypeata (2021-2040)

Figure 136 (projection of the Maxent model for *Spatula clypeata* onto environmental variables) is quite similar to Figure 135: favourable conditions for this species are found in North America (light blue colours are more distributed in the north, therefore, the conditions for this specie have improved without becoming favourable), in Europe the conditions are still favourable and increase moving eastwards, in the south-easternmost part of the Asian continent conditions are still favourable, although they are slightly worse than in the previous map (Fig. 135). Green areas are found also in the southernmost part of South America. Conditions in Asia become more favourable, without reaching perfect conditions for this species.

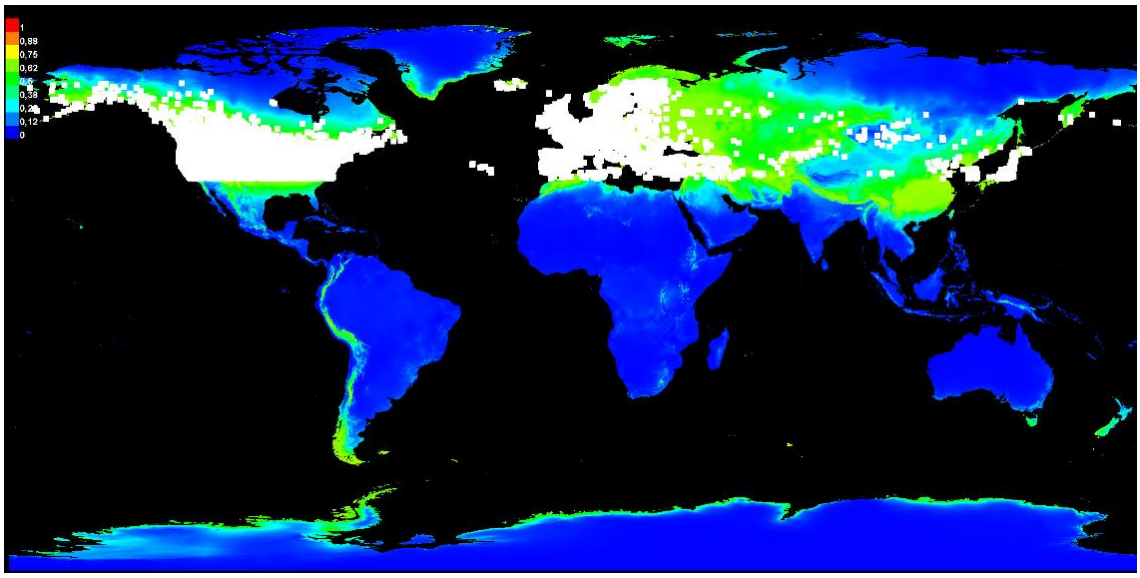

Figure 136: projection of the Maxent model for Spatula clypeata onto the environmental variables (2021-2040)

The following picture compares the environmental similarity of variables in the projection 2021-2040 to the environmental data used for training the model (Figure 137).

In Figure 137, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while there are blue positive values. In the Venice lagoon (North-East Italy), the value tends to 31,6. It means that the values in this point are not novels, yet they are not extremely equal to the median values in layers.

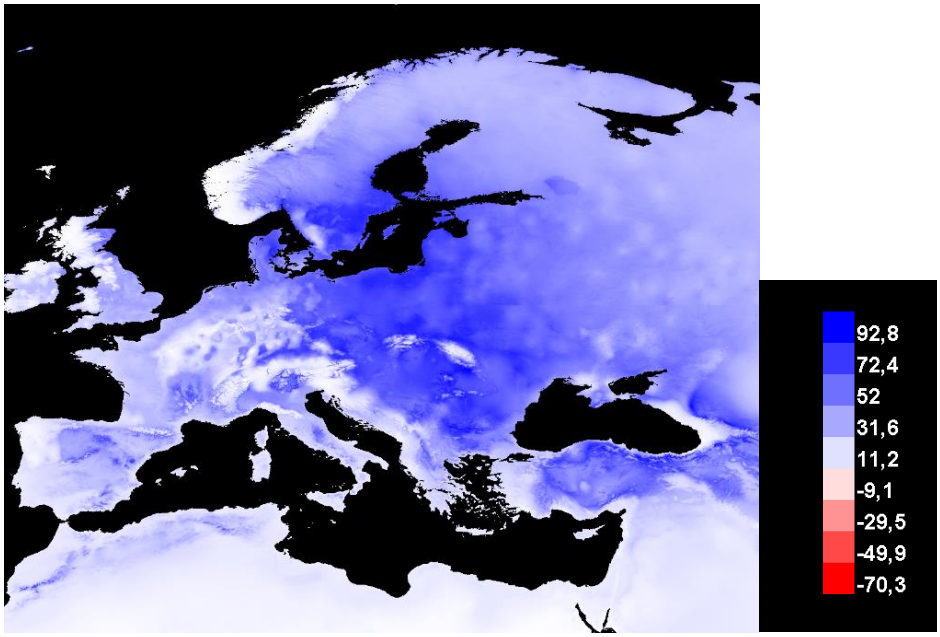

Figure 137: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Spatula clypeata* for the future predictions 2021-2040 (Fig.138). It can be noticed that plot shows that the single most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Spatula clypeata*. However, other variables that contain useful information for the prediction of the distribution of this species in the future are and bio.11 (mean temperature of the coldest quarter), and tmax.12. While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.12 (annual precipitation) is not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain really useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is tmax.2, which therefore appears to have the most information that isn't present in the other variables.

Therefore, also for *Spatula clypeata*, temperature plays a major role in the physiological well-being of this species.

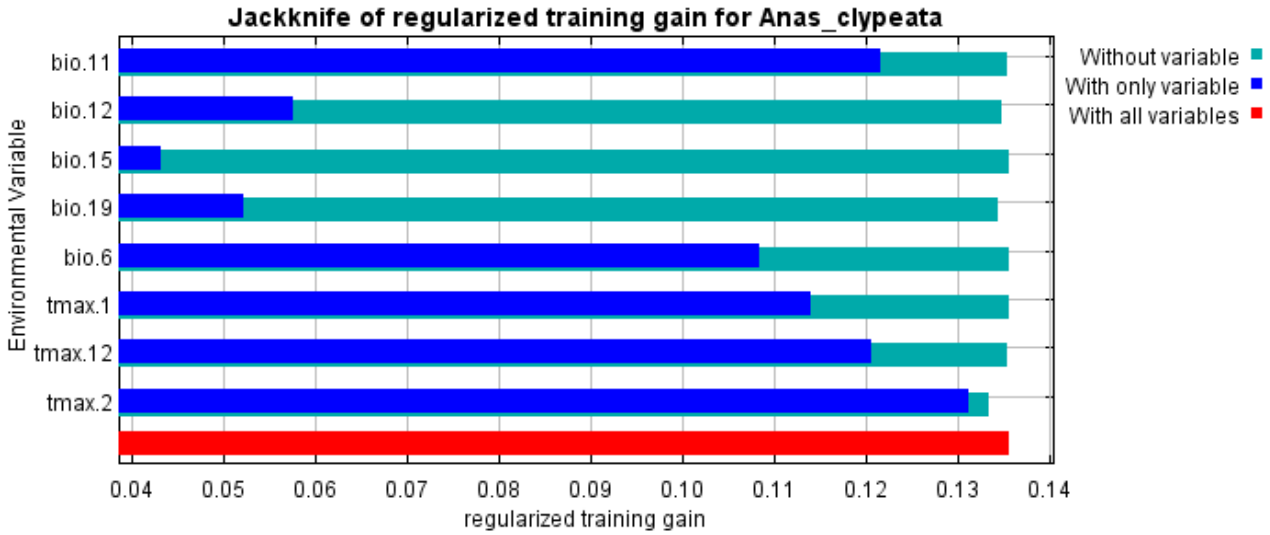

Figure 138: Jackknife of regularized training gain for Spatula clypeata (2021-2040)

As was mentioned, temperature plays an important role for *Spatula clypeata*, as can be noticed from the following response curves. In Figure 139, it can be seen that the temperature range in which the probability of finding *Spatula clypeata* is highest is between -5°C and 17°C, while it is noticeable that in the coldest quarter (bio.11), the average temperature range in which the chance of finding *Spatula clypeata* is higher is between – 10°C and 10°C (Fig.140).

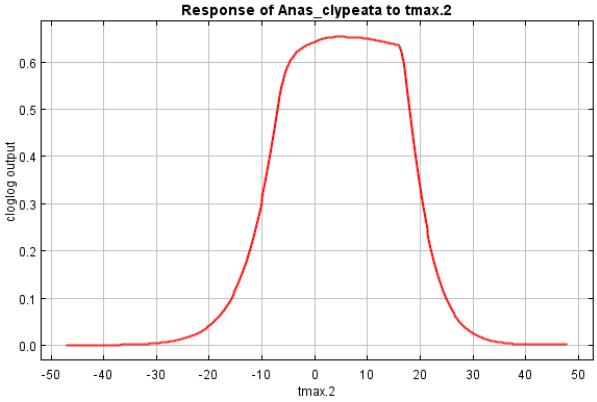

Figure 139: Response of Spatula clypeata to tmax.2

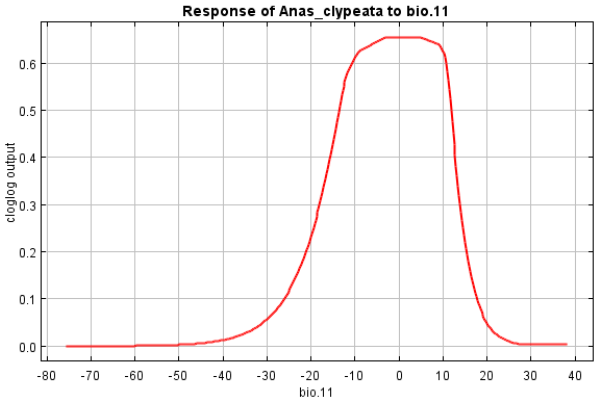

Figure 140: Response of Spatula clypeata to bio.11

Spatula clypeata prediction between 2081-2100

The plot represented in Figure 141 verifies how much the model analysis is accurate. In this case, the training data in the graph below of Figure 141 is AUC = 0.586, thus higher than AUC = 0.5 (random prediction). It means that the model performs better than a random model would.

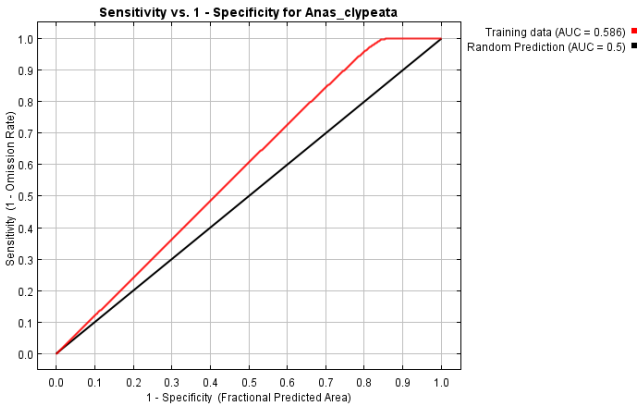

Figure 141: receiver operating characteristic (ROC) curve for the same data

Figure 142 shows a representation of Maxent model for *Spatula clypeata*, highlighting areas with favourable predicted conditions. The locations used for training are in all Europe (as for *Anas acuta*, *Anas crecca*, *Anas penelope*, *Anas platyrhynchos*, *Anas querquedula*, *Anas strepera*, *Aythya ferina*, and *Aythya fuligula*), (Fig. 25 – 39 – 54 – 69 – 83 – 97 – 112 – 127), in North America, in Japan and partly in central Asia. Green areas are as well in Europe, south-eastern part of Asia, in the southernmost area of South America, and in North America. There are few green coloured zones in eastern and central eastern area of the Asian continent.

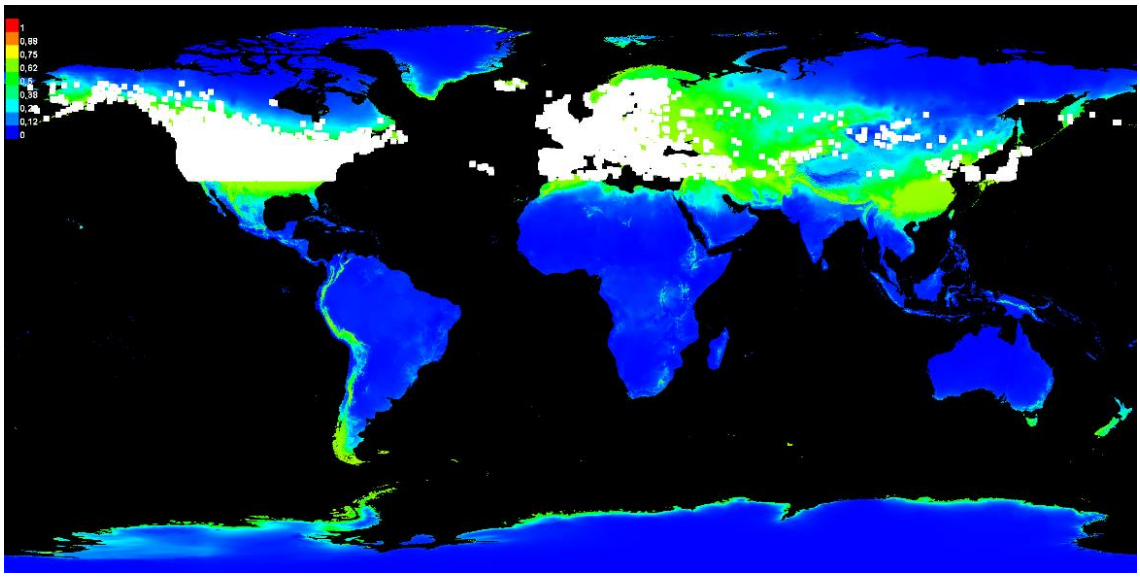

Figure 142: Representation of the model for Spatula clypeata (2081-2100)

The map in Figure 143 shows the projection of the model for *Spatula clyepata* onto the environental variables (2081-2100). What is different, comparing the of Figure 142 is that in the eastern part of the Eurasian continent, from north to south, conditions improve greatly becoming favourable in the centre and along the easternmost coasts, improving, without however becoming favourable, in much of the Asian continent: these areas will not yet be suitable for hosting this species, but they are well on their way. North of the American continent, favourable conditions for *Spatula clypeata* will also improve, becoming more suitable for hosting this species. Also in Europe the conditions are favourable and partly in the southernmost part of South America.

As the expected favourable conditions for this species increase considerably towards the north, it could mean that, in the future, it could hypothetically affect the migratory route of this species, thus causing potential damage not only to the species itself but also to the ecological balances that migration ensures.

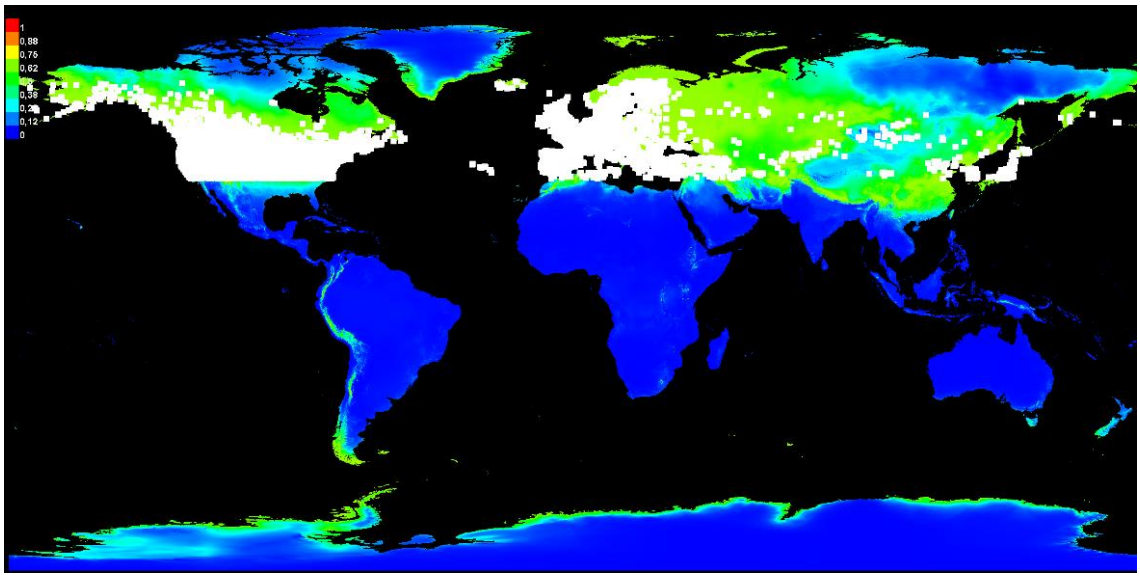

Figure 143: projection of the Maxent model for Spatula clypeata onto the environmental variables (2081-2100)

The following picture compares the environmental similarity of variables in the projection 2081-2100 to the environmental data used for training the model (Figure 144).

In Figure 144, there are no red points (negative values - values outside the training range), therefore there are not hotlayer values outside the range, while there are blue positive values. The map shows a change in the Venice lagoon area, the value has decreased compared to the model for 2021-2040 (Fig. 137), it is around 13, meaning that the value is approaching negative. Negative values mean “novel climate”, as so during projections, predicted variables can assume values outside the training range.

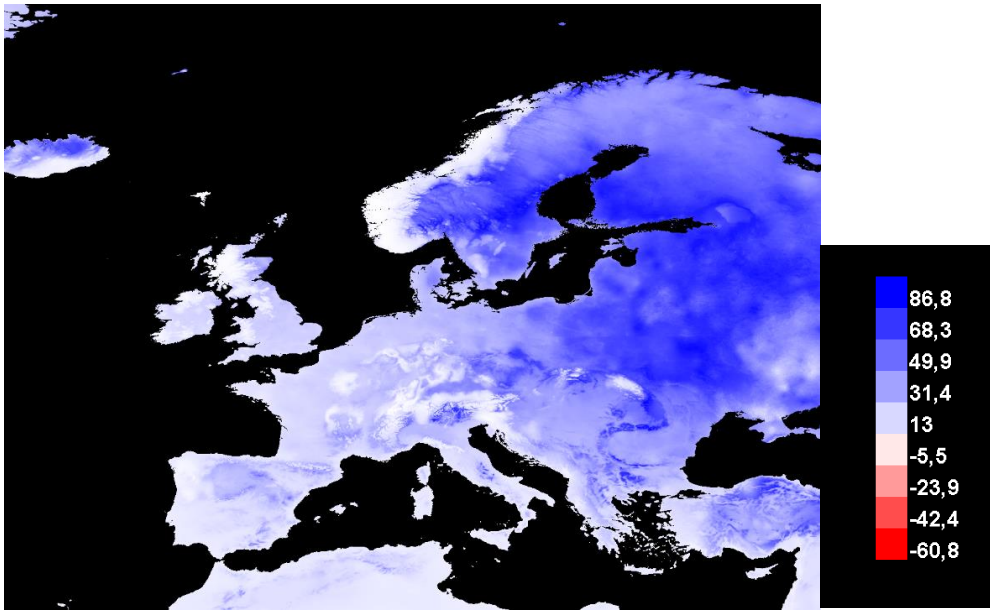

Figure 144: how novel each point is in the hotlayers climate conditions

The following picture shows the results of the jackknife test of variable importance for *Spatula clypeata* for the future predictions 2081-2100 (Fig.145). It can be noticed that plot time shows that the single most efficient variable for the distribution prediction is tmax.2 (blue line), it means that this variable contains useful information to estimate the distribution of *Spatula clypeata*. However, other variables that contain useful information for the prediction of the distribution of this species in the future are and bio.11 (mean temperature of the coldest quarter), and tmax.12. While, the least useful information is bio.15 (Precipitation Seasonality (Coefficient of Variation)); also, variable bio.19 (precipitation of coldest quarter) and bio.12 (annual precipitation) are not a very useful information for this species. On the other hand, the light blue lines show that none of the environmental variables used contain really useful information that is not included in other variables: a single omission of each variable does not shorten very much the light blue line. However, the environmental variable that decreases the gain the most when it is omitted is tmax.2, which therefore appears to have the most information that isn't present in the other variables. Therefore, also for *Spatula clypeata*, temperature plays a major role in the physiological well-being of this species.

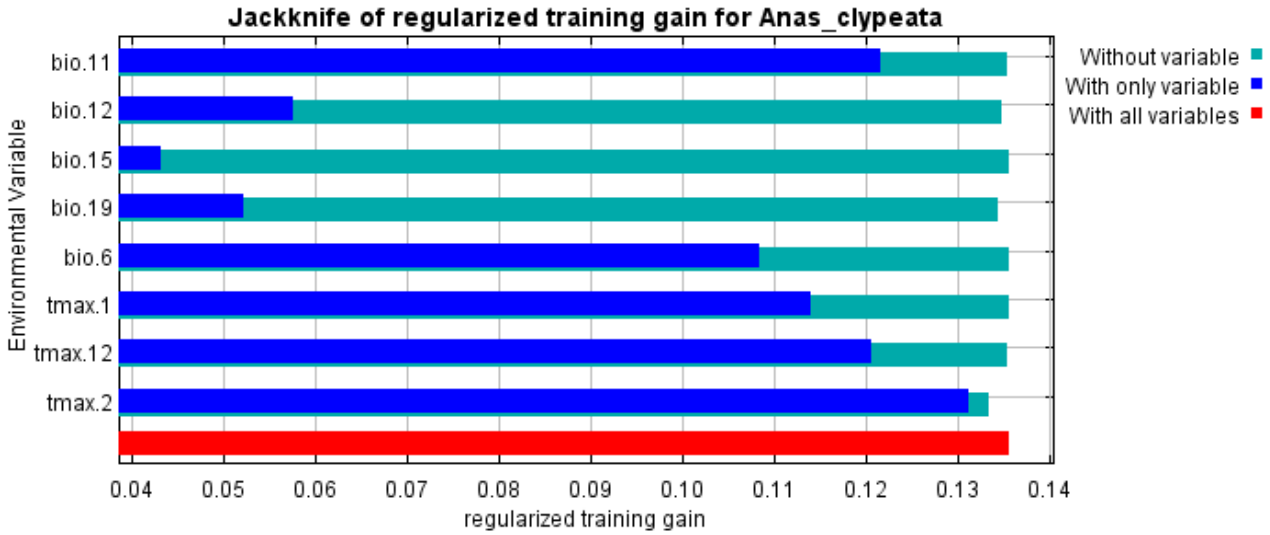

Figure 145: Jackknife of regularized training gain for Spatula clypeata (2081-2100)

As was mentioned, temperature plays an important role for *Spatula clypeata*, as can be noticed from the following response curves. In Figure 146, it can be seen that the temperature range in which the probability of finding *Spatula clypeata* is highest is between -5°C and 17°C, while it is noticeable that in the coldest quarter (bio.11), the average temperature range in which the chance of finding *Spatula clypeata* is higher is between – 10°C and 10°C (Fig.147). As can be seen from the graph in Figure 148, on the other hand, rainfall plays an important but secondary role in the well-being of this species: the range in which the probability of finding *Spatula clypeata* is greatest goes from 400 to 2500, after which the line becomes constant.

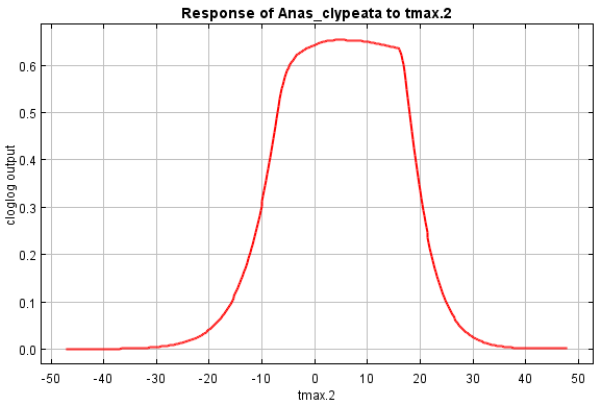

Figure 146: Response of Spatula clypeata to tmax.2

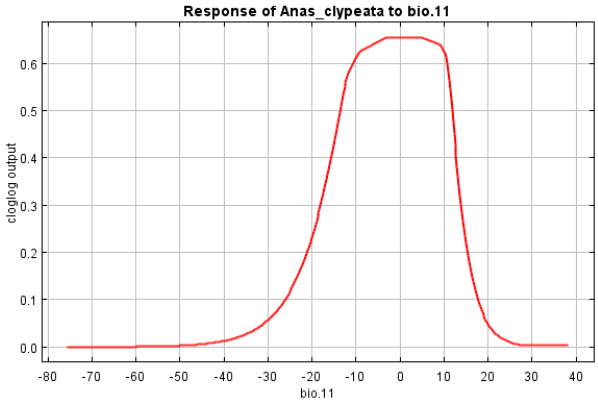

Figure 147: Response of Spatula clypeata to bio.11

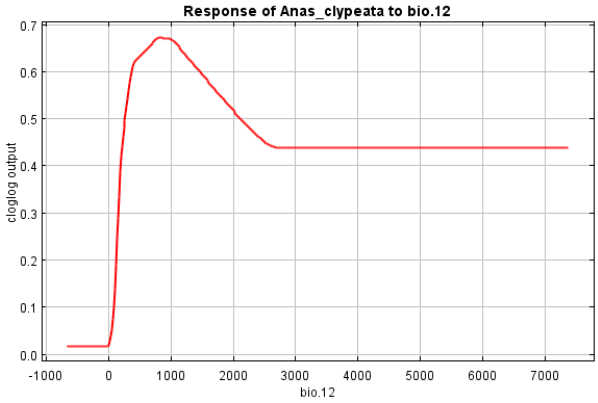

Figure 148: Response of Spatula clypeata to bio.12

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