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Characterisation of fish communities in different marine coastal habitats from southern Italy by using BRUVS



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Mestrado em Biologia Marinha

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Characterisation of fish communities in different marine coastal habitats
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Abstract:

This study characterizes the fish community structure of the coast of Calabria in the Ionian and the Tyrrhenian Sea regarding their habitats (rocky, sandy and seagrass) and their location in either one of the seas. The communities were located in 18 sites that are part of the 13 SACs of the Natura 2000 network identified according to the "Habitat" directive. The sites were examined with the use of BRUVS. The fish communities were mainly characterized by their respective habitat and secondarily by their location in either the Ionian or the Tyrrhenian Sea. Communities in the Tyrrhenian Sea had a higher detectability of fish and a higher species richness than species in the Ionian Sea. The detectability and number of species in the habitats was highest in rocky habitats, followed by seagrass and sandy habitats with the lowest number of species and the lowest detectability. Species richness is correlated with the benthic complexity of the habitats as well as their food availability. The benthic complexity is highest in rocky habitats followed by seagrass habitats and sandy habitats with the lowest complexity in its benthic structure. The detectability is mainly influenced by the availability of food. The food availability is influenced by the productivity of the habitat and other factors like upwelling or nutrient input by estuaries. The most productive habitat in this study was the rocky habitat, another influence in the productivity of the habitats is the upwelling of the Sicilian coast fuelling the production of the waters of the Tyrrhenian coast. On the Ionian site a similar effect can be seen in habitats located at an estuary increasing the production of the surrounding habitats.

Resumo

This study was performed in the Mediterranean Sea examining the differences of coastal fish communities of Calabria, southern Italy. The Calabrian coast is split into the Tyrrhenian coast and the Ionian coast located on the eastern and western coast of the region, respectively. Both seas are separated by the Strait of Messina, separating the island of Sicily from Calabria on the mainland of Italy. The Strait of Messina together with the Strait of Sicily are separating the Eastern basin from the Western basin, containing the Tyrrhenian and the Ionian Sea respectively. The area is characterised by a high biodiversity and productivity. Because of its high productivity the area is also highly important to support the local population

The study was conducted in 18 sites, 13 of which are located in the Tyrrhenian Sea and 5 in the Ionian Sea. These 18 study sites were located inside of 13 Special Areas of Conservation (SACs) of the Natura 2000 network along the coast covering three different habitats in both seas, rocky habitat, sandy habitat, and seagrass habitat. The habitat was defined by rocky > seagrass > sandy meaning that a rocky habitat with sandy or seagrass patches is still defined as rocky, as well as a sandy habitat covered partially by seagrass patches is considered a seagrass habitat and not a sandy habitat. 8 of the 18 habitats were located in rocky habitats, while 5 sites are located in sandy and seagrass habitats each. The sites were studied using baited remote underwater video systems (BRUVS). The BRUVS are benthic film camera systems equipped with a bait cage, mainly filled with small fish like for example sardines and fish food to attract fish into the field of view of the cameras. The videos then were analysed in shorter videos of maximum 2 minutes to evaluate the maximum number of individuals of each species visible in one frame within the 2 minutes video called maxN. The detected data were analysed regarding their community composition in the different habitats, the different seas and comparing the communities of the habitat against the respective habitat in the other sea. The community comparisons were performed using PERMANOVA and Kruskal–Wallis tests.

In this study a total of 49 different species were detected, of the 49 different sightings only one could not be identified to the species level but only the genus level. Furthermore, different habitats showed different species numbers and different species and community compositions. While rocky habitats hosted the most species with 38 species, followed by seagrass habitats with 34 species and sandy habitats with 14 species. Of the 49 observed species one species, *Seriola fasciata* Bloch, 1793, was an allochthonous species, 3 species were endemic species to the Mediterranean and 45 species were autochthonous species to the Mediterranean Sea. Of the 45 autochthonous species detected 9 were categorised as thermophilic species, characterizing them as species extending their range poleward with rising water temperatures.

The communities between the Ionian Sea and the Tyrrhenian Sea differ significantly from each other. A higher number of species were detected in the Tyrrhenian Sea (44) than in the Ionian Sea (32). Apart of the higher species count in the Tyrrhenian Sea, the detectability in the Tyrrhenian Sea also exceeds the detectability of fish in the Ionian Sea.

Thermophilic species in the Tyrrhenian Sea were detected with a more than three times higher rate than in the Ionian Sea. Not only the detectability of thermophilic species differed but also the number of species in the respective seas differed, with a more species sighted in the Tyrrhenian Sea (8) than in the Ionian Sea (5).

The communities did not just differ between the two seas but differences between the habitats regarding to their location in either the Ionian or Tyrrhenian Sea were detected. Rocky and sandy habitats differed significantly between the two seas while no differences were found in sandy habitats.

Apart of the communities in the different seas, differences between the three habitats –rocky, sandy, seagrass– have been detected as well. Statistically significant differences were detected between sandy and seagrass habitat and sandy and rocky habitat. Rocky habitats were characterised by the highest number of species as well as the highest detectability in average, followed by seagrass habitats. Sandy habitats had the lowest number of species and the lowest average detectability as well. The biodiversity in the three habitats, represented by the Shannon–Index, has the highest value in seagrass habitats, followed by sandy habitats and rocky habitats with the lowest biodiversity index.

The detectability of fish of high commercial importance and the number of species detected follow the general community trend. The highest detectability and species count is still located in rocky habitats while sandy habitats show the lowest detectability with seagrass being located between the two other habitats.

The allochthonous species was detected on both sides of the Calabrian coast. It was detected in rocky and sandy habitats but was absence in seagrass habitats. The detectability in rocky and sandy habitats is very low with a detectability of 0.025/min and 0.029/min.

The presence of *S. fasciata*, as an allochthonous species originating the Atlantic Ocean, in just sandy and rocky habitats can be explained by considering its preferred habitat. The species prefers deep habitats between 50-130 meter and rocky reefs or waters above sandy seafloor as its habitats.

The differences between the fish communities of the different habitats can be explained by mainly two reasons. Habitats with a higher benthic structural complexity are supposed to shelter a higher abundance and species richness than habitats that have a less complex

benthic structure. A high complexity in the benthic structure offers protection for smaller fish from predators and also a more diverse benthic community. The highest structural complexity is given in rocky habitats explaining the high abundance and species richness in the studied sites. Seagrass meadows also have a complex benthic structure sheltering small fish in between the leaves. Rocky and seagrass habitats are also known to have a higher productivity than sandy habitats, providing more food to fish living in these habitats. This explains the higher abundance of fish in and above those habitats as they were detected in this study. The benthic habitat though is not the only factor that can influence fish communities. The productivity of a region can also be influenced by a higher availability of nutrients provided by either upwelling or estuaries. This influence of the productivity of an area was detected in two sandy sites in the Ionian Sea located in front of an estuary showing a higher number of species and a higher detectability than other sandy areas.

Seagrass habitats have the highest biodiversity of the three examined habitats. This is due to an equal abundance of the present fish and their value as a reproductive and nursery area for different fish species. Even though rocky habitats had the highest number of detected species their level of biodiversity shows the lowest value. This is related to an uneven distribution of the abundance mostly favouring *Chromis chromis* Linnaeus, 1758 with the highest detectability in rocky habitats. The high biodiversity in sandy habitats is due to the higher number of species in the estuary sandy sites.

The statistical tests not only showed statistical differences between the habitats but also considering the two Seas. As already shown, the different habitats highly influence the fish communities. The Tyrrhenian coast is dominated by rocky habitat with big areas of seagrass meadows while the Ionian coast is dominated by sandy habitat with only smaller areas of seagrass habitat. This different habitat preconditions also in condition with a higher nutrient input in the Tyrrhenian Sea due to a coastal upwelling on the eastern coast of Sicily lead to a higher productivity of the area. These factors turn the Tyrrhenian coast of Calabria into a biodiversity hotspot with high fish abundance. Also, the average water temperature of the Tyrrhenian coast of Calabria is higher than of the Ionian coast. This correlated with the higher productivity of the Tyrrhenian waters leads to a higher presence of thermophilic fish in the Tyrrhenian Sea.

Este estudo foi realizado no Mar Mediterrâneo, e foram examinadas as diferenças entre as comunidades de peixes costeiros da Calábria, no sul de Itália. A costa calabresa divide-se em costa do Tirreno e costa Jónica, localizadas na costa oriental e ocidental da Calábria, respetivamente. Ambos os mares são separados pelo estreito de Messina, que separa a ilha da Sicília da Calábria. O estreito de Messina, juntamente com o estreito da Sicília, separa a bacia oriental da bacia ocidental, que contém o mar Tirreno e o mar Jónico, respetivamente. Esta zona caracteriza-se por uma elevada biodiversidade e produtividade e, conseqüentemente, é também muito importante para o sustento da população local.

O estudo foi realizado em 18 locais, 13 dos quais localizados no mar Tirreno e 5 no mar Jónico. Os 18 locais de estudo estavam localizados no interior de 13 Zonas Especiais de Conservação (ZEC) da rede Natura 2000 ao longo da costa, abrangendo três habitats diferentes em ambos os mares: habitat rochoso, habitat arenoso e habitat de ervas marinhas. O habitat foi definido por rochoso > ervas marinhas > arenoso, o que significa que um habitat rochoso com manchas de areia ou ervas marinhas continua a ser definido como rochoso, assim como um habitat arenoso parcialmente coberto por manchas de ervas marinhas é considerado um habitat de ervas marinhas e não um habitat arenoso. Dos 18 habitats, 8 situavam-se em habitats rochosos, enquanto 5 sítios se situavam em habitats arenosos e de ervas marinhas.

Os locais foram estudados utilizando sistemas de vídeo subaquático remoto com isco (BRUVS). Os BRUVS são sistemas de câmaras de filmar bentónicas equipadas com uma caixa de isco, com maioritariamente pequenos peixes, nomeadamente sardinhas, e comida de peixe para atrair os mesmos para o campo de visão das câmaras. Posteriormente, os vídeos foram analisados em vídeos mais curtos, com um total de 2 minutos, para avaliar o número máximo de indivíduos de cada espécie visíveis num fotograma do vídeo de 2 minutos, denominado maxN. Os dados detetados foram analisados em relação à composição da comunidade nos diferentes habitats, nos diferentes mares e comparando as comunidades do habitat com o respetivo habitat no outro mar. As comparações das comunidades foram efetuadas utilizando os testes PERMANOVA e Kruskal-Wallis.

Neste estudo, foram identificadas 49 espécies, das quais apenas uma não pode ser identificada ao nível da espécie, mas sim ao nível do género. Além disso, os diferentes habitats apresentaram diferentes números de espécies e diferentes composições de espécies e comunidades. Os habitats rochosos acolheram o maior número, com 38 espécies, seguidos dos habitats de ervas marinhas, com 34 espécies, e dos habitats arenosos, com 14 espécies. Das 49 espécies observadas, *Seriola fasciata* Bloch, 1793 era uma espécie alóctone, 3 espécies eram endémicas do Mediterrâneo e 45 espécies eram autóctones do Mar Mediterrâneo.

Das 45 espécies autóctones detetadas, 9 foram classificadas como termófilas, o que as caracteriza como espécies que estenderão potencialmente a sua área de distribuição em direção ao pólo com o aumento da temperatura da água.

As comunidades entre o mar Jónico e o mar Tirreno diferem significativamente entre si. Foi detetado um maior número de espécies no mar Tirreno (44) do que no mar Jónico (32). Adicionalmente, a detetabilidade de peixes no mar Tirreno também excedeu a do mar Jónico.

As espécies termofílicas do mar Tirreno foram detetadas com uma taxa três vezes superior à do mar Jónico. Não só a detetabilidade das espécies termófilas diferiu como também o número de espécies nos respetivos mares diferiu, com mais espécies avistadas no mar Tirreno (8) do que no mar Jónico (5). As comunidades não diferiram apenas entre os dois mares, mas também foram observadas diferenças entre os habitats relativamente à sua localização no mar Jónico ou no mar Tirreno. Os habitats rochosos e arenosos diferiram significativamente entre os dois mares, não tendo sido observadas diferenças nos habitats arenosos.

Para além das comunidades nos diferentes mares, foram igualmente observadas diferenças entre os três habitats - rochoso, arenoso e com ervas marinhas. Foram registadas variações estatisticamente significativas entre os habitats arenosos e de ervas marinhas e os habitats arenosos e rochosos. Os habitats rochosos caracterizaram-se pelo maior número de espécies, bem como pela maior detetabilidade média, seguidos dos habitats de ervas marinhas. Os habitats arenosos registaram o menor número de espécies e também a menor detetabilidade média. A biodiversidade nos três habitats, representada pelo índice de Shannon, tem o valor mais elevado nos habitats de ervas marinhas, seguidos dos habitats arenosos e dos habitats rochosos com o índice de biodiversidade mais baixo.

A detetabilidade de peixes de elevada importância comercial e o número de espécies identificadas seguem a tendência geral da comunidade. A maior detetabilidade e o maior número de espécies continuam a situar-se nos habitats rochosos, enquanto os habitats arenosos apresentam a menor detetabilidade, situando-se as ervas marinhas entre os dois outros habitats.

A espécie alóctone foi observada em ambos os lados da costa calabresa. Foi identificada em habitats rochosos e arenosos, e estava ausente nos habitats de ervas marinhas. A detetabilidade nos habitats rochosos e arenosos é muito baixa, com um valor de 0,025/min e 0,029/min.

As diferenças entre as comunidades de peixes dos diferentes habitats podem ser explicadas principalmente por duas razões. Os habitats com uma complexidade estrutural bentónica mais elevada deverão albergar uma maior abundância e riqueza de espécies do que os habitats com uma estrutura bentónica menos complexa. Uma elevada complexidade da estrutura

bentónica oferece proteção aos peixes mais pequenos contra os predadores e também uma comunidade bentónica mais diversificada. A maior complexidade estrutural é registada nos habitats rochosos, o que explica a elevada abundância e riqueza de espécies nos sítios estudados. Os prados de ervas marinhas também têm uma estrutura bentónica complexa, que abriga pequenos peixes entre as folhas. Os habitats rochosos e de ervas marinhas são também conhecidos por terem uma produtividade mais elevada do que os habitats arenosos, fornecendo mais alimentos aos peixes que vivem nestes locais. Consequentemente, estes habitats têm maior abundância de peixes, tal como foi concluído neste estudo. No entanto, o habitat bentónico não é o único fator que pode influenciar as comunidades de peixes. A produtividade de uma região também pode ser influenciada por uma maior disponibilidade de nutrientes fornecidos por afloramentos ou estuários. Esta influência da produtividade de uma zona foi observada em dois locais arenosos no mar Jónico, situados em frente a um estuário, que apresentam um maior número de espécies e uma maior detetabilidade do que outras zonas arenosas.

Os habitats de ervas marinhas apresentam a maior biodiversidade dos três habitats examinados. Este facto deve-se a uma abundância igual dos peixes presentes e a sua função como área de reprodução e berçário para diferentes espécies de peixes. Embora os habitats rochosos tenham registado o maior número de espécies identificadas, o seu nível de biodiversidade apresenta o valor mais baixo. Este facto está relacionado com uma distribuição desigual da abundância, favorecendo sobretudo *Chromis chromis* Linnaeus, 1758, com a maior detetabilidade nos habitats rochosos. A elevada biodiversidade nos habitats arenosos deve-se ao maior número de espécies nos locais arenosos do estuário.

A estatística não só mostrou diferenças estatísticas entre os habitats, mas também entre os dois mares. Como já foi demonstrado, os diferentes habitats influenciam fortemente as comunidades de peixes. A costa do Tirreno é dominada por um habitat rochoso com grandes áreas de pradarias de ervas marinhas, enquanto que a costa do Jónico é dominada por um habitat arenoso, com apenas pequenas áreas de habitat de ervas marinhas. Estas diferentes condições de habitat, também associadas a um maior aporte de nutrientes no mar Tirreno devido a uma ressurgência costeira na costa oriental da Sicília, conduzem a uma maior produtividade da zona. Assim, estes fatores transformam a costa tirrena da Calábria num hotspot de biodiversidade com elevada abundância de peixes. Além disso, a temperatura média da água na costa tirrena da Calábria é mais elevada do que na costa jónica. Este facto, correlacionado com a maior produtividade das águas do Tirreno, leva a uma maior presença de peixes termófilos no mar Tirreno.

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Contents

Abstract:	III
Resumo	IV
Acknowledgements	X
I. List of abbreviations, acronyms and symbols	XII
II. List of Tables and Figures:	XIII
III. General introduction	XIV
IV. References general introduction	XX
Abstract:	2
1. Introduction	3
2. Material and Methods.....	4
2.1. Study region.....	4
2.2. Sampling design	4
2.3. Analysis of the BRUVS videos.....	6
2.4. Data analyses.....	6
2.4.2. Hierarchical cluster analysis.....	6
2.4.3. Statistical analyses	7
2.4.4. Species richness and biodiversity	7
3. Results.....	7
3.1. Data analyses.....	7
4.2. Species-accumulation curve	9
4.3. Hierarchical cluster analysis.....	10
4.4. Species richness mapping	11
4.5. Biodiversity.....	12
4.6. Species of high commercial importance	13
4.7. Thermophilic species	13
4.8. Statistical analyses	14
4. Discussion.....	16
4.1. Alien species	16
4.2. Thermophilic species	16
4.3. Biodiversity in different habitats.....	17
4.4. Species of high commercial value.....	18
4.5. Comparison of biodiversity between the Tyrrhenian and the Ionian Sea.....	18
4.6. Summary	19
5. References.....	21
6. Attachment.....	26

I. List of abbreviations, acronyms and symbols

AL	Allochthonous species
AU	Autochthonous
BRUVS	Baited Remote Underwater Video System
comp.	Compare
DD	Data Deficient
E	Endemic species
EEA	European Environment Agency
EN	Endangered
GES	Good Ecological Status
I	Ionian Sea
IPCC	International Panel on Climate Change
IUCN	International Union for Conservation of Nature
LC	Least Concerned
maxN	the maximum amount of individuals per each fish species in any one frame
MME	Mass Mortality Event
MPA	Marine Protected Area
NIS	Non-Indigenous Species
RUV	Remote Underwater Video system
SAC/ZEC	Special Area of Conservation/Zone Especiais de Conservação
SM	Strait of Messina
SST	Sea Surface Temperature
T	Tyrrhenian Sea
T1st	time of first arrival/time of first fed.
TH	Thermophilic species
VU	Vulnerable

II. List of Tables and Figures:

Tables:

- Table 2.1: List and characterization (Sea, SAC no., coordinates, habitat type, sampling date and soaking time) of sampling sites
- Table 3.1: List of species and their characteristics.
- Table 3.2: Number of species at the sampling sites and the respective Shannon-Indices.
- Table 3.3: Shannon-Indices by habitats and seas.
- Table 3.4: Results of PERMANOVA comparing all sites by habitat and seas.
- Table 3.5: Results of the comparison of the habitats regarding the differences in detectability between the Ionian and the Tyrrhenian Sea.
- Table 3.6: Results of pairwise PERMANOVA comparing the fish communities of different habitats.
- Table 3.7: Results of PERMANOVA comparing the communities of species with high commercial value from all sites by habitat and seas.
- Table 3.8: Results of pairwise PERMANOVA comparing the communities of species with high commercial value.
- Table 3.9: : Results of PERMANOVA comparing the detectability of communities of thermophilic species by habitat and seas.

Figures:

- Figure 3.1: Species-accumulation curve of each site.
- Figure 3.2: Dendrogram of hierarchical clustered sampling sites.
- Figure 3.3: Map of Calabria with the sampling sites and their species richness.
- Figure 3.4: Map of Calabria with the sampling sites and the detectability of thermophilic species.

III. General introduction

Climate change and its impact on the world's oceans and seas is a topic that gained more and more interest in the last decades resulting in a high volume of research activity (IPCC, 2014). The rising sea surface temperatures (SSTs), as one of the impacts of climate change, are detectable all over the world (EEA, 2012). Southern Europe is mainly impacted by higher summer temperatures (IPCC, 2014). The average temperature between 2002-2011 rose, compared to 1850-1899, by $1.3 \pm 0.11^{\circ}\text{C}$ (IPCC, 2014). As a result to climate change the average sea levels are rising worldwide (Menéndez and Woodworth, 2010, Hoegh-Guldberg and Bruno, 2010). Another impact on climate change on the ocean is a decrease in primary production, a decrease in habitat creating organisms like seagrass, Mangroves and corals as well as range shifts and changes in the community and food web structure (Giorgi, 2006 and references therein).

Due to its enclosed nature, the Mediterranean Sea is highly impacted by climate change. The Mediterranean region is suspected to be one of the hot-spots for climate change, meaning the sensible response of the ecosystem to climate change (Giorgi and Lionello, 2008, Cerrano et al., 2000). Higher SSTs have a severe impact on the different habitats. Multiple studies stated the sensible reaction of benthic individuals inhabiting rocky habitats, leading to mass mortality events (MMEs) in invertebrates and gorgonians (Bensoussan et al., 2010, Garrabou et al., 2009) a high impact was detected in the central Tyrrhenian Sea more precisely the gulf of Naples (Duarte et al., 2018). The influence on seagrass habitats are also widely impacted by the rise in the average SST. A higher water temperature triggers different adaptive responses in the dominating seagrass *Posidonia oceanica*. The higher temperatures lead to an earlier and more common sexual reproduction event in *P. oceanica*. A higher rate of sexual reproduction leads to a higher genetic diversity that can lead to a higher resilience against rising water temperatures (Marín-Guirao et al., 2019, Marbà and Duarte, 2010). Higher temperatures also cause a decreased in recruitment of seagrass seedlings and a higher shoot mortality leading to a reduced biomass of seagrass biomass (Jordà et al., 2012). Duarte et al. (2018) is predicting an extinction of *P. oceanica* as early as 2049 ± 10 years without any additional conservational effort. Another effect of rising water temperatures is also the poleward migration of thermophilic herbivorous fish increasing the grazing pressure on the seagrass leaves (Pergent et al., 2014, Marbà et al., 2015). This effect adding up with the increased shoot mortality pose a severe threat to seagrass populations in the Mediterranean Sea. The influences of climate change on sandy habitats in the Mediterranean Sea is less studied than the influence on other habitats. Similar to other habitats rising in the water temperature has a stronger effect on sessile organisms than on mobile species (Coma et al., 2009). Another impact of rising temperatures is the prolongation of the so-called summer condition. The

summer condition is an interaction of low food availabilities due to the oligotrophic conditions of the Mediterranean Sea and the increased need of nutrients and food to react on heat stress. This effect leads to a higher mortality in organisms living in oligotrophic regions. This effect is even increased in sandy habitats due to its lower production in general (Sbragaglia et al., 2020). Another impact of the temperature increase is the tropicalization and meridionalization of the fish communities in the Mediterranean Sea (Cheung et al., 2009). This large scale poleward shift of fish species changes the fish community and threatens the fish stocks in enclosed Seas like the Mediterranean Sea (Coll et al., 2010).

All these effects on the Mediterranean Sea show a great risk to one of the marine biodiversity hot spots in the world with more than 17,000 marine species and a high proportion of endemic species (Coll et al., 2010). The high level of biodiversity, species richness and endemism is related to the historic changes shaping the communities in the Mediterranean Sea (Coll et al., 2010). The Mediterranean Sea originates from the Tethys Sea connecting the Atlantic Ocean with the Indo-Pacific Ocean. Therefore, the Tethys Sea has been habitat to flora and fauna from both Oceans also after the closure of the Tethys Sea in the Miocene (Coll et al., 2010). In the Messinian stage also the connection to the Atlantic Ocean was closed. This complete closure of the Mediterranean Sea led to the Messinian salinity crisis (MSC). The loss of the A significant drop in sea surface level triggered by the lack of water inflow from the Atlantic Ocean led to a separation of the Mediterranean Sea into two basins, the eastern and western Basin. Those two basins were separated by what is today known as the Strait of Sicily (Bianchi and Morri, 2000). This separation into the two separated basins with an increase in salinity did trigger mass extinction events but also allopatric speciation events from surviving organisms separated from the Atlantic Ocean and from the other basin (Rouchy and Caruso, 2006, Bianchi et al., 2011, Coll et al., 2010). After the reopening of the connection between the Mediterranean Sea and the Atlantic a repopulation by Atlantic species and a reconnection between the eastern and western basin happened (Bianchi and Morri, 2000). These events and the semi enclosed nature of the Mediterranean Sea contributed to the high level of biodiversity and endemism in the Mediterranean.

The previously explained importance of the Strait of Sicily for the evolution of biodiversity in the MSC (Cucco et al., 2016) as well as its role as a natural soft barrier still separating the eastern from the western Mediterranean basin (Azzaro et al., 2007). Another important impact on biodiversity and productivity nowadays is also related to Sicily. The western coast of Sicily is part of an upwelling system bringing nutrient rich water from higher depths to shallower water layers increasing the productivity of this region and of the Tyrrhenian coast (Cucco et al., 2016). The influence of the Strait of Sicily as a soft barrier and due to different water circulations stops the upwelling on the western Sicilian coast to also highly impact the Ionian Sea adjacent to the

Tyrrhenian Sea but located in the eastern basin (Populus et al., 2017). The maritime region around Calabria is also of particular interest because of its diverse benthic habitats. The Tyrrhenian coast is dominated by rocky habitats with a high abundance of seagrass meadows, while the Ionian coast of Calabria is dominated by sandy habitats with fewer areas populated by seagrass (Guidetti, 2000). Rocky habitats are known to shelter a high number of species as well as being highly productive. These factors are related to the high benthic complexity in rocky habitats giving shelter to smaller fish and organisms as well as providing food by algal growth and benthic organisms attached to hard substrate (Giakoumi and Kokkoris, 2013, Pergent et al., 2014). Seagrass habitats are known to shelter even a higher number of species and having a higher biodiversity than rocky habitats. This is due to their function as an area of reproduction and nursery for many fish. The endemic seagrass *P. oceanica* hosts between 20 and 25% of the species present in the Mediterranean Sea (Boudouresque and Meinesz, 1983, Guidetti, 2000, Azzurro, 2008). While rocky habitats are a hotspot for biodiversity they also favour the thermophilic expansion of thermophilic fish since most of these fish originate from rocky habitats (Guidetti, 2000). These factors make the Tyrrhenian coast of Calabria not only a hotspot of biodiversity within the Mediterranean Sea but also highly impacted by the thermophilic expansion as a reaction to climate change stated in earlier paragraphs. Sandy habitats shelter less species and have a lower abundance of fish than rocky and seagrass habitats (Giakoumi and Kokkoris, 2013, FAO, 2023) though they are an important habitat to specialised species adapted to live on soft substrate.

The differences between the Ionian and the Tyrrhenian coast of Calabria mentioned above together with its close special distance makes this area a good place to research the broad diversity of fish communities in the Mediterranean Sea. Fish species of all three habitats can be researched as well as the differences between the two seas and therefor also the two basins of the Mediterranean Sea.

The Calabrian coast is also a highly important fisheries area supporting more than 2400 fishermen of the local population in small scale fisheries (McGeady et al., 2023). The combination of a highly diverse ecosystem, the fishing pressure, other anthropogenic stressors like noise pollution by boats and the pressure of climate change, especially in the face of water temperature rising, also brings up the need for a conservational effort to protect these ecosystems. All over the Mediterranean Sea there are marine protected areas (MPAs) that cover an area of 6% of the whole Mediterranean Sea (Fraschetti et al., 2022). Within those MPAs a high/good ecological status (GES) is achieved. But evaluating the whole Mediterranean Sea the ecological status varies strongly and it is categorized as a moderate ecological status (Mouillot et al., 2011). This discrepancy between the MPAs and the rest of the Mediterranean Sea is likely also related to the planning and managing of the MPAs, not

being scientifically evaluated or properly planned in the first place. Some areas of high biodiversity and importance to the ecosystem are not included in MPAs, while other areas that are protected have a smaller impact on the restoration of the ecological status of the Mediterranean (Barnes, 1952). The Calabrian coast has a total of 23 MPAs. 22 of them are special areas of conservation (SACs) included in the Natura 2000 network, located equally distributed on both coastlines of Calabria. One additional MPA, that is not part of the Natura 2000 network, is the big national marine park “Capo Rizzuto” located on the Ionian coast of Calabria.

The urge for more scientific evaluation, planning and research to protect the Mediterranean Sea also brings up the need for different survey methods. There are multiple different options to study the fish ecology of different sites. These methods are categorizable into two groups, extractive/invasive techniques, and non-extractive/non-invasive techniques. Extractive techniques are practices where fish are being removed from their habitat such as fishing activities of any kind, including trawling, long line surveys or sein netting. Non-invasive methods are methods mostly using video cameras to observe fish communities. The first use of video cameras in a marine environment was already published by Ellis and DeMartini (1995). This video camera system consisted of one camera without any bait involved. Since the first usage of video cameras setups the technique developed in different methods, one of them is the baited remote underwater video setup (BRUVS). BRUVS occurred later in 1995 by Ellis and DeMartini (1995). This setup was built from a metal frame holding one video camera and a bait container (Mallet and Pelletier, 2014, Whitmarsh et al., 2017). The first breakthrough in scientific work for BRUVS happened in 2007 with a sudden increase in BRUVS papers (Whitmarsh et al., 2017) with a second more recent peak in 2021 (compare literature research conducted in Attachment S1). The technique was first mainly used in Oceania with more than 70% of papers published until 2016 associated with Oceania (Whitmarsh et al., 2017). This dominance regarding the location is reduced in more recent papers. Between 2016 and the published papers until 09/2023 only ~42% of the papers are associated to Oceania and ~21% of the papers are related to research in Europe (compare Attachment S1).

Not all BRUVS are the same, there are major differences in the setup of the BRUVS. One of the major differences is related to the orientation of the camera (Mallet and Pelletier, 2014, Whitmarsh et al., 2017). The camera can be setup in a vertical and horizontal orientation. Both setups have different application areas but mostly horizontal BRUVS are used in the literature due to its more variable application and also easier deployment than of vertical BRUVS (Whitmarsh et al., 2017). Another major difference in the BRUVS setup also concerns the cameras. Setup with one camera so called mono-BRUVS and setups with two cameras, stereo-BRUVS, are used in the literature with a small advantage of mono-BRUVS regarding

the number of publications (Whitmarsh et al., 2017). But Mallet and Pelletier (2014) as well as Ricker (1975) see the only advantage of mono-BRUVS over stereo-BRUVS in their easier handling and lower price. The advantages of stereo-BRUVS are numerous. The biggest advantage of stereo-BRUVS is the possibility to accurately measure the length of fish and other organism from the videos. By the measurement of size an estimation for the biomass present in the videos is possible (Watson et al., 2009) as well as recruitment dynamics in the populations (Whitmarsh et al., 2017). Another advantage of the stereo-BRUVS setup is the measurement of the visibility in the sampling site. These measurements help comparing different studies (Bernard and Götz, 2012).

Another influence on the effectivity of BRUVS is the usage of different bait types. Different studies compare the use of different bait types also against remote underwater video systems (RUV) (Harvey et al., 2007, Dorman et al., 2012, Walsh et al., 2017). Multiple studies agreed on the preferred use of oily fish like Sardines as bait, since studies with Sardines show the best results throughout different groups of fish (Wraith et al., 2013, Bernard and Götz, 2012, Harvey et al., 2007, Dorman et al., 2012). The use of bait also increases the replicability between replicas, especially when compared to RUV replicas (Harvey et al., 2007). The use of bait also leads to an increased detectability of differences between different habitats (Dorman et al., 2012, Whitmarsh et al., 2017). But the use of bait also increases the detectability of predating and scavenging fish species (Birt et al., 2021). This might lead to an overestimation of these fish species in the observed communities. Apart of the used type of bait, the soaking time of the BRUVS also has an impact on the detection of the numbers of species and their detected abundance. For different habitats and climate zones different soaking times were suggested by different studies (Harasti et al., 2015, Gladstone et al., 2012, Santana-Garcon et al., 2014, Birt et al., 2021). Harasti et al. (2015) and Gladstone et al. (2012) studied the optimal soaking time for rocky and reef habitats, suggesting a soaking time of 15 to 30 minutes in tropical or subtropical regions and a 60 minutes for temperate regions. In estuaries Santana-Garcon et al. (2014) suggested a soaking time of 60 to 90 minutes to capture comparable data. The longest suggested soaking time with 120 minutes is given by Priede et al. (1994) for pelagic surveys.

Apart from the different setup variations explained above the video analysis method used has a big influence on the results of the study. In general, four different methods are used for different applications. The most often used method is the method of maxN (Whitmarsh et al., 2017). When using maxN the maximum number of individuals per species in any one frame of a whole video or predefined parts of the video is counted. T1st is another method used and stands for the time of first arrival or time of first fed. With this method an estimation of the distance travelled by a specific species to arrive at the BRUVS can be given. The method of

the MeanCount uses the random frames throughout the video, counting the number of individuals per species in each selected frame. According to Whitmarsh et al. (2017) this method is less precise than the use of maxN. The last option of analysing BRUVS videos is the restricted counting of a number of individuals of a specific species. This option is mostly used for large species that are distinguishable by their individual characteristics like sharks and rays (Whitmarsh et al., 2017).

The different video analysis methods are also used for different application possibilities. The most used application of BRUVS is in the analysis of Teleosts or Chondrichthyans mostly assessing fish communities in MPAs (Nalmpanti et al., 2023, Bernard and Götz, 2012). The aims of BRUVS surveys also include the comparison of fish communities in different habitats (e.g. Whitmarsh et al., 2017). Another big part of BRUVS studies is also the comparison of BRUVS with other methods, invasive as well as non-invasive methods. The last group of studies are species specific studies that are interests in the behaviour of this species (Nalmpanti et al., 2023, Fedra and Machan, 1979).

The usage of BRUVS and video techniques in the Mediterranean is summarized in the following paragraph. The first use of any kind of video technique was by Bozzano and Sardà (2002) in form of a RUV. The first usage of BRUVS was by Nalmpanti et al. (2023). In total 22 studies using BRUVS were conducted until the end of 2022, 17 of these studies were performed after 2015 and are on the rise since then. Most of the studies in the Mediterranean were conducted in the central Tyrrhenian Sea and the western basin in general (Nalmpanti et al., 2023). Furthermore, Whitmarsh et al. (2017) also stated, that most studies are focused on benthic and benthopelagic fish in shallow habitats, while BRUVS are the only method also used to study depths up to 500 meters.

Since the usage of BRUVS is a fairly recent method that is still on the rise different papers agree on the more intense use of BRUVS in the future (Mallet and Pelletier, 2014, Nalmpanti et al., 2023, Whitmarsh et al., 2017). Since multiple studies agree on the advantages of stereo-BURVS over mono-BRUVS, as well as the general advantages of BRUVS over other methods like RUVs, the usage of stereo-BRUVS will be more common in the future.

Not only Nalmpanti et al. (2023) stresses the need of a more standardised sampling protocol to increase the value of the conducted research regarding the comparability of the different studies (Whitmarsh et al., 2017). The authors though also don't want to limit the progress that is coming in the following years of this young research method and therefore suggest a number of parameters that should be given in all studies conducted. Therefore, the progress is less limited than with the implementation of a strict protocol but still provides enough information to compare the different approaches (Yokes et al., 2011).

IV. References general introduction

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Characterisation of fish communities in different marine coastal habitats from southern Italy by using BRUVS

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Abstract:

This study characterizes the fish community structure of the coast of Calabria in the Ionian and the Tyrrhenian Sea regarding their habitats (rocky, sandy and seagrass) and their location in either one of the seas. The communities were located in 18 sites that are part of the 13 SACs of the Natura 2000 network identified according to the "Habitat" directive. The sites were examined with the use of BRUVS. The fish communities were mainly characterized by their respective habitat and secondarily by their location in either the Ionian or the Tyrrhenian Sea. Communities in the Tyrrhenian Sea had a higher detectability of fish and a higher species richness than species in the Ionian Sea. The detectability and number of species in the habitats was highest in rocky habitats, followed by seagrass and sandy habitats with the lowest number of species and the lowest detectability. Species richness was correlated with benthic complexity of the habitats as well as their food availability. The benthic complexity is the highest in rocky habitats followed by seagrass habitats and sandy habitats with the lowest complexity in its benthic structure. The detectability is mainly influenced by the availability of food. The food availability is influenced by the productivity of the habitat and other factors like upwelling or nutrient input by estuaries. The most productive habitat in this study was the rocky habitat, another influence in the productivity of the habitats is the upwelling of the Sicilian coast fuelling the production of the waters of the Tyrrhenian coast. On the Ionian site a similar effect can be seen in habitats located at an estuary increasing the production of the surrounding habitats.

1. Introduction

The Mediterranean Sea with its over 17000 species is considered a hotspot for biodiversity and endemic marine species (Coll et al., 2010). It is split into the eastern and western basins by the Strait of Sicily and the Strait of Messina (SM). The SM separates the island of Sicily from the Italian mainland and is situated on the southern coast of Calabria. The SM also separates the Tyrrhenian Sea in the western basin from the Ionian Sea in the eastern basin. Due to the seafloor geomorphology of the SM and currents from the Tyrrhenian and Ionian Seas, upwelling occurs on both sides of it. These upwellings result in great biodiversity in all levels of the food web, forming a hotspot for biodiversity in the adjacent waters of Calabria and Sicily (Coll et al., 2010, Azzaro et al., 2007).

Due to these high rates of biodiversity, the southern Italian coast is of particular conservation interest. On the coastlines of the Tyrrhenian and Ionian Seas, more than 150 km² and more than 130 km², respectively, are protected by 11 protected areas on each coast. All of the 22 protected areas belong to the Natura 2000 Network. In addition to the Natura2000 Network the marine protected area “Capo Rizzuto” on the Ionian coast protects 147 km² of coastal habitats, overlapping with one Natura2000 area. Alongside conservation, regional fisheries play an important role in supporting the local population with 2474 crew members (FAO, 2023).

Even though there are a lot of different protected areas along the coastline and a good knowledge about fish biodiversity in the Mediterranean Sea in general, little is known about the distribution and biodiversity on a smaller scale, especially in the protected areas. To gain knowledge on fish biomass and biodiversity, in the past, extractive methods like trawling or acoustic methods were used to gather data on the biodiversity of a specific area. Those techniques are highly invasive and not suitable to perform in protected areas (Mallet and Pelletier, 2014). Therefore, the use of baited remote underwater video systems (BRUVSs) is a good alternative to gather ecological data on biodiversity and biomass without having a negative, disturbing impact on the ecosystem (Whitmarsh et al., 2014, McGeady et al., 2023). A BRUVS is a technique that uses bait, normally in the form of dead fish or industrial fish bait, to attract fish and capture them on either one or two cameras (Whitmarsh et al., 2017, Mallet and Pelletier, 2014). Another advantage of BRUVSs is their variability. They can be used in all kinds of habitats such as rocky reefs, seagrass and mudflats, even though they are primarily used in rocky or coral reefs (Whitmarsh et al., 2017).

Regarding the lack of knowledge about the characteristics of coastal fish communities on the Calabrian coasts and their high importance for the support of the local economy, population and their conservational value this study aims to gain a more detailed understanding of the fish communities in the protected areas along the coast.

This study aims to examine:

- i) the fish communities and their differences in the three habitats,
- ii) the differences between the fish communities of the same habitats regarding to their location,
- iii) the differences between fish communities in the two seas of the Calabrian coasts,
- iv) the influence of the seas and habitats on the distribution of thermophilic fish and on fish species of high commercial importance.

2. Material and Methods

2.1. Study region

The study was conducted on the southern Italian (Calabria) coast of the Tyrrhenian and Ionian Seas, which are part of the western and eastern basins of the Mediterranean Sea, respectively. A total of 18 sites were sampled, of which 13 are located in the Tyrrhenian Sea, while 5 sites are located in the Ionian Sea. The sampling sites are part of 13 SACs that are protected under the Habitat Directive and are part of the Natura 2000 Network on the Calabrian coast. Detailed information on all the sampling sites can be found in Table 2.1.

2.2. Sampling design

The sampling period lasted from the 26th of July to the 28th of October in 2022 as well as from the 29th of May to the 14th of July in 2023.

The exact locations for the BRUVSs' deployment were chosen by the benthic habitats of the SACs. The coordinates, habitat type, SAC identification number, sampling date and the soaking time at each site are shown in Table 2.1. The soaking time was calculated from the time the BRUVS touched the ground to when it started to move upwards again. The soaking time at the site ranged from ~49:42 minutes (Fondali di Pizzo Calabro; IT9340092) to ~314:32 minutes (Fondali Crosia-Pietrapaola-Cariati; IT9310048) and was dependent on the timing of the boat routes as well as the legal permits to enter the sites. Four regions were sampled twice at different spots, Fondali Scogli di Isca (IT9310039), Foce del Fiume Crati (IT9310044), Fondali di Pizzo Calabro (IT9340092) and Fondali Capo Cozzo - S. Irene (IT9340094), to cover different types of habitats or regions inside those SACs. The sampling depths ranged from depths of 8.1 meters to 26.4 meters.

The BRUVS is produced by SeaGIS. The cameras are 2 GoPro Hero 8 Black with a resolution of 1920x1080 and a frame rate of 60 frames per second. The videos at every site were cut into shorter videos of 11:47 minutes for technical reasons.

Table 2.1: List and characterization (Sea, SAC no., coordinates, habitat type, sampling date and soaking time) of sampling sites

Name	ID Code	Sea	SAC number	Coordinates	Habitat type	Sampling date	Depths (m)	Temperature (°C)	Soaking time (h:min)
Fondali Isola di Dino-Capo Scalea	di281022	Tyrrhenian Sea	IT9310035	39°52'32"N 15°46'21"E	rocky	28.10.2022	26.4	21	2:06
Fondali Isola di Cirella-Diamante	ci281022	Tyrrhenian Sea	IT9310036	39°42'02"N 15°48'07"E	rocky	28.10.2022	18.1	22	1:54
Fondali Scogli di Isca	sdi070522	Tyrrhenian Sea	IT9310039	39°08'50"N 16°03'29"E	rocky	05.07.2022	14.7	26	1:20
Fondali Scogli di Isca	is030822	Tyrrhenian Sea	IT9310039	39°08'59"N 16°03'26"E	seagrass	03.08.2022	16.0	27.5	1:56
Foce del Fiume Crati	focs260722	Ionian Sea	IT9310044	39°43'29"N 16°31'54"E	sandy	26.07.2022	15.1	26	0:53
Lago La Vota	lv030822	Tyrrhenian Sea	IT9330087	38°56'32"N 16°9'41"E	sandy	03.08.2022	-	-	1:14
Fondali Capo Cozzo - S. Irene	si200922	Tyrrhenian Sea	T9340094	38°43'54"N 16°01'55"E	seagrass	20.09.2022	19.6	24	2:02
Fondali di Pizzo Calabro	fdp210922	Tyrrhenian Sea	IT9340092	38°44'19"N 16°09'29"E	seagrass	21.09.2022	19.3	26	1:26
Seabed of Capo Vaticano	cv210922	Tyrrhenian Sea	IT9340093	38°36'16"N 15°50'51"E	rocky	21.09.2022	18.1	26	1:46
Fondali Capo Cozzo - S. Irene	si180622	Ionian Sea	IT9340094	38°43'40"N 16°00'18"E	rocky	18.06.2022	15.4	25.3	1:04
Fondali Capo Cozzo - S. Irene	br200922	Ionian Sea	IT9340094	38°43'50"N 16°00'15"E	rocky	20.09.2022	16.9	26	1:53
Calanchi di Palizzi Marina	cp190822	Ionian Sea	IT9350144	37°54'60"N 16°00'23"E	sandy	19.08.2022	11.8	26.3	1:46
Spiaggia di Brancaleone	cb190822	Ionian Sea	IT9350160	38°02'19"N 16°08'50"E	rocky	19.08.2022	12.6	19.7	0:58
Fondali di Scilla	fs010922	Tyrrhenian Sea	IT9350173	38°15'23"N 15°42'48"E	rocky	01.09.2022	20.7	27	1:55
Costa Viola	cv010922	Tyrrhenian Sea	IT9350300	38°15'06"N 15°41'44"E	rocky	01.09.2022	16.6	27	1:40
Fondali di Pizzo Calabro	fdp290523	Tyrrhenian Sea	IT9340092	38°44'48"N 16°08'48"E	sandy	29.05.2022	16.2	26.8	0:41
Foce del Fiume Crati	focs260623	Ionian Sea	IT9310044	39°43'43"N 16°31'44"E	sandy	26.06.2023	15	-	1:56
Fondali Crosia-Pietrapaola-Cariati	ma140723	Ionian Sea	IT9310048	39°33'25"N 16°51'11"E	seagrass	14.07.2023	8.1	27.5	5:14

The habitat type was finally determined into rocky, sandy or seagrass habitat on the obtained videos. Sites that would fit into more than one habitat type were categorized by the following order: rocky habitat > seagrass habitat > sandy habitat. This means that rocky habitats with small badges of seagrass are determined as being rocky habitats, and sandy habitats with a patchy distribution of seagrass are determined as being seagrass habitats.

2.3. Analysis of the BRUVS videos

For the video analysis, only footage of the right camera of the BRUVS was used. The obtained video material was analysed in video editing software for precise viewing of the imagery. A 27" monitor was used for the screening of the videos. Fish identification was performed by their morphology and colour with the help of fishbase.org and Louisy (2020) and was supervised by an experienced researcher. The fish were determined to the genus level wherever possible. One sighting could just be identified at the family level.

Each video was split into five sections of 2 minutes each and a last section of 1:47 minutes. Due to technical reasons, the video recording had to be started and ended inside the boat above water, which can result in different section lengths for the first and last section of each site. For each section, the maximum amount of individuals per each fish species in any one frame (maxN) (Priede et al., 1994) was determined to avoid counting single individuals multiple times and obtain a conservative abundance estimation. For species of high abundance (maxN > 20), estimations of maxN were used.

2.4. Data analyses

2.4.1. Species-accumulation curve

Species-accumulation curves were produced for every site. The sampling time, representing the sampling effort, was correlated with the number of species found at each site. The species-accumulation curves were computed using R version 4.3.0 (R Core Team, 2023) with the RStudio interface 2023.6.1.524 (R Studio Team, 2023) using the packages ggbreak (Shuangbin et al., 2021), ggplot2 (Wickham, 2016) and readxl (Wickham and Bryan, 2023).

2.4.2. Hierarchical cluster analysis

The cluster analysis between the different sites was performed with the detectability data of each species at each site. The clustering was performed using RStudio again. Multiple packages such as dendextend (Galili, 2015) and stats were used. The distances of the sites were calculated using the Bray–Curtis dissimilarity index (Bray and Curtis, 1957), using the vegan package (Oksanen et al., 2022). The paired clustering method was used to arrange the clustering.

2.4.3. Statistical analyses

Statistical analyses were performed also using RStudio. The packages *vegan* (Oksanen et al., 2022) and *pairwiseAdonis* (Martinez Arbizu, 2017) were used to perform permutational multivariate analysis of variances (PERMANOVAs) (Anderson, 2001) and pairwise PERMANOVAs, respectively. For the PERMANOVAs, the distance matrix calculated in chapter 2.4.2 using the Bray–Curtis dissimilarity index was used.

2.4.4. Species richness and biodiversity

The detected species richness at each sampling site was displayed by circles of different sizes on a map according to the sampling location. The map was created with QGIS 3.22.5 (QGIS Development Team, 2023) based on a Google Maps satellite map (Google, 2023) of Calabria and the Mediterranean Sea.

The biodiversity was calculated using the Shannon diversity index (Shannon, 1948). To account for the different sampling efforts, the detectability per minute of the species was used. The different indices were calculated using the *vegan* package in RStudio. To compare the biodiversity in the different locations, Hutcheson's t-test (Hutcheson, 1970) from the *ecolTest* (Salinas and Ramirez-Delgado, 2021) package was used.

3. Results

3.1. Data analyses

A total of 1914.66 min of video material was sighted and a total of 49 fish species were determined of which 38 were present in rocky habitats, 14 in sandy habitats and 34 species were found in seagrass habitats. While only six species were present in all three different habitats, eight species were found only in rocky habitats, four only in sandy habitats and six exclusively in seagrass habitats. In the Ionian Sea, 32 species were present while 44 were present in the Tyrrhenian Sea. Of the 49 species recorded, 45 are autochthonous, 3 are endemic to the Mediterranean and one is listed as an allochthonous species. By the IUCN, 3 species are “Data deficient” (“DD”), 43 species are listed as “Least concerned” (“LC”), two species are listed as “Vulnerable” (“VU”) and one as “Endangered” (EN”) in the Mediterranean Sea.

Table 3.1: List of species and their characteristics. Each species is described by characteristics like their commercial importance, conservation status, origin, and distribution. The conservation statuses are taken from the IUCN Red List. If the statuses in the Mediterranean Sea and on the Global scale are not equal, the global conservation status is added behind the dash. The origin of the species are separated into 3 groups, autochthonous ("AU"), endemic ("E"), and alien/allochthonous ("AL"). Species that are considered thermophilic and expanding northwards are marked with a "TH". The distribution of the species is split in either the Tyrrhenian Sea ("T"), Ionian Sea ("I"), and in both ("T/I"). References are found in the end of the table under the respective numbers.

Species	Family	Commercial importance	Conservation status	Endemic/alien and thermophilic species	Tyrrhenian/Ionian Sea
<i>Anthias anthias</i> ¹	Anthiidae	Low	LC	AU	T
<i>Apogon imberbis</i> ²	Apogonidae	Low	LC	AU	T
<i>Balistes capriscus</i> ^{3/4}	Balistidae	Medium	DD/VU	AU + TH	T
<i>Boops boops</i> ⁵	Sparidae	High	LC	AU	T/I
<i>Bothus podas</i> ⁶	Bothidae	Medium	LC	AU	T/I
<i>Chelon labrosus</i> ⁷	Mugilidae	Low	LC	AU	T/I
<i>Chromis chromis</i> ⁸	Pomacentridae	Low	LC	AU	T/I
<i>Coris julis</i> ⁹	Labridae	Medium	LC	AU	T/I
<i>Dentex dentex</i> ¹⁰	Sparidae	High	VU	AU	T
<i>Diplodus annularis</i> ¹¹	Sparidae	High	LC	AU	T/I
<i>Diplodus puntazzo</i> ¹²	Sparidae	High	LC	AU	T/I
<i>Diplodus sargus</i> ¹³	Sparidae	Medium	LC	E	T/I
<i>Diplodus vulgaris</i> ¹⁴	Sparidae	High	LC	AU	T/I
<i>Echelus myrus</i> ¹⁵	Ophichidae	No	LC	AU	I
<i>Epinephelus costae</i> ¹⁶	Serranidae	High	DD	AU + TH	T/I
<i>Epinephelus marginatus</i> ¹⁷	Serranidae	High	EN	AU + TH	T
<i>Gobius geniporus</i> ¹⁸	Gobiidae	Low	NL	E	T
<i>Lithognathus mormyrus</i> ¹⁹	Sparidae	High	LC	AU	I
<i>Mugil cephalus</i> ²⁰	Mugilidae	High	LC	AU	T
<i>Mullus barbatus</i> ²¹	Mullidae	High	LC	AU	T/I
<i>Mullus surmuletus</i> ²²	Mullidae	High	LC	AU	T/I
<i>Muraena helena</i> ²³	Muraenidae	Low	LC	AU	T/I
<i>Myliobatis aquila</i> ^{24/25}	Myliobatidae	Low	VU/CR	AU	I
<i>Oblada melanura</i> ²⁶	Sparidae	Medium	LC	AU	T/I
<i>Pagellus acarne</i> ²⁷	Sparidae	Medium	LC	AU	T/I
<i>Pagrus pagrus</i> ²⁸	Sparidae	High	LC	AU	T/I
<i>Parablennius rouxi</i> ²⁹	Blenniidae	No	LC	AU	T
<i>Pteroplatytrygon violacea</i> ³⁰	Dasyatidae	Low	LC	AU	T
<i>Sarda sarda</i> ³¹	Scombridae	High	LC	AU	T
<i>Sardinella aurita</i> ³²	Clupeidae	High	LC	AU + TH	T/I
<i>Sarpa salpa</i> ³³	Sparidae	High	LC	AU	T/I
<i>Scorpaena spp.</i>	Scorpaenidae	-	LC	AU	T
<i>Seriola dumerili</i> ³⁴	Carangidae	High	LC	AU	T/I
<i>Seriola fasciata</i> ³⁵	Carangidae	Low	LC	AL	T/I
<i>Serranus cabrilla</i> ³⁶	Serranidae	Low	LC	AU	T
<i>Serranus scriba</i> ³⁷	Serranidae	Low	LC	AU	T/I
<i>Sparisoma cretense</i> ³⁸	Scaridae	Medium	LC	AU + TH	T
<i>Sparus aurata</i> ³⁹	Sparidae	High	LC	AU	T
<i>Sphyaena sphyraena</i> ⁴⁰	Sphyraenidae	Medium	LC	AU + TH	T/I

<i>Spicara maena</i> ⁴¹	Centracanthidae	Medium	LC	AU	T/I
<i>Spondylisoma cantharus</i> ⁴²	Sparidae	High	LC	AU	T/I
<i>Sprattus sprattus</i> ^{43/44}	Clupeidae	High	DD/LC	AU	T
<i>Symphodus doderleini</i> ⁴⁵	Labridae	Low	LC	E	T/I
<i>Symphodus roissali</i> ⁴⁶	Labridae	Low	LC	AU	T
<i>Symphodus tinca</i> ⁴⁷	Labridae	Low	LC	AU	T/I
<i>Thalassoma pavo</i> ⁴⁸	Labridae	Medium	LC	AU + TH	T
<i>Trachinotus ovatus</i> ⁴⁹	Trachinotidae	Medium	LC	AU + TH	I
<i>Trachurus trachurus</i> ^{50/51}	Carangidae	High	LC/VU	AU	I
<i>Xyrichtys novacula</i> ⁵²	Labridae	High	LC	AU + TH	T/I

¹ (Yokes et al., 2011a)	¹⁴ (Bizsel et al., 2011e)	²⁷ (Bizsel et al., 2011h)	⁴⁰ (Yokes et al., 2011g)
² (Yokes et al., 2011i)	¹⁵ (Papakonstantinou et al., 2011)	²⁸ (Bizsel et al., 2011i)	⁴¹ (Francour et al., 2011)
³ (Liu et al., 2015)	¹⁶ (Sadovy et al., 2011)	²⁹ (Williams et al., 2014)	⁴² (Bizsel et al., 2011i)
⁴ (Rijnsdorp and Papakonstantinou, 2015)	¹⁷ (Cornish, 2011)	³⁰ (Baum et al., 2016)	⁴³ (Di Natale et al., 2011d)
⁵ (Bizsel et al., 2011a)	¹⁸ (Kovacic et al., 2014)	³¹ (Di Natale et al., 2011e)	⁴⁴ (Nedreaas et al., 2018)
⁶ (Golani et al., 2011a)	¹⁹ (Bizsel et al., 2011f)	³² (Di Natale et al., 2011c)	⁴⁵ (Pollard, 2014)
⁷ (Yokes et al., 2011d)	²⁰ (Camara et al., 2019)	³³ (Bizsel et al., 2011j)	⁴⁶ (Bilecenoglu et al., 2011b)
⁸ (Yokes et al., 2011h)	²¹ (Craig and Pollard, 2015)	³⁴ (Herrera and Smith-Vaniz, 2015a)	⁴⁷ (Bilecenoglu et al., 2011c)
⁹ (Bilecenoglu et al., 2011a)	²² (Yokes et al., 2011e)	³⁵ (Herrera and Smith-Vaniz, 2015b)	⁴⁸ (Bilecenoglu et al., 2011d)
¹⁰ (Bizsel et al., 2011b)	²³ (Golani et al., 2011b)	³⁶ (Yokes et al., 2011b)	⁴⁹ (Di Natale et al., 2011b)
¹¹ (Bizsel et al., 2011c)	²⁴ (Serena et al., 2016)	³⁷ (Yokes et al., 2011c)	⁵⁰ (Di Natale et al., 2011a)
¹² (Bizsel et al., 2011d)	²⁵ (Jabado et al., 2021)	³⁸ (Yokes et al., 2011f)	⁵¹ (Smith-Vaniz et al., 2015)
¹³ (Russell, 2014)	²⁶ (Bizsel et al., 2011g)	³⁹ (Bizsel et al., 2011k)	⁵² (Bilecenoglu et al., 2011e)

4.2. Species-accumulation curve

Species-accumulation curves for all the sites correlated with the soaking time (Fig. 3.1). The different sites can be distinguished by different colours while the habitats are marked with different shapes of the data points. Most of the time, the species count reached a plateau, with the exception of si200922 and sdi070522 where additional species were detected close to the end of the soaking time. The time is shown on the x-axis with a break at 170 min to obtain a higher resolution for sites with less sampling time than ma140723. The graph shows that sites from sandy habitats (compare Table 2.1), symbolised with triangular time markers, group up with a species count of 3–6 different species. Sites with rocky or seagrass habitats represented by round or squared markers, respectively, mix all together with species counts between 11 and 22 species. Regarding the number of observed species, the site ma140723 reached the highest count with a total of 22 species, followed by si200922 with 20 species. Both sites are covered by seagrass habitats. Site cv210922 has the highest species count for sites with rocky habitats with 19 species counted. The highest number of observed species in sites with sandy habitats are six in the sites fccs260722 and fccs260623.

Species accumulation curve

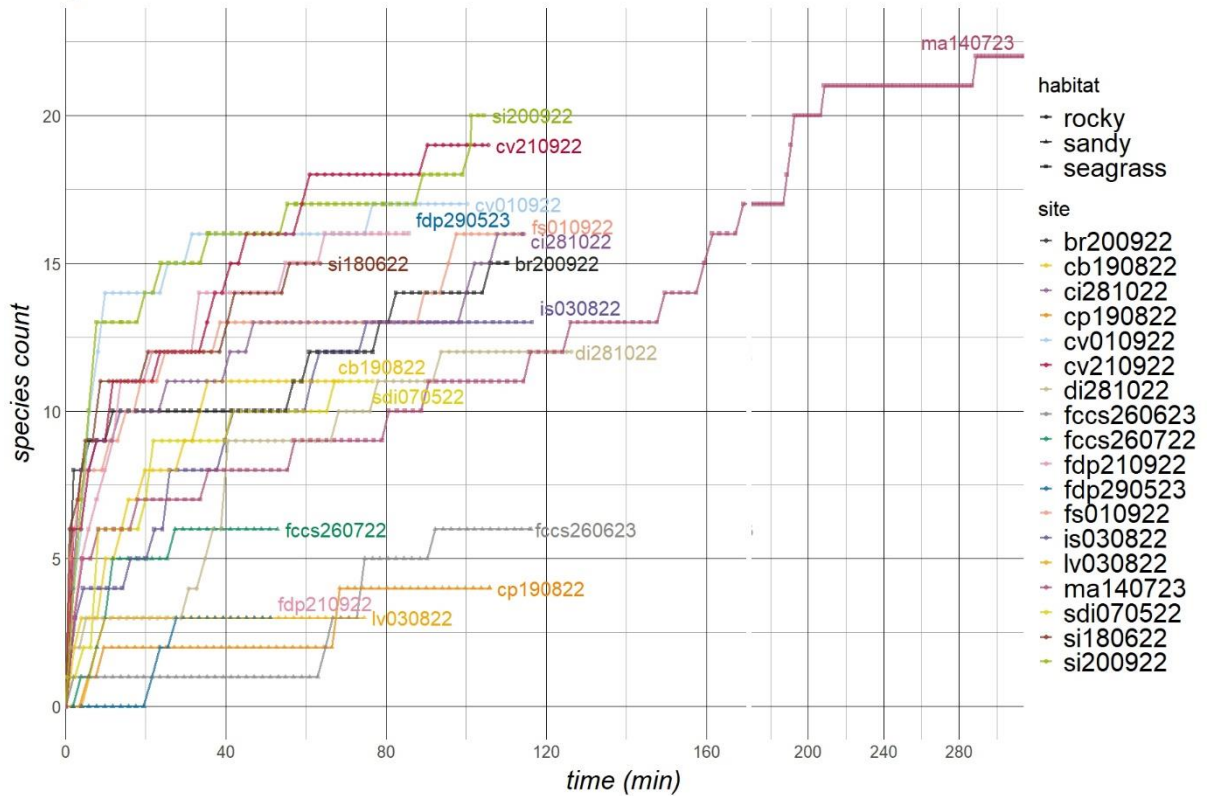


Figure 3.1: Species-accumulation curve of each site. The graphs show the detection of species in correlation to the time. The number of species is shown on the y-axis and the time in minutes is shown on the x-axis. The x-axis is split at a value of 170.0 min to change the scale for a higher resolution in the smaller values. The graphs are colour-coded related to the sampling site, as shown in the legend. The datapoints of each graph are shaped according to their habitat. Datapoints from rocky habitats have circular, sandy habitats have triangular and seagrass habitats have cubic datapoints.

4.3. Hierarchical cluster analysis

In Figure 3.2, the sites clustered by the detectability of each of their species are shown. The site labels are colour-coded in red, green, and orange for rocky, seagrass and sandy habitats, respectively. The dendrogram splits into two branches at the beginning, where the lower branch clusters all the sandy habitats and “cb190822” as a rocky habitat. Meanwhile the upper branch clusters only sites from rocky and seagrass habitats plus “fccs260623” as a site with a sandy habitat. Whereas sandy habitats cluster mostly with sandy habitats, in the upper branch, sites do not necessarily cluster by habitat.

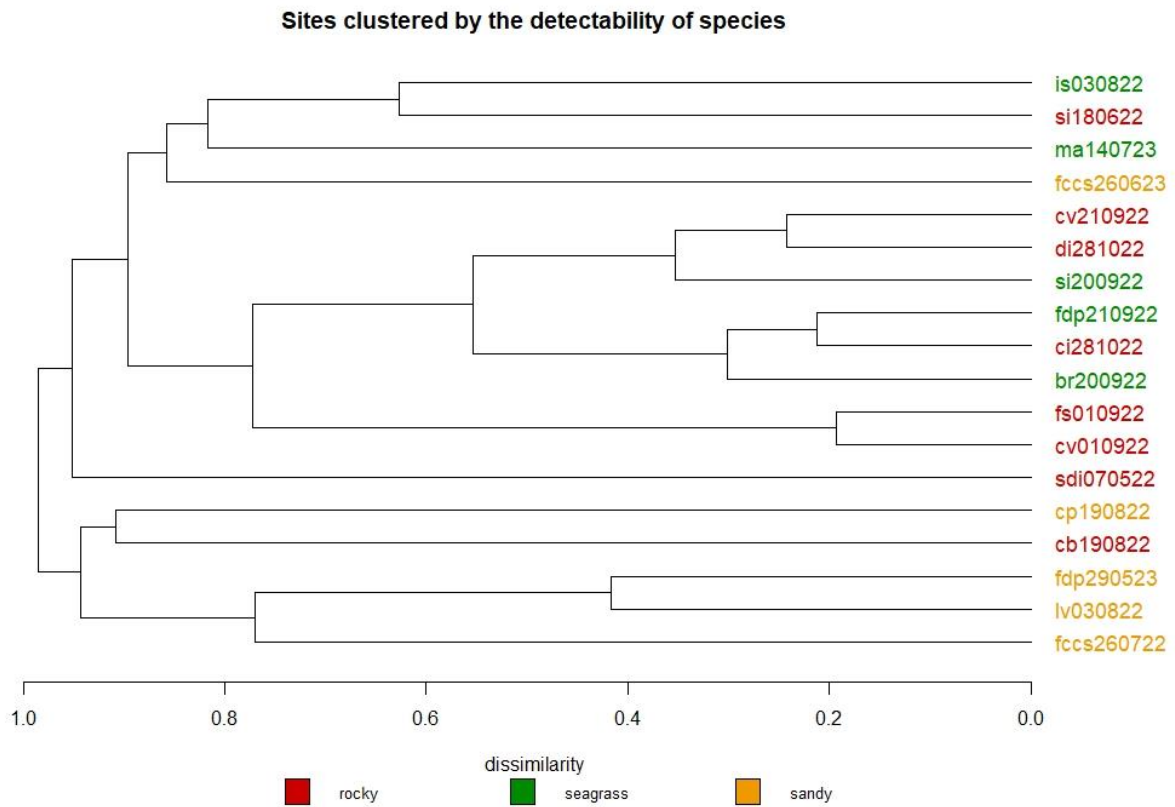


Figure 3.2: Dendrogram of hierarchical clustered sampling sites. The dendrogram shows the sampling sites clustered by the dissimilarities of the detectability of the species. The distance was calculated using the Bray–Curtis dissimilarity index. The labels of the sampling sites are colour-coded corresponding to the habitats, with rocky, seagrass and sandy present in red, green and orange, respectively. The shorter the distance between two sites, the smaller the dissimilarity is between them.

4.4. Species richness mapping

The species richness differs strongly between the sites and habitats as can be seen in Figure 3.3 and Table 3.2. The centre dot of each site locates the exact location of the sampling site while the size of the circle around symbolizes the number of species at this specific location. The sampling point markers are colour-coded depending on the different habitats present. Sites located in a rocky habitat are red, in a sandy habitat are yellow, and in a seagrass habitat are light green. The species richness ranges from 3 species at “Lago La Volta” (lv030822) and “Fondali di Pizzo Calabro” (fdp290723) to up to 22

Table 3.2: Number of species at the sampling sites and the respective Shannon-Indices

Sampling site	Species count	Shannon-Index
br200922	15	1.594
cb190822	11	1.266
ci281022	16	1.576
cp190822	4	0.957
cv010922	17	0.658
cv210922	19	1.266
di281022	12	0.567
fccs260623	6	1.292
fccs260722	6	1.462
fdp210922	3	1.327
fdp290523	16	0.895
fs010922	16	0.636
is030822	13	1.343
lv030822	3	0.914
ma140723	22	2.089
sdi070522	11	1.022
si180622	15	1.796
si200922	20	1.449

species at “Fondali Crosia-Pietrapaola-Cariati” (ma140723). A detailed list of the number of species at each site can be seen in Table 3.2.

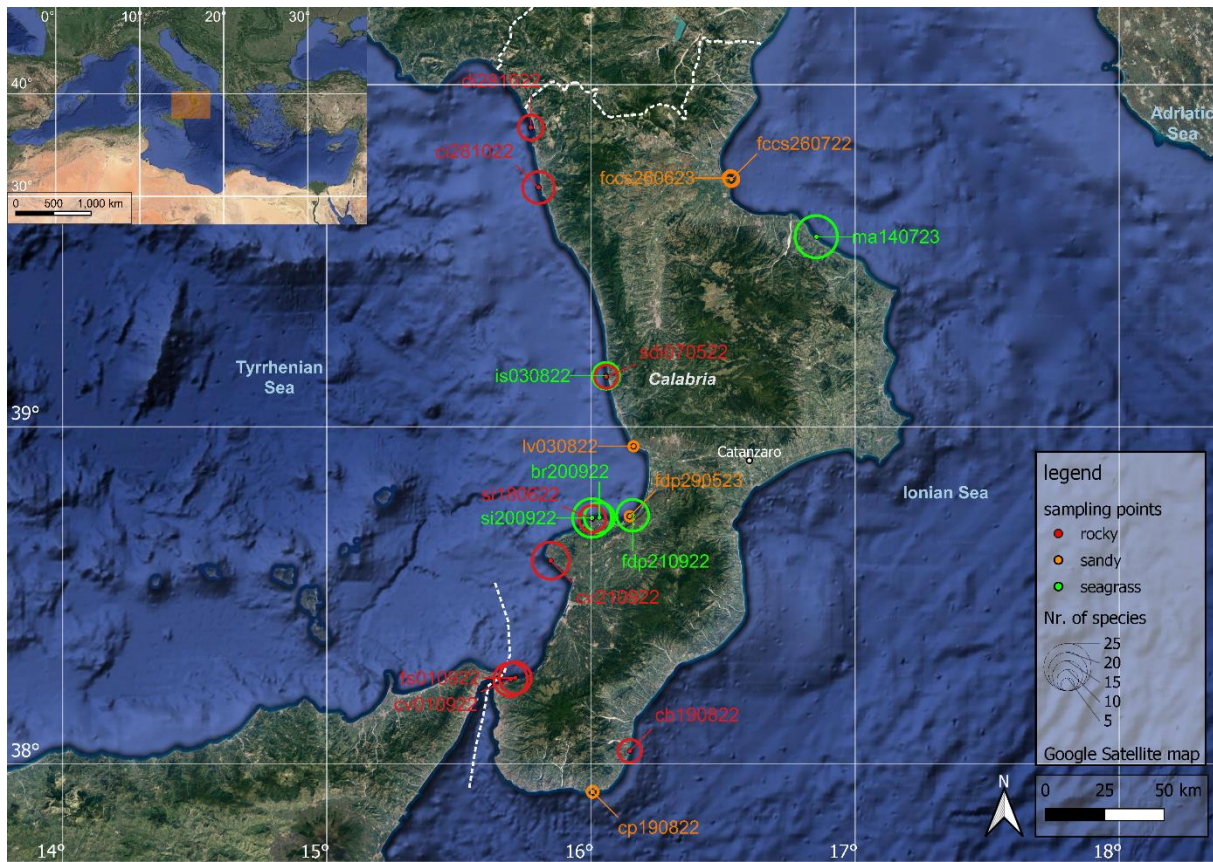


Figure 3.3: Map of Calabria with the sampling sites and their species richness. The map shows Calabria, parts of Sicily and the adjacent waters. The map in the top left corner shows the Mediterranean Sea with its surrounding countries, the area shown on the big map is marked with an orange square for better orientation. Sampling sites are marked by small points on the map, surrounded by circles of different sizes. The sampling sites are colour-coded regarding their habitat: whereas rocky habitats are coloured red, sandy habitats are orange and seagrass habitats are green. The size of the surrounding circles are correlated to the number of species detected at the site. Sites with higher species counts have larger circles than sites with a lower species count.

4.5. Biodiversity

The biodiversity represented by the Shannon-Index. The Shannon-Index for each site is shown in Table 3.2. The Shannon-indices of rocky, sandy and seagrass habitats are 1.18, 1.86 and 2.19, respectively (compare Table 3.3). The Shannon-Index was also calculated for each habitat by the respective Sea, the results can be seen in Table 3.3. The highest Shannon-Index was calculated for Seagrass habitats in total. The only big difference between the two seas was detected in sandy habitats being 1.03 in the Tyrrhenian Sea and 1.74 in the Ionian Sea. Comparing the Shannon-Indices of the different habitats, significant differences between the habitats were

Table 3.3: Shannon-Indices by habitats and seas.

Habitat	Shannon-Index
Rocky total	1.18
Rocky Tyrrhenian	1.14
Rocky Ionian	1.27
Sandy total	1.86
Sandy Tyrrhenian	1.03
Sandy Ionian	1.74
Seagrass total	2.19
Seagrass Tyrrhenian	2.05
Seagrass Ionian	2.09

only found between rocky and seagrass habitats (Hutcheson t-statistic = -3.198, df = 5.649, p-value = 0.002) between sandy and rocky (p = 0.242) or sandy and seagrass (p = 0.555) no statistically significant differences could be detected.

4.6. Species of high commercial importance

The species stated as of high commercial importance in Table 3.1 were analysed separately. For each habitat, regardless of their location in the Ionian Sea versus the Tyrrhenian Sea. The highest detectability of species of high commercial importance is the highest in rocky habitats with an average detectability of 0.33/min, followed by seagrass habitats with 0.21/min. Sandy habitats have the lowest detectability with 0.11/min. 17 commercial fish species were caught on camera in rocky habitats, 7 in sandy habitats and 14 in seagrass habitats.

4.7. Thermophilic species

Thermophilic species were detected in all habitats and seas of the sampled area. The map in figure 3.4. that shows the sampling sites with the respective detectability of thermophilic species. In the Ionian Sea five thermophilic species were detected while eight were detected

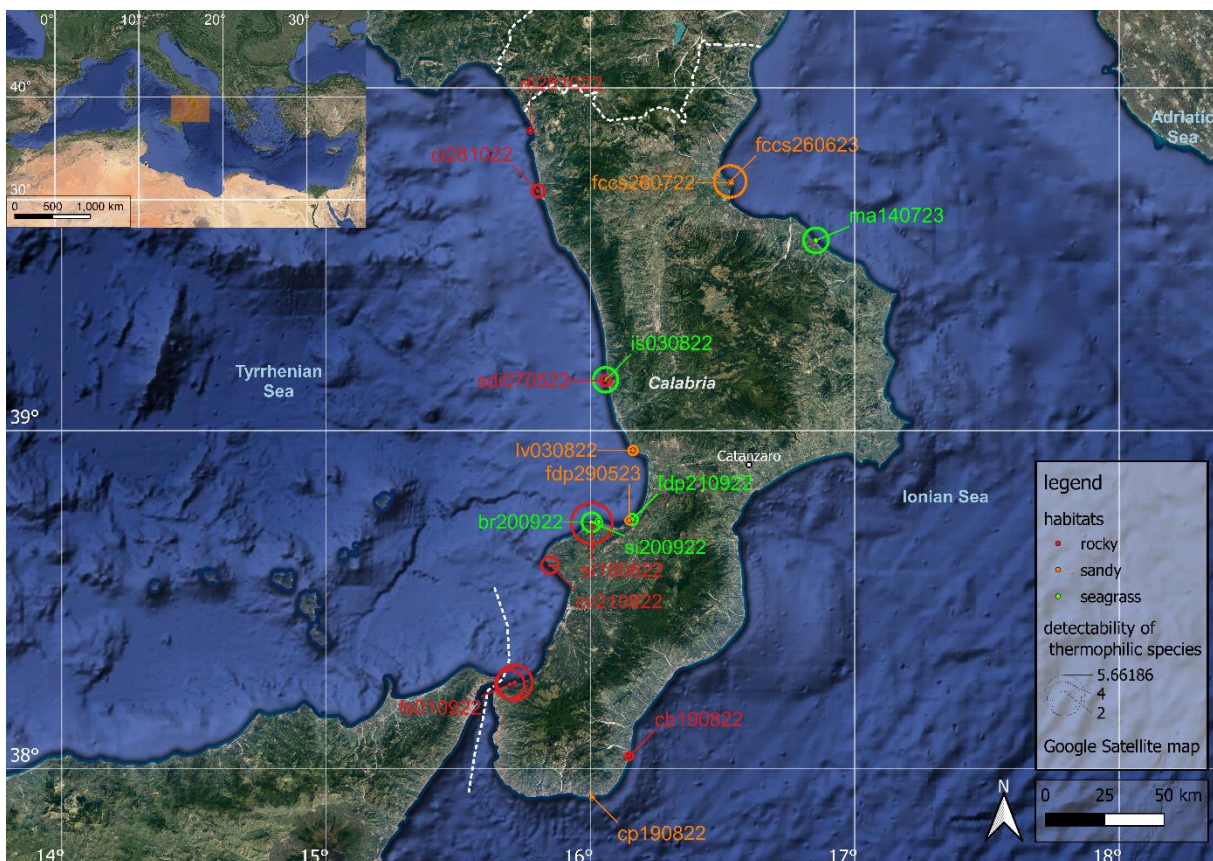


Figure 3.4: Map of Calabria with the sampling sites and the detectability of thermophilic species. The map shows Calabria, parts of Sicily and the adjacent waters. The map in the top left corner shows the Mediterranean Sea with its surrounding countries, the area shown on the big map is marked with an orange square for better orientation. Sampling sites are marked by small points on the map, surrounded by circles of different sizes. The sampling sites are colour-coded regarding their habitat: whereas rocky habitats are coloured red, sandy habitats are orange and seagrass habitats are green. The size of the surrounding circles are correlated to the number of species detected at the site. Sites with higher species counts have larger circles than sites with a lower species count.

in the Tyrrhenian Sea. On average, thermophilic species had a detectability of 0.624/min in the Ionian Sea and 2.016/min in the Tyrrhenian Sea. In the Tyrrhenian Sea thermophilic species were detected in all sites, in two of the five sites of the Ionian Sea no thermophilic species were detected.

4.8. Statistical analyses

The statistical analyses focused on finding statistical results on the different groupings of the sampling sites. The sites were grouped by their subregion in the Mediterranean Sea, called just seas in the following, and by their habitats. The results of the

Table 3.4: Results of PERMANOVA comparing all sites by habitat and seas. Df = degrees of freedom, SumOfSqs = sum of squares, R2 = SumOfSqs(x)/SumOfSqs(Total), F = values of F-statistics, Pr(>F) = p-value.

	Df	SumOfSqs	R2	F	Pr(>F)
Habitats	2	1.686280797	0.248730023	2.601867729	0.001
Seas	1	0.556554176	0.082092931	1.717484245	0.047
Residual	14	4.536727768	0.669177046	-	-
Total	17	6.779562741	1	-	-

PERMANOVAs can be found in Table 3.4 and Table 3.6. A significance level of $\alpha = 0.05$ was adopted for all tests. The tests show that the habitat type ($p=0.001$), as well as the seas ($p=0.022$) have a significant impact on the species detectability (compare tab. 3.4). Also, the correlation of the habitat type and the seas have a significant impact on the species detectability ($p=0.010$) (compare tab. 3.4).

Comparing the habitats against each other regarding their location in either the Ionian or Tyrrhenian Sea, rocky and sandy habitats show statistically significant differences between the community composition (rocky: $p<0.001$ and sandy: $p = 0.006$). The only habitat that shows no statistically significant changes in the community composition between the sites in the Tyrrhenian and the Ionian Sea is the seagrass habitat ($p=0.068$).

Table 3.5: Results of the comparison of the habitats regarding the differences in detectability between the Ionian and the Tyrrhenian Sea. n = number of observations, statistic = Kruskal–Wallis rank sum statistic, df = degree of freedom, p = p-value

Habitat	n	statistic	df	p
rocky	98	18.50511	1	<0.001
sandy	98	7.345801	1	0.007
seagrass	98	3.341677	1	0.068

The pairwise comparison between the individual habitats shows that the detectability of the respective species in rocky and seagrass habitats is not statistically significantly different ($p=0.114$). Rocky and sandy habitats have statistical differences considering the respective detectability between the two habitats ($p=0.001$) as well as the between seagrass and sandy habitats ($p=0.007$) (compare Table 3.6).

Table 3.6: Results of pairwise PERMANOVA comparing the fish communities of different habitats. Df = degrees of freedoms, SumOfSqs = Sum of squares, R2 = SumOfSqs(x)/SumOfSqs(Total), F = values of F-statistics, Pr(>F) = p-value

rocky-seagrass	Df	SumOfSqs	R2	F	Pr(>F)
Habitats	1	0.460063071	0.116373181	1.448694137	0.114
Residuals	11	3.493279673	0.883626819	-	-
Total	12	3.953342744	1	-	-
rocky-sandy	Df	SumOfSqs	R2	F	Pr(>F)
Habitats	1	1.084301	0.214425	3.002477	0.001
Residuals	11	3.97249	0.785575	-	-
Total	12	5.056791	1	-	-
rocky-sandy	Df	SumOfSqs	R2	F	Pr(>F)
Habitats	1	1.027632124	0.274150298	3.021565447	0.007
Residuals	8	2.720793952	0.725849702	-	-
Total	9	3.748426077	1	-	-

Statistical comparison between the different habitats and the seas regarding the species of commercial importance showed that the habitat has a high significance ($p = 0.001$) while the location in either the Ionian or the Tyrrhenian Sea had no statistical significance ($p = 0.392$) (compare Table 3.7). Comparing the habitats against each other regardless of their location showed statistically significant differences in the detectability of highly commercial species between rocky and seagrass habitats ($p = 0.028$), rocky and sandy habitats ($p = 0.001$) but no significant differences between seagrass and sandy habitats (comp. Table 3.8)

Table 3.7: Results of PERMANOVA comparing the communities of species with high commercial value from all sites by habitat and seas. Df = degrees of freedom, SumOfSqs = sum of squares, R2 = SumOfSqs(x)/SumOfSqs(Total), F = values of F-statistics, Pr(>F) = p-value.

	Df	SumOfSqs	R2	F	Pr(>F)
Habitats	2	1.5458	0.2272	2.2125	0.001
Seas	1	0.3681	0.0541	1.0538	0.392
Residual	14	4.8907	0.7187	-	-
Total	17	6.8046	1	-	-

Table 3.8: Results of pairwise PERMANOVA comparing the communities of species with high commercial value. Df = degrees of freedoms, SumOfSqs = Sum of squares, R2 = SumOfSqs(x)/SumOfSqs(Total), F = values of F-statistics, Pr(>F) = p-value

rocky-seagrass	Df	SumOfSqs	R2	F	Pr(>F)
Habitats	1	0.6247	0.1523	1.9766	0.028
Residuals	11	3.4765	0.8477	-	-
Total	12	4.1011	1	-	-
rocky-sandy	Df	SumOfSqs	R2	F	Pr(>F)
Habitats	1	1.0198	0.2028	2.7985	0.001
Residuals	11	4.0086	0.7972	-	-
Total	12	5.0284	1	-	-
seagrass-sandy	Df	SumOfSqs	R2	F	Pr(>F)
Habitats	1	0.6446	0.1753	1.7005	0.076
Residuals	8	3.0325	0.8247	-	-
Total	9	3.6771	1	-	-

Analysing the detectability of thermophilic species, using a PERMANOVA analysis, comparing the Tyrrhenian Sea versus the Ionian Sea showing no statistical evidence of significant differences between those two (p = 0.37) (comp. Table 3.9).

Table 3.9: Results of PERMANOVA comparing the detectability of communities of thermophilic species by habitat and seas. Df = degrees of freedom, SumOfSqs = sum of squares, R2 = SumOfSqs(x)/SumOfSqs(Total), F = values of F-statistics, Pr(>F) = p-value.

	Df	SumOfSqs	R2	F	Pr(>F)
Seas	1	0.4530	0.0720	1.0865	0.37
Residual	14	5.8369	0.9280	-	-
Total	15	6.2899	1.0000	-	-

4. Discussion

4.1. Alien species

As the only allochthonous species detected during all sampling *S. fasciata* is present only in rocky and sandy habitats on both sides of the Calabrian coast but absent in seagrass habitats in either the Ionian or Tyrrhenian Sea. *S. fasciata*'s preferred habitats are rocky reefs but they are also present in open water above sandy habitats, in depth between 50 and 130m (Smith-Vaniz, 2015). Therefore, the absence in seagrass habitats is not surprising, as well as the low detectability of this species in general (Ionian Sea: 0.011/min, Tyrrhenian Sea: 0.008/min) due to the maximum sampling depth of 26.4 m. The detectability in multiple sites in both basins of the Mediterranean Sea also shows that *S. fasciata* might have already established a more permanent presence in both the Tyrrhenian Sea as well as the Ionian Sea.

4.2. Thermophilic species

Apart of non-indigenous species (NIS), thermophilic fish species that are indigenous to the Mediterranean Sea expanding northwards with rising water temperatures, also can change the characteristics of a fish population along the coast (Walther et al., 2002, Perry et al., 2005). The statistical test did not show significant differences comparing the Ionian Sea against the Tyrrhenian Sea. This might also be related to the small number of thermophilic species in this study. Comparing the higher abundance and number of thermophilic fish species in both the Ionian and Tyrrhenian Sea, the higher abundance and diversity in the Tyrrhenian Sea over the Ionian Sea might be explained by different annual temperature fluctuations and different average minimum temperatures in both seas. Whereas the north-eastern Ionian Sea is colder than the south-western Tyrrhenian where the sample locations are located, even though the

eastern basin is generally colder than the western basin due to the inflow of colder Atlantic water (Shaltout and Omstedt, 2014, Lejeune et al., 2010). Sbragaglia et al. (2020) also figured out, that in the Adriatic/Ionian basin the meridionalization, meaning the poleward expansion of thermophilic species, is lagging behind in this trend compared to the Tyrrhenian basin. Another reason for the lower detection of thermophilic fish species in the Tyrrhenian Sea might be the habitat preference of most thermophilic species to more complex habitats like rocky-reefs or seagrass (Azzurro, 2008) also explaining the higher number of species detected in the rocky and seagrass habitats sampled. With only one rocky and one seagrass habitat sampled in the Ionian Sea, the chance of missing species in this sampling region is likely.

4.3. Biodiversity in different habitats

The complexity of the benthic structure of a marine habitat does not only have an impact on the detectability and presence of thermophilic fishes but also shows in our data as a general trend counting the number of species detected in rocky and seagrass habitats being more than double the counted species in sandy habitats. A lot of fish prefer complex benthic structures over flat sandy habitats for multiple reasons like shelter from predators between seagrass or in small caves (Guidetti, 2000, Giakoumi and Kokkoris, 2013) or their reproductive cycle where eggs are attached to hard substrates, for example *C. chromis* (Pinnegar, 2018). Another reason for the higher number of species and higher detectability of the species supposedly is the higher productivity of such areas and therefore the higher availability of food (Giakoumi and Kokkoris, 2013). Another factor regarding detecting the abundance of fish in seagrass habitats discussed by Whitmarsh et al. (2014) is the reduced field of view by seagrass leaves, that might reduce the detectability of more fish.

Similarities between rocky and seagrass habitats in respect to species detectability and composition has been detected by different studies in the past (Giakoumi and Kokkoris, 2013 and references therein, La Mesa et al., 2011). The detected differences between the rocky and sandy or seagrass and sandy and similarity between rocky and seagrass habitats is also visible in the cluster analysis grouping most of the sites with sandy habitat with a big distance to sites with rocky or seagrass habitat. Regarding the biodiversity in the habitats, Guidetti (2000) stated in the Adriatic Sea that s with a lower fish biodiversity and abundance. In this study, the overall number of species were the highest in rocky habitats as well as the detectability/abundance of fish which is in contrary to the literature. When considering a mixture of the habitats, previous studies (Giakoumi and Kokkoris, 2013) imply a higher diversity in mixed habitats. Separating the sites in just three habitats not accounting for habitat mixtures of rocky habitats with seagrass and sandy parts are possible. The highest number of species counted in a single site though is registered in a seagrass habitat. This leads to the assumption that the overrepresentation of sites with rocky habitats and the unaccounted mixture of habitats leading

to this result in a former study in the Mediterranean (Guidetti, 2000). Regarding the highest biodiversity on the species level, seagrass habitats have a higher biodiversity than both rocky and sandy habitats, while sandy habitats show a higher biodiversity than rocky habitats. The high value might be due to the high abundance of *C. chromis* as the predominant species in rocky habitats lowering the Shannon-Index. Another reason for the biodiversity in sandy habitats may be the location of fccs260722 and fccs260623 in front of a river mouth. River mouths can increase the primary production in the surrounding waters (Harrison and Whitfield, 2012) which can cause a higher abundance of fish (Ware and Thomson, 2005) and can also result in the higher biodiversity observed even though the number of detected species was still low compared to the other habitats. Supporting this assumption is the higher number of species detected in the Ionian Sea in contrast to the sandy habitats in the Tyrrhenian Sea.

4.4. Species of high commercial value

The detectability data for commercially important species for all habitats and seas differ from the trends described in the previous paragraph. The even distribution of species and their abundance in both the Tyrrhenian and Ionian Sea is in contrary to the pattern of the whole population while the general pattern regarding the habitats is equal to the whole community. Significant differences were detected between rocky and seagrass habitats as well as between rocky and sandy habitats, while no statistically significant differences were detected between seagrass and sandy habitats. An explanation therefore is the higher percentage of species with commercial value more likely to occur in sandy habitats as well as the fact that the most common species detected *C. chromis* is no species of high commercial value and only present in rocky and seagrass habitats. Even though the literature supposes that more species of commercial importance share their preferred habitat in rocky and sandy or rocky and seagrass habitats (compare references in Table 3.1) so no statistical differences would be expected between those habitats while only a few species have their preferred habitat in sandy and seagrass habitats. Also taking into account the detectability/abundance that is supposed to be the highest in rocky habitats, followed by seagrass habitats and the lowest in sandy habitats (Guidetti, 2000). These differences in fish abundance and therefore detectability in the habitats, seagrass and sandy habitats are more similar than between rocky and seagrass habitats that also share a higher number of species.

4.5. Comparison of biodiversity between the Tyrrhenian and the Ionian Sea

Even though, the Ionian and Tyrrhenian Sea are just separated by the Strait of Messina, there are differences between the two areas. While the Tyrrhenian coast of Calabria is mainly dominated by rocky habitats with a wide distribution of seagrass, mainly *Possidonia oceanica* Delile, the benthic habitat of Ionian coast of Calabria is mainly dominated by sandy habitat with

fewer distribution of seagrass (Populus et al., 2017). In former studies seagrass habitats, especially of *P. oceanica* were pointed out to host up to 20-25% of the Mediterranean species and also being highly important as a spawning ground and nursery for different fish species (Pergent-Martini and Le Ravallec, 2007, Boudouresque and Meinesz, 1983). Another difference is the coastal upwelling on the eastern coast of Sicily influencing the waters of the Tyrrhenian coast (Azzaro et al., 2007) leading to a high productivity in this area and making it one of the highest fish species richness in the Mediterranean around Sicily (Coll et al., 2012). This upwelling also seems to have an influence on the Tyrrhenian coast of Calabria as it is marked as an ecosystem hotspot in . Regarding the Ionian coast of Calabria Coll et al. (2012) assessed the cumulative risks for the biodiversity higher than in the Tyrrhenian Sea, symbolising the higher pressure for fish and other marine organisms in the Ionian basin of the coast of Calabria. These differences in benthic habitat, nutrient support and environmental pressure is also visible in the detectability data. The average detectability of a fish per minute in the Ionian Sea is lower than in the Tyrrhenian Sea in all habitats, with the exception of sandy habitats which reason was discusses above under point 4.3.. Also, the numbers of species detected in the Tyrrhenian Sea is higher than in the Ionian Sea supporting the thesis of a biodiversity hotspot in the Tyrrhenian Sea.

4.6. Summary

Summarizing we can say that the fish communities are mainly characterized by the habitat and their location in one of the seas. The differences between the communities of rocky and sandy or seagrass and sandy habitats are related to the complexity of the benthic habitat regarding their species composition and diversity and the productivity of the respective habitat regarding their abundance. More complex habitats like rocky and seagrass habitats have higher biodiversity than the less complex sandy habitats. The differences between the Ionian and Tyrrhenian Sea are caused by differences in the conditions of the two basins, starting with the higher coverage of rocky and seagrass in coastal areas in the Tyrrhenian Sea and more sandy habitats with less seagrass resulting in a higher diversity and higher abundance in the Tyrrhenian Sea. Another fact that is supporting the higher abundance/detectability of fish is the increased availability of nutrients and productivity on the Tyrrhenian coast due to an upwelling effect on the coast of Sicily. Due to water dynamics and temperature differences between the Ionian and the Tyrrhenian Sea, the number of indigenous thermophilic species and their detectability in the Tyrrhenian Sea is higher than in the Ionian Sea due to higher average water temperatures on the Tyrrhenian coast. The differences in productivity of the two seas though do not represent in species of high commercial interest, in average they are equally detectable in both seas but differ in habitats, while rocky habitats have the highest number of species and detectability, followed by seagrass and sandy habitats.

Further study in this area is needed. To get a more detailed view on the influence of the habitats a finer grouping of the habitats would be useful for example also comparing mixtures of habitats as it was suggested by Giakoumi and Kokkoris (2013). By analysing the length of the detected fish with the help of the stereo camera setup and specialised software more information on the fish communities could be found out regarding their age and possible spawning and nursing areas in specific sites and habitats. Furthermore, to examine the different SACs a more detailed sampling including multiple sites per SAC and different sampling periods would also give a clearer view on the effectivity of the respective SAC regarding the fish community.

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6. Attachment

Attachment S1: Results of the Literature research at Web of Science and Scopus using the following specifications:

- Keywords: (“baited” AND “video”) OR “BRUVS”
- Publication year: 2016 – 2023
- Search conducted:24.09.2023

Results:

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