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Mark-Recapture method applied by Photo-Identification to a population of bottlenose dolphin (*Tursiops truncatus*, Montagu 1821) present in the Gulf of Catania

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ABSTRACT

Common bottlenose dolphin (*Tursiops truncatus*) is known to be a regular species in the Mediterranean, as well as in the waters of the Gulf of Catania, Ionian Sea, as it presents a strong site fidelity. Nevertheless, its population dynamics and social intraspecific relations in Sicily are little known. This research has been conducted within the monitoring project "Dolphin watching and conservation in the Gulf of Catania" led by the Marecamp association from May to October 2019. In order to supervise the health status of a bottlenose dolphin's local population and to better understand its social structure, it was used the non-invasive photo-identification method, that allowed to capture and recapture these organisms through the natural marks of their dorsal fin. Since this work would like to update to 2019 the Marecamp catalog of this cetacean, all the photos collected have been selected, edited and analyzed using the Darwin software, that compares digital images of the dorsal fins of new dolphins with a database of previously identified dolphin fins. Later, to define the social structure, the Socprog software was utilized and, using association indexes, provided information about the existing interactions among the individuals within the population. During season 2019, 8 individuals were recaptured, while 7 new individuals were captured and added to the catalogue, confirming the residency of this species in the Gulf of Catania, despite the high anthropic impact existing in the area. The social structure analyses instead, confirmed the tendency of this species of forming fission-fusion communities, in spite of the existence of more stabilized couples. In the end, future researches will help to better understand the associations dynamics among individuals and the reasons that led them to establish a certain fidelity to particular subareas and to continue the monitoring of the examined population considering the elevated anthropization of the Gulf.

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INTRODUCTION

This research has been conducted within the project "Dolphin watching and conservation in the Gulf of Catania" led by the Marecamp association from May to October 2019. The area of study lays in the eastern Sicily, as perceivable by the name of the project, in the Gulf of Catania, a section of the Ionian Sea delimited to the north by the Fiumefreddo's river (Catania) and to the south by Capo Campolato (Siracusa).

The Gulf of Catania, due to its productivity and morphology of different origins, allows the settlement of many organisms. In fact, despite the anthropic impact that characterizes the area, the cetaceans' presence is consolidated and all the species regular in the Mediterranean Sea find the gulf an ideal habitat to reside.

1. Cetaceans and their evolutive adjustments

Cetaceans are marine mammals belonging to the infraorder Cetacea. The first traditional theory about Cetaceans evolution stated that they had diverged from Mesonchya, carnivorous ungulate. Recently, thanks to molecular dates, scientists found out that Cetaceans are related to Artiodactyls, even-toed ungulates (*Thewissen et al., 2001*). So, it was established an order which could gather Cetaceans and Artiodactyls: Certatiodactyla. Cetaceans are divided in two parvorders: Mysticeti and Odontoceti. The first parvorder has a filter- feeder system and includes right whales, bowhead whales, rorquals, pygmy right whales, and gray whales; the second one consists of toothed whales like dolphins, porpoises, belugas, narwhals, beaked whales and sperm whales. Having evolved from terrestrial ancestor, Cetaceans have developed remarkable anatomical and physiological adjustments to lead a complete aquatic life: hydrodynamic streamlined shape; dorsal fin on the back; forward limbs have turned into pectoral fins; the tail extremity is flat and formed by two lobes; posterior limbs are absents; on the top of the head there is a blowhole; fur disappears completely after the first six months of life; auricle is absent; female and male genitals are hidden into the body (*Adam, 2007*).

1.1. Breathing

Mammal's respiratory system is formed by lungs, where gas exchanges with blood take place, and by airways, designated to carry air from the outside to lungs and vice versa. Respiratory system's basic structures of marine mammals are very similar to those belonging to terrestrial mammals, but they show some adjustments to the aquatic environment (*Wartzok, 2009*). A very reduced pulmonary leftover volume and a more elastic structure of the airways and of the rib cage simplify the lungs collapse due to the pressure increase throughout dives. The lungs collapse removes air from the exchange surfaces reducing the possibility that the nitrogen could move through the bloodstream and being sent to the tissues (*Poli and Fabbri, 2012*). The respiratory system's adjustments entailed some adjustments of the cardiovascular system and of the metabolic activities. Marine mammals have a high quantity of dissolved oxygen in their blood because of the superior blood volume, besides a very high concentration of myoglobin in skeletal muscles. Marine mammals that perform dives, as other pulmonated vertebrates, are characterized by reflexed mechanisms, defined as "*dive reflex*", which reduce the heart rate causing peripheral vasoconstriction and the blood deflection to the most important organs. Finally, they can plug the acidity caused by CO_2 and lactic acid accumulation formed during the prolonged apneas (*Poli and Fabbri, 2012*).

The cetaceans breathing occurs through the blowholes located on the top of the head so that the animal only needs to exhibit the upper part of its body out of the water to breath. Blowholes are provided with a sphincter that, with a mechanism partly triggered by mechanoreceptors, allows its closing while the cetacean is underwater and its opening when it comes to light. However, the blowhole opening can be volunteer in order to reduce the inspiration time by having already emptied lungs and airways during the emersion.

The cetaceans' lungs are protected by an extremely flexible rib cage that allows them to renew a great quantity of air with only one breath. Moreover, the exchange surface of cetaceans' lungs is considerably larger than other mammals and gas exchanges can occur faster. In the end, air limited in the lungs is also used to communicate by emitting sounds at different frequencies (*Wartzok, 2009*).

1.2 Cardiovascular system

The marine mammals' basic structures of the cardiovascular system are not that different from the ones of the terrestrial mammals, because they only differ for some adjustments related to the dive, the thermoregulation and body mass.

Cetaceans can accomplish very long dives and, in order to do that, a reduction of the heartbeat happens together with a vasoconstriction in some body districts. Brain is reached by blood through the thoracic aorta which splits itself in several intervertebral arteries to make a thick net of very thin vessels lying very close to each other, called *retia mirabilia*, entering the cranial cavity. In dolphins, *retia mirabilia* are allocated in the thoracic cavity, neck, vertebral channel, around the optic nerve and in the uterus (*Ponganis, 2018*). The thoracic net is furnished by the aorta's vessels, whose anastomosis form a complex spongy structure next to chest sides, expanded around the vertebras, constituting the most important refueling of arterial blood in the brain. These vascular connections ensure that cetaceans' brain could receive blood at a non- pulsatile pressure with a minimum difference between systolic and diastolic pressure even in deep dives, where the water pressure could stop the bloodstream (*Poli and. Fabbri, 2012*). Apparently, the *retia mirabilia* presence, beyond reducing the pressure

fluctuations determined by the heart pulsatile flow, is related to the species capacity of diving; in fact, the *retia mirabilia* guarantees a constant refueling of blood inside the brain during the long diastolic phases that occur while diving (*Ponganis, 2018*).
Another peculiar adjustment of the cetaceans' cardiovascular system is the arrangement of blood vessels and arteries set in parallel at the dorsal, pectoral and caudal fins level, where blood flows in the opposite direction. The contact among these vessels and the opposite blood direction can facilitate the countercurrent heat exchange and contribute to the thermoregulation (*Poli and Fabbri, 2012*).

1.3 Thermoregulation

Cetaceans are furless and, as thermic insulation, they have the whole body covered with blubber, except for the dorsal, pectoral and caudal fins, composed by varied layers, whose lipidic composition and connective tissue contents may vary from one species to another. The blubber is used to offset the high-water thermal conductivity but, when the environmental temperature is too hot, or after an elevated swimming activity, cetaceans can transfer the warmth in exceed through some thermal windows (*Poli and Fabbri, 2012*). Thermal windows are represented by the previously mentioned fins blubber lacking. In these areas, the main arteries bringing warm blood, run on the surface and are surrounded by venous vessels (periarterial venous net) so that the heat of the arterial blood, through a countercurrent exchange, could be transferred to the vessels in order to take it back to the middle of the body therefore to limit the dispersion (*Noren et al., 1999*). Such phenomenon occurs in cold waters. Instead, in warm waters it is essential to consume the heat in excess. For this aim, a central artery's vasodilatation takes place by constricting the vessels around. Consequently, once the blood riches the surface in contact with the water, it frees the warmth in exceed in order to go back colder to the middle of the body. Another strategy to cool the whole body consists in keeping the caudal fin out of the water so the evaporation cools the blood that pass through it (*Poli and Fabbri, 2012*).
It could seem that vasoconstriction, which occur during the dives by reducing the oxygen, can compromise the thermoregulation strategies by reducing the bloodstream to the thermal windows, but, in the end, a time strategy is adopted: the heat dissipation decreases during the dives and largely is pushed back to the post-dive period, when the

requirement to preserve the oxygen is reduced. In this way, these two phenomena, potentially in conflict, appear coordinated (*Noren et al., 1999*).

1.4 Osmoregulation

Marine mammals live in a hyperosmotic habitat, so they need to keep water, which tends to leave the body. As terrestrial mammals, marine mammals control the hydro-saline equilibrium by the kidney, but their kidneys are composed by hundreds of single lobes named reniculate kidneys (*Ortiz, 2001*). Each reniculate kidney is made up by a cortical portion split from the medullary one by a muscle fibers and elastic connective layer and includes a very long single medullary pyramid inserted in a single goblet. This whole structure makes the filtering surface much bigger than a single kidney of equal volume and, time after time, it can considerably increase both the filtered blood volume and the produced urine volume (*Poli and Fabbri*, *2012*). The reticulate kidneys can oppose the high hydrostatic pressure effects in order to minimize the hypovolaemia due to the liquids amount outside the cellular compartment. To keep a correct osmolarity, it is important that the kidneys produce a more concentrate urine in relation to its tissues and seawater (*Ortiz, 2001*). A fundamental hormone thay controls the water elimination in mammals is the antidiuretic hormone (ADH). ADH has an antidiuretic effect but is still unknown its physiological contribute. Also, the bloodstream can contribute to oppose the dehydration. The marine mammals' bloodstream is extremely variable, and, during the dives, it can be interrupted. The bloodstream increases after the meals and decreases during the fasting, suggesting that, when the animal doesn't insert water with food, a reduction of the renal flux involves a water saving. These kind of adaptative responses are possible because marine mammals' kidneys are highly resistant to ischemia and reperfusion damages (*Poli and. Fabbri, 2012*).

1.5 Species of cetaceans in the Gulf of Catania

In the Mediterranean Sea are present 19 species of cetaceans and they can be grouped in 3 categories: regular, random and accidental species. In the Gulf of Catania, as in the whole Mediterranean Sea, there are 8 regular species, divided in coastal (which prefer shallow waters, 500 m of depth), pelagic (founded in deep waters higher than 2000 m) and deep scarp species (normally located at 1000-1500 m of depth). To the first category belongs the bottlenose dolphin (*Tursiops truncatus*) while pelagic species which accomplish great dives are the common dolphin (*Delphinus delphis*), the fin whale (*Balaenoptera physalus*) and the striped dolphin (*Stenella coeuraloalba*); in the end, among the species of deep scarp there are the Risso's dolphin (*Grampus griseus*), the sperm whale (*Physeter catodon*) and the Cuvier's beaked whale (*Ziphius cavirostris*) (*Monaco, 2008*).

Here below, the species observed during my monitoring activity are described.

1.5.1 Bottlenose dolphin (Tursiops truncatus, Montagu 1821*)*

The bottlenose dolphin (*Tursiops truncatus*) is one of the most common cetaceans in the Mediterranean Sea and is widespread globally. These dolphins occur in all the tropical and temperate regions and typically inhabit shallow and coastal waters even if they have also been found in the oceanic waters. Anyway, it seems that bottlenose dolphin distribution is a result of the habitat structure, social interactions, predation risk, prey distribution and breeding success (*Blasi et al., 2015*). These cetaceans present strong site fidelity and, time after time, has led to a significant habitat partitioning all over its range (*Welles et al., 2019*). In fact, studies based on mitochondrial and nuclear DNA analyses have assured that bottlenose dolphins inhabiting the Mediterranean Sea are genetically differentiated from the ones occupying the North Atlantic Ocean and the Scottish waters (*Bearzi et al., 2008*). So, depending on the sea bottoms topography and on the physical-chemical- biological parameters, five populations were recognized: Black Sea, eastern Mediterranean, western Mediterranean, eastern North Atlantic and Scottish. While the Black Sea's population is the most differentiated from the others, both the Mediterranean's populations present important genetic differentiation, as well as the eastern North Atlantic with the Scottish and the Mediterranean with the eastern North Atlantic, although the latter is the weakest of all (*Bearzi et al., 2008*).

The bottlenose dolphin is an expert swimmer able of exceeding a speed of 30 km/h and completing apneas 8 minutes long, reaching a -600m in depth. Males are slightly bigger than the females and adults measure 3-4 m in length. Usually they are characterized by a grey coloration, darker on the back and whitish on the belly, however at birth they are lighter than the adult coloration (*Rogan et al., 2000*). The head has a well-developed melon and a short and stocky rostrum while the pectoral fins are shorts and thins and the dorsal fin, located in the middle of the back, is prominent, tall and stride with a slightly hooked tip. The worldwide bottlenose dolphins' communities are described as fission-fusion societies where individuals associate in small groups (Fig. 1.1) which composition varies dynamically several times per day (*Lusseau et al., 2003*). This species has a very complex social structure: males use to join small pods and females may or may not live in bands, depends on the reproductive state of the individual (*Lusseau et al., 2003*); female and male groups associate during the breeding season (*Blasi et al., 2015*).

Fig. 1.1: Small group of three bottlenose dolphins swimming together. Photo by Marecamp.

Depending on area, season and trophic niche, bottlenose dolphins can assume different behavior, especially in foraging behavior and prey preferences (*Bearzi et al., 2008*). The most hunted preys are demersal species like European hake (*Merluccius merluccius*), European conger (*Conger conger*), red mullet (*Mullus barbatus*), striped red mullet (*Mullus surmuletus*), common cuttlefish (*Sepia officinalis*), common octopus (*Octopus vulgaris*) and other bony fishes and mollusks (*Bearzi et al., 2008*).

In 2006, the Mediterranean bottlenose dolphin subpopulation has been listed as “Vulnerable” according to the IUCN Red List of Threatened Species, beyond being inserted in the Appendix II of the CITES. As a matter of fact, bottlenose dolphins are subject to several threats, most of them caused by human activities. Until the early 1960's, especially in the northern Adriatic Sea, fishermen used to kill dolphins in order to reduce competition for fish considering that their diet consists of many commercial species (*Blasi et al., 2015*). Fishermen reactions caused a decline of bottlenose dolphins by at least 50% over the past 50 years and information suggests similar trends for the northwestern Mediterranean (*Welles et al., 2019*). Nowadays, overfishing of dolphins' preys can influence not only the behavior but also the distribution of bottlenose dolphin (*Blasi et al., 2015*). Most of the times, when the dolphin is not killed, it gets injured due to trammel or trawling nets. Moreover, trawling nets cause damages to the sea bottom bringing to a local habitat loss. Other causes of bottlenose dolphin's decline may be related to climate change, disturbance caused by boat traffic and chemical pollution: in particular, bottlenose dolphins carry a very high concentration level of organochlorine compounds in their tissues, higher than any other dolphin species in the western Mediterranean (*Gonzalvo et al., 2014*).

1.5.2 Striped dolphin (Stenella coeruleoalba, Meyen 1833*)*

The striped dolphin (*Stenella coeruleoalba*) is a small cosmopolitan cetacean distributed in warm-temperate, subtropical and tropical waters and is the most common cetacean species in the western Mediterranean (*Galov et al., 2009*). Despite its abundance in the Mediterranean Sea, it cannot be considered a resident species in the Adriatic Sea as the bottlenose dolphin, because the striped dolphin prefers inhabiting highly productive deep waters (1000-2000 m) beyond the continental shelf and, by knowing the Adriatic's bathymetry, it's easy to see why it has been rarely sighted in this region of the eastern Mediterranean (*Gomez De Segura et al., 2008*). However, in some Mediterranean areas, as the Italian waters, striped dolphins don't prefer such deep waters practicing a diurnal offshore-inshore movement (*Gomez De Segura et al., 2008*). The striped dolphin's distribution is not only related to water depth but also to temperature: in some areas, like the Liguro-Provençal basin, the striped dolphin seems to be correlated with warm oceanic currents which move seasonally (*Gomez De Segura et al., 2006*). In a genetic study conducted by *Garcia-Martinez et al. (1999)* by using mtDNA analysis in order to estimate the status of the European waters' species, it has found out the existence of two different populations: the Mediterranean one and the Atlantic one, with very low gene flow between them (*Santos et al., 2008*). Moreover, small genetic differences have been discovered among the individuals in both eastern and western Mediterranean Sea, suggesting a limited dispersal range between the two areas (*Rosso et al., 2008*), but recent researches suggest that, since the striped dolphin experienced a demographic expansion, this could have led to a geographic muddling of the past differentiated groups within the Mediterranean (*Gaspari et al., 2019*). The striped dolphin is one of the most agile and quick cetaceans, able to swim until 40km/h and to accomplish apneas of few minutes while reaching depths like -200 m. Its maximum length is 2.56 m and it was detected a wide variation in external size between the Mediterranean and the Atlantic populations but also between the southern and the northern Mediterranean because it seems that the southern individuals are much larger than the northern ones (*Rosso et al., 2008*). One of the most peculiar characteristic of this species is its pigmentation that may vary at both individual and group level; in fact, the striped dolphin has a bluish grey pigmentation, white belly and light grey hips with distinctive blue and white side stripes and spinal blaze that could differ among individuals (*Rosso et al., 2008*). The dorsal fin little and slightly hooked, while the pectoral fins are tapered. The head, instead, presents a curved melon and a long thin rostrum (Fig.1.2).

Fig. 1.2: A striped dolphin swimming in the Gulf of Catania's waters of which it can be noted its morphology. Photo by A. Bucceri.

A typical community of striped dolphins is composed by cohesive groups of 25-100 individuals and they rarely associate with other species of cetaceans. Since the groups are so numerous, often it occurs three kinds of schools: juvenile, breeding adults and non-breeding adults. Striped dolphins are very active, energetic and sociable animals and often they perform many aerial behaviors such as chin slaps, breaching (jumping out of the water), and bow- riding (swimming along the wave formed by a boat or a ship, while twisting and jumping) (*Archer, 2009*). In general, males reach sexual maturity around the 9 years of age, while female between 5 and 14 years of age; mating is seasonal with pregnancy lasting12-13 months and nursing between 12-18 months (*Santos et al., 2008*). Little it's known about the feeding behavior of the striped dolphins: they dive until a depth of -200 m for feeding on mesopelagic fish, cephalopods and crustaceans to a lesser amount and usually their foraging occurs around dusk or early night when preys migrate closer to the surface (*Dede et al., 2016*).

The Mediterranean striped dolphin has been assessed as "Vulnerable" according to the IUCN Red List of Threatened Species due to a suspected reduction in population of >30% over the past 60 years and is also listed in Appendix II of the CITES (*Braulik, 2019*). Even tough, this species belongs to the cetaceans legally protected by many national and international agreements, it suffers from several threats due to anthropic activities: marine debris, chemical pollution, land-based changes as tourism and agriculture, climate change, depletion of marine resources, acoustic contamination (*Gomez De Segura et al., 2006*) and the use of drift nets in some areas although it has been banned by all the EU countries in the Mediterranean Sea (*Fortuna et al, 2007*). All these factors have been caused, and still causing, decline in habitat quality, 2/3 reduction in mean school size, food availability, incidental mortality in fisheries, effects of pollutants and pathogens (*Braulik, 2019*) as the morbillivirus epizootic that affected the striped dolphin in the 90ies because of the habitat degradation which intensified natural factors arousing cetaceans' mortality (*Gomez De Segura et al., 2006*).

1.5.3 Common dolphin (Delphinus delphis, Linnaeus 1758*)*

The short beaked common dolphin (*Delphinus delphis*) is a small odontocete widely distributed in tropical to cool temperate regions in both hemispheres, occurring in some enclosed seas and in all major ocean basins, with the only exception of the high latitude Arctic and Southern oceans (*Jefferson et al., 2009*). Common dolphins usually exhibit seasonal inshore/offshore movement, inhabiting coastal water during spring and summer and moving further offshore in autumn; moreover, it seems that they also practice this inshore/offshore movement daily, corresponding with the exploitation of different food sources and preys' movement (*Thompson et al., 2013*). These cetaceans occupy a vast range of habitats: upwelling modified waters, continental shelf waters, along the continental shelf break and slope, oceanic areas and over prominent underwater topography as sea escarpments and seamounts (*Jefferson et al., 2009*).

Until 1994, all the worldwide common dolphins had been identified as a single species, *D. delphis*, but Heyning and Perrin (1994) proved the existence of two different species based on the length of the beak: the short beaked common dolphin (*D. delphis*) and the long beaked common dolphin (*D. capensis*) that also have different habitat preferences (*Jefferson et al., 2009*). Successively, studies based on skull morphometrical data recognized the existence of five *D. delphis* subpopulations: United States/ Canada East coast, northwestern Europe, West Africa, Mediterranean Sea and Black Sea (*Jefferson et al., 2009*). Genetic studies supported the skull morphometrical data by highlighting a relevant level of divergence between Mediterranean and Atlantic populations, probably related to prey deletion, habitat fragmentation and population decline occurred in the Mediterranean, but also a genetic segregation between eastern and western regions of the basin (*Mirimin et al., 2009*). Moreover, while there are no significant genetic differences between Mediterranean and Black sea, the Aegean and Alboran portions of the basin seem to be only isolated (*Bearzi, 2003*).

The common dolphin is the fastest cetacean among the ones described, able to swim to a speed of 65 km/h and to dive to -280 m of depth. It is characterized by a slender torpedo-shaped body and a coloration which may vary within and between populations: while the back is dark grey and the stomach white, on the hips a yellow hourglass expands from the head to the hip (Fig. 1.3), becoming light grey closer to the tail and, in the end, there are three black lines that join respectively the tiny and dark pectoral fin to the inferior jaw, the eye to the beak and the last one elapses long the genital zone (*Murphy et al., 2008*).

Fig. 1.3: Common dolphin in emergence showing its particular yellow hourglass. Photo by Centro Ricerca Cetacei.

Mediterranean common dolphins' communities are constituted usually by groups of 50 up to 70 individuals, with aggregation of 100 - 600 dolphins occasionally recorded, while in the Ionian Sea groups rarely include more than 15 individuals and never were observed groups larger than 40 dolphins (*Filby et al., 2010*). Often, they form a multi-species association with other cetaceans such as striped dolphin *Stenella coeruleoalba* and pilot whale *Globicephala* sp. (*Thompson et al., 2013*). Normally, larger groups and groups containing calves have been found in the shallowest waters that may provide a shelter for nursing females and the probably reason why common dolphins' groups containing juveniles were observed in such larger groups size lies in the allomaternal care (*Filby et al., 2010*). Males attain sexual maturity at 11 years of age, ranging from 195 to 233 cm in length, while females attain it between 9 and 10 years of age with a body length ranged between 183-216 cm (*Murphy et al., 2008*). Moreover, this species adopts a particular feeding behavior consisting in an apparent cooperation between school members and operating a selection when their preferred species are abundant (*Murphy et al., 2008*). Unfortunately, common dolphins' prey preference makes them susceptible to trawl fisheries targeting the same species (*Thompson et al., 2013*). Mainly in winter, common dolphins prey on small pelagic fishes in inshore areas, whereas in summer they feed mostly nocturnally on squids and mesopelagic fishes beyond the continental shelf edge (*Murphy et al., 2008*).

Despite its name, the common dolphin, at least in the Mediterranean Sea, it's not that common anymore. As a matter of fact, in 2003 the IUCN Red List has assessed the

Mediterranean subpopulation as “Endangered”, while, worldwide, this species has been listed as “Least Concern”. But what does really happen? The common dolphin has faced a major decline in distribution and abundance of more than 50% over the last three generations (*Bearzi et al., 2003*). Although, the causes of its reduction are not fully understood, they may have not be ceased or be reversible: no index of abundance is available to prove a real fade but the gradual disappearance of common dolphins from the Balearic, Ligurian and Adriatic Sea and Provençal basin, as the relevant decline in pod encounter rate observed in the eastern Ionian Sea, make believe that such phenomenon has occurred (*Bearzi, 2003*). Several factors have been considered as possible cause of the Mediterranean common dolphin’s decline: natural fluctuations, human activities, climate change, prey depletion, contamination by xenobiotics, fishery by catch, direct killing. Among the environmental fluctuations, one hypothesis has become more popular, that is striped dolphins coming from the Atlantic Ocean invaded common dolphins’ niche causing the Mediterranean subpopulation’s decline. Furthermore, some studies conducted by Sanford and Petchey in 1999 showed that small changes in climate, like the increasing seawater temperature, could cause larger effects on the marine communities as alteration of food webs and function of marine ecosystem (*Bearzi et al., 2003*). On the other hand, fishery by catch has now stopped but it operated for many years and certainly it had some consequences on the population (*Bearzi, 2003*). Since the 1970’s, international organizations have been aware about the conservation problems affecting common dolphins but so little has always been accomplished to preserve this species in the Mediterranean Sea. Even though the UNEP Mediterranean Action Plan (Barcelona, 1975) recommended how important it would be to have some conservation measures to preserve this species, it never specified what these measures should have been. Still, the Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic Area (ACCOBAMS) proposed to evaluate the common dolphin’s status in order to estimate distribution and abundance, identifying possible threats and critical habitats but, currently, the last assessment is dated 2003. In the end, common dolphins inhabiting the Mediterranean Sea haven’t been listed yet in the CITES Appendix II.

2. Existing agreements in the Mediterranean and in the study area for marine conservation

The area of study chosen for this research is the Gulf of Catania that lies in the eastern Sicily. This basin is a very productive area, distinguished by different types of seabed and hydrodynamics conditions. Although the presence of the MPA "Isole Ciclopi" generates a positively impact on the area, both on the environmental and economic side, the Gulf of Catania is affected by anthropic activities, putting at risk the ecosystem's health.

As the gulf is rich in cetaceans' species, it should be applied a conservation plan in order to decrease the threats which damage these organisms, as settled by the ACCOBAMS, which doesn't preclude the normal social-economic development of the area.

2.1 The Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) and the Pelagos Sanctuary

The Agreement on the Conservation of Cetaceans in the Black Sea, Mediterranean Sea and Contiguous Atlantic Area (ACCOBAMS) is a cooperation tool for the conservation of marine biodiversity in the Mediterranean Sea and the Black Sea. Its aim is to reduce threats affecting cetaceans and to improve our knowledge about these animals. The directive imposes the States members to realize a detailed conservation plan for the cetaceans, based on the legislation respect forbidding the intentional cetaceans catch, on the measures to reduce to the minimum the accidental catch and, finally, on marine protected areas creation.

The ACCOBAMS agreement derives from the Secretariats cooperation of three conventions: the Barcelona convention about the marine environment and Mediterranean coast preservation, the Bonn convention about the migrant species conservation belonging to wild fauna, the Berna convention about European wild fauna and natural habitats conservation. The Bucharest convention about the Black Sea preservation against pollution joined the convention group later. ACCOBAMS was signed in 1996 and entered in force in 2001 (*Accobams, 2019*).

The agreement area consists of all the maritime waters of the Mediterranean Sea, Black Sea and the contiguous Atlantic region west of the Straits of Gibraltar. It is also included the Pelagos Sanctuary dedicated to marine mammals in the northwest Mediterranean and created by Italy, France and Monaco. ACCOBAMS is the first agreement connecting the countries of these subregions to work together for cetacean conservation. One innovative aspect of this agreement is to involve non-riparian countries whose maritime activities are credible to jeopardize cetacean conservation.

After the ACCOBAMS institution, the northwest Mediterranean countries worked together to institute an international marine protected area in the corso-ligure-provençal basin, the Pelagos Sanctuary, because this region has always been highly frequented by a numerous population of marine mammals attracted by a high primary production, besides of being an area submitted to an elevated pressure due to anthropic activities like some fishery techniques, pollution, urbanization, naval strike, etc. The Sanctuary creation's path took part on the Italian side, on non-governmental organization's initiative, and became more effective to an international level when the Parties realized that the marine mammals' preservation could take place only through an integrated management of the Sanctuary area; in fact, in Rome was signed an agreement by France, Italy and the Monaco's Principality in 1999 which entered in force in 2001, in order to pursue an action of community management. So, the agreement's aim is to promote arranged and balanced actions among the signatory Parties for the cetaceans' protection and their habitats against all the possible threats such as pollution, noise, catch and accidental wounds. In the end, the Sanctuary has to protect the marine mammals conciliating the peaceful development of socio-economical activities with the needed safeguard of the habitats and species living within *(Santuario Pelagos*, *2019*).

2.2 The Gulf of Catania

The Gulf of Catania is a section of the Ionian Sea included between Fiumefreddo's river (Catania), which delimits it to the north, and Capo Campolato (Augusta, SR), which delimits it to the south (Fig. 2.1).

Fig. 2.1: Image of the Gulf of Catania created with Google Earth.

The Gulf of Catania is very productive thanks to the Simeto and S. Leonardo rivers' mouth and to the currents coming from the Messina's Strait circulation. In fact, in correspondence with the Messina's Strait it was identified a general inversion in the superficial and deep currents' trend and with direction of propagation alternately to the north and to the south, ruled by the tide's inversions with microtidal regime that happen in the Ionic and Thyrrenian basins daily (*Carboni et al., 2009*).

The coastline is 85 km long and characterized by different types of coasts: in the central-northern section, high and rocky shores prevail, with little wide beaches due to the erosive processes and to the backward cliffs, and with often rocky sea bottoms; in the central-southern section there are shallow shores with wide beaches, defined by dunes to the inland, and with sandy sea bottoms (*Carboni et al., 2009*).

The rocky shore extents from Capo Mulini to the Catania's harbor and it is formed by high and extremely heterogeneous coasts which may be rectilinear or jagged because of the presence of bays and inlets created by lava bodies. In this section of the Gulf of Catania, the beaches are constituted by moderately or low classed sands, round and spherical lava rocks, pebbles mixed with sandy-rocky sediments, but all of them overlooks the rocks. Some of these rocks have cyclopic size, like the famous ones of the Marine Protected Area "Isole Ciclopi". A sandy shore expands from the Catania's harbor to Agnone Bagni (Augusta, SR) and is identified by well-classed middle or rough yellow- whitish sands, with a prevalence of quartz grains with a smaller quantity of calcite and heavy minerals. Contrary to the rocky shore, which has no continental platform and presents high depths a few meters away from the coast, the sandy shore is characterized by maximum depth at -20 m until 3 miles from the coast (*Monaco et al., 2016*). The sand's layers may be very thin or of middle size, usually they are mixed and locally alternated to faint sands or sandy silt. Shelly lags, with abundant clutches and mussels' biosoma with predominant *Tellina* sp., *Cardidae* and lesser gastropods, are widespread but irregular. In this trait of coastline, the sand has the same constant composition of the Simeto river's sand which is the best tributary of solid supplies and nutrients to the Gulf of Catania's area (*Carboni et al., 2009*). In the end, the most southern tract of the Gulf is constituted of calcareous rocks.

The coastline is ruled by two different hydrodynamic conditions respectively referred to the northern and to the southern shore. The northern shore can be considered as a *reflective shoreline*, characterized by a steep coast outline that directly receives the energy produced by the breaking of the waves' motion. By this way, the energy is reflexed by the beach and spread for refraction along the coast. In the end, there is no bottom morphology and the sea bottom is relatively steep. On the other hand, the southern shore is formed by a *dissipative shoreline*, where the coastline receives a softened energetic impact because of the breaking of the waves' motion far from the water edge; the sea bottom presents some characteristic sandy planks located at some distance from each other and from the coast that dissipate the energy coming from the waves' motion before it pours out directly along the coast (*Carboni et al., 2009*).

For what concerns the physical- chemical parameters in the Gulf of Catania are those typical of the Ionian Sea. The water's temperature varies very often year round, with a maximum temperature of 26°C on the surface and a minimum temperature of 14°C in the deep. The oxygen's saturation has a value included between the 90% and the 100%, while the salinity is enumerated between 38.27‰ and 38.62‰ (*Di Stefano et al., 2013*).

The Gulf of Catania is submitted to a strong anthropic impact due to the several commercial activities taking place on the coast, the tourism, the increasing urbanization often illegal which generates habitat loss, chemical and acoustic pollution, etc. All these hazards represent a threat to all the cetaceans inhabiting the Ionian Sea and, in the end, most of those species are listed as at risk.

2.2.1 The *Marine Protected Area "Isole Ciclopi"*

The Gulf of Catania has always represented an ideal habitat for the settlement of many organisms because of its productivity and morphology of different origins. Since the area is located near the Messina's Strait and, in the last 30 years, the Catania's harbor has become the most important seaport of the island, the marine traffic has growth involving a hazard for the ecosystem and all the species living in it. So, in order to conserve the ecosystem and biodiversity, in 1989, the Marine Protected Area "Isole Ciclopi" was founded in the middle of the gulf.

The area around the "Isole Ciclopi" shows a unique ecosystem, characterized by many species of invertebrates and vertebrates, even of algal taxa. In the early 80s, people understood the ecological importance of the area and realized the need of the ecosystem's preservation. Later, the sea belonging to "Isole Ciclopi" was recognized as "biological protection area" because site of reproductive and increase processes of different marine species and, subsequently, it has been forbidden any activity pertinent to fishery which could put at risk the production and the increase of the marine flora and fauna. The institution of the Marine Protected Area (MPA) "Isole Ciclopi" contributed to the maintenance and improvement of the natural state of the environment, in the composition and structure of floral-fauna biocoenosis and in all that processes, trophic dynamics and ecological connections which define the global functionality of the marine ecosystem.

Thanks to its foundation, as in the MPA as in the whole gulf, many research and educative programs are encouraged to transmit a greater knowledge and sensibility about the marine ecosystems and its inhabitants to the local population. The MPA "Isole Ciclopi" rises in the village of Acitrezza, and covers a surface of 628 hectares for a 6.236 m of coastline. Within the MPA is situated a little archipelago of volcanic origins formed by the Lachea island and cliffs of different shapes and sizes named "sea stacks" or "faraglioni" (Fig. 2.2). The most impressive sea stacks are the Big Sea Stack, the Middle Sea Stack and the Little Sea Stack (*Cantone, 2000*).

Fig. 2.2: The distinctives “faraglioni” of the MPA “Isole Ciclopi” at sunrise. Photo by A. Bucceri.

In the Pleistocene Age, the area facing Aci Trezza was constituted by a typically white clayish sea bottom. Later, about 500.000 years ago, beneath the clayish sea bottoms, the firsts vulcanological events in the area happened, thanks to which, over the centuries, the Mt. Etna was generated. Consequently, to the underwater lava emissions, it was established a raising of the whole area which led to the surfacing of a subvolcanic mass which, originally, expanded for about 1 km but, after the tectonic movements and the erosive activity of the sea, it broke apart in the typical “Isole Ciclopi” that we know. Proof of these events is the typical black coloring of the lava stone of the mentioned above natural formations and the presence on the top, especially in the Lachea island, of white Pleistocene clays. “Isole Ciclopi” are made of rocks columnar fissuring formed after the contact between clays and magma which, slowly cooling down, gave rise to basalt columns made up of prisms (*Cristofolini, 2000*).

“Isole Ciclopi” are surrounded by two different types of sea bottoms: the sandy one, which expands in the sea area among the islands and the coast with a maximum depth of -12m,

and the rocky one, which expands along the east side of Isola Lachea descending to a depth of -35m (*Cristofolini, 2000*).

The MPA was named “Isole Ciclopi” for the myth told by Homer in the “Odyssey” under which the sea stacks are the rocks threw by Polyphemus against Ulysses while escaping.

The biodiversity’s abundance in the MPA “Isole Ciclopi” is very important, enough to be object of study since the 19th century. In fact, studies conducted in this area, beyond confirming the species’ abundance of every zoologic class, described new taxa, especially of mollusks, bryozoa and polychaeta (*Cantone, 2003*).

Rocks of the supralittoral zone are characterized by the presence of the gastropod *Littorina neritoides* and of the isopod *Ligia italica*. Instead, in the upper intertidal zone, fasten to the rocks, there are barnacles like *Chthamalus stellatus* and *C. depressus* and some mollusks belonging to the genders *Patella* and *Chiton*. In the southern part of the above-mentioned zone *Actinia equina*, a red anthozoan commonly named as “*tomato of the sea*” are observed.

Going deep, the most common organisms are the gastropod *Bolinus brandaris*, a murex provided of a long syphon and numerous thorns, the nudibranch *Flabellina affinis* equipped with a vivid coloration and the cephalopod *Octopus vulgaris*.

Very important is the presence of crustaceans as sea cicadas (*Scyllarides latus*), lobsters (*Palinurus elephas*) and hermit crabs such as *Dardanus calidus*.

On the archipelago’s bottom, have been observed some echinoderms: *Paracentrotus lividus* (a female sea urchin), *Arbacia lixula* (a male sea urchin) and *Echinaster sepositus* (red starfish). Other organisms present on the ocean floor are *Holothuria tubulosa* (sea cucumber) which slither by carrying on the inside a little symbiont fish (*Carapus acus*), the ascidians *Halocynthia papillosa* (sea potato), *Microcosmus vulgaris* (sea lemon), *Phallusia mamillata* (sea cone). Among the polychaeta species found in this area the most common is *Hermodice carunculata*, or rather staggers which wanders on rocks and seaweeds looking for food. Another polychaeta that inhabits the MPA’s bottoms is *Sabella spallanzani*, which, contrary to the first one, lead a sedentary lifestyle; such annelid lives in tubes from which branchial clumps apt at filtration come out.

Among the sciaphilous benthic organisms it’s good to remind the poriferan *Petrosia ficiformis*, the anthozoan *Astroides calycularis* and the gorgonians: *Eunicella cavolinii* (or sea fan) and *Eunicella singularis* (or white gorgonian).

On sandy bottoms is common to encounter Bivalvia mollusks such as *Pinna nobilis*, *Pinna rudis*, *Acanthocardia aculeata*, *Venus verrucosa* and *Pecten jacobeus* and gastropods as *Nassarius mutabilis*.

The most representative fishes are *Dentex dentex* (snapper), *Sparus aurata* (gilthead bream), diplodus, *Oblada melanura* (sea bream), *Lithognatus mormyrus* (striped seabream), *Epinephelus marginatus* (grouper), *Boops boops* (bogue), *Muraena helena* (moray) and in particular the parrotfish *Sparisoma cretense*, arrived in the Mediterranean from the Suez channel due to the lessepsian migrations.

Besides a great animal biodiversity, the MPA's bottoms are formed of a wide algal variety. Starting with the intertidal zone, it's possible to distinguish a typical sequence of populations of vegetal association as *Bangia atropurpurea*, *Porphyra leucosticte, Rissoella verruculosa* and *Nemalion helminthoides, Lithophyllum lichenoides, Corallina elongata* and *Ceramium ciliatum*.

The supralittoral zone is basically constituted by grouping of brown photophilic seaweeds, in connection to the hydrodynamism and to the bright intensity of the area, belonging to the genre *Cystoseira*. Lately, the *Cystoseira* found at high depth is retreating because of the expansion of tropical species such as *Caulerpa racemosa*.

Another algal species, endemic of the Mediterranean Sea, which is frequent to observe in the sandy ocean floor of the MPA is *Posidonia oceanica* but, where sands get mixed up with mud, it is interrupted by some little zones of *Cymodocea nodosa*.

The preservation and conservation of such biodiversity not only generates ecological and environmental benefits but also benefits on an economic and social level. The marine protected area "Isole Ciclopi", as all the MPAs, is characterized by the *spillover* effect, that is when the optimal conditions of fishes in a marine protected area lead to more abundant stocks even in the areas where the commercial fishery is allowed (*National Geographic, 2019*). In fact, one of the consequences of the *spillover* effect is a direct benefit over fishery activities in terms of profit's improvement in the surrounding non-protected areas.

3. The importance of the mark-recapture method

The mark-recapture method has proven to be a great tool for quantifying various demographic parameters, as for terrestrial as for aquatic animals. Moreover, the long-term nature of mark-recapture studies is important, not only for answering many fundamental questions related to population dynamics, but also for the species' conservation. This non-invasive and cheap technique allows to study small populations (20-30 animals) and species that are difficult to investigate, generally by photo-identifying them or tagging them (*Lettinik and Armstrong, 2003*).

The mark-recapture method's success can be guaranteed by some studies here reported. *Fontoura-da-Silva et al. (2013)* used this method to study bivalves and gastropods in Brasil and they were able to monitor the population of *Tegula viridula* for two years and to begin monitoring a population of *Diplodon* sp.

The mark-recapture's success resides also in the study led by *Kanive et al. (2015)* where, using 6 years of this method's data, they found evidence about similar survival rates for male and female adult and sub-adult white sharks off the coast of central California.

One last example is the study carried out on *Octopus vulgaris* by *Mereu et al. (2015)*, thanks to which it was obtained the first growth results in the Mediterranean Sea for small to medium specimens in the wild.

In the end, the progressive use of the mark-recapture method could give the chance to answer to most of that questions regarding the population's structure and dynamic, for a better understanding of the examined species' ecology and for managing the species conservation.

4. PURPOSE OF THE RESEARCH

This work is part of the project "Dolphin watching and conservation in the Gulf of Catania", led by the no-profit association Marecamp, which purpose is, since 2014, collecting data to take a census about dolphins and whales in the Gulf of Catania and to supervise their health status while promoting their conservation through education at sea and eco-tourist activities (Fig. 4.1).

Fig. 4.1: Tourists taking pictures of striped dolphins on board the Marecamp's vessel during a dolphin watching eco-tour.

Since populations of common bottlenose dolphin are known to be regular in the waters of the Gulf of Catania (*Monaco et al., 2016*) the main purpose of this work is to evaluate the health status of a local population of *Tursiops truncatus,* by monitoring its presence in the area of study and trying to comprehend, as well, the social structure.

Therefore, to accomplish this aim, this thesis would like to update to 2019 the Marecamp catalogue of bottlenose dolphin of the Gulf of Catania using the photo-identification method to compare ancient dorsal fins images collected from 1997 to 2018 with pictures recorded from May to October 2019, in order to prove the presence of individuals already identified in the area and, eventually, to add new specimens to the catalogue. Moreover, the photo-ID technique could be very helpful to figure out the associations existing among the individuals within the population. For this reason, it would be fundamental to accomplish temporal analyses in two-year (1997-1998, 2004-2005, 2018-2019) and three-year (2003-2004-2005) period, by choosing the years where more individuals were sighted, in order to compare how the associations among individuals change in time and to understand if there are any couples who are stabilized in time and the existence of steady groups, despite the commonly known tendency of bottlenose dolphins to create fission-fusion societies.

5. MATERIALS AND METHODS

5.1 Field work

The data collection took place during the Marecamp's monitoring from May to October 2019, where I participated to most of the *surveys*. For the monitoring activities were utilized:

- 7.20 m inflatable boat with a 150 horses Honda engine;
- Binoculars with enlargement of 7x50;
- Nikon Coolpix P1000 Camera;
- eTrex Garmin GPS.

During the *surveys* were collected all the data about sighting (Annex 1) and observation (Annex 2) such as date and time, geographical coordinates, direction, and speed of navigation, meteorological-marine conditions, marine traffic, species sighted (indicating the total number of individuals and juveniles), the animals' behavior and any useful notes.

5.2 The Photo-Identification method

Photo-identification is a non-invasive method used to identify individuals over time and across space on the base of natural marks, such as nicks and notches along fin edges in dolphins and whales. In the last decade, consequently to the advent of the high resolution digital cameras, systematic protocols for supplying and analyzing images and the use of software in order to support the matching of individuals, the productivity of the photo-identification has improved becoming a dependable and largely used tool to better understand the ecology of wildlife populations so that it can suggest conservation and managements actions. The long-term nature of this method allows gaining data about populations' dimensions, distribution, reproductive rate, residency, migrations and intraspecific relationships within groups (*Salazar-Gomez, 2011*).

For small cetaceans like bottlenose dolphins, the most identifying feature is the dorsal fin which scrapes and tatters easily but there are other peculiarities that may help to recognize individuals: scratches and wound marks, shape of the dorsal fin, pigment patterns and shading of the fin and the upper body. Marks' longevity and changeability are very important to recognize those features which identify an individual over time, but marks may not last forever, it seems that only dorsal fin tatters endure for life (*Würsig and Jefferson, 1990*). Morphological traits may vary among species but there are some requirements they need to satisfy (*Associaciò Cetacea, 2013*):

- Recognizable over time: an individual can be recognized over time by multiple features;
- Singularity: marks must be unique in every individual in order to allow researchers to differentiate from each other, so the complexity of the mark is fundamental;
- Same resighting probability: every individual should have the equal probability to be identified over time thanks to its morphological traits, although some individuals are better marked than others.

The photo-ID method can be applied from shore, from airplanes and, most common, from boats. Studies managed from the boat, as the one of this work, must respect the pod by not disturbing it or even impeding feeding and socializing activities. So, the best approach is to use a small (<10m) and maneuverable vessel, with limited speed, which allows a close encounter to the animals. Photos should be taken as perpendicular to the body axis as possible and the fin and the back must be large enough in the picture in order to distinguish nicks of, at least, 1 cm (*Würsig and Jefferson, 1990*).

Later a catalogue with all the photo-identified organisms in the study area is created in order to highlight the natural marks collected through the years by the single individuals and to monitor how they vary in time. Moreover, it's very important to update the catalogue with new photos.

The catalogue of bottlenose dolphins of the Gulf of Catania was created by the local association Ketos as a result of several *surveys* accomplished from 1997 to 2008, thanks to which 39 individuals were identified (*Monaco et al., 2010*). With the update of the catalogue to 2018 made by the Marecamp association, it was possible to add newer photos of 3 individuals previously classified, while other specimens were verified, and 10 more individuals were classified reaching a total of 49 bottlenose dolphins classified (*Monaco et al., 2019*).

In summer 2019, in the framework of the project "Dolphin watching and conservation in the Gulf of Catania", new photos of bottlenose dolphins' dorsal fins present in the Gulf were taken. In order to analyze and match the new photos with those of the old catalogue, they were split for sighting and, successively, only the best ones in term of angle, resolution, focalization, etc., were selected for the matching. Analyses were achieved using the Darwin software and the manual method of *Würsig and Würsig* (1977) for a more accurate comparison. Before uploading the photos on Darwin, they were cut and, eventually, edited for a better determination of the profile by the software.

5.2.1 The Darwin software

Darwin is a computer vision system developed by the Eckerd College and created with the aim of helping researchers to identify individuals of bottlenose dolphin, *Tursiops truncatus*, making easier the comparison of digital images of the dorsal fins of new dolphins with a database of previously identified dolphin fins (*Stanley, 1995*). The latter is created by uploading an image for each fin side if collected, otherwise it is uploaded just the image of the side taken. Moreover, textual information about sighting data for each of the past-identified dolphins is included together with the digital dorsal fin image and an estimate of the fin outline. The fin outline, made with a semi-automated process used by the software, is utilized to formulate a sketch-based query of the dolphin database (Fig. 5.1). The system employs a variety of image processing and computer vision algorithms to accomplish the matching process, very important to recognize those fins identified before which, most closely, look like the unknown fin (*Wilkin and Debure, 1999*). The catalogue has been shown to the researcher in rank order for comparison with the new fin image.

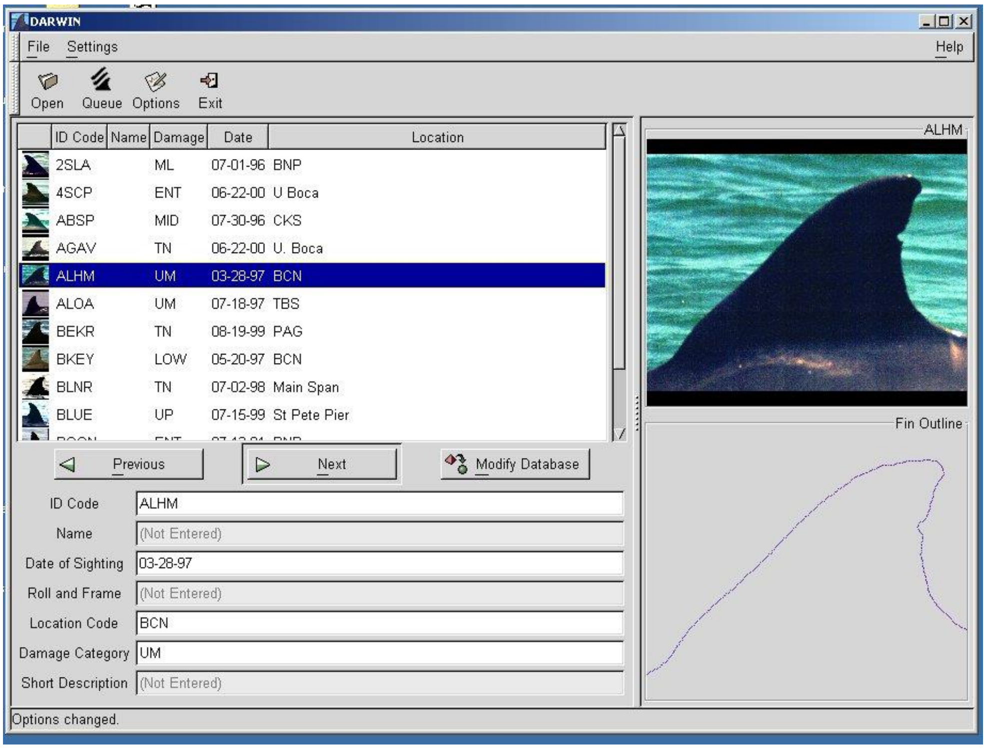


Fig. 5.1: To the left it's shown an example of images and sighting data of the database. To the right it's represented an individual's image and outline. Screenshot from the *Manual Photo-Identification* by Eckerd College.

When a researcher is working out to identify an unknown dolphin, a digital image of a dolphin dorsal fin must be imported and, with the cursor, it has to be approximately traced a general outline of the leading and trailing edges of the dorsal fin. The center of the trace launches the positions of a series of evenly distributed points set along the edge of the fin and provides a limited space for the automated repositioning of the points. Darwin utilizes active contours (Fig. 5.2) to move the points from their initial positions to the current edge of the fin. Once the points have been adequately reset, the researcher has the option to manually relocate individual points along the edge of the fin (Fig. 5.2). This opportunity is fundamental since the program considers photographic effects such as shiny spots as scratches and notches. Moreover, parameters of the active contour which encourage the convergence toward a smooth outline, may cause the automatic repositioning to miss nicks or notches with extreme angles (*Stanley, 1995*).

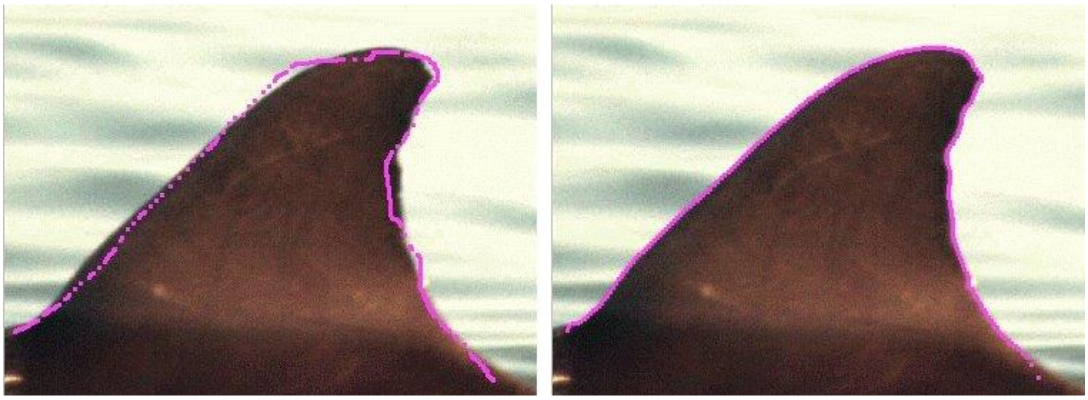


Fig. 5.2: The fin on the left represents the automated outline traced by the software, while the fin on the right represents the outline correctly set along the trailing edge by the researcher. Screenshot from the *Manual Photo-Identification* by Eckerd College.

Once the outline is traced, a one-dimensional representation of the dorsal fin outline made up of edge orientations of the piecewise approximation of the fin outline, is produced during the even spacing procedure. This chain code type representation is utilized in the identification of significant feature points of the fin outline. Dorsal fin outlines carry very few unvaryingly recognizable features for alignment. As illustrated in Fig. 5.3, the Darwin system automatically settles: 1) the start of the leading edge; 2) the end of the leading edge (where the leading edge angle begins to bend toward the fin tip); 3) the tip of the dorsal fin; 4) the most pronounced notch on the trailing edge; 5) the end of the trailing edge (*Wilkin and Debure, 1999*).

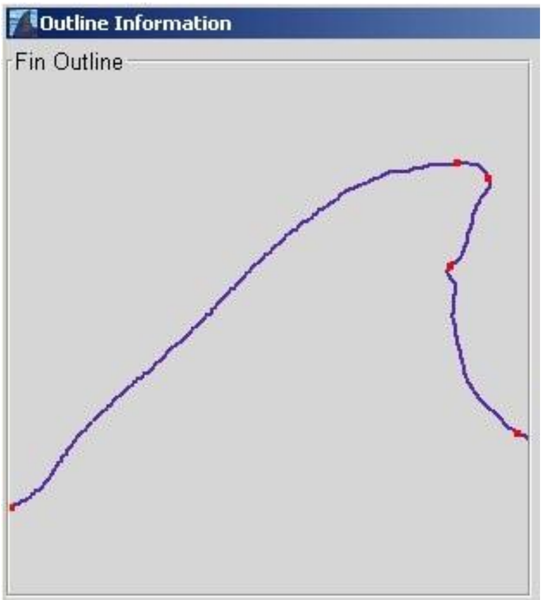


Fig. 5.3: Fin outline with features indicated. Screenshot from the *Manual Photo-Identification* by Eckerd College.

In the end, the profile created can be added to the database or be matched with the profiles included in it.

5.2.2 The Mark-recapture method

The mark-recapture method is a common technique used by researchers to assess size and structure of populations, survival and recruitment rates and movement patterns of wildlife. It is based on catching few individuals of the population, marking them, releasing them and then recapturing or resighting them without capture (*Hammond, 2009*).

Thanks to the natural marks of cetaceans, the photo-identification is the best way to capture and mark these organisms because of the capture's difficulties and their vulnerability in being handled.

The mark-recapture model must follow some assumptions to be applied:

- Marks are permanent at least until the end of the period of study;
- Marks are unique and correctly recognized;
- After marking, individuals are immediately released;
- Marked and non-marked individuals must have the equal probabilities to be captured;
- Captures are independent between occasion;
- The population is closed within primary periods;
- Survival probabilities are the same for all individuals (*de Mello et al., 2019*).

For this reason, in order to estimate the bottlenose dolphin population, present in the Gulf of Catania, it was created an Excel matrix containing the capture data of each single bottlenose dolphin photo-identified in the study area according to the sightings. In the matrix, the presence or the absence of an individual is respectively indicated as the number 1 or as 0.

5.3 Instrument to study population structure

Data obtained from the mark-recapture method could be used to define the social structure of dolphins' population. Analysis can be made for all the individuals sighted in 3 or more different sessions, by creating an association matrix based on the number of sightings; in fact, the minimum number of recaptures requested may vary from 2 to 6 in relation to data and analysis type. Next, the obtained values are used to calculate association indexes referred to the groups assembled from the identified individuals using specific software (*Monaco, 2008*).

5.3.1 Association indexes

As one of the aims of this study is to better understand the associations that mark the social structure of the bottlenose dolphin population of the Gulf of Catania, it is essential to properly introduce the association indexes used in the following analysis.

An association (or similarity) index is one of the most common type of relationship measure used, thank to which is possible to establish what kind of relationship exists between couples of individuals within a particular population, through a similarity coefficient, which provides the association degree. Usually, the similarity coefficient varies from 0 to 1; depending on cases of completely disjointed observations, lacking common ground, otherwise equal observations among them (*Whitehead, 2009*). The similarity coefficient estimates the quantity of time in which pairs of individuals are associating and high values show individuals that associate a lot, low values that they only occasionally do. Typically, association indexes between an individual and itself are set at 1.0.

For this work the *Simple Ratio Index* and the *Half Weight Index* were used.

The *Simple Ratio Index* (SRI) represents the samples' number where the individual *a* is associated to the individual *b*, in correlation to the number of times in which *a* and *b* where sighted simultaneously. The relation who defines this index is:

$$SR= X/ X + Y_a + Y_b$$

X: number of times in which *a* and *b* were identified together within the same group;

Y_a: number of times in which *a* was identified in the whole sightings;

Y_b: number of times in which *b* was identified in the whole sightings.

The *Half Weight Index* (HWI), also known as Dice or Sorensen index, is very useful in Marine Ecology and probably is the more appropriate index for studies regarding the photo-identification technique, because this latter has the tendency to underestimate the number of simultaneous sightings of more organisms. The HWI is expressed by the following equation:

$$HWI = X/\{X + Y_{ab} + 0.5\,(Y_a + Y_b)\}$$

X: number of times in which both *a* and *b* individuals were identified together within the same group;

Y_{ab}: number of times in which the *a* and the *b* individuals were recognized at the same time in different group's clusters;

Y_a: represents the whole number of sightings of the individual *a*;

Y_b: number of times in which *b* was identified in the whole sightings.

When the association matrix is uploaded to the Socprog program, applying the various indexes, the grids of association and other graphics regarding the association among individuals are created.

5.3.2 *The Socprog software*

Socprog is a set of programs that processes data about associations and interactions among animals previously identified, by supplying social structure analyses. Moreover, Socprog is written in MATLAB language, a very technical computing language provided with high performance (*Whitehead, 2009*).

As shown in Fig. 5.4, this software is very useful for population and movement analyses too, but for this work it has dwelt on social analyses.

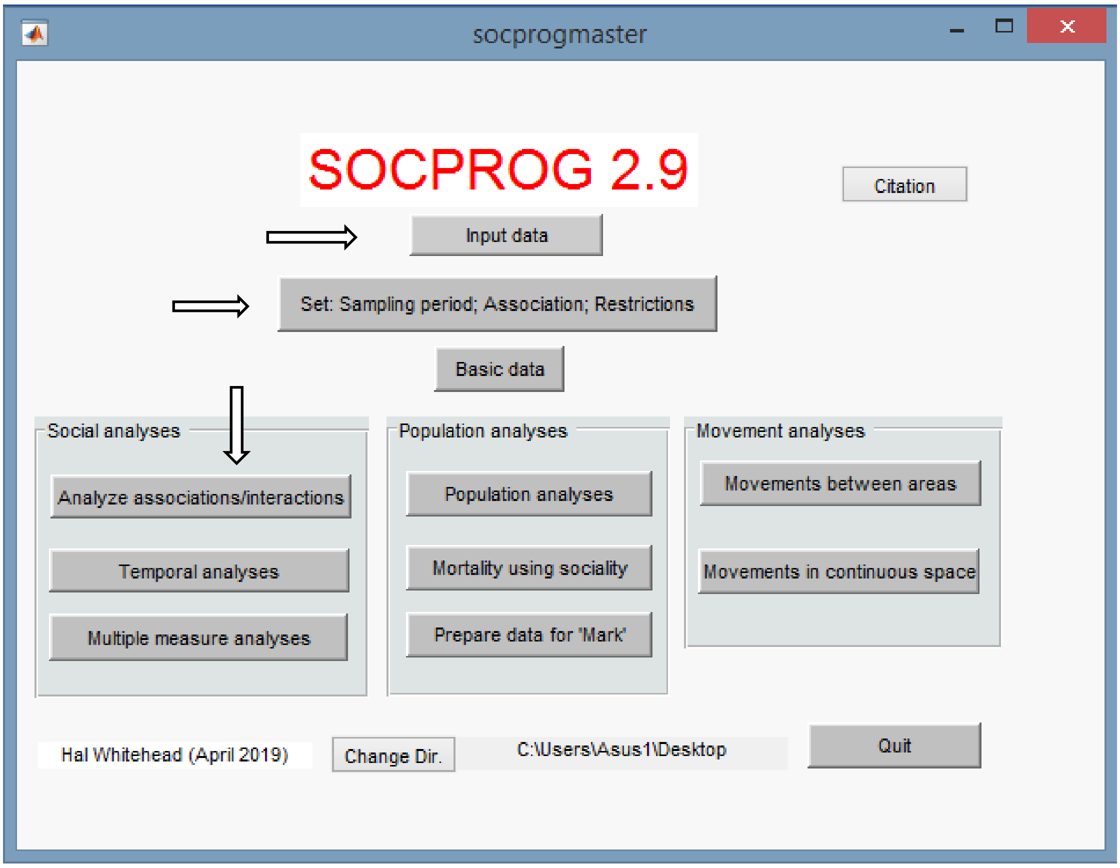


Fig. 5.4: Interactive interface of the Socprog software where are indicated the functions utilized for population analysis.

First of all, it is necessary to input data and the main source used by Socprog is the Excel worksheet but, otherwise, it can also be entered as ASCII file. The primary data file includes records or lines that correspond to an observation. Depending upon the observation, the latter may regard the individual (linear mode), a dyad (dyadic mode) and a group of individuals (group mode). The one utilized for this work is the group mode where the membership of the group observed is recorded together with some additional information like date, time, behavior, etc.

The second step to assess the social analyses is to set the sampling period, the association and the potential restrictions. If the association data are recorded with date and time, the operator can choose any sampling period (years, decades, days, hours). To define association measures instead, there are many possibilities for determining associations between two or more individuals in a sampling period, but here it has been selected the "group variable" that assembles pairs if observed at least once in the same group during the sampling period; usually, this association option is already set in group mode by default. Socprog allows to make analyses happen on a part of the data set and so restrictions can be made on individuals, records, groups or combinations of these. In the end, analyses can be restricted to animals observed more than a certain minimum number of times, data collected in defined periods of the year, data collected after a specific date etc.

The final step is to analyze the association indices. As mentioned before, for this research, it has been chosen the Simple Ratio Index to define association by the presence in the same group and the Half Weight Index for number of groups. In the association analyses screen, there are several options to verify, but it will take into consideration:

1. List association matrix
2. Distribution of association (plot)
3. Association complexity
4. Network diagram
5. Hierarchical cluster analysis

List association matrix: procedure that computes an association matrix among individuals.

Distribution of association (plot): this function allows to plot histograms of association indexes which can be of four types: association indices (all non-diagonal elements), mean association indices (by individual, ignoring diagonal elements), maximum association indices (by individual, ignoring diagonal elements) and sum of association indices (by individual, including diagonal elements, which are usually 1.0 for association indices). The latter is the one used in these analyses.

Association complexity: it provides a measure of association complexity for the population subject matter of the research using mixture models which group together relationship measures, as association indices, into relationship types. Mixture models are carried out with an array of number of types of relationships, defined as number of mixtures.

Network diagram: also called sociogram, it represents the relationship's strength, and so the values of the association index, among individuals. Individuals are figured as nodes linked among them by lines that vary in thickness. The thickness degree is proportional to the strength of the relationships.

Hierarchical cluster analysis: this function generates clusters hierarchically formed, represented as dendrogram or tree-diagram where individuals are placed on one axis while the association's degree on the other one.

Sociograms were very useful since they allow to graphicly represent both the associations sighted among individuals by the observer and the ones not seen. For this reason, it was chosen to accomplish two different temporal analyses: one based on two-year periods, analyzing the 1997-1998, 2004-2005 and 2018-2019 years, and the other one based on the three-year period 2003-2004-2005. Temporal analyses will permit to better understand how the associations among bottlenose dolphins vary in time considering also, thanks to the use of the Half Weight Index, the possibility of the existence of associations not sighted, besides figuring out for how long stabilized couples tend to stay together and if, despite the tendency to form fission-fusion societies, individuals that show a certain fidelity to a specific group of the pod exist.

6. RESULTS AND DISCUSSION

In this chapter the results obtained from the analyses will be analyzed and discussed. The results are here divided in three blocks: the first block examines the observation effort, that is the cetaceans' research in their natural environment with the visual task of sighting them; the second one analyzes the population of the Gulf of Catania, focusing on the specimens identified in the 2019's season; the third and last block focuses on the social structure of the local population of bottlenose dolphins analyzing the associations existing among the individuals.

6.1 Observation effort

The data analyzed for this research have been collected during several *surveys*, reaching a total amount of 300 hours in observation on the field for 1500 nautical miles covered from May to October. In the above-mentioned period, I took part to 10 *surveys* accomplishing an observation effort equal to 28 hours, for an amount of 183 nautical miles covered (Fig. 6.1).

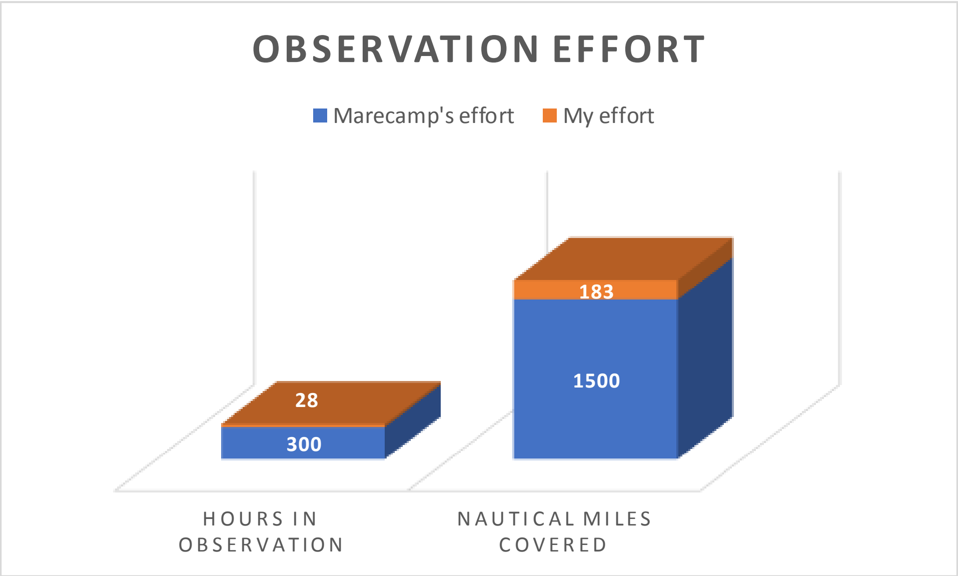


Fig. 6.1: Graphic representation of the nautical miles covered in relation to the hours of observation accomplished by Marecamp and me in 2019.

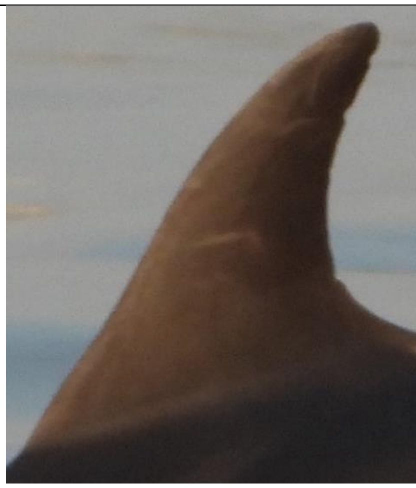
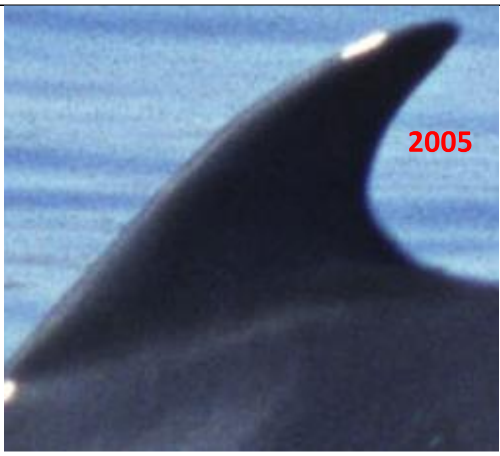
In the period considered, the bottlenose dolphins were sighted in 12 *surveys*, in 9 of which it was possible to conduct specific Photo-ID sessions. Dates of the sighting are the following, most of all they took place in the northern part of the Gulf, except for the one accomplished on September 1st that occurred in the southern section of the study area.

- 10/05/2019
- 19/07/2019
- 29/07/2019
- 05/08/2019
- 06/08/2019
- 27/08/2019a
- 27/08/2019b
- 01/09/2019
- 14/09/2019
- 16/09/2019
- 23/09/2019
- 01/10/2019

Moreover, the total amount of photos collected during these *surveys* was 1130 and, after accurate selections based on the pictures' quality, the photos analyzed, from which the following results were pulled out, were 178.

6.2 Presence and identification of the bottlenose dolphins

Once the photographic analysis has been accomplished, it comes to light that the individuals identified during the monitoring activity in summer 2019 were 15. Among these 15 specimens, the bottlenose dolphins recaptured were 8, specifically ID 05, ID 06, ID 12, ID 33, ID 40, ID 42, ID 47 and ID 49 (Fig. 6.1), while the new ones added to the catalogue were 7, by reaching so a total of 56 organisms identified in the Gulf of Catania (Fig. 6.2).

	Old photos belonging to the catalogue	New photos
ID05	 2004	 2019
ID06	 2008	 2019
ID12	 2005	 2019
ID33	 2018	 2019

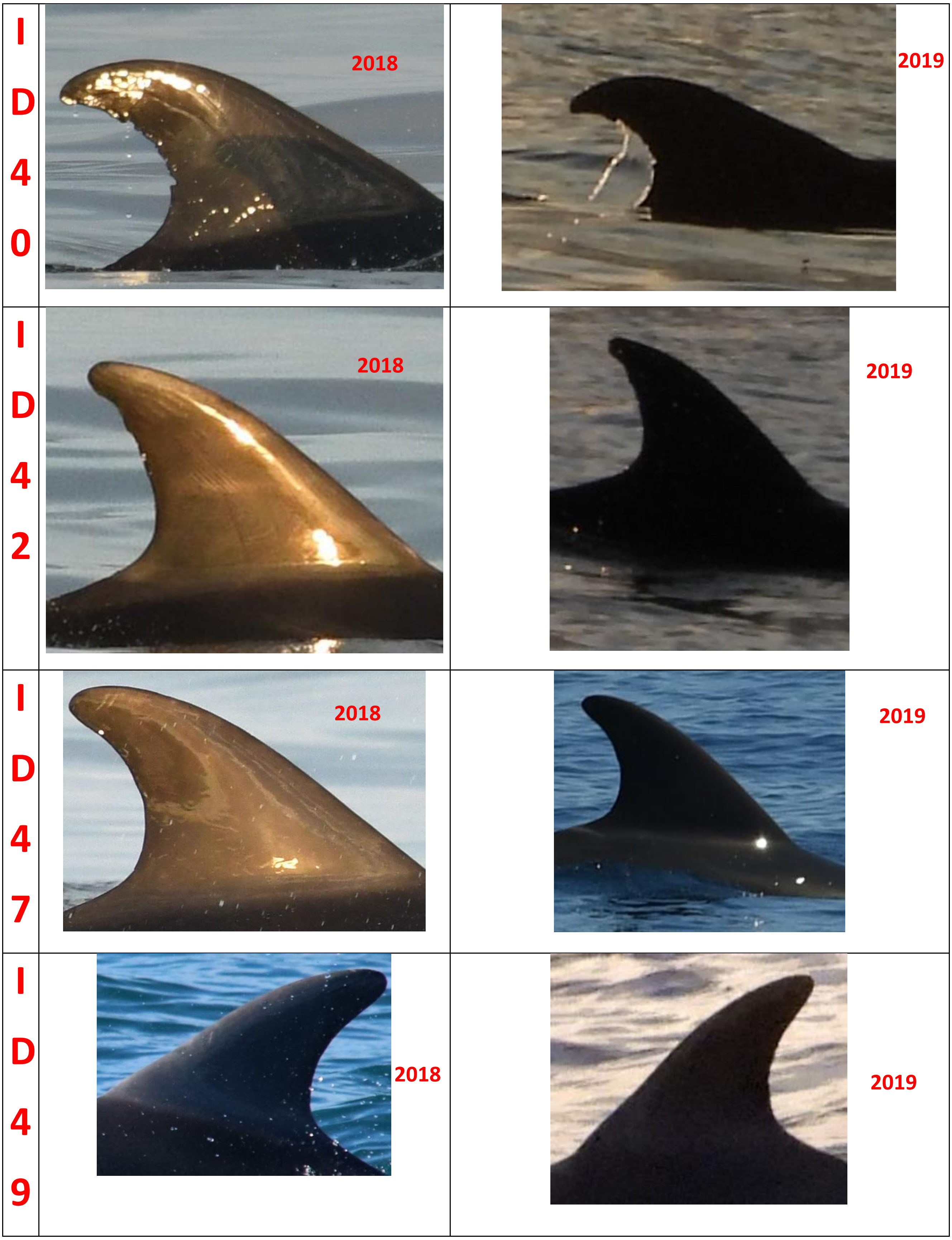


Fig. 6.1: Comparison between the bottlenose dolphins belonging to the catalogue and the ones recaptured during the 2019 season. In the column on the left there are the photos belonging to the old catalogue, while in the column on the right there are the photos taken in 2019.

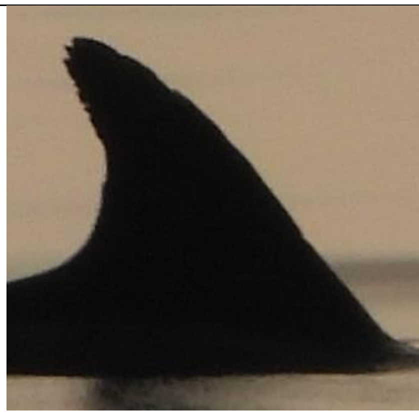
New bottlenose dolphins identified in 2019	
 ID 50	 ID 51
 ID 52	 ID 53
 ID 54	 ID 55
 ID 56	

Fig. 6.2: New bottlenose dolphins captured during the 2019 season.

To recognize the specimens, the notches were fundamentals because they last forever and define the dolphins' fingerprint (*Würsig and Jefferson, 1990*). As described in the "Materials and methods" chapter, for this research we used the Darwin software that, overlapping the fins outlines (Fig. 6.3 and Fig. 6.4), permitted the identification of the individuals. However, the software wasn't always efficient because, for the dolphins lacking nicks and notches, false matches were created. In this case, the visual method *Würsig and Würsig* (1977) helped to identify the organisms through the fin morphology.

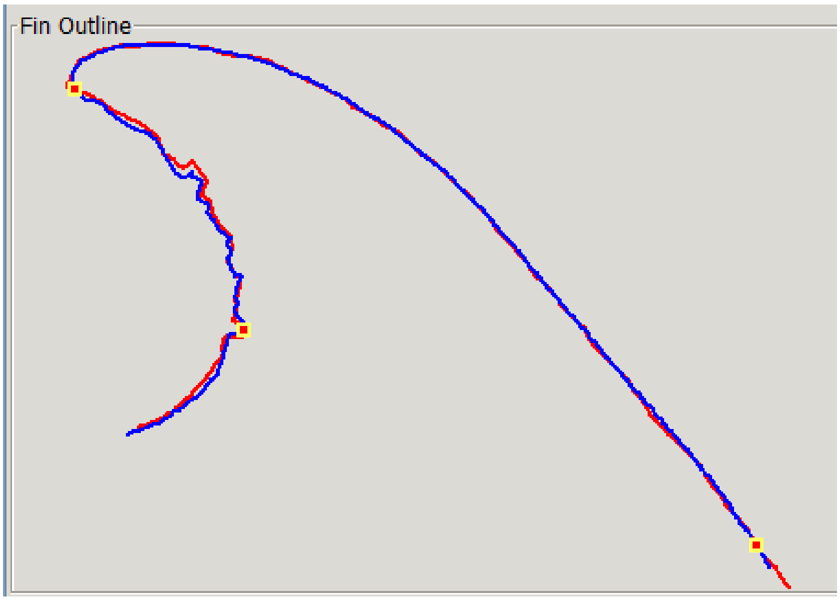


Fig. 6.3: Screenshot of one of the matches accomplished by Darwin. Here the notches are well visible and unmistakable.

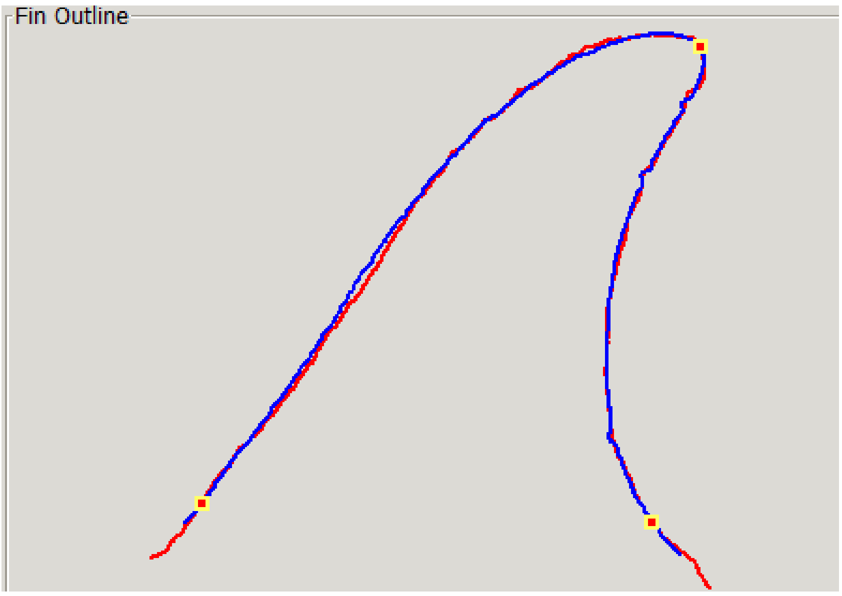


Fig. 6.4: Screenshot of the overlapping fins outlines made by Darwin.

A matrix containing all the data about the capture history of each photo-identified dolphin, concerning sightings from 1997 to 2019, was created in order to better comprehend the structure of the bottlenose dolphin's local population (Annex 3). Comparing new photos collected from 2018 with the old catalogue, 6 individuals have been recaptured: ID 10, ID 12, ID 33 and ID 35 in 2018, whereas ID 05, ID 06, ID 12 and ID 33 in 2019. At the same time, within two years 17 new specimens were identified, some of which classified in 2018 have been found again in 2019. These data are very important because they affirm that the gulf of Catania continue to offer a good habitat for the residency of this species, as proved by the finding of the oldest animals resident in the area as also the discovery of new individuals that state the population's sustenance (*Monaco, 2008*). Moreover, among the bottlenose dolphins identified during the 2019 season, couples mother-calf were sighted but not identified, since they didn't move close to the vessel probably to prevent risks, meaning that the Gulf is a good reproductive area. In the end, despite the intense anthropic impact existing in the Gulf, caused by several commercial activities taking place on the coast, the tourism, the increasing urbanization, chemical and acoustic pollution especially due to marine traffic, *Tursiops truncatus* still lives in the area, also adapting his behavior and distribution depending on local fishing activities and different pressures near the coast (*Di Stefano, 2013*).

The following image (Fig. 6.5) shows the total number of photos taken for each animal considered in these analyses. It can be noticed that individuals showing a superior number of photos than others, aren't necessarily more frequent in the area but that they are characterized by morphologic characteristics that consent an easiest identification.

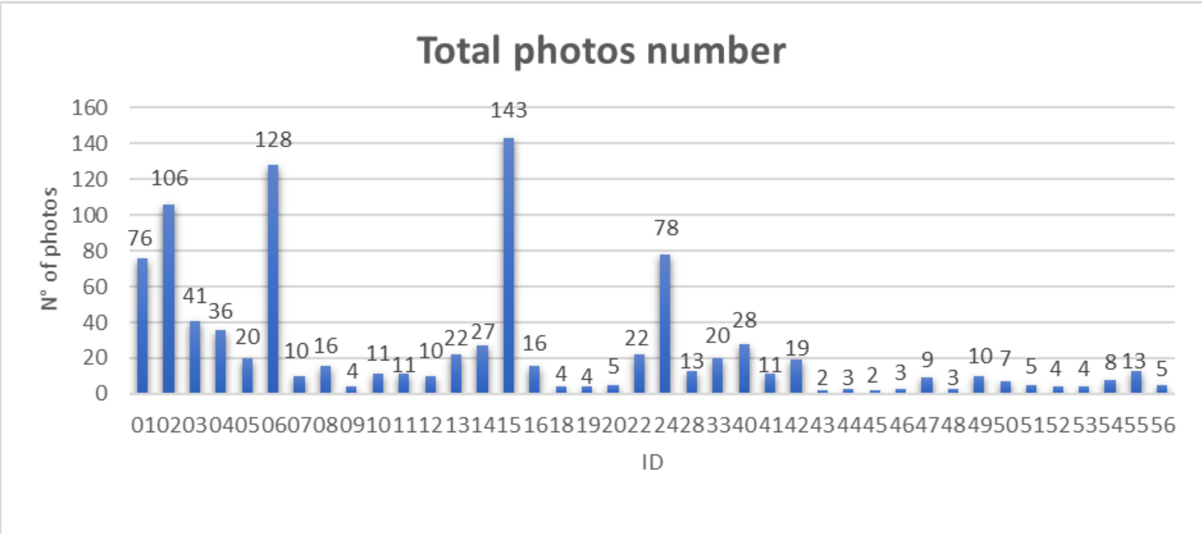


Fig. 6.5: Number of photos collected for each bottlenose dolphin present in the catalogue.

6.2.1 Social structure of the population

Results obtained by applying the mark-recapture method were used to define the social structure of the bottlenose dolphin's population studied.

First of all, it was created an association matrix including all the individuals recaptured a number of times ≥ 6 (Tab. 1). The organisms reported in Tab. 1 are 9 and, among them, IDs 05, 06 and 12 were sighted in 2019, while the recaptures of the other individuals are ceased to 2008, because they haven't been sighted again yet.

Then, after uploading to Socprog all the data regarding the presences of *Tursiops truncatus* identified for each sighting, the corresponding association matrixes were created by applying the Simple Ratio and Half Weight association indexes.

Tables 2 and 3, respectively created using the Simple Ratio Index and the Half Weight Index, represent the association matrixes *n x n*, where *n* is the ID number of the individuals observed, while the highlighted diagonal shows the number of times in which each animal was sighted with itself. Consequently, the matrixes acquired from the analysis are symmetrical.

ID 01	8	4	4	2	3	4	4	3	4
ID 03	4	6	3	2	2	5	3	2	1
ID 04	4	3	6	2	1	4	3	2	0
ID 05	2	2	2	6	2	2	2	2	0
ID 06	3	2	1	2	7	2	1	1	2
ID 08	4	5	4	2	2	6	3	2	1
ID 10	4	3	3	2	1	3	7	5	1
ID 12	3	2	2	2	1	2	5	8	1
ID 15	4	1	0	0	2	1	1	1	7
	ID 01	ID 03	ID 04	ID 05	ID 06	ID 08	ID 10	ID 12	ID 15

Tab. 1: Association matrix among 9 of the bottlenose dolphins photo-identified in the Gulf of Catania from 1997 to 2019 individuals and recaptured a number of times ≥ 6. The values on the highlighted diagonal represent the association of each animal with itself, while the other values indicate the simultaneous sightings among the IDs.

01	1.00								
03	0.40	1.00							
04	0.40	0.33	1.00						
05	0.17	0.20	0.20	1.00					
06	0.25	0.18	0.08	0.18	1.00				
08	0.40	0.71	0.50	0.20	0.18	1.00			
10	0.36	0.30	0.30	0.18	0.08	0.30	1.00		
12	0.23	0.17	0.17	0.17	0.07	0.17	0.50	1.00	
15	0.36	0.08	0.00	0.00	0.17	0.08	0.08	0.07	1.00
	01	03	04	05	06	08	10	12	15

Tab. 2: Association matrix obtained through the application of the Simple Ratio Index.

01	1.00								
03	0.57	1.00							
04	0.57	0.50	1.00						
05	0.29	0.33	0.33	1.00					
06	0.40	0.31	0.15	0.31	1.00				
08	0.57	0.83	0.67	0.33	0.31	1.00			
10	0.53	0.46	0.46	0.31	0.14	0.46	1.00		
12	0.38	0.29	0.29	0.29	0.13	0.29	0.67	1.00	
15	0.53	0.15	0.00	0.00	0.29	0.15	0.14	0.13	1.00
	01	03	04	05	06	08	10	12	15

Tab. 3: Association matrix obtained through the application of the Half Weight Index.

Considering the values obtained in Tab. 2 and Tab. 3, analyses regarding the distribution of associations indexes (Fig. 6.7 and Fig. 6.8) and the association complexity were accomplished (Fig. 6.9 and Fig. 6.10).

The first histogram (Fig. 6.7) was realized through the Simple Ratio Index and the y-axis represents the individuals' number while the x-axis the sum of association indices for each of the 9 individuals reported in Tab. 2. The sum of association indices was gained by adding the similarity coefficients reported in the column and row of Tab.2 correspondents to each ID. The columns represented in the graphic indicate the group constituted by the individuals which indexes sum falls in the same values' range.

Contrary to the first histogram, to create the second one (Fig. 6.8) it was used the Half Weight Index and the sum of association indices was obtained by summing the values reported in Tab. 3 on the basis of the same modalities of the previous one. It can be noticed that, in this case, the values range is higher compared to the one of the histogram realized with the SRI and, consequently, the individuals' grouping is different.

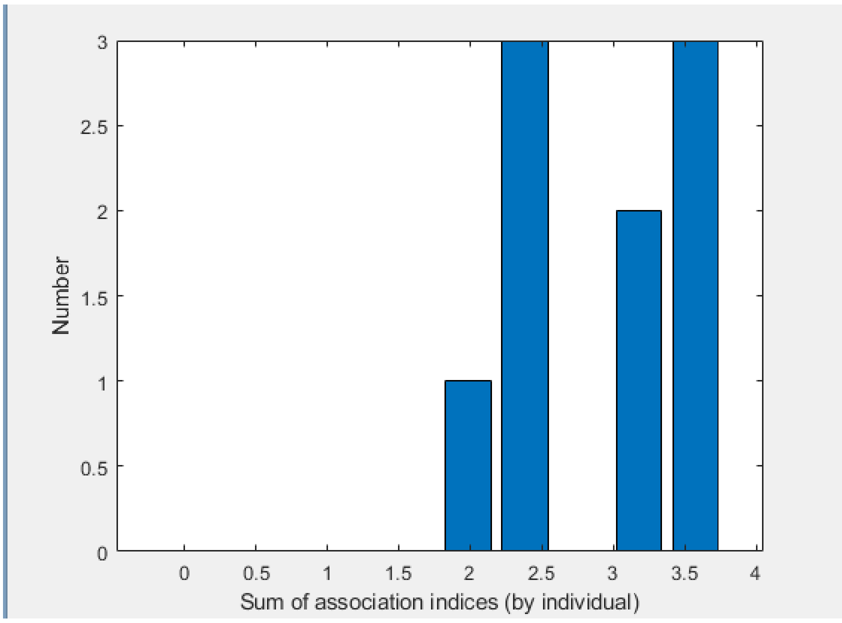


Fig. 6.7: Frequencies distribution about the SRI of the 9 bottlenose dolphins' sample recaptured ≥ 6 times.

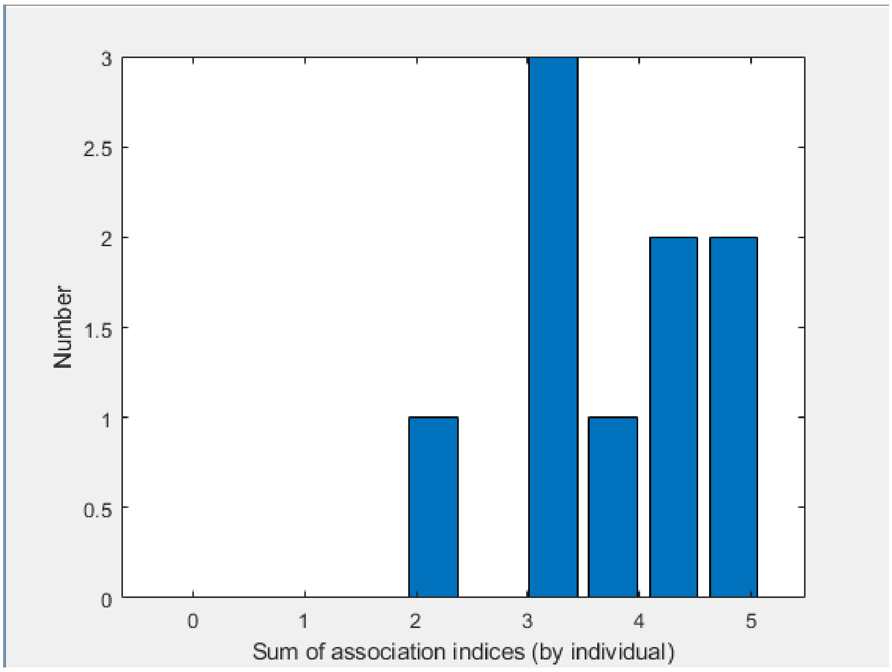


Fig. 6.8: Frequencies distribution about the HWI of the 9 bottlenose dolphins' sample recaptured ≥ 6 times.

Fig. 6.9 and Fig. 6.10 show the association complexity, that is the estimated distribution of real association indices from the normal mixture model and the estimate of overdispersion. While the red curve represents the estimated relationship classes, on the x-axis are reported the similarity coefficients gained through the SRI, for the first graphic, and the HWI for the second one, the y-axis represents, instead, the proportion of association indices. Columns in both graphics represent the similarity coefficients reported in Tab. 2 and Tab. 3, by representing so the association's degree of the sample considered. It can be noticed that in both graphics, columns are assembled on the left side, meaning that there is a low degree of association among the individuals of the sample; in Fig. 6.10, as it can be realized by the columns disposition, the similarity coefficients' values are higher but, since most of them are grouped between 0.3 and 0.6, we still can confirm the existing low degree of associations. The columns are 15 in both graphics because there are 15 different values for the similarity coefficients, as it can be seen in Tab. 2 and Tab. 3.

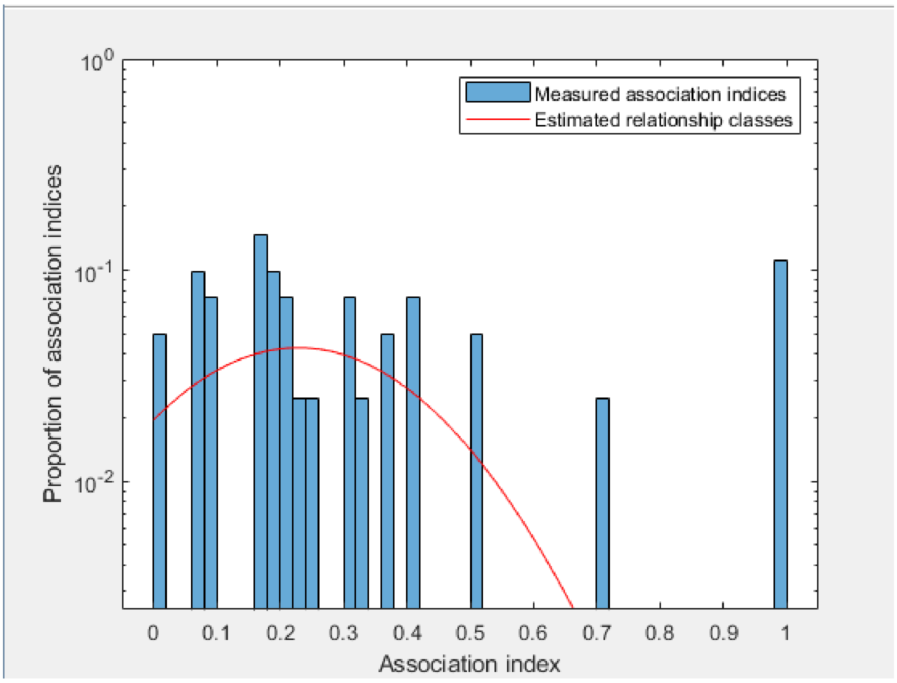


Fig. 6.9: Distribution of measured association index for the 9 bottlenose dolphins' sample recaptured ≥ 6 times together with estimated relationship classes. This graphic was obtained through the calculation of the SRI.

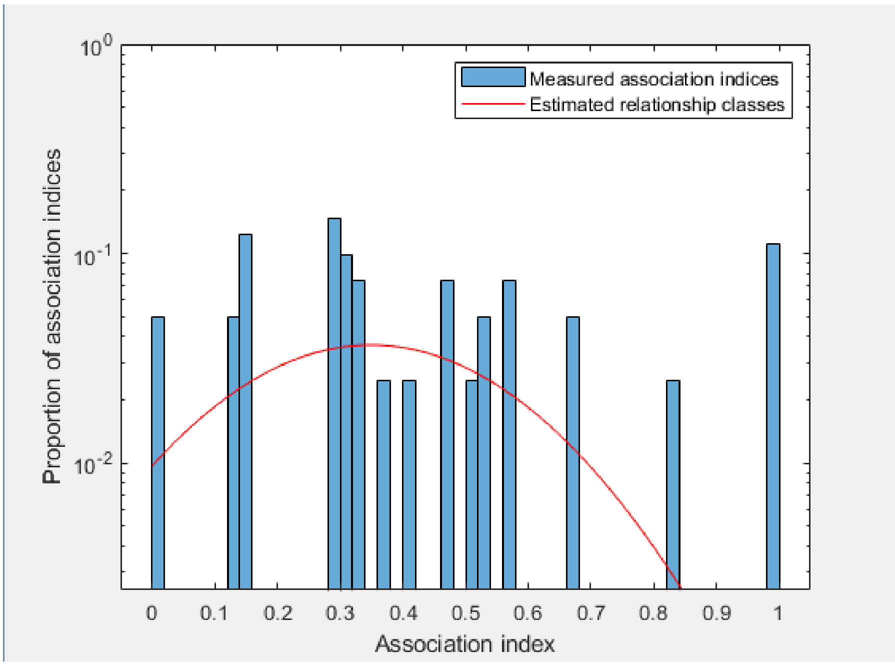


Fig. 6.10: Distribution of measured association index for the 9 bottlenose dolphins' sample recaptured ≥ 6 times together with estimated relationship classes. This graphic was obtained through the calculation of the HWI.

So, from the graphics reported above (Fig. 6.7, Fig. 6.8, Fig. 6.9 and Fig. 6.10), it can be confirmed that the population's sample considered is formed by individuals which continuously mingle among them within the population. These results affirm what it is known from literature (*Lusseau et al., 2003*), that coastal bottlenose dolphins tend to assemble a *fission-fusion* society. In Tab. 3, the high similarity coefficients' values gained for ID 03 and ID 08 (0.83), ID 10 and ID 12 (0.67) and for ID 04 and ID 01 (0.57), show the existence of stabilized couples even if many couples interchange in time by exchanging the members of one group with the ones of another.

Data extracted from the association matrixes have been represented using different sociograms. Results acquired through the SRI and the HWI show both the probability that two organisms are sighted together given that one has been seen (Fig. 6.11) and the possibility of missing individuals when they are together, which is equal to the probability of missing them when they are apart (Fig. 6.12). For this reason, the sociogram realized through the calculation of the HWI presents a thicker net of associations in relation to the other sociogram, precisely because it shows even the associations that the observer didn't see. In fact, graphicly, the HW sociogram differs from the SR sociogram precisely for the presence of ephemeral bonds, like the ones that link the ID 15 with the ID 08 or the ID 06 with the ID 12, that, correctly, are absent in the SR sociogram. However, in both cases there is a more persistent fidelity in only half of the individuals examined (right side of the graph).

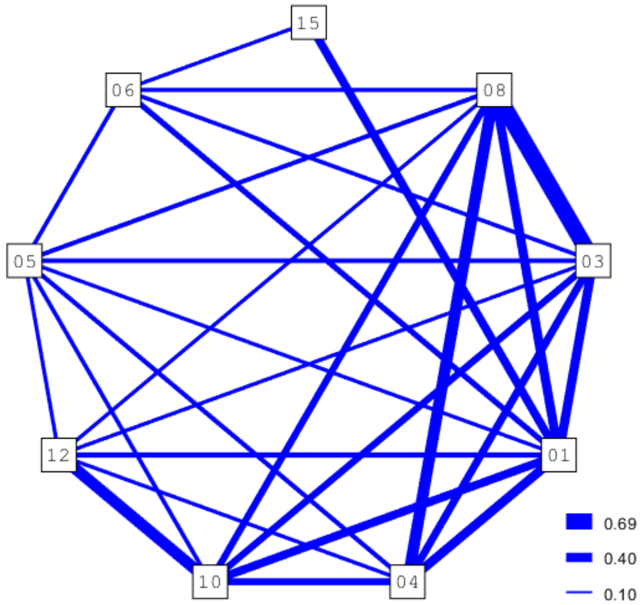


Fig. 6.11: Sociogram acquired through the calculation of the SRI referring to the sample of 9 bottlenose dolphins photo-identified in the Gulf of Catania and recaptured a number of times ≥ 6. The numbers in the squares are the bottlenose dolphins' IDs.

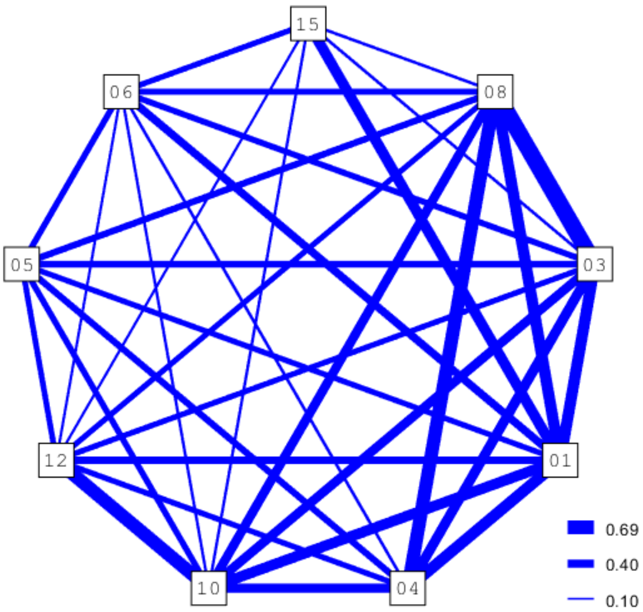


Fig. 6.12: Sociogram acquired through the calculation of the HWI referring to the sample of 9 bottlenose dolphins photo-identified in the Gulf of Catania and recaptured a number of times ≥ 6. The numbers in the squares are the bottlenose dolphins' IDs.

Other sociograms were created to compare how the associations among individuals change in time. In order to do that, the following sociograms are related to comparisons of the number of organisms with specific relationship in two-year (1997-1998, 2004-2005 and 2018- 2019) and three-year period (2003-2004-2005). These years have been chosen because more individuals were sighted, by allowing so to gain an exacter vision of bottlenose dolphin's social structure in the study area.

The 1997-1998's sociogram (Fig. 6.13) is characterized by widespread strong bonds meaning that the individuals interact often, with a predominance on the right side of the circumference. So, it can be noticed that there are 6 animals that accomplish 7 relationship, 2 organisms 10 relationship and 3 individuals 4 relationship. Consequently, the 3 specimens that accomplish 4 relationship tend to form a more stable group subject to less variations. Therefore, results show that the bottlenose dolphins are more faithful to the pod than to a single individual.

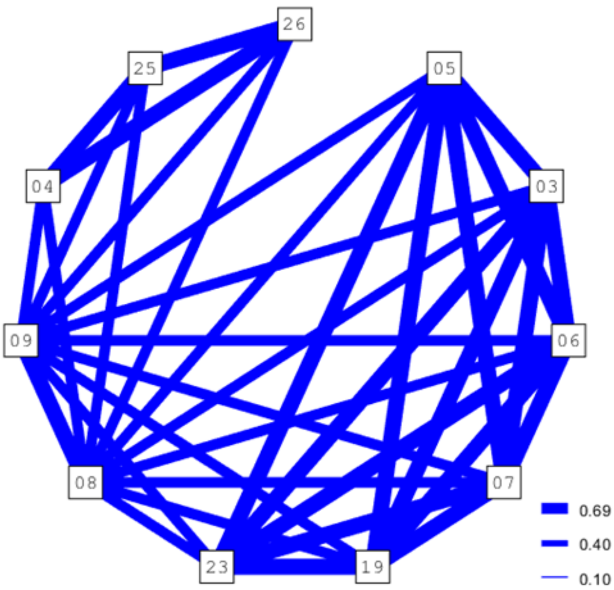


Fig. 6.13: Sociogram representing the associations among individuals in the two- years period 1997-1998.

In the 2004-2005's sociogram (Fig. 6.14), instead, a clear division of the circumference exists, and it can be observed that, while the right side has strong bonds meaning that the individuals enroll a lot, the left side is characterized by few associations. From the analysis of this sociogram comes to light that there are 2 individuals that accomplish 9 relationships, 3 specimens 8 relationship, 3 organisms 6 relationships, 2 individuals 5 relationships, 2 specimens 3 relationships, 4 organisms 4 relationships, 4 individuals 2 relationships, 2 specimens 1 relationship, with an average of 5 partner for each specimen and some individuals having not relationships between each other.

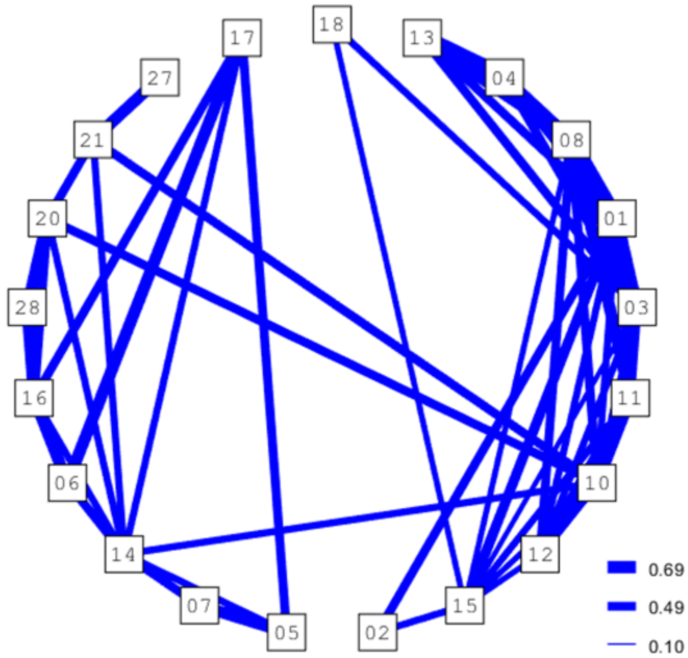


Fig. 6.14: Sociogram representing the associations among individuals in the two-years period 2004-2005.

The 2018-2019's sociogram (Fig. 6.15) is characterized by a greater variation of the relationships because 1 individual accomplishes 16 different relationships, 2 specimens 15 relationship, 2 organisms 12 relationships, 1 specimen 11 relationships, 5individuals 10 relationships, 1 organisms 9 relationships, 1 individual 8 relationships, 7 specimens 6 relationships, 3 organisms 5 relationships, 1 individual 2 relationships.

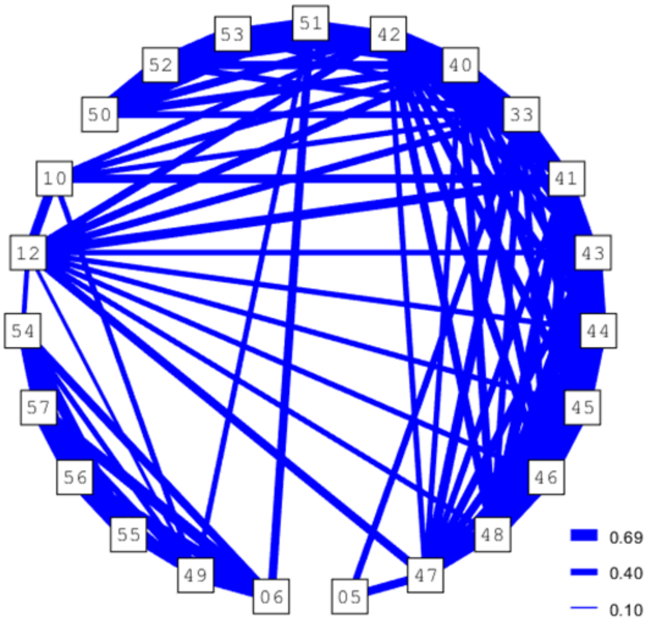


Fig. 6.15: Sociogram representing the associations among individuals in the two- years period 2018-2019.

In the end, about this two-year period comparison, we can say that bottlenose dolphins' societies tend to associate in small groups which composition varies dynamically several times and even if stabilized couples exist, they interchange in time anyway. In the short time, it can be also noticed their tendency to form steady groups in average of about 9 individuals, but also the presence of some individuals having not relationships between each other or linked less than others to the pod.

The 2003-2004-2005's sociogram (Fig. 6.16) presents a very thick net, where having more individuals the interactions' variations increase. In fact, 1 specimen accomplish 19 relationships, 4 organisms 18 relationships, 3 individuals 17 relationships, 2 specimens 16 relationships, 5 organisms 15 relationships, 1 organism 14 relationships, 1 specimen 11 relationships, 2 individuals 8 relationships, 1 organism 5 relationships, 2 specimens 4 relationships, 2 individuals 2 relationships and 1 organism 1 relationship. Moreover, a strong association can be highlighted for IDs on the right side, rather than those on the left poorest in relationships and partners.

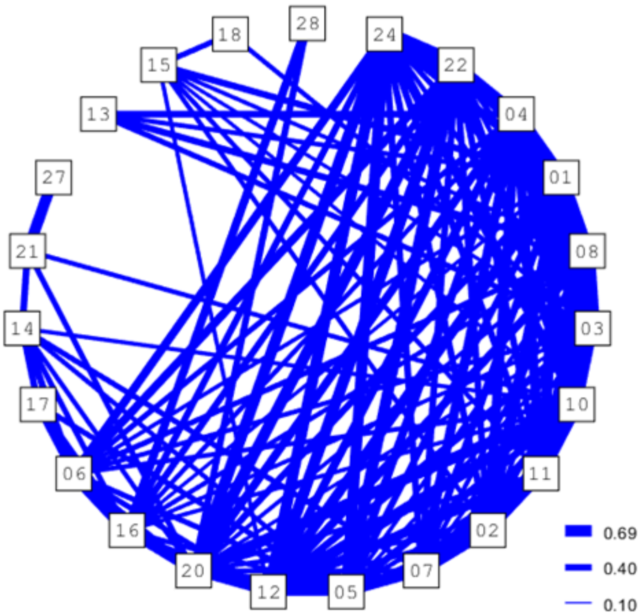


Fig. 6.16: Sociogram representing the associations among individuals in the three-years period 2003-2004-2005.

It is to notice that the number of relationships between individuals does not correspond to the number of individuals observed together in a sighting. So, while on one occasion it is possible to observe a herd composed of an average of 6 individuals ±3, the same ones, during a two-year period can interact with other specimens in different subgroups. Dolphins with fewer relationships can be associated with juveniles who do not yet have enough photos of recognition or otherwise show less visible markings, or to adult leaders strongly linked to a particular area or to certain individuals (*Gonzalvo et al., 2014*).

An interesting result come from the temporal fidelity analysis that shows the persistence of some couples which last up to 7 years like the case of the IDs 3 and 8 from 1998 to 2005. It has also been seen that groups persisting over time do not exceed 4 individuals (*Monaco et al., 2019*).

Starting from the association matrix (Fig. 6.17) with all the animals of the catalog having 6 or more reference photos, also a network analysis was performed.

Interaction rate: All
Total counts, Symmetric

	01	03	04	05	06	08	10	12	15
01	0.00								
03	4.00	0.00							
04	4.00	3.00	0.00						
05	2.00	2.00	2.00	0.00					
06	3.00	2.00	1.00	2.00	0.00				
08	4.00	5.00	4.00	2.00	2.00	0.00			
10	4.00	3.00	3.00	2.00	1.00	3.00	0.00		
12	3.00	2.00	2.00	2.00	1.00	2.00	5.00	0.00	
15	4.00	1.00	0.00	0.00	2.00	1.00	1.00	1.00	0.00

Fig. 6.17: Association matrix of the all bottlenose dolphins present in the catalogue with 6 or more photos of reference.

Calculations considered affinity and strength of the IDs associations, assigning them a clustering coefficient (Fig. 6.18) after having transformed them into a simplified network diagram, showing a nucleus of the 3 most correlated specimens in good communication with 2 other animals, and then a series of other satellite individuals that are part of the same population and usually tighten stronger relationships with at least 3 IDs (Fig. 6.19).

Network analysis statistics
Interactions
File: simgrpn.xlsx
Sampling period:
Restrictions: No restrictions
Interaction rate: All
Total counts, Symmetric

ID	Affinity	Strength	Eigenvector centrality	Reach	Clustering coefficient
01	18.14	28.00	0.44	508.00	0.42
03	20.55	22.00	0.38	452.00	0.54
04	21.79	19.00	0.34	414.00	0.61
05	20.86	14.00	0.25	292.00	0.58
06	20.07	14.00	0.24	281.00	0.53
08	20.26	23.00	0.39	466.00	0.53
10	20.27	22.00	0.38	446.00	0.53
12	20.78	18.00	0.31	374.00	0.55
15	22.50	10.00	0.18	225.00	0.61

	Affinity	Strength	Eigenvector centrality	Reach	Clustering coefficient
Overall means	20.58(1.21)	18.89(5.56)	0.32(0.09)	384.22(97.42)	0.55(0.06)

Fig. 6.18: Network analysis statistics reporting ID affinity, strength, eigenvector centrality, reach and clustering coefficient.

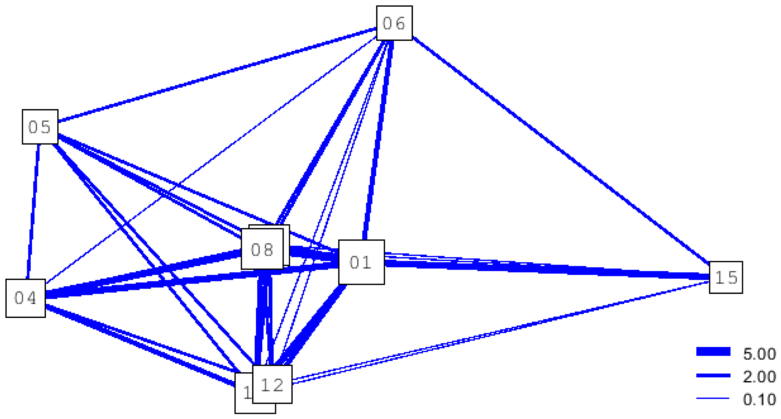


Fig. 6.19: Network diagram showing a nucleus of the 3 most correlated specimens in good communication with 2 other animals.

From the cluster analysis, it has been obtained a dendrogram (Fig. 6.20) showing that the individuals have been grouped together in statistics units minimizing the inner logic distance to each group and maximizing the one among groups. The hierarchical organization shows on the y's axis the individual's ID, while on the x's axis their association degree.

Clustering using average linkage presents a cophenetic correlation coefficient of 0.65; clustering using complete linkage results have a cophenetic correlation coefficient of 0.57, with a maximum modularity related to gregariousness of 0.14429 (Fig. 6.21).

Moreover, analyses show an association complexity of the population equal to 0.686 (Fig. 6.22) and a 0.137 arrangement modularity (Fig. 6.23). While analysis of the complexity using mixture models (Poisson) show value up to 1.097 with a mean of association of 2.4 (Fig. 6.24).

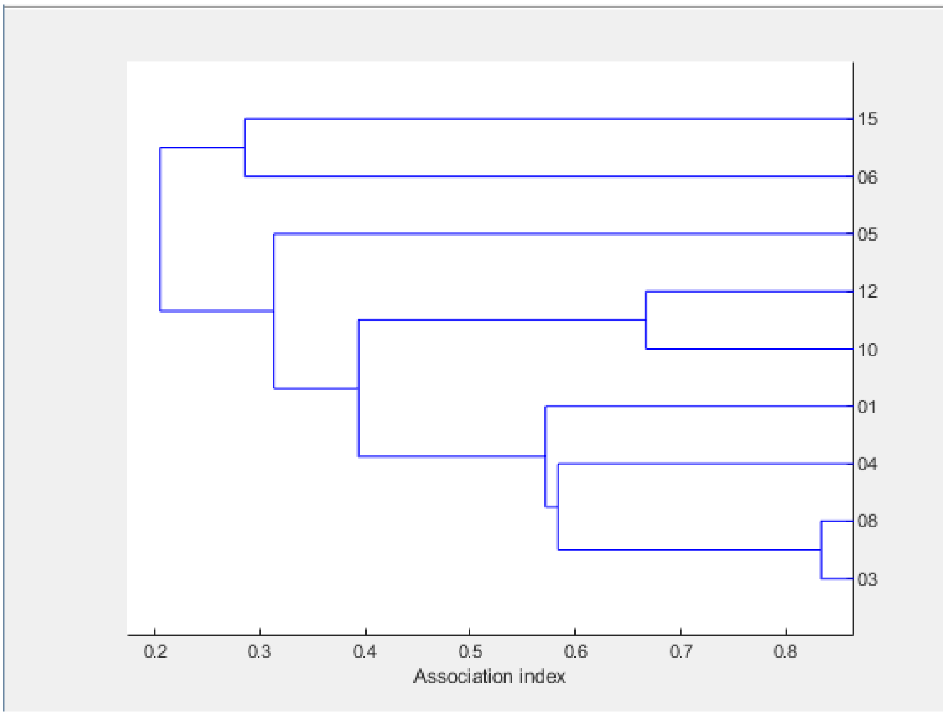


Fig. 6.20: Dendrogram of the population's sample obtained with Socprog using association index. Data here reported refer to the individuals recaptured a number of times ≥ 6 in the period 1997-2019.

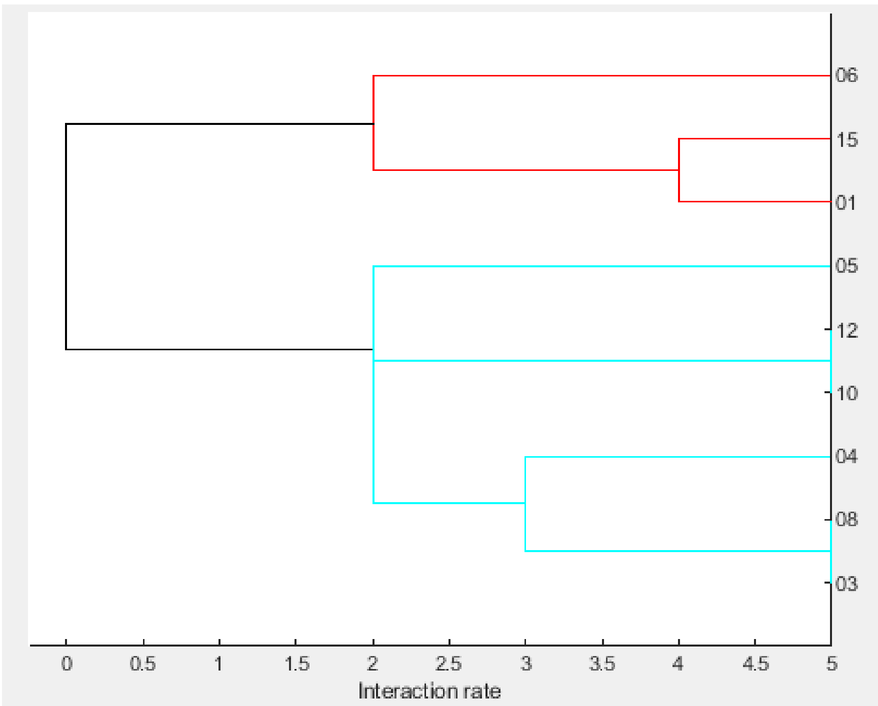


Fig. 6.21: Clustering with interaction rate realized using the complete linkage.

```
Analysis of association complexity by fitting Normal mixture model
Number of associations =    36
   Mean association =  1.1
   Number of classes = 2
   Mean associations of classes      = 1.020 1.301
   Standard deviations of classes   = 0.235 0.819
   Proportional use of classes       = 0.659 0.341
   Association complexity (entropy) = 0.686
# mixtures      LL          ICL       Association Complexity
 1             27.70      -62.567           -0.000
 2             21.35      -60.619            0.686
 3             18.12      -64.903            0.618
```

Fig. 6.22: Resolutive screen obtained with the Socprog software.

```
Assignment of individuals to clusters (eigs near zero indicate uncertainty)
  using eigenvector method of Newman (2006)
  Individual    eig   Cluster
          03 -0.4469   1
          04 -0.2157   1
          05  0.1120   1
          08 -0.4589   1
          01  0.2251   2
          06  0.4119   2
          15  0.6762   2
          10  0.4019   3
          12  0.6076   3

Modularity of this arrangement is 0.137
```

Fig. 6.23: Resolutive screen showing the assignment of individual to clusters using eigenvector method of Newman.

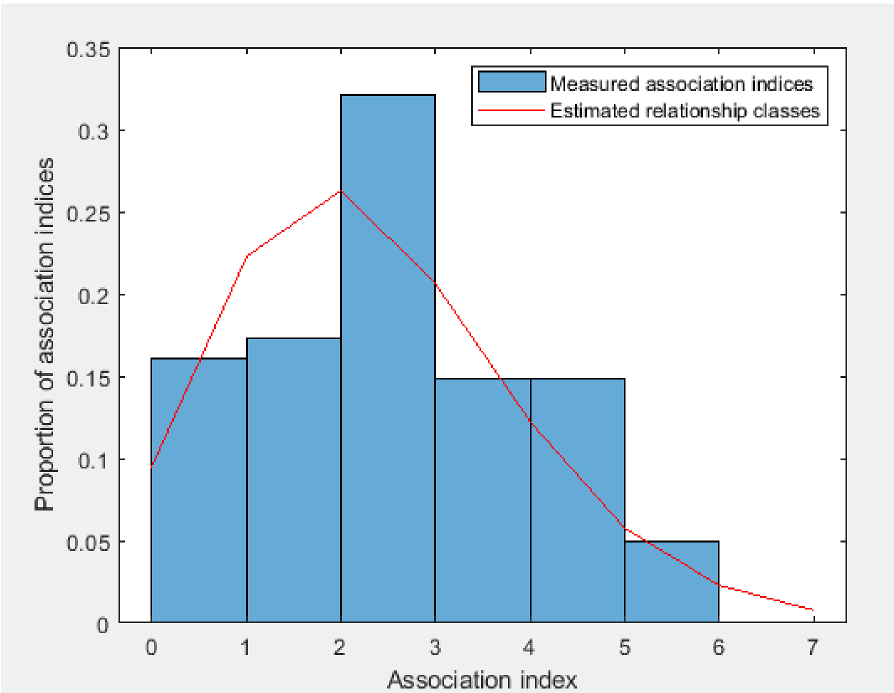


Fig. 6.24: Association complexity by fitting Poisson mixture for n° 36 associations.

All these preliminary data were used for estimating the population's size. To accomplish this esteem, the Hansen method was used, which is based on the number of animals recognized and sets up the following relation:

$$S = R + u/r$$

Where:

S is the size of the considered group;

R is the number of the photo-identified animals recognizable;

u represents the number of photos belonging to individuals non recognizable;

r is the average number of photos of each photo-identified animal.

The result is the prevision of the total number of the photo-identified animals (recognizable and non) and so an esteem of the individuals number belonging to the considered group (*Monaco, 2008*). By applying the Hansen formula, the values referring to the data of the bottlenose dolphins in the Gulf of Catania are reported in the following table (Tab. 4). In the end, the population results composed by 63 specimens.

S	63.42
R	56
u	178
r	23.97

Tab. 4: Factors used for the esteem's calculation of the bottlenose dolphin population present in the Gulf of Catania.

Instead, considering the mean of the examined population

$$est.\mu_{source} = M_x \pm (t * est.\sigma_M)$$

where

M_x - mean of the sample

t - t-ratio for the p value which corresponds to chosen confidence level for non-directional test.

$est.\sigma_M$ - estimate of the standard deviation of the sampling distribution of sample means (or standard error of the mean)

and calculating

$$est.\sigma_M = \sqrt{\frac{\frac{\sum (X_i - M_x)^2}{N-1}}{N}}$$

Hence, once organized the 22 years of data collected by Ketos and Marecamp in 3 blocks, corresponding to the 3 different periods of updating of the catalogue of the bottlenose dolphin identified in the Gulf of Catania, we can estimate to date a mean of 44.33 ±38.59 resident individuals composing the local population, with a 95% confidence level.

Furthermore, the Fig. 6.25 shows the cumulative number of identified individuals in relation to the number of photo-ID sessions carried out during the sightings occurred from 1997 to 2019. When this discovery curve will tend to the asymptote, it can be assessed that all the individuals of the population are identified, answering also to issues linked to the state of population, if closed or opened to low or high flow of periodical migrations. Nevertheless, the asymptote of the following graphic is based only on the last sightings occurred in 2019 in which always the same 8 identified individuals were sighted, assuming that the population is composed only by a few specimens. We know, instead, that in the same sightings other specimens were sighted but, for lacking photos or bad resolution of the latter, they haven’t been identified. Anyway, photos related to these surveys are still being analyzed with new software that probably will enable to recognize new juvenile individuals. Moreover, if also future results will lead to a flat curve, to declare the discovery curve's stop, most of the individuals of the catalogue should be find again more than one time.

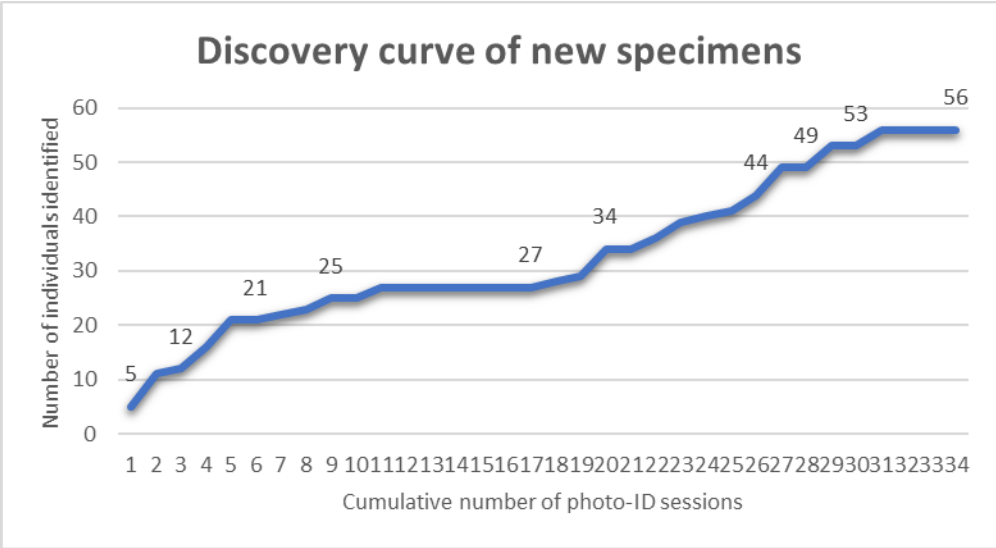


Fig. 6.25: Discovery curve of new specimens. The x axis represents the cumulative number of photo-ID sessions during sightings from 1997 to date, while the y axis is the number of individuals identified.

However, the study showed significant shifts of different IDs within the Gulf, as individuals sighted in the northern part, then observed in the southern section and vice versa, not only by a distance of years but within the same year or season. For instance, this is the case of ID 12 that in August 2019 was sighted to the north, whereas in September 2019 to the south. Still, in 2005 the ID 10 was sighted in the south area, while in 2018 in the north part, showing also areas of preference depending on the biological activities carried out such as *feeding in area*, *feeding in net*, *socializing* or *traveling*.

7. CONCLUSIONS

The Gulf of Catania represents a great resource for the eastern Sicily because of its productivity, its biodiversity and its heterogeneous morphology (*Carboni et al., 2009*). Despite the intense anthropic activities that take part within, the gulf is still considered an ideal habitat for the settlements of many organisms, included top predator like the bottlenose dolphin (*Monaco et al., 2019*). The monitoring activity conducted in the study area has confirmed the great abundance of cetaceans in its waters, because the bottlenose dolphin wasn't the only species sighted, but other observed species during *surveys* were numerous striped dolphins, and also common dolphins, sperm whales, as well as other important high mobile species like tunas, sea turtles and swordfish.

The photo-identification and mark-recapture methods used for this preliminary study were very useful and efficient tools thanks to which it was possible to confirm for the 2019 the presence of 15 individuals of *Tursiops truncatus* in the Gulf of Catania, 8 of which recaptured and 7 new specimens. The 10 years of interruption of the monitoring activity in the study area makes difficult to determine long term dynamics of the local population of bottlenose dolphin as well (*Monaco et al., 2019*). However, in the last two years, were recaptured many dolphins belonging to the old catalogue, indicating a good sustenance of the population. At the same time, as showed by the discovery curve, we have to considered that the entire local population of bottlenose dolphin has not yet been fully cataloged and it is much more numerous than the 56 animals recognized to date.

The photos comparison has permitted a better understanding about the social structure of the population in the different years of the monitoring. Association indexes confirms the existence of some stabilized couples and trios lasting up to 7 years, and many individuals which have a low degree of association and constantly mix among themselves following a *fission-fusion* pattern among the identified animals.

Future monitoring surveys will certainly give a clearer scene about the health status of the local population of bottlenose dolphin, as also a greater knowledge about the association dynamics between individuals and reasons that push them to join or leave a pod, or to establish a certain fidelity to particular subareas (*Lusseau et al., 2003*). Further in-depth analysis on social structure will also allow to recognize behavioral changes between the juvenile and adult phases and related preferences and can help to monitor female-calf groups during their growth.

Moreover, future researches are essentials to understand if, from 1997 to 2019, part of the population left the area or is dead. In this case, once the properly checks will be accomplished, it will be possible to update the catalogue only considering the organisms identified in the last years including juveniles or bordering immigrants. Otherwise, more intense monitoring activities, like the ones carried out during the first years of monitoring, could still help to recapture more of the old identified individuals by gaining so a clearer vision of this generally resident and long-lived population, confirming, at the same time, the real slope of the discovery curve.

Sighting of *Tursiops truncatus* occurred along the whole coastal area of the Gulf, where for marine wildlife several threats of anthropogenic origin exist, and especially the *homerange* of dolphins overlap with intense human activities such as marine traffic and fishing. For this reason, further surveys should be essentials to monitor the local population of bottlenose dolphin and how they continue to adapt their ecology to the surrounding environment. Spatiotemporal studies are also suggested in order to better investigate distribution and seasonality of the species, as well as the possible risks of leaving the gulf of Catania.

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Good wind!

Thank you, next.

ANNEXES

CAMPAGNA DI MONITORAGGIO CETACEI E CHELONI MARINI NELL'AMBITO DEL PROGETTO DOLPHIN WATCHING AND CONSERVATION IN THE GULF OF

SURVEY AVVISTAMENTO CETACEI N° ______

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A V V. N.	AVVISTATORI	DATA E ORA	POSIZIONE					CETACEI			COMPORTAMENTO >>NAVE/piattaf.			N. NATANTI			NOTE
			LATIT.	LONGIT.	DIST.	ANG.	DIR.	SPECIE	N. TOT.	N. JUV.	AV.	AL.	I.	P	M	G	
			N	E													
			N	E													
			N	E													
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			N	E													

Annex 1: Survey for collecting sighting data about cetaceans.

CAMPAGNA DI MONITORAGGIO CETACEI E CHELONI MARINI NELL'AMBITO DEL PROGETTO DOLPHIN WATCHING AND CONSERVATION IN THE GULF OF CATANIA.

SURVEY OSSERVAZIONE N° ______

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	POSIZIONE		NAVE			CONDIZIONI METEO-MARINE					
DATA E ORA	LATITUDINE	LONGITUDINE	ROTTA	VEL.	ATTIV.	CIELO	VISIB.	MAR.	VENTO	NATANTI	NOTE
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									
	N	E									

Annex 2: Survey of observation used during the monitoring.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
1	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	0	1	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	0	1	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
6	0	1	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0
7	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	1	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
11	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0	0	1	0	0	1	0	0
13	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	1	0	0	0	0	0	1
34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
37	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0
43	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	1
48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1	0
50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
51	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0
52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
54	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0
55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0
56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0

Annex 3: Capture data of the 57 photo-identified bottlenose dolphins in the Gulf of Catania. The first row states the gradual number of sightings, while the first column contains the ID number of each photo-identified individual in the Gulf of Catania.