University of the Azores
Department of Biology

Identification of Skates, Rays and Mantas Off the coast of São Miguel Island, Azores: preliminary study of potential tourist development

(Scientific period of training)

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Abstract

Rajiformes are a group within the cartilaginous fish that have become increasingly studied over the last decades. However, these animals still remain poorly studied in the archipelago of the Azores. Little is known about their assemblages, biology, social structure etc. This study has given us a glimpse of the more common species that exist off the Coast of São Miguel Island and their possible seasonal variation considering the fact that they appeared scarce during the winter months (February to May 2008) and more abundant during the summer. *D. pastinaca* and *Myliobatis* aquila were the only species registered during the dives carried out for this work, from February to September 2008, while *Mobula mobular* was registered during whale-watching trips.

Information on the potential touristic interest was also gathered from questionnaires handed out to the stakeholders, where a high (almost 50%) interest was shown in this activity. 85% of the people that were questioned showed they would be willing to participate in dives with rays, skates and manta-rays and pay the same or more compared to normal dives. This information is important, however, more studies on these animals' behaviour need to be undertaken.

Key words: Rajiformes, Diving, Species Identification, behaviour, underwater tourism, Azores.

1. Introduction

1.1 The Azores Archipelago

The Azores Archipelago (37° to 40°N and 25° to 31°W) is located in the Atlantic Ocean (Fig. 1). The Archipelago consists of nine islands spread over the triple junction between the Eurasian, African and North American tectonic plates, the so-called Azores triple junction (FERNANDES et al. 2006). The movement of these three major plates forms an underwater mountain chain, the Mid-Atlantic Ridge, which runs through the Atlantic Ocean and the Arctic Ocean. On top of this constantly active process a hotspot or mantle plume was formed near the area of the triple junction. As a result, the oceanic crust in this region thickened and formed a submarine plateau called the Azores Microplate, only 4km below sea level (MORTON et al. 1998).

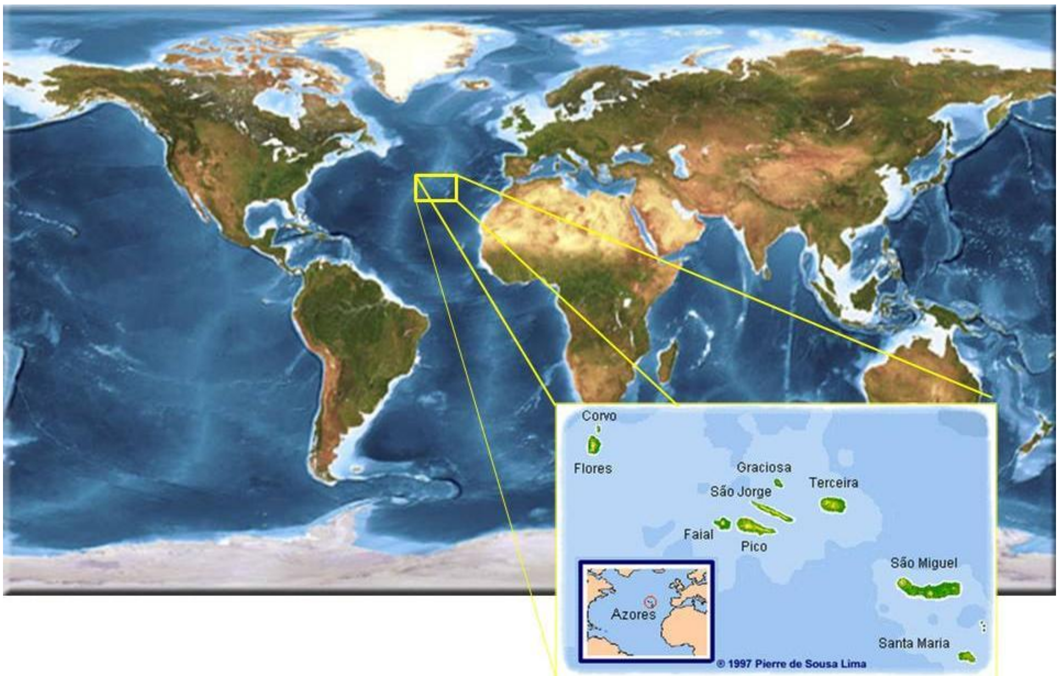

Figure 1-Bathimetric image of the Earth and location of the Azorean archipelago. Retrieved and adapted from Planetary Visions 2008.

The nine islands of the Azores are divided into three groups: the Eastern Group, consisting of Santa Maria and São Miguel; the Central Group, comprising Terceira, Graciosa, São Jorge, Pico and Faial; and the Western Group, consisting of Flores and Corvo. The first two groups sit mostly upon the Azorean Microplate whereas the last arises from the American Plate (MORTON *et al*. 1998).

The oceanographic circulation is complex, partly due to the volcanic processes and it is influenced by the Gulf Stream, the North Atlantic Current and the Azorean Current (SANTOS et al. 1995). The position on the ridge means that deep water is close to shore, and due to the complex circulation patterns and upwelling of nutrient rich deep water currents against the steep walls of the islands, food is abundant in these waters. Due to these factors the Azorean waters offer one of the best habitats of the world for marine fauna (MORTON et al. 1998).

1.2 Rajiformes

This group, skates and rays, differ from other groups of elasmobranches in the possession of more inferiorly placed gill slits and a thoroughly depressed form (BRESER, Jr. & ROSEN 1966)

1.2.1 Classification

The elasmobranches, more specifically the Rajiformes are scientifically classified in the following order (EBERT & COMPAGNO 2007) (see appendix I – Scientific classification of Rajiformes):

- Kingdom Animalia (Animals)
- Phylum Chordata (Chordates)
- Subphylum Vertebrata (Vertebrates)
- Class Chondricthyes (Cartilaginous fishes)
- Subclass Elasmobranchii (Sharks and Rays)
- Superorder Batoidea (Rays)
- Order Rajiformes (Batoids)
- Suborder Torpedinoidei
  - Family Torpedinidae

The species referenced for the Azores are *Torpedo nobiliana,* Bonaparte 1835, Atlantic torpedo ray (WHITEHEAD 1984; DEBELIUS 1997; SANTOS *et al.* 1997; MENEZES 2003), *T. Marmorata,* Marbled torpedo ray (DEBELIUS 1997).

- Suborder Rajoidei
  - Family Rajidae

The number of valid skate species has increased exponentially, with more species having been described since 1950 than had been described in the previous 200 years. Much of the renaissance in skate systematics has largely been through the efforts of a few individuals who through author–coauthor collaboration have accounted for 78 of the 131 species described since 1948 and for nine of 13 genera named since 1950 (EBERT & COMPAGNO 2007).

A variety of species in this family have been referenced for the Azores, *Dipturus batis*, Linnaeus 1758, (MENEZES 2003) common name Grey skate, *D. oxyrinchus* , L. 1758, (MENEZES 2003) known as the Long-nosed skate, *Leucoraja fullonica* (MENEZES 2003), *Raja clavata,* L. 1758, known as the Thornback ray (GOMES 1996; DEBELIUS 1997; SANTOS *et al*. 1997; MENEZES 2003; GALLAGHER *et al*. 2006; RODRIGUES 2007), *R. brachyura,* Lafont 1873, (SANTOS *et al.* 1997), *R. (Rajella) bigelowi,* Stehmann 1978, (WHITEHEAD 1984; SANTOS *et al.* 1997), *R. fullonica,* L. 1758, (Santos *et al*., 1997), *R. maderensis,* Lowe 1839, Madeira skate (DEBELIUS 1997, SANTOS *et al.* 1997), *R. radiata,* Donavan 1808, Starry skate (WHITEHEAD 1984; DEBELIUS 1997).

- Suborder Myliobatoidei
    - Family Dasyatidae

The following species have been registered as existing species in the Azores: *Dasyatis centroura,* Mitchill 1815, common name Roughtail stingray (DEBELIUS 1997), *D. pastinaca,* L. 1758, (WHITEHEAD 1984; AZEVEDO 1997; DEBELIUS 1997; PATZNER *et al.* 1992; SANTOS *et al.* 1997; HARMELIN-VIVIEN *et al*. 2001; MENEZES 2003), known as the Common stingray, *D. violácea,* Bonaparte 1832, (SANTOS *et al*. 1997) and *Taeniura grabata,* E. Geoffroy Saint-Hilaire 1817, called the Round stingray (SALDANHA 1995; DEBELIUS 1997; SANTOS *et al*. 1997).

- Family Myliobatoidea

Myliobatis aquila, L. 1958, (WHITEHEAD 1984; SALDANHA 1995; DEBELIUS 1997; PATZNER *et al.*1992; SANTOS *et al*. 1997; HARMLIN-VIVIEN *et al*. 2001) commonly called the Eagle-ray is the only observed species of this family in the Azores archipelago.

- Family Mobulidae

Manta birostris, Donndorff 1798, (DEBELIUS 1997; SANTOD *et al*. 1997), known as the Manta-ray, the largest ray, pelagic, but is usually observed near reefs in pursuit of plankton (OLDFIELD 2005), *Mobula mobular,* Bonnaterre 1788, (SALDANHA 1995; DEBELIUS 1997; SANTOS *et al*. 1997; HARMELIN-VIVIEN *et al*. 2001), commonly called the Mediterranean mobula and *M. tarapacana*, Phílippi 1892, (DEBELIUS 1997), known as the Sicklefin mobula, are the 3 species of jamantas referenced for the Azores.

1.2.2 Biology, Social structure and behaviour

The skeleton of sharks, rays and chimaeras is made of more or less calcified cartilage. Its vertebral column, extending from the head to the upper tip of the caudal fin, consists of 60 to 420 vertebrae, depending on the species. All fins have basal cartilaginous skeletons connecting them with the body (DEBELIUS 1997). Cartilaginous fish are carnivorous; but among many opportunists, feeding on everything they can devour, there are also specialists preferring certain food items. Eagle (*Myliobatis aquila*) and Cow-nose rays (*Rhinoptera bonasus),* for example, mainly prefer mussels. However, food preference depends not only on species, but also on the age of the individual. Young Eagle rays search for mussels at the surface of the substrate, while adults dig in the sediment for them. Stingrays and Eagle rays have developed a special crushing dentition to crack open the armours and shells of crabs, sea snails and sea-urchins (DEBELIUS 1997).

Electric stingrays, Family Torpedinidae, have soft skin and entirely naked, soft and flabby bodies; disc fleshy towards margins and thicker than in most other batoids; well-developed and powerful electric organs along side of their heads within the anterior part of disc and a caudal fin well developed (WHITEHEAD *et al*. 1989).

Skates (Rajiformes: Rajoidei) are a highly diverse fish group, comprising more valid species than any other group of cartilaginous fishes. The high degree of endemism exhibited by the skates is somewhat enigmatic given their relatively conserved body morphology and apparent restrictive habitat, e.g. soft bottom substrates. Skates are primarily marine benthic dwellers found from the intertidal down to depths in excess of 3,000 m. They are most diverse at higher latitudes and in deepwater, but are replaced in shallower, warm temperate to tropical waters by stingrays (Myliobatodei) (EBERT & COMPAGNO 2007).

Skates of the family Rajidae show parts of their body, if not the entire body, and tail covered with prickles, thornlets and/ or thorns; margins of disc at least thin and not fleshy, body mostly firm; electric organs in the tail only and very low powered and the caudal fin is rudimentary (WHITEHEAD 1984). This group is the only group of elasmobranches that are oviparous (BREDER, Jr. & ROSEN 1966).

Dasyatids have discs no more than 1.3 times as broad as long; tails equal to or considerably longer than the distance from the cloaca to the tip of their snout and the floor of their mouths with row of bulbose papillae (WHITEHEAD 1984).

The myliobatoids have a subrostral lobe undivided and several fleshy papillae on the floor of their mouths. They also have stingers attached to their tails which are formed by a modified placoid scale; the skin surrounding the scale is venomous. A stingray will thrust its barb into the skin of whatever steps on it or otherwise molests it. The barb is not filled with venom, it is actually the skin surrounding it that is toxic (OLDFIELD 2005).

Members from the Family Mobulidae have heads distinctly marked off from their bodies and eyes and spiracles on the sides of their heads, pectoral fins anteriorly separated and forming two thin cephalic fins and teeth minute and in bands of many series (WHITEHEAD 1984). In contrast to the manta-ray, mobulas have subterminal mouths with teeth in both jaws. *Mobula tarapacana* differs from the other 2 mobulid species in the Azores by the absence of a caudal fin, an elongated disc with a “long neck”, short cephalic fins and spiracle in an elongated longitudinal slit (NOTARBARTOLO-DI-SCIARA 1987).

1.3 Threats, Conservation and tourism

In 1974, the Portuguese Government agreed to adhere to the tenets of the Convention on the International Trade in Endangered Species (CITES), an arm of the International Union for the Conservation of Nature (IUCN) to either halt or limit trade in endangered flora and fauna (MORTON *et al*. 1998).

Stingrays of the family Dasyatidae occur worldwide in a variety of habitats, and are becoming increasingly important as a fisheries resource, particularly in developing countries (FRANCIS 1998), which is becoming a large threat to theses species communities. Many aspects of their biology (e.g., reproduction, diet, physiology) have been relatively well studied (e.g., SNELSON *et al*. 1988; GILLIAM & SULLIVAN 1993; SISNEROS & TRICAS 2000), however, there remains much to study about behavioural aspects such as migration patterns and diel and seasonal variations.

Five mobulid species, i.e. *Manta birostris, Mobula japanica, M. munkiana, M. tarapacana* and *M. thurstoni*, are currently listed as Vulnerable by the *IUCN Red List for Threatened Animals* for at least part of their distribution.

Around the world today, tourism is emerging as a strong industry. One aspect of tourism which is making a significant contribution to the global economy is marine tourism or ecotourism. Orams (1999) defines marine tourism as recreational activities that involve travel away from one's place of residence and which have as their host or focus the marine environment.

Stingrays are currently hand fed as part of dive and snorkel ventures in locations such as Tahiti, Maldives and the Caribbean. The most publicised stingray site is that of 'Stingray City' in the Cayman Islands, where some 30 Southern Atlantic Stingrays (*Dasyatis americana*) attract more than 100 000 tourists per year (NEW TRAVELLER 2008). Marine tourism presents a policy dilemma because it has both positive and negative impacts on society. On the one hand, it generates significant incomes for regional and national economies. However, on the other hand, it contributes to the destruction of valuable marine resources. In the last three decades, a number of approaches for managing marine resources have been proposed. One of these is the creation of marine protected areas (MPAs) (ASAFU-ADJAYE, J. & S. TAPSUWAN 2008). MPAs have been acknowledged in several international agreements (e.g. Agenda 21, Convention on Biological Diversity, 1992; United Nations Conference for Economic Development (UNCED), 1993) as a priority mechanism for the sustainable development of coastal and marine resources. In recent years, stakeholder involvement in tourism planning has become increasingly important (PEARCE *et al.* 1998). Hall and Lew (1998) consider public involvement fundamental because plans not supported by stakeholders will be difficult to implement and often fall short of their goals (HENDEE *et al.* 1990). Stakeholders include those parties directly affected by changes to an area, such as visitors themselves, plus those indirectly affected (e.g. local communities). Those managing or providing tourism opportunities, such as government departments, developers and tour operators are also considered stakeholders (NEWSOME *et al*. 2002).

Nowadays, the tourism industry in the Azores flourishes with activities like whale watching, swimming with dolphins and recreational diving. It would be interesting to know how viable a touristic activity with rays, skates and manta-rays would be in the Azores archipelago. Implementing this kind of activity could also serve as a nature conservation tool by creating programmes and other type of resources for people, locals and tourists, to be informed about nature and the benefits of keeping it alive.

1.4 Underwater photography and television

Both photography and television have been increasingly employed as a means of recording data on structure, ecology and behaviour of marine organisms. These media have the important advantage of being non-destructive, non-selective and a ready means of description and demonstration of phenomena which cannot easily be portrayed in any other way. For biological studies, photography has usually been an adjunct rather than as the prime means of investigation. However, in certain circumstances photography or TV may be the only practical means of investigation. The use of photography and television underwater raises a number of problems: Refraction of light at the air /glass/water interfaces situated at or in front of the camera lens; transmission of light through sea water, which is subject to absorption, and to the effects of suspended particles, which is selective for different wave lengths; provision of a suitable watertight underwater case, with optical port and associated controls; provision of a light source and orientation and control of the camera to provide the required information (HOLME & McINTYRE 1984).

1.4.1 Optical problems

The main optical problems encountered are due to light absorption and turbidity. Except under the most favourable conditions (bright sunlight, clear water, shallow depth), artificial light is needed to illuminate the subject. Light passing through water is electively absorbed for different wavelengths. Red light is rapidly absorbed, while blue and green penetrate farther, giving the characteristic blue-green cast to underwater scenes. Suspended particles are always present to a greater or lesser extent, and show up as bright specks where they are illuminated by the light source (HOLME & McINTYRE 1984).

1.5 Diving

Modern diving techniques can be classified according to type of breathing mixture and whether the diver is free-swimming or tethered to the surface by the life-support umbilicus. At present, almost all diving associated with benthic research is carried out with air as the breathing mixture and in most cases with the free-swimming “aqualung” system (frequently known as SCUBA: self-contained underwater breathing apparatus) (HOLME & McINTYRE 1984).

1.5.1 Limitations of the diving technique

SCUBA diving using air is the simplest and cheapest means of conducting research underwater. In addition to time limit imposed by the volume of breathing mixture carried by the SCUBA diver, three main physical factors limit efficiency: depth, temperature and visibility. Other factors such as sea state, currents and dangerous animals will also affect diving activities but these tend to be localised or short-term effects. The time of a dive to >10m on air is limited according to depth by the risk due to inert gas absorption on decompression, the bottom time limits can be calculated by using a table that interrelates all the different variables such as depth and pressure group (appendix III) (HOLME & McINTYRE 1984).

A part of the present work aims to contribute to the knowledge on Rajiforme species, their identification and possible seasonal variations in behaviour and the other part is dedicated to studying the potential touristic interest that tourists and locals may have toward diving with rays, skates and/ or manta-rays off the Coast of São Miguel Island, Azores.

2. Materials & Methods

Firstly, a bibliographic research was undertaken to identify the species that were already registered for the Azores archipelago. Eight species were selected as the most common species and therefore the target species for this study. Dasyatis *centroura, D. pastinaca, Manta birostris, Mobula mobular, M. tarapacana, Myliobatis aquila, Taeniura grabata* and *Torpedo nobiliana.*

Different types of data were gathered from diving and questionnaires aiming to identify the species observed off the Coast of São Miguel Island and to do a preliminary evaluation of the potential touristic interest in diving with these animals.

2.1 Diving

Data was gathered between February and September 2008 from various local SCUBA divers and divers working for Nerus (a touristic diving company). Dives took place in 9 different spots off the coast of São Miguel Island (Fig. 2), (1) Arcos do Hotel da Caloura, (2) Dori, (3) Ilhéu de São Roque, (4) Luso, (5) Recife da cadeia (Ponta Delgada), (6) Recife da Lagoa, (7) Recife do porto de Ponta Delgada, (8) Ribeirinha and (9) Santa Clara. Some dives were initiated from shore and others from boats.

Figure 2- Locations where dives took place off the coast of São Miguel island. Retrieved and adapted from Eurosun, 2008.

All dives were carried out between the depths of 10m and 25m with a maximum time of 50 minutes which are within the limits of SCUBA diving described by Holme & McIntyre (1984). Basic SCUBA diving gear was used, wetsuit, mask and snorkel, boots, fins, gloves, hood, weights and belt, buoyancy compensator (SCUBA-BCD), regulator set, computer, compass, cylinder and other accessories (Fig. 3).

Figure 3 – Basic Scuba gear used by the divers during this work. Images retrieved and adapted from Divers Discount Supply, 2008.

For each observation a register sheet (appendix II) was filled in with different information concerning the location, depth, type of sea bottom, species observed, size of the animal, sex and other observations such as behaviour. To facilitate the identification of the species and sex of the individuals, the registration sheet included an identification table describing each species, these descriptions were taken from Whitehead *et al*. (1984), and the differences between male and female.

Additionally, images were taken with a Sony Digital camera with an underwater-proof casing (Fig.4) to try obtain a better and easier identification.

Figure 4 – Digital Camera and corresponding underwater-proof casing used in the dives.

2.2 Questionnaire

A questionnaire (appendix III) was elaborated to evaluate the potential touristic interest in diving with rays, skates and manta-rays in the Azores. The questionnaire was simple and short, consisting of 6 multiple choice and/ or short answer questions, to avoid lack of cooperation by the stakeholders. The questionnaires were handed out to students of the University of the Azores whom have been diving or have interest in diving, to different local divers with varied experience and to diving and whale watching companies to be able to target the tourists, these were all considered stakeholders.

2.3 Data analysis

The data gathered from the dives and the questionnaires was processed on Microsoft Excel, where elaborate tables were created (appendixes VI and VII). Various comparisons and crossing of information was carried out to look for possible patterns occurring within the different variables.

3. Results

Many dives were carried out off the Coast of São Miguel Island, 41 individuals were registered in 23 different dives, between February and September 2008. In total, 34 individuals were identified as *D. pastinaca*, ranging between 20 and 100cm, and 7 as *M. aquila,* ranging between 40 and 70cm in disc width (DW) (appendix VI).

Due to weather conditions in the winter season, in this case from February to May included, fewer dives were carried out which resulted in the registration of only two individuals, both of the same species (*D. pastinaca*) (Fig. 4).

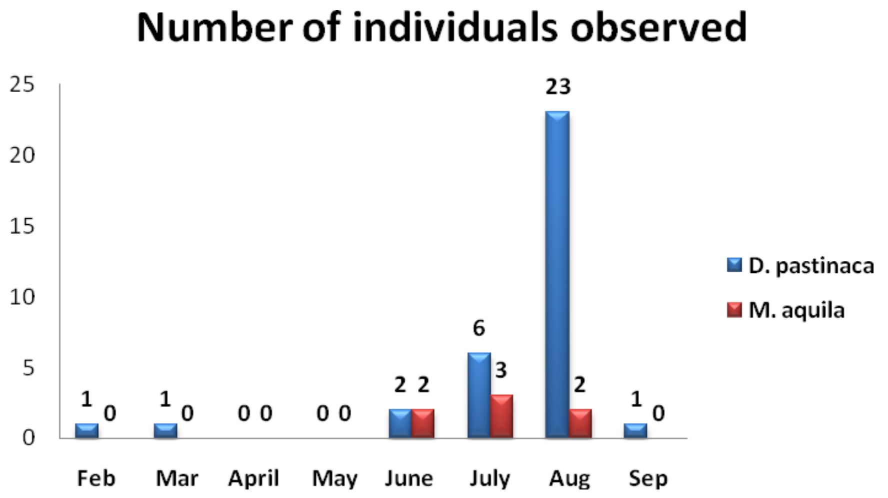

Figure 4- Number of individuals and species observed and registered during each month for the dives.

August is the month that shows the highest number of registrations in total, 25, where 23 individuals are *D. pastinaca* and 2 individuals are *M. aquila*. This also occurred because the number of dives in August was much higher due to the good weather conditions permitting a more regular dive plan.

Additionally, two Mediterranean rays (*M. mobular*) were observed and registered, this took place during whale-watching trips. These trips are usually further away from the coast, offshore, and the whale watching boats cross the path of these animals that are known to inhabit open waters here in the Azores rather than benthic habitats like the stingrays and skates.

The sex of the observed individuals turned out to be quite difficult. As a result the sex of only 9 individuals was determined, all being registered as females, as shown in appendix VI. The diver that identified these females added that it appeared as if all the individuals were females and that no males had yet been observed this year.

The questionnaires became an important and interesting tool for this study, which allowed us to evaluate the different aspects of interest and touristic potential for underwater tourism. The people that answered the questionnaire ranged between the ages of 18 and 50 years, 66% were male and 34% female.

When comparing the level of interest with the 3 groups of animals it was possible to distinguish that the majority of the people (32 out of 45) that answered the questionnaire showed most interest (1) in seeing manta-rays (Fig.5), 23 people showed some interest (2) in seeing rays, 24 people showed the least interest (3) in seeing skates and 4 people, out of the 45 that were interviewed, showed no interest (4) in seeing any of these groups of animals.

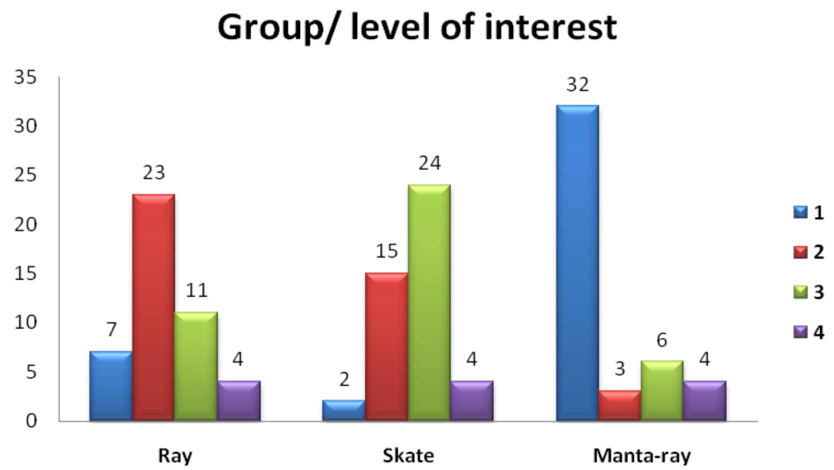

Figure 5–Different interest levels, (4) no interest; (3) least interest; (2) some interest; (1) most interest, corresponding to the different groups of animals.

After correlating the group of animals to the level of interest that a person has, it is interesting to evaluate if the degree of experience in diving also influences the level of interest that a person has in observing these fish. In Figure 6 it is clear that people with little or no experience show the least interest. 12 questionnees with little experience have a normal interest in these animals whereas people who are experienced show a normal interest and 7 show a high interest. The most interesting to see is that every person that had a high level of experience (quite experienced), in this case 4 people, showed the highest level of interest as well and even people with no experience show a high level of interest in observing these animals. In total, 23 people (over 50%

of questionees), regardless of their degree of experience, showed a high interest in these animals compared to other fish.

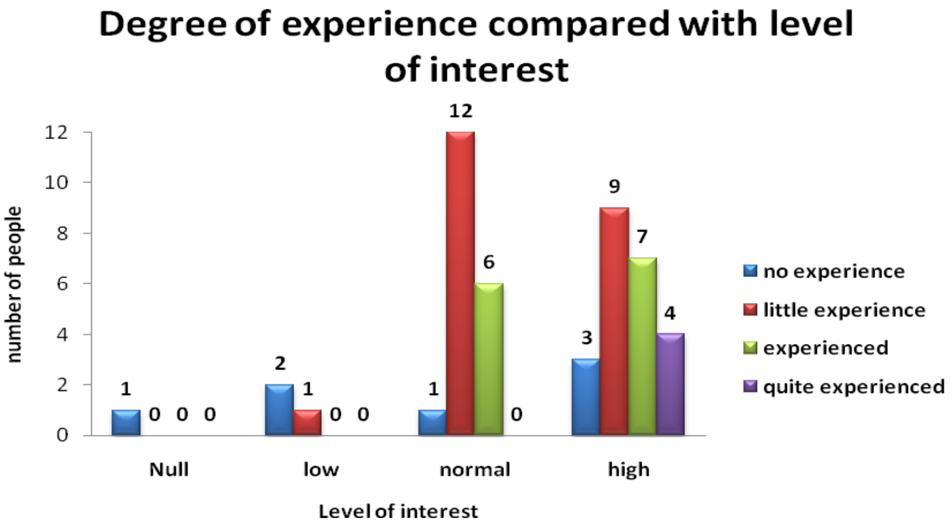

Figure 6–Levels of interest (null, low, normal and high) compared to the individual degree of experience in diving (no experience, little experience, experienced and quite experienced).

To be able to study the possibility of creating underwater tourism with rays, skates and/ or manta-rays, it was necessary to know if people, local divers, tourists and others, would be willing to participate in dives and how much they would be willing to pay compared to a normal touristic dive.

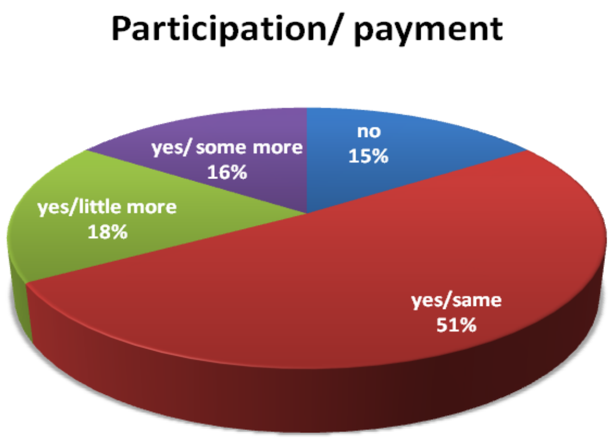

Figure 7– Percentages of people willing or not (yes; no) to participate in dives with these animals and how much they would pay (same; little more; some more) for a dive compared to a normal recreational dive.

Figure 7 shows that 51% of the people that answered the questionnaire said they would participate (yes) and they would be willing to pay the same as a normal dive. Interestingly, 18% said they would participate and pay a little more and 16% said they would participate and be willing to pay some more. In total, 85% of the stakeholders are willing to participate in touristic dives and pay.

Images captured on the digital camera were not of the sufficient in quantity or quality for scientific research.

4. Discussion

Out of 3 different species recorded during this study (*D. pastinaca, M. aquila* and *M. mobular)*, *D. pastinaca* was the species that appeared to be more common due to the number of observations being higher. This type of assumption may be incorrect. Looking at the table of data from the dives (appendix VI) we note that 12 of the dives (52%) were done in one spot, Dori, and it may be possible that other species are more abundant in other localities. Movements of these animals may also influence this type of data recordings. The data shows that during the winter months, February to May, the animals seem to be scarce in terms of number of observations, this may be explained by the seasonal variations these animals have been known to have. The measurements of rate of movement (ROM) for a benthic batoid species, *Dasyatis lata,* were studied recently where rays were found to utilize significantly larger activity spaces at night than during the day. Rates of movement were also significantly higher at night than during the day (CARTAMIL *et al.* 2003). This may explain the apparent absence of these animals during the day as they might be resting and they are more active at night. During the day they remain hidden from the divers' eyes, for they are known to burry themselves in the sand. This may be a strategy of defence, as they wouldn't be seen by their predators, a hunting method or just a normal behaviour they have while resting. These aspects are yet to be studied.

To explain seasonal variation it has also been mentioned that after mating season occurs, in the spring time, it is followed by a peak in abundance during summer, ray numbers decrease dramatically by late autumn (May), increasing once more in spring (PORT *et al*. 2008).

Temperature is the most important and least well documented environmental entity affecting reproduction and feeding of elasmobranch fishes, but it is unclear to what extent these fish may exploit behavioural thermoregulation to optimize physiological processes (FANGUE & BENNETT 2003). Atlantic stingrays are one of the most thermally tolerant fish known, enduring temperatures between 0.7°C and 43°C (BIGELOW & SCHROEDER 1953, SNELSON *et al*.1988, FANGUE & BENNETT 2003).

Movement and distribution of Atlantic stingrays are dictated, in part, by temperature effects on physiology (FANGUE & BENNETT 2003), some researchers argue that these fishes maximize efficiency by feeding in warm waters, and then moving to cooler temperatures to slow evacuation rates, thereby allocating more time for nutrient absorption (WURTSBURGH & NEVERMAN 1988, CAREY & SCHAROLD 1990, HOPKINS & CECH 1994, MATERN *et al*. 2000). Seasonal migrations to deeper water in winter were also recorded in the thornback ray *(Raja clavata*), and were suggested as prey-related feeding migrations to forage on crabs (HUNTER *et al*., 2005).

The number of females of *Raja clavata, R. radiata*, and *R. batis* is frequently greatly in excess of that of males. This ratio was also found in other species such as *R. erinacea, R. laevis* and even in sharks. This could lead us to infer that it is possible that these animals segregate into unisexual groups. It is believed that gravid females tend to form more compact schools than the males and, consequently, are more subject to capture in large numbers (BREDER, Jr. & ROSEN 1966). This could be true for other species of elasmobranch animals. The same type of behaviour could occur in the species *D. pastinaca*, which could explain the apparent singular presence of females. Our data shows that only a few animals' sex was determined and more so that all of the animals were females. Future studies of this reproductive behaviour would be interesting to undergo.

Recreational dives and whale-watching is a flourishing industry in the Azores, the tourist community is growing and considering that these animals do exist in Azorean waters, tourism with rays, skates and manta-rays does not seem to be such an unreasonable idea.

The questionnaires that were handed out indicate that there is a high interest (1 being the highest and 4 no interest) in seeing these animals, mostly manta-rays, and that tourists and even experienced local divers would be willing to participate and pay the same or more than a normal recreational dive (85% of people surveyed), which indicates that there may be a possibility of success in introducing underwater tourism diving with rays in the Azores. This activity would also bring more tourism to the island and would be very good for the region's economy, as it is known to have a very high income rate.

Information collected from people that were interviewed, indicate that Mobulids (*M. birostris, M. mobular, M. tarapacana)* are observed almost daily during the summer months, which may indicate a seasonal pattern since this seems to occur yearly. They are mostly observed during the whale-watching outings. These boats go farther out to open sea to observe different types of cetaceans and they cross the path of the manta-rays often during the summer months. This explains the lack of observations for these animals for the dives. These fish have been observed in various locations all over the archipelago.

More information about manta-rays was gathered from personal conversations with workers within the whale-watching companies. It was confirmed that manta-rays are seen every year during the summer season, between July and mid September, and quite often. At least this year, they were observed numerously, but not registered, off the coast of São Miguel, Santa Maria and Faial. All observations that were talked about, except one very rare situation where a manta-ray was seen by a diver close to the coastline, were on boats and a few miles off the coast. A local diver also said that at the Formigas, consisting of a sand bank and a few very small islets, southeast off the Coast of São Miguel Island, many manta-rays are observed. Most of the time, information from local divers, whale-watching companies and local fisherman becomes important and gives a better and more global understanding of the reality when joined with the scientific data.

Digital cameras and photography are an excellent tool for scientific research (HOLME & McINTYRE 1984). Due to many of the limitations, such as lack of experience, insufficient dives, underwater conditions (turbidity), no light source on the underwater-proof casing and others, the images taken were not of sufficient quality and quantity to consider as an important result for this work, even though the images did contribute for an easier identification of an individual of *D. pastinaca.*

5. Conclusions

Results suggest that the observed scarcity of stingrays, rays and skates from shallow waters in winter may be due to their movement to deeper water (PORT *et al*. 2008). This could be an explanation for the little observations of these animals for the diel, and possibly, seasonal movements of these species. It could be suggested that they move to shallower and warmer waters to forage during the day (due as well to prey availability) and at night move toward deeper and cooler waters. As opposed to a long-distance migration which is assumed to occur during the summer months for the mobulids at the Azores archipelago. These animals may be passing by on their way to another location and the Azores archipelago a mid-stop, or this may be a final destination, during the summer, of a migration, where these animals come to feed and/ or reproduce in these waters. However, due to the small number of these animals observed and registered and the differences in behaviours observed, this work only provides a glimpse into the seasonal behaviour, species and touristic potential of these animals and is a starting point for further studies of these and other elasmobranch species for the archipelago of the Azores.

To study this hypothesis, a more structured and consistent dive plan would be needed, comprising of more frequent dives over a longer period and with a higher efficiency, as opposed to the method of data collection in this study. The registrations gathered for this study were occasional and opportunist, the animals were registered when they were observed mainly in touristic, recreational dives. Few dives were purposely carried out for the observation of these animals due to weather condition at times, non-existing dive partners, lack of equipment and logistics. With more directional dives at a higher frequency, the observations would give a better view of the occurrence and probability of seeing or not these animals and more data could be collected. Data collected about the manta-rays was also scarce due to very little information about these animals in the Azores. For a future study, the local whale-watching companies would be better candidates for collaboration and data collection. Instead of coastal dives, more surface observations should be carried out offshore which then could incorporate the dives after knowing where the animals are. This method would be similar to whale-watching, maybe it could be called manta-watching.

To further elucidate possible seasonal movements of these animals, further research should include increasing the sample size, in this case the number of dives and boat trips for observation, and the total duration of the work (one or two year period). Studies with satellite monitors could be interesting for these animals to find out about their migration patterns and study their seasonal behaviour. A good method studied and described by Port *et al*. 2008 to study various aspects of these animals, such as diel vertical movements, would be the method developed for PSAT attachment, which proved successful in stingrays, *Dasyatis brevidaudata* and can be applied for other species of rays, skates and manta-rays. PSAT tags have a great advantage over conventional tags or other archival tags since they do not require the recapture of tagged fish to obtain data collected over several months.

In addition, to further investigate ecological interactions between these dominant predators (CARTAMIL *et al.* 2003), in the Azores, future studies should also focus on the abundance and energetics of these species as well as the availability of prey species in this area.

For future studies on tourism potential, it is beneficial to follow similar methods used by Lewis & Newsome (2003) which had high inputs from stakeholders. More surveys and questionnaires could be carried out in the future targeting the local public as potential tourists, those managing or providing tourism opportunities, such as government departments, developers and tour operators to report these stakeholder's interests and concerns with regard to ray, skate and/ or manta-ray tourism in the Azores. To date in the Azores this type of tourism had never been thought of. However, a more thorough analysis of the biological and seasonal variations and possible impacts this activity may have upon the area and communities needs to be undertaken to be able to analyse the viability of this activity. Tourist sites normally include feeding the animals to allure the animals and have shown ecological implications of an increase in stingray numbers which include a potential impact on their natural prey if the rays were to feed away from the sites (Department of Environment, 2008). Other concerns include increased susceptibility of the rays to disease, limited nourishment, alterations in their natural behaviour, death from ingesting litter and water fouling (Department of Environment, 2008). Management actions are recommended to reduce impacts on the rays, eliminate risks to visitors and increase visitor satisfaction.

Although *Raja clavata* (Linnaeus, 1758) was not a target species for this work due to the fact that it inhabits lower depths (50 to 150m), which are out of the limits for SCUBA diving, It is important to note that it is on the Red List of the IUCN- International Union for the Conservation of Nature, and therefore an endangered species. Considering that *R. clavata* is a commercially targeted species in the Azores archipelago (GALLAGHER *et al.* 2006; RODRIGUES 2007), future studies should be carried out to find out the possible impact that the Azorean fisheries are or may be having on this species.

6. Acknowledgements

Firstly, I would like to thank my parents for all the effort and sacrifices they made for me to be able to study far away from home. Believe it or not, it is very difficult keeping up two separate homes. More importantly, I am grateful to them for having always supported me in my decisions, even when they were a little “crazy”. I also want to thank my brothers for always being there when I needed them.

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Without less consideration, I would like to thank Paulo Luis and Dinnis Geraldes (Nerus), whom I worked in cooperation with, for having been critical in collecting data and additional information for me. If it weren´t for their positive go ahead from the get go, I probably wouldn´t have pursued this idea till the end.

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Thank you.

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Appendices

Kingdom Animalia (animals)

All animals are members of the Kingdom Animalia, also called Metazoa. All members of the Animalia are multicellular, and all are heterotrophs (that is, they rely directly or indirectly on other organisms for their nourishment). Most ingest food and digest it in an internal cavity.

Animal cells lack the rigid cell walls that characterize plant cells. The bodies of most animals (all except sponges) are made up of cells organized into tissues, each tissue specialized to some degree to perform specific functions. In most, tissues are organized into even more specialized organs. Most animals are capable of complex and relatively rapid movement compared to plants and other organisms. Most reproduce sexually, by means of differentiated eggs and sperm. Most animals are diploid, meaning that the cells of adults contain two copies of the genetic material. The development of most animals is characterized by distinctive stages, including a zygote, formed by the product of the first few division of cells following fertilization; a blastula, which is a hollow ball of cells formed by the developing zygote; and a gastrula, which is formed when the blastula folds in on itself to form a double-walled structure with an opening to the outside, the blastopore.

Somewhere around 9 or 10 million species of animals inhabit the earth; the exact number is not known and even our estimates are very rough. Animals range in size from no more than a few cells to organisms weighing many tons, such as blue whales and giant squid. By far most species of animals are insects, with groups such as molluscs and nematodes also being especially diverse. By this measure our own group, the vertebrates, is relatively inconsequential.

Phylum Chordata (chordates)

Chordates are defined as organisms that possess a structure called a notochord, at least during some part of their development. The notochord is a rod that extends most of the length of the body when it is fully developed. Lying dorsal to the gut but ventral to the central nervous system, it stiffens the body and acts as support during locomotion. Other characteristics shared by chordates include the following:

- bilateral symmetry
- segmented body, including segmented muscles
- three germ layers and a well-developed coelom
- single, dorsal, hollow nerve cord, usually with an enlarged anterior end (brain)
- tail projecting beyond (posterior to) the anus at some stage of development
- pharyngeal pouches present at some stage of development
- ventral heart, with dorsal and ventral blood vessels and a closed blood system
- complete digestive system
- bony or cartilaginous endoskeleton usually present

Subphylum Vertebrata (vertebrates)

Vertebrates, which include fishes, reptiles, amphibians, birds, and mammals, all share a vertebral column, or a chain of bony elements (vertebrae) that run along the dorsal surface from head to tail and form the main skeletal axis of the body. The vertebral column surrounds and more or less replaces the notochord as the chief "stiffener" of the body in locomotion. Some characteristics shared by most or all vertebrates (in addition to those traits shared among all chordates) include the following:

- integument of two divisions, including an outer epidermis and an inner dermis; integument often modified to produce hair, scales, feathers, glands, horn, etc.
- replacement of notochord by vertebral column more or less complete, depending on group
- bony or cartilaginous endoskeleton consisting of cranium, visceral arches, limb girdles, and 2 pairs of appendages
- muscular, perforated pharynx; this structure is the site of gills in fishes but is much reduced in adult land-dwelling forms (although it is extremely important in embryonic development of all vertebrates)
- movements provided by muscles attached to endoskeleton
- digestive system with large digestive glands, liver, and pancreas
- ventral heart with 2-4 chambers

- blood with red blood corpuscles containing hemoglobin, and in addition, white corpuscles
- well developed body cavity (coelom) containing visceral systems
- paired kidneys with ducts to drain waste to exterior
- most vertebrates with two sexes, each with paired gonads (there are some exceptions)
- general body plan consisting of head, trunk, 2 pairs of appendages, and post-anal tail (but these structures are highly modified in many vertebrates and sometimes absent).

Class Chondrichthyes

This group includes around 1000 species in two subclasses: Elasmobranchii, sharks and rays, and Holocephali, the chimerae. Chondrichthyes arose in the Silurian period approximately 450 million years ago, around the same time as bony fishes. Within the Elasmobranchii, recognizably modern sharks had arisen by the Jurassic period, and rays and skates, the order Rajiformes, had evolved by the end of the Cretaceous period. Rajiformes contains about 456 species and differs from sharks by having their pectoral fins fused to the sides of their heads and by having ventral rather than lateral gill slits (OLDFIELD 2005).

Subclass Elasmobranchii

All the living Chondrihthyes are included in this subclass or in the Holocephali. The majority are in the Elasmobranchii. This large group comprising of all the true sharks and the rays and skates, shows a remarkable uniformity, so far as known, in reproductive behaviour, specially as compared with variations in other habits or details of physical structure. The sharks and rays have oviparous and viviparous members (BREDER, Jr. & ROSEN 1966).

Superorder Batoidea

Batoidea is a superorder of cartilaginous fish containing more than 500 described species in thirteen families. They are commonly known as rays, but that term is also used specifically for batoids in the order Rajiformes, the "true rays". Batoids include stingrays**,** skates**,** electric rays**,** guitarfishes and sawfishes**.**

Batoids are most closely related to sharks and young batoids look very much like young sharks. Indeed according to recent DNA analyses the catshark is more closely related to the batoids than to other sharks.

Batoids are flat-bodied, and, like sharks, are a species of cartilaginous marine fish, meaning they have a boneless skeleton made of a tough, elastic substance. Most batoids have 5 ventral slot-like body openings called gill slits that lead from the gills, Hexatrygonidae have 6. Batoid gill slits lie under the pectoral fins on the underside, whereas a shark's are on the sides of the head. Most batoids have a flat, disk-like body, with the exception of the guitarfishes and sawfishes, while most sharks have a streamlined body. Many species of batoid have developed their pectoral fins into broad flat wing-like appendages. The anal fin is absent. The eyes and spiracles are located on top of the head (WIKKIPEDIA 2008).

Order Rajiformes

Rajiformes contains the suborders Pristoidei, Rhinobatoidei, Torpedinoidei, Rajoidei and Myliobatoidei. Pristoidei, sawfishes, are ovoviviparous. Rhinobatoidei, Rajoidei, the skates, inhabit deep water and high latitudes and reproduce by laying eggs. Myliobatoidei, the stingrays, generally inhabit tropical inshore waters, reproduce by giving birth, and usually have stingers attached to their tails. The barb is a modified placoid scale (the type of scale covering elasmobranches), and is periodically shed. It is covered with toxic epidermal tissue and can be very dangerous (OLDFIELD 2005).

Appendix II- Registration sheet for each dive and the observed individuals

Folha de registo de avistamentos de espécies Rajiformes

Universidade dos Açores - Departamento de Biologia
Estágio científico de Identificação e Conservação das espécies Rajiformes de São Miguel, Açores
Elaborado por Sabrina Garcia em colaboração com a Nerus.

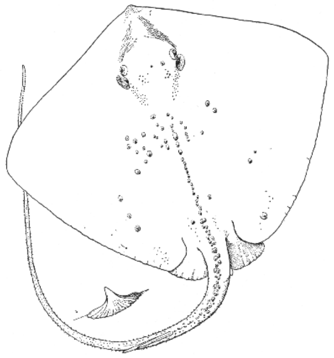
Nome:_______________________________________ **Data:__________________**

Local de avistamento:____
(Coordenadas, condições particulares, etc.)

Este documento é importante para o estudo das espécies Rajiformes, assim, é imprescindível que seja devolvido ao local ou pessoa de quem a obtiveram. Obrigada pela sua colaboração.

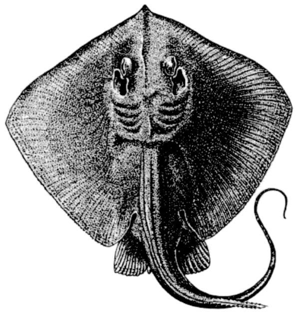
Espécie	Prof.	Tamanho (cm)	Sexo (M/F)	Observações (comportamento, descrição do local, alimentação, etc.)

Ujes



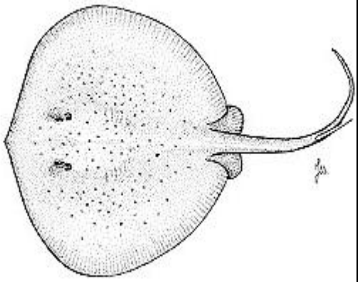
Dasyatis centroura

Dorso castanho-escuro, por vezes com espinhos no disco e na cauda. Animais grandes, com largura do disco de 1m a 1,5m, podendo atingir mais de 2m. Cauda longa e flexível, sem crista após o espinho.



Dasyatis pastinaca

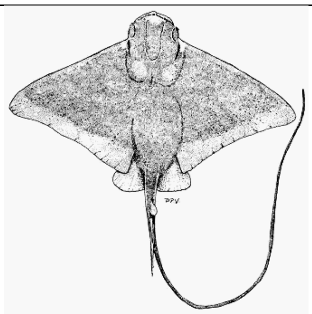
Mais pequena que *D. centroura*, com largura de disco entre 45 a 60 cm. Sem espinhos ou tubérculos no disco. Cauda longa e flexível, prega membranosa na parte superior, após o espinho.



Taeniura grabata

Disco quase circular, ligeiramente mais largo do que comprido, a cauda curta e pouco flexível, com prega membranosa na parte inferior, após o espinho. Largura do disco até 1 m.

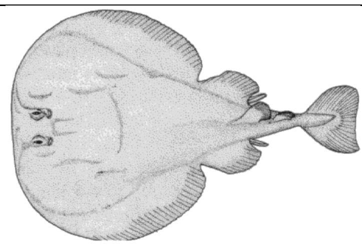
Ratão



Myliobatis aquila

Cabeça elevada com o focinho curto e arredondado. Sem barbatana caudal, dorso preto-acastanhado. Largura do disco até 80 cm.

Tremelga negra



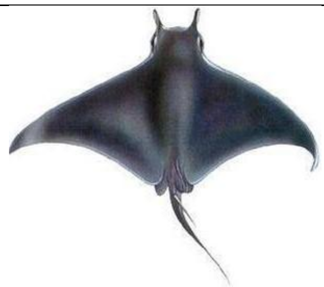
Torpedo nobiliana

Corpo arredondado em forma de disco, barbatana caudal em forma de pá. Coloração dorsal lisa, preta ou cinzento-escuro. Atinge 1,8 m em comprimento.

Jamantas

Manta birostris

Lobos cefálicos grandes e brancos, enrolados durante a natação e desenrolados durante a alimentação. Dorso liso e escuro, boca terminal. Podem atingir envergaduras entre 1 e 6,7 metros



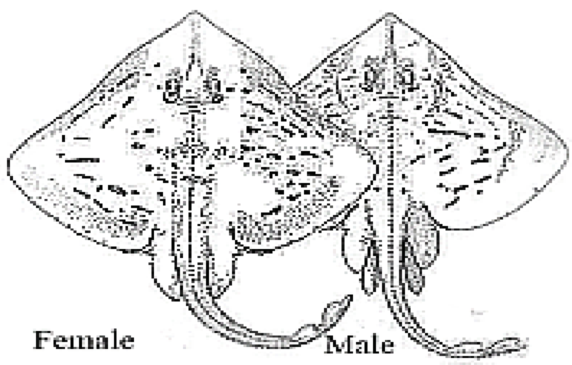
Mobula mobular

Cauda muito longa com crista e espinhos. Lobos cefálicas pequenos, apresenta o dorso preto, podem crescer até ao 5 metros

Mobula tarapacana

Pode atingir cerca de 3 metros. A sua coloração pode ter algumas variações, sendo a parte dorsal azul escura, verde escura ou acastanhada

Distinção sexual



Apendix III- Questionnaire

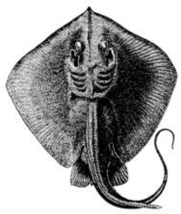
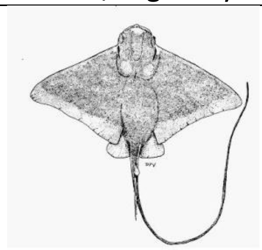
University of the Azores-Biology Department

Inquérito/Questionnaire

Sabrina A. M. Garcia

Este inquérito foi elaborado com o objectivo de obter informação sobre o potencial turístico que poderá existir nos Açores em relação ao mergulho dirigido às raias, ujes e jamantas. Estes dados irão contribuir para o meu estágio científico no curso de Biologia Marinha.

This questionnaire aims to assess the potential touristic interest in diving with rays, skates and manta-rays in the Azores. This data will contribute to my final year project in Marine Biology.

Uje/Sting-Ray	Raia/Skate	Ratão/Eagle-ray	Jamanta/Manta-ray
			
Dasyatis pastinaca	*Raja clavata*	*Myliobatis aquila*	*Manta birostris*

Nome (facultativo) / Name (optional):

____

Sexo/ Gender:_________ Idade/ Age:__________

Português

1. Qual é a sua experiência de mergulho?

— Inexperiente
— Pouco experiente
— Experiente
— Muito experiente

2. Quais dos seguintes já observou?

— Raias
— Ujes e/ ou ratões
— Jamantas
— Nenhum acima referido

English

1. How much experience do you have in diving?

— No experience
— Little experience
— Experienced
— Quite experienced

2. Which of the following have you observed?

— Rays
— Skates and/ or Eagle-rays
— Manta-rays
— None of the obove

3. Em relação a outros peixes, como classifica o seu interesse por estes animais?

- Nulo
- Pequeno
- Normal
- Alto

4. Se tiver interesse nestes animais, assinale com os números 1, 2 e 3 a ordem de preferência.

- Raia
- Uje e /ou ratão
- Jamanta

5. Participaria num mergulho cujo principal objectivo fosse a observação destes animais?

- Sim
- Não

6. Se respondeu positivamente à pergunta 5., indique quanto estaria disposto a pagar, em relação a um mergulho normal.

- Menos
- O mesmo
- Pouco mais
- Algo mais
- Muito mais

3. Comparing to other fish, how would you classify your interest in these animals?

- Null
- Low
- Normal
- High

4. If you are interested in these animals, show us your preference using the numbers 1, 2 and 3.

- Rays
- Skates and/ or eagle-rays
- Manta-rays

5. Would you participate in a dive which the main objective was to observe these animals?

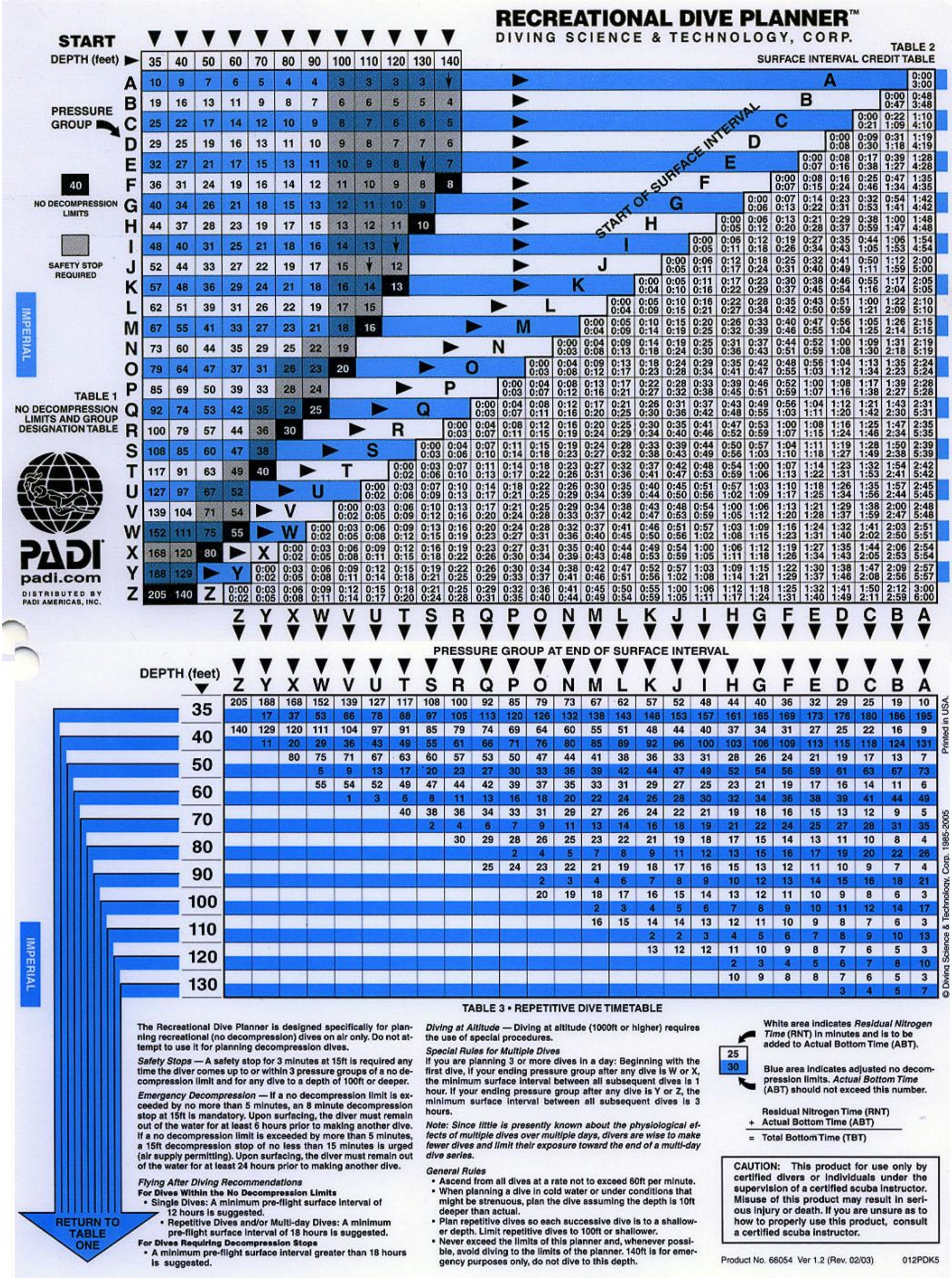
- Yes
- No

6. If you answered yes to number 5., indicate how much you would be willing to pay, comparing to a normal dive.

- Less
- Same
- Little more
- Some more
- Much more

Obrigada pela sua cooperação. / Thank you for your cooperation.

Appendix IV- PADI dive table



RECREATIONAL DIVE PLANNER™
DIVING SCIENCE & TECHNOLOGY, CORP.

IMPERIAL

TABLE 1 — NO DECOMPRESSION LIMITS AND GROUP DESIGNATION TABLE

START

PRESSURE GROUP / DEPTH (feet)	35	40	50	60	70	80	90	100	110	120	130	140
A	10	9	7	6	5	4	4	3	3	3	3	↓
B	19	16	13	11	9	8	7	6	6	5	5	4
C	25	22	17	14	12	10	9	8	7	6	6	5
D	29	25	19	16	13	11	10	9	8	7	7	6
E	32	27	21	17	15	13	11	10	9	8	↓	7
F	36	31	24	19	16	14	12	11	10	9	8	8
G	40	34	26	21	18	15	13	12	11	10	9	
H	44	37	28	23	19	17	15	13	12	11	10	
I	48	40	31	25	21	18	16	14	13	↓		
J	52	44	33	27	22	19	17	15	↓	12		
K	57	48	36	29	24	21	18	16	14	13		
L	62	51	39	31	26	22	19	17	15			
M	67	55	41	33	27	23	21	18	16			
N	73	60	44	35	29	25	22	19				
O	79	64	47	37	31	26	23	20				
P	85	69	50	39	33	28	24					
Q	92	74	53	42	35	29	25					
R	100	79	57	44	36	30						
S	108	85	60	47	38							
T	117	91	63	49	40							
U	127	97	67	52								
V	139	104	71	54								
W	152	111	75	55								
X	168	120	80									
Y	188	129										
Z	205	140										

40 — NO DECOMPRESSION LIMITS

SAFETY STOP REQUIRED

TABLE 2 — SURFACE INTERVAL CREDIT TABLE

START OF SURFACE INTERVAL

Group	Z	Y	X	W	V	U	T	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
A																										0:00 3:00
B																									0:00 0:47	0:48 3:48
C																								0:00 0:21	0:22 1:09	1:10 4:10
D																							0:00 0:08	0:09 0:30	0:31 1:18	1:19 4:19
E																						0:00 0:07	0:08 0:16	0:17 0:38	0:39 1:27	1:28 4:28
F																					0:00 0:07	0:08 0:15	0:16 0:24	0:25 0:46	0:47 1:34	1:35 4:35
G																				0:00 0:06	0:07 0:13	0:14 0:22	0:23 0:31	0:32 0:53	0:54 1:41	1:42 4:42
H																			0:00 0:05	0:06 0:12	0:13 0:20	0:21 0:28	0:29 0:37	0:38 0:59	1:00 1:47	1:48 4:48
I																		0:00 0:05	0:06 0:11	0:12 0:18	0:19 0:26	0:27 0:34	0:35 0:43	0:44 1:05	1:06 1:53	1:54 4:54
J																	0:00 0:05	0:06 0:11	0:12 0:17	0:18 0:24	0:25 0:31	0:32 0:40	0:41 0:49	0:50 1:11	1:12 1:59	2:00 5:00
K																0:00 0:04	0:05 0:10	0:11 0:16	0:17 0:22	0:23 0:29	0:30 0:37	0:38 0:45	0:46 0:54	0:55 1:16	1:17 2:04	2:05 5:05
L															0:00 0:04	0:05 0:09	0:10 0:15	0:16 0:21	0:22 0:27	0:28 0:34	0:35 0:42	0:43 0:50	0:51 0:59	1:00 1:21	1:22 2:09	2:10 5:10
M														0:00 0:04	0:05 0:09	0:10 0:14	0:15 0:19	0:20 0:25	0:26 0:32	0:33 0:39	0:40 0:46	0:47 0:55	0:56 1:04	1:05 1:25	1:26 2:14	2:15 5:15
N													0:00 0:03	0:04 0:08	0:09 0:13	0:14 0:18	0:19 0:24	0:25 0:30	0:31 0:36	0:37 0:43	0:44 0:51	0:52 0:59	1:00 1:08	1:09 1:30	1:31 2:18	2:19 5:19
O												0:00 0:03	0:04 0:08	0:09 0:12	0:13 0:17	0:18 0:23	0:24 0:28	0:29 0:34	0:35 0:41	0:42 0:47	0:48 0:55	0:56 1:03	1:04 1:12	1:13 1:34	1:35 2:23	2:24 5:24
P											0:00 0:03	0:04 0:07	0:08 0:12	0:13 0:16	0:17 0:21	0:22 0:27	0:28 0:32	0:33 0:38	0:39 0:45	0:46 0:51	0:52 0:59	1:00 1:07	1:08 1:16	1:17 1:38	1:39 2:27	2:28 5:28
Q										0:00 0:03	0:04 0:07	0:08 0:11	0:12 0:16	0:17 0:20	0:21 0:25	0:26 0:30	0:31 0:36	0:37 0:42	0:43 0:48	0:49 0:55	0:56 1:03	1:04 1:11	1:12 1:20	1:21 1:42	1:43 2:30	2:31 5:31
R									0:00 0:03	0:04 0:07	0:08 0:11	0:12 0:15	0:16 0:19	0:20 0:24	0:25 0:29	0:30 0:34	0:35 0:40	0:41 0:46	0:47 0:52	0:53 0:59	1:00 1:07	1:08 1:15	1:16 1:24	1:25 1:46	1:47 2:34	2:35 5:35
S								0:00 0:03	0:04 0:06	0:07 0:10	0:11 0:14	0:15 0:18	0:19 0:23	0:24 0:27	0:28 0:32	0:33 0:38	0:39 0:43	0:44 0:49	0:50 0:56	0:57 1:03	1:04 1:10	1:11 1:18	1:19 1:27	1:28 1:49	1:50 2:38	2:39 5:39
T							0:00 0:02	0:03 0:06	0:07 0:10	0:11 0:13	0:14 0:17	0:18 0:22	0:23 0:26	0:27 0:31	0:32 0:36	0:37 0:41	0:42 0:47	0:48 0:53	0:54 0:59	1:00 1:06	1:07 1:13	1:14 1:22	1:23 1:31	1:32 1:53	1:54 2:41	2:42 5:42
U						0:00 0:02	0:03 0:06	0:07 0:09	0:10 0:13	0:14 0:17	0:18 0:21	0:22 0:25	0:26 0:29	0:30 0:34	0:35 0:39	0:40 0:44	0:45 0:50	0:51 0:56	0:57 1:02	1:03 1:09	1:10 1:17	1:18 1:25	1:26 1:34	1:35 1:56	1:57 2:44	2:45 5:45
V					0:00 0:02	0:03 0:05	0:06 0:09	0:10 0:12	0:13 0:16	0:17 0:20	0:21 0:24	0:25 0:28	0:29 0:33	0:34 0:37	0:38 0:42	0:43 0:47	0:48 0:53	0:54 0:59	1:00 1:05	1:06 1:12	1:13 1:20	1:21 1:28	1:29 1:37	1:38 1:59	2:00 2:47	2:48 5:48
W				0:00 0:02	0:03 0:05	0:06 0:08	0:09 0:12	0:13 0:15	0:16 0:19	0:20 0:23	0:24 0:27	0:28 0:31	0:32 0:36	0:37 0:40	0:41 0:45	0:46 0:50	0:51 0:56	0:57 1:02	1:03 1:08	1:09 1:15	1:16 1:23	1:24 1:31	1:32 1:40	1:41 2:02	2:03 2:50	2:51 5:51
X			0:00 0:02	0:03 0:05	0:06 0:08	0:09 0:11	0:12 0:15	0:16 0:18	0:19 0:22	0:23 0:26	0:27 0:30	0:31 0:34	0:35 0:39	0:40 0:43	0:44 0:48	0:49 0:53	0:54 0:59	1:00 1:05	1:06 1:11	1:12 1:18	1:19 1:26	1:27 1:34	1:35 1:43	1:44 2:05	2:06 2:53	2:54 5:54
Y		0:00 0:02	0:03 0:05	0:06 0:08	0:09 0:11	0:12 0:14	0:15 0:18	0:19 0:21	0:22 0:25	0:26 0:29	0:30 0:33	0:34 0:37	0:38 0:41	0:42 0:46	0:47 0:51	0:52 0:56	0:57 1:02	1:03 1:08	1:09 1:14	1:15 1:21	1:22 1:29	1:30 1:37	1:38 1:46	1:47 2:08	2:09 2:56	2:57 5:57
Z	0:00 0:02	0:03 0:05	0:06 0:08	0:09 0:11	0:12 0:14	0:15 0:17	0:18 0:20	0:21 0:24	0:25 0:28	0:29 0:31	0:32 0:35	0:36 0:40	0:41 0:44	0:45 0:49	0:50 0:54	0:55 0:59	1:00 1:05	1:06 1:11	1:12 1:17	1:18 1:24	1:25 1:31	1:32 1:40	1:41 1:49	1:50 2:11	2:12 2:59	3:00 6:00

PRESSURE GROUP AT END OF SURFACE INTERVAL

TABLE 3 • REPETITIVE DIVE TIMETABLE

DEPTH (feet)	Z	Y	X	W	V	U	T	S	R	Q	P	O	N	M	L	K	J	I	H	G	F	E	D	C	B	A
35	205	188	168	152	139	127	117	108	100	92	85	79	73	67	62	57	52	48	44	40	36	32	29	25	19	10
		17	37	53	66	78	88	97	105	113	120	126	132	138	143	148	153	157	161	165	169	173	176	180	186	195
40	140	129	120	111	104	97	91	85	79	74	69	64	60	55	51	48	44	40	37	34	31	27	25	22	16	9
		11	20	29	36	43	49	55	61	66	71	76	80	85	89	92	96	100	103	106	109	113	115	118	124	131
50			80	75	71	67	63	60	57	53	50	47	44	41	38	36	33	31	28	26	24	21	19	17	13	7
				5	9	13	17	20	23	27	30	33	36	39	42	44	47	49	52	54	56	59	61	63	67	73
60				55	54	52	49	47	44	42	39	37	35	33	31	29	27	25	23	21	19	17	16	14	11	6
					1	3	6	8	11	13	16	18	20	22	24	26	28	30	32	34	36	38	39	41	44	49
70							40	38	36	34	33	31	29	27	26	24	22	21	19	18	16	15	13	12	9	5
								2	4	6	7	9	11	13	14	16	18	19	21	22	24	25	27	28	31	35
80									30	29	28	26	25	23	22	21	19	18	17	15	14	13	11	10	8	4
											2	4	5	7	8	9	11	12	13	15	16	17	19	20	22	26
90										25	24	23	22	21	19	18	17	16	15	13	12	11	10	9	7	4
												2	3	4	6	7	8	9	10	12	13	14	15	16	18	21
100												20	19	18	17	16	15	14	13	12	11	10	9	8	6	3
														2	3	4	5	6	7	8	9	10	11	12	14	17
110														16	15	14	14	13	12	11	10	9	8	7	6	3
																2	2	3	4	5	6	7	8	9	10	13
120																13	12	12	11	10	9	8	7	6	5	3
																			2	3	4	5	6	7	8	10
130																			10	9	8	8	7	6	5	3
																							3	4	5	7

RETURN TO TABLE ONE

IMPERIAL

The Recreational Dive Planner is designed specifically for planning recreational (no decompression) dives on air only. Do not attempt to use it for planning decompression dives.

Safety Stops — A safety stop for 3 minutes at 15ft is required any time the diver comes up to or within 3 pressure groups of a no decompression limit and for any dive to a depth of 100ft or deeper.

Emergency Decompression — If a no decompression limit is exceeded by no more than 5 minutes, an 8 minute decompression stop at 15ft is mandatory. Upon surfacing, the diver must remain out of the water for at least 6 hours prior to making another dive. If a no decompression limit is exceeded by more than 5 minutes, a 15ft decompression stop of no less than 15 minutes is urged (air supply permitting). Upon surfacing, the diver must remain out of the water for at least 24 hours prior to making another dive.

Flying After Diving Recommendations

For Dives Within the No Decompression Limits

- Single Dives: A minimum pre-flight surface interval of 12 hours is suggested.
- Repetitive Dives and/or Multi-day Dives: A minimum pre-flight surface interval of 18 hours is suggested.

For Dives Requiring Decompression Stops

- A minimum pre-flight surface interval greater than 18 hours is suggested.

Diving at Altitude — Diving at altitude (1000ft or higher) requires the use of special procedures.

Special Rules for Multiple Dives
If you are planning 3 or more dives in a day: Beginning with the first dive, if your ending pressure group after any dive is W or X, the minimum surface interval between all subsequent dives is 1 hour. If your ending pressure group after any dive is Y or Z, the minimum surface interval between all subsequent dives is 3 hours.

Note: Since little is presently known about the physiological effects of multiple dives over multiple days, divers are wise to make fewer dives and limit their exposure toward the end of a multi-day dive series.

General Rules

- Ascend from all dives at a rate not to exceed 60ft per minute.
- When planning a dive in cold water or under conditions that might be strenuous, plan the dive assuming the depth is 10ft deeper than actual.
- Plan repetitive dives so each successive dive is to a shallower depth. Limit repetitive dives to 100ft or shallower.
- Never exceed the limits of this planner and, whenever possible, avoid diving to the limits of the planner. 140ft is for emergency purposes only, do not dive to this depth.

25 — White area indicates *Residual Nitrogen Time* (RNT) in minutes and is to be added to Actual Bottom Time (ABT).

30 — Blue area indicates adjusted no decompression limits. *Actual Bottom Time* (ABT) should not exceed this number.

Residual Nitrogen Time (RNT)
\+ Actual Bottom Time (ABT)
= Total Bottom Time (TBT)

CAUTION: This product for use only by certified divers or individuals under the supervision of a certified scuba instructor. Misuse of this product may result in serious injury or death. If you are unsure as to how to properly use this product, consult a certified scuba instructor.

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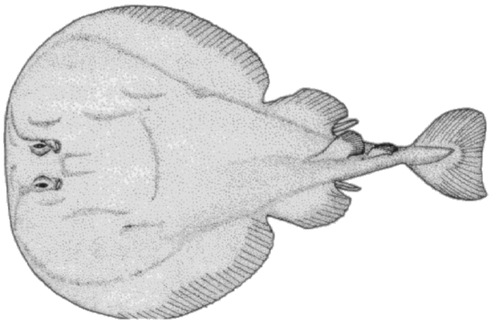
Appendix V- Illustrations and photos of some species referred in this work

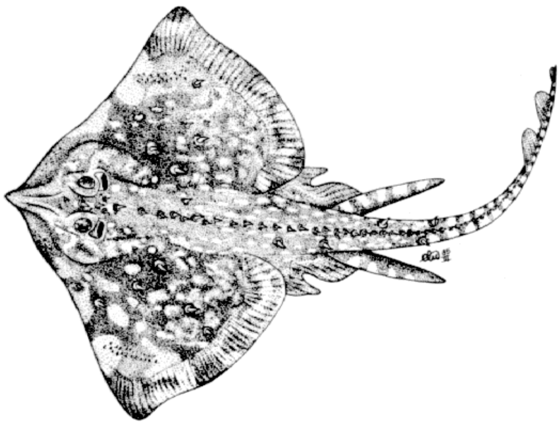
Torpedinidae




Torpedo nobiliana (Bonaparte, 1835)
Atlantic Torpedo ray


Torpedo marmorata (Risso)
Marbled Torpedo ray

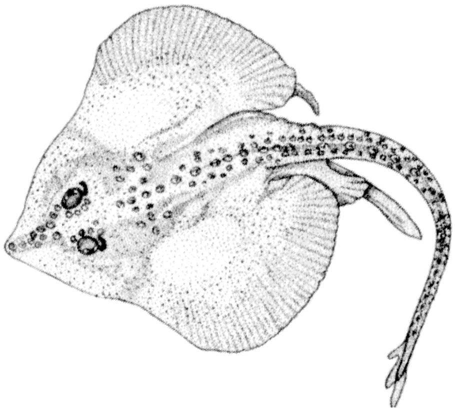
Rajidae



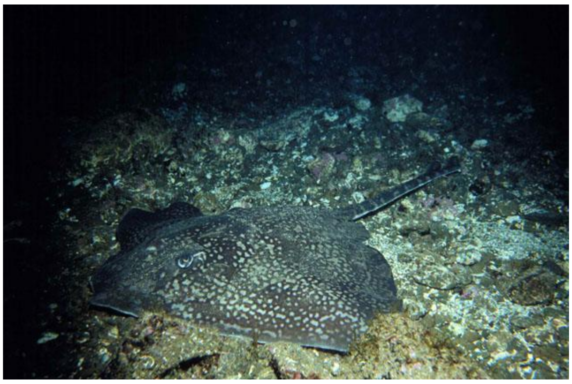

Raja clavata (Linnaeus, 1758)
Thornback ray

Raja brachyura (Lafont, 1873)

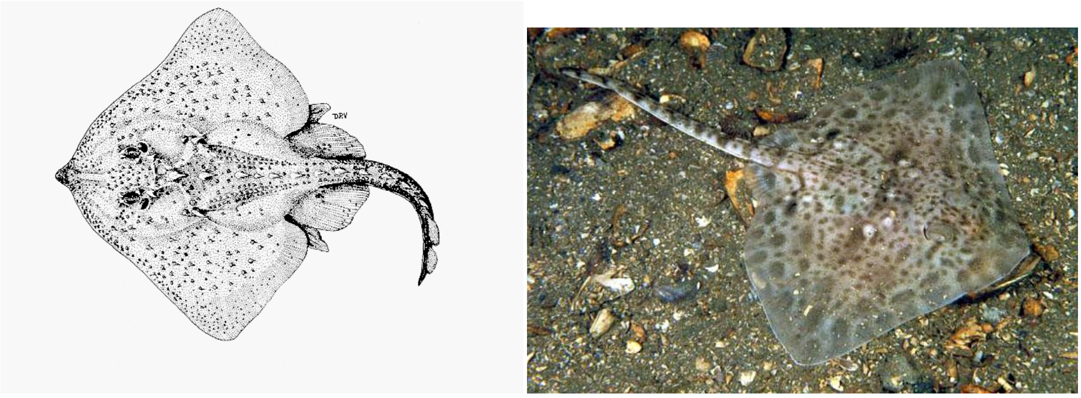
Blonde skate



Raja (Rajella) bigelowi (Stehmann, 1978)
Bigelow's skate

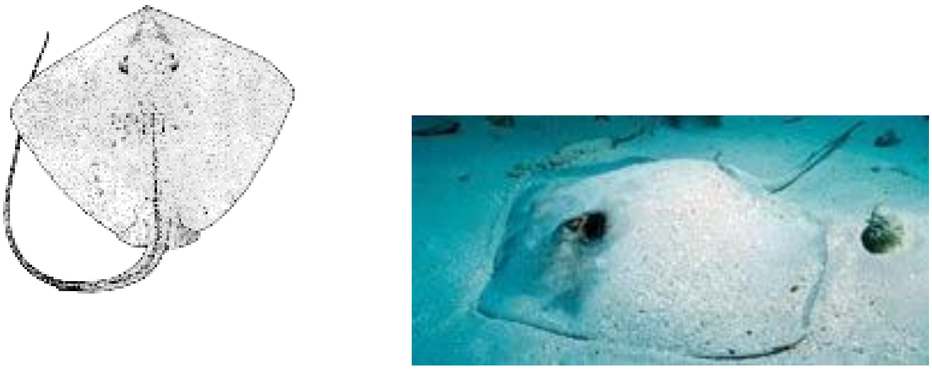


Raja maderensis (Lowe, 1839)
Madeira skate

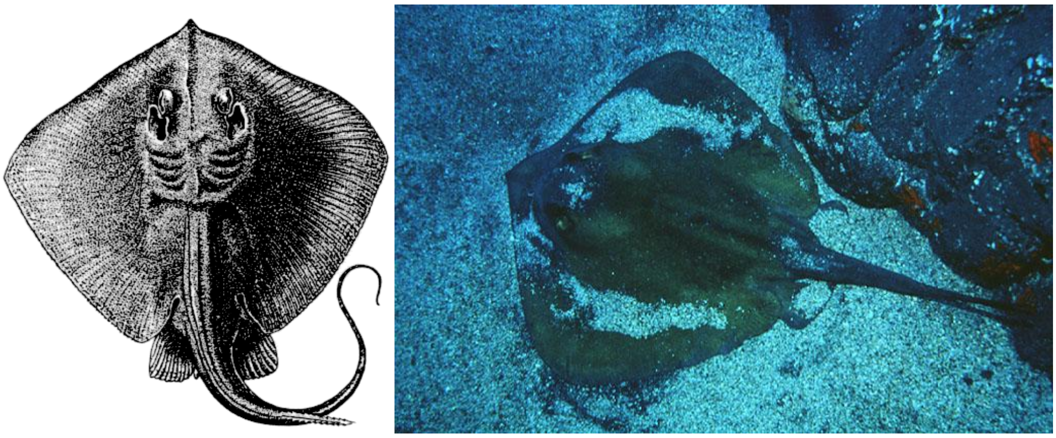


Raja radiata (Donavan, 1808)
Starry skate

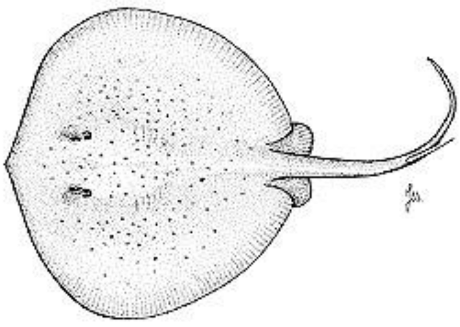
Dasyatidae



Dasyatis centroura (Debelius, ,1997)
Roughtail stingray

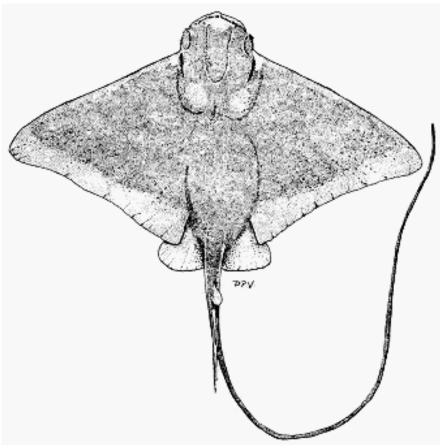


Dasyatis pastinaca (L., 1758)
Common stingray



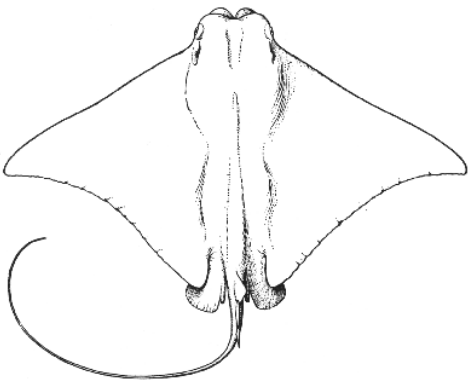

Taeniura grabata (E. Geoffroy Saint-Hilaire,1817)
Round stingray

Myliobatoidea




Myliobatis aquila (L., 1958)
Common Eagle-ray

Rhinopteridae

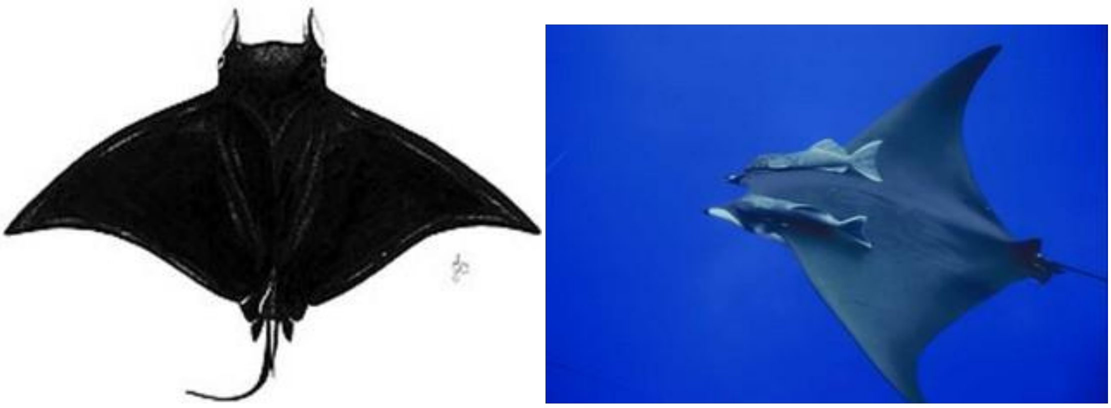



Rhinoptera bonasus
Cow-nose ray

Mobulidae

Manta birostris (Donndorff, 1798)
Manta-ray

Mobula mobular (Bonnaterre, 1788)
Mediterranean mobula



Mobula tarapacana (Philippi, 1892)
Sicklefin mobula

Appendix VI- Table of data gathered from the registration sheets for each dive

Table 1- Data gathered from the registration sheets for each dive

dive number	dive spot	date	climatic conditions	depth	bottom type	observations	Species	Size (DW)	sex
1	Dori	18-02-2008	**N/Inf**	18m	sand	stopped, moving away from divers	D. pastinaca	50cm	**N/Inf**
2	Recife do Porto	12-03-2008	**N/Inf**	14m	reef/sand	Movement	D. pastinaca	50cm	**N/Inf**
3	Dori	02-06-2008	**N/Inf**	19m	sand	feeding /movement	D. pastinaca	40cm	**N/Inf**
4	Santa Clara	07-06-2008	**N/Inf**	16m	sand	feeding /movement	D. pastinaca	30cm	**N/Inf**
5	Ribeirinha	17-06-2008	sunny	16m	sand	stopped, moving away from divers	M. aquila	70cm	**N/Inf**
6	Recife da cadeia	18-06-2008	sunny	15m	reef	**N/Inf**	M. aquila	40cm	**N/Inf**
7	Recife da Lagoa	02-07-2008	sunny	19m	reef/sand	Stopped	M. aquila	60cm	**N/Inf**
8	Dori	16-07-2008	sunny	19m	sand	Stopped	D. pastinaca	100cm	**N/Inf**
9	Dori	19-07-2008	sunny	19m	sand	stopped/ socialization, both animals together	D. pastinaca	30cm	**N/Inf**
							D. pastinaca	40cm	**N/Inf**
10	Dori	27-07-2008	sunny	19m	sand	Stopped	D. pastinaca	30cm	**N/Inf**
							D. pastinaca	45cm	**N/Inf**
11	Ilheu São roque	28-07-2008	sunny	8m	rock/sand	Stopped	D. pastinaca	35cm	**N/Inf**
12	Arcos Hotel Caloura	29-07-2008	sunny	18m	rock/sand	**N/Inf**	M. aquila	40cm	**N/Inf**
13	Recife Cadeia	31-07-2008	sunny	15m	reef	Movement	M. aquila	50-60cm	**N/Inf**
14	Ilheu São roque	01-08-2008	sunny	8m	rock/sand	Feeding	D. pastinaca	50cm	**N/Inf**
15	Dori	02-08-2008	sunny	19m	sand	Stopped	D. pastinaca	80-100cm	**N/Inf**
16	Dori	06-08-2008	sunny	19m	sand	Movement	D. pastinaca	40cm	**N/Inf**
						Stopped	D. pastinaca	80cm	F
						Stopped	D. pastinaca	80cm	F

N/Inf- No information

17	Luso (200m from port of Lagoa)	07-08-2008	sunny	22m	reef/sand	about 5 individuals were together stopped or socializing	D. pastinaca	30- 60cm	F
							D. pastinaca		F
							D. pastinaca		F
							D. pastinaca		F
							D. pastinaca		F
							D. pastinaca		**N/Inf**
							D. pastinaca		**N/Inf**
							D. pastinaca		**N/Inf**
							D. pastinaca		**N/Inf**
							D. pastinaca		**N/Inf**
							D. pastinaca		**N/Inf**
18	Recife da cadeia	08-08-2008	sunny	15m	reef	Movement	D. pastinaca	50cm	F
							M. aquila	50cm	**N/Inf**
							M. aquila	70cm	F
19	Dori	15-08-2008	sunny	19m	sand	**N/Inf**	D. pastinaca	30cm	**N/Inf**
						N/Inf	D. pastinaca	40cm	**N/Inf**
20	Dori	17-08-2008	sunny	19m	sand	**N/Inf**	D. pastinaca	40cm	**N/Inf**
21	6 miles offshore, caloura	18-08-2008	sunny	0m	water surface	feeding /movement (whale watching)	M. mobular	250-300cm	**N/Inf**
22	Dori	23-08-2008	sunny	19m	sand	**N/Inf**	D. pastinaca	20cm	**N/Inf**
						N/Inf	D. pastinaca	40cm	**N/Inf**
23	Dori	24-08-2008	sunny	19m	sand	**N/Inf**	D. pastinaca	70cm	**N/Inf**
24	10 miles offshore Ponta delgada	24-08-2008	sunny	20m	open water	movement (whale watching)	M. mobular	250cm	**N/Inf**
25	Dori	03-09-2008	little clouds	19m	sand	stopped, moving away from divers	D. pastinaca	35cm	**N/Inf**

N/Inf- No information

Appendix VII- Table of data gathered from the Questionnaires

Table II- Data from Questionnaires

			quest 1	quest 2	quest 3	quest 4			quest 5	quest 6
number	**gender**	**age**	**level of experience**	**observed**	**interest level**	**Ray**	**Skate**	**Manta-ray**	**participation**	**Payment**
1	M	22	little experience	none	high	1	3	2	yes	same
2	F	27	experienced	ray, manta-ray	high	3	2	1	yes	little more
3	M	24	little experience	ray	normal	2	3	1	yes	little more
4	M	27	very experienced	all	high	2	3	1	yes	same
5	F	22	little experience	ray, skate	high	3	2	1	yes	same
6	M	50	very experienced	all	high	3	2	1	no	**N/A**
7	M	**N/A**	little experience	skate	normal	2	3	1	yes	little more
8	F	33	little experience	all	high	4	4	4	no	**N/A**
9	F	24	little experience	skate/ eagle-ray	normal	3	2	1	yes	same
10	F	28	experienced	skate, manta-ray	normal	3	2	1	yes	same
11	M	37	very experienced	all	high	2	3	1	yes	same
12	M	35	experienced	all	normal	1	2	3	no	**N/A**
13	M	27	no experience	none	high	2	3	1	yes	some more
14	M	18	experienced	skate, manta-ray	high	3	2	1	yes	same
15	M	31	little experience	skate/ eagle-ray	normal	2	3	1	yes	some more
16	F	18	little experience	skate/ eagle-ray	high	2	3	1	yes	little more
17	M	31	experienced	all	normal	2	3	1	no	**N/A**
18	M	21	experienced	skate/ eagle-ray	high	2	3	1	yes	same
19	M	**N/A**	no experience	none	low	1	3	2	yes	little more
20	M	21	little experience	skate/ eagle-ray	normal	2	3	1	yes	same
21	F	24	little experience	ray, manta-ray	high	2	3	1	yes	same
22	M	**N/A**	little experience	all	high	2	3	1	no	**N/A**
23	M	32	little experience	all	high	3	2	1	yes	same

N/A- Not answered

24	M	**N/A**	little experience	all	normal	2	3	1	no	N/A
25	M	27	very experienced	all	high	2	3	1	yes	same
26	M	33	experienced	all	high	3	2	1	yes	some more
27	F	30	no experience	ray, manta-ray	normal	2	3	1	yes	same
28	M	26	experienced	ray, skate	high	3	2	1	yes	same
29	M	22	no experience	manta-ray	high	2	3	1	yes	same
30	F	19	little experience	ray	normal	2	1	3	yes	same
31	F	29	no experience	none	high	1	2	3	yes	same
32	M	24	little experience	ray, skate	normal	2	3	1	yes	little more
33	M	31	experienced	ray, skate	high	2	3	1	yes	little more
34	F	21	little experience	ray, skate	high	2	1	3	yes	same
35	F	20	little experience	none	normal	3	2	1	yes	same
36	F	21	experienced	skate/ eagle-ray	high	2	3	1	yes	some more
37	M	21	little experience	skate/ eagle-ray	normal	1	2	3	yes	some more
38	**N/A**	**N/A**	experienced	ray, manta-ray	normal	1	3	2	yes	some more
39	M	27	no experience	manta-ray	low	4	4	4	no	**N/A**
40	F	36	little experience	skate/ eagle-ray	low	4	4	4	yes	same
41	M	25	no experience	none	Null	4	4	4	yes	same
42	M	32	experienced	none	normal	3	2	1	yes	same
43	M	29	little experience	ray	high	2	3	1	yes	little more
44	M	42	little experience	none	normal	1	2	3	yes	same
45	F	22	little experience	ray, skate	normal	2	3	1	yes	some more

N/A- Not answered