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ASSESSING THE FISHERY AND ECOLOGY OF SHARKS IN THE UNITED ARAB EMIRATES

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This dissertation is submitted in partial fulfillment of the requirements
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Under the direction of Dr. Saif M. Al Ghais

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Declaration of Original Work

I, Rima W. Jabado, the undersigned, a graduate student at the United Arab Emirates University (UAEU) and the author of the dissertation titled "The Fishery, Ecology and Trade in Sharks in the United Arab Emirates", hereby solemnly declare that this dissertation is an original work done and prepared by me under the guidance of Dr. Saif M. Al Ghais, in the College of Science at UAEU. This work has not previously formed the basis for the award of any degree, diploma or similar title at this or any other university. The materials borrowed from other sources and included in my dissertation have been properly acknowledged.

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ABSTRACT

Large scale shark population declines have been documented worldwide due to overexploitation and the lack of adequate management frameworks to conserve shark stocks. This study aimed at gaining an understanding of the national shark fishery and the trade in shark products from the United Arab Emirates (UAE). Data were collected from June 2010 to October 2012 through interviews with local fishermen, market and landing site surveys, fishery independent surveys, and stomach content analysis.

Interviews with local fishermen (n=126) provided information on the fishery characteristics and established that sharks were increasingly targeted due to their high value in the global fin trade industry. Fishermen confirmed that changes in species composition, abundance, and size of sharks have been ongoing for over two decades raising concerns about the sustainability of this fishery.

Catch data and genetic analyses established that 30 species of sharks were found in UAE Gulf waters. Landings were dominated by six species, *Carcharhinus sorrah*, *Rhizoprionodon acutus*, *Carcharhinus limbatus*, *Loxodon macrorhinus*, *Carcharhinus dussumieri,* and *Mustelus mosis*, representing over 90% of the total catches. Most of these species were small bodied sharks while large bodied species were mostly below the size of maturation possibly suggesting recruitment overfishing. A fishery independent survey of sharks in nearshore areas also indicated a low level of abundance of sharks in waters off Dubai and Abu Dhabi. Data on the relative abundance, distribution, and various aspects of the biology of all species encountered were collected. Furthermore, a dietary study of stomach contents of *R. acutus* and *L. macrorhinus* provided information on their feeding habits suggesting that they have

different preferences for their prey. Trade data were limited to products from the UAE and Oman, including meat and fins, and indicated that the majority of species traded were at global risk of extinction based on IUCN Red List classification.

Results from the various studies undertaken suggest that these species are likely to be overexploited and that management measures will need to take into account the precautionary principle. There is an urgent need to formulate effective conservation and management plans to prevent further declines in a number of species. The data gathered can now serve as a reference to managers, fisheries scientists, and other stakeholders to prioritize future research, as well as lay foundations for the development and implementation of national management plans for the protection and conservation of sharks.

ABSTRACT (ARABIC)

ملخـــص الدراســـــــــــة

لقد تم توثيق تراجع أعداد أسماك القرش على نطاق واسع في جميع أنحاء العالم بسبب الاستغلال الجائر وعدم وجود اسس إدارية كافية للحفاظ على مخزون أسماك القرش. هذه الدراسة تهدف إلى فهم مصايد أسماك القرش الوطنية والتجارة في منتجاتها من دولة الإمارات العربية المتحدة. وقد تم تجميع البيانات في الفترة من يونيو 2010 إلى أكتوبر 2012 عن طريق المقابلات مع الصياديين المواطنين، وأسواق الإنزال السمكي، والمسح الميداني للمصايد، وتحليل المحتوي المعوي.

اسفرت المقابلات مع الصيادين الوطنيين (عدد 126 مقابلة) عن توفر معلومات عن الخصائص السمكية، وأثبتت أن أسماك القرش مستهدفة بسبب قيمتها العالية في مجال التجارة العالمية لزعانف أسماك القرش. وأكد الصيادين أن أنواع أسماك القرش، ووفرتها، وأحجامها مستمرة في التغير منذ أكثر من عقدين من الزمان، مما يثير المخاوف والتساؤلات حول استدامة هذا المورد السمكي.

أثبتت البيانات والتحليلات الجينية أن هنالك 30 نوعا من أسماك القرش في مياه الخليج التابعة لدولة الإمارات. وتتسيد أسواق الإنزال السمكي ستة أنواع منها وهي *Carcharhinus sorrah, Rhizoprionodon acutus, Carcharhinus limbatus, Loxodon macrorhinus, Carcharhinus dussumieri,* and *Mustelus mosis* حيث تمثل أكثر من 90% من مجموع الاسماك المصادة. وغالبية هذه الأنواع من أسماك القرش من النوع الصغير حجماً بينما الأنواع الكبيرة في الحجم غالبا ما تكون بحجم أقل من حجم النضوج الجنسي مما يوحي بوجود عمليات صيد جائرة لهذه الأسماك. وأشارت مسوحات مصائد الأسماك في السواحل القريبة إلى انخفاض في وفرة أسماك القرس في مياه كل من دبي وأبوظبي. وقد تم تجميع البيانات عن الوفرة النسبية، والتوزيع، ومختلف الجوانب الأحيائية لكل الكائنات الحية التي تم رصدها وجمهعا.

إضافة إلى ذلك ، فقد تم إجراء دراسة غذائية للمحتوى المعوي لكل من *R. acutus* و*L. macrorhinus* للحصول على معلومات عن العادات الغذائية أكدت الدراسة بأن لكل منها تفضيلات غذائية مختلفة. انحصرت

البيانات التجارية في المنتجات من دولة لإمارات العربية المتحدة وسلطنة عمان، والتي تشتمل على اللحوم والزعانف، وأشارت إلى أن غالبية الأنواع المتاجر بها معرضة لخطر الأنقراض العالمي على حسب تصنيف القائمة الحمراء للاتحاد الدولي لصون الطيعة IUCN.

وتشير النتائج من مختلف الدراسات التي أجريت أن هذه الأنواع من المرجح أن تكون واقعة تحت وطأة الاستغلال الجائر وأن التدابير الإدارية تحتاج إلى أن تأخذ بعين الاعتبار مبدأ الحيطة والحذر. كما إن هنالك حاجة ملحة لصياغة خطط المحافظة والإدارة لمنع المزيد من التناقص في أعداد أنواع أسماك القرش. وأن البيانات التي تم تجميعها وتحليلها يمكنها الآن أن تكون مرجعاً للمدراء، وعلماء مصائد الأسماك، وغيرهم من الشركاء لتحديد أولويات البحث العلمي في المستقبل، بالإضافة إلى وضع الأسس اللازمة لتطوير وتنفيذ خطط إدارية وطنية لحماية وحفظ أسماك القرش.

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I don't remember when my fascination with sharks actually started, but it seems like they have always held me captivated by their mystery and grace. Undertaking my own project on sharks was a dream come true and an experience I will never forget. It has inspired me to believe that anything can be done however impossible it may seem at times. The journey has been exhilarating and has allowed me to forge new friendships, take risks, and spend some incredible moments discovering sharks in the region, the true nature of the relationship between Emiratis, their heritage, the sea, and the animals that abound in it.

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ACRONYMS

AED	Arab Emirates Dirham
BOLD	Barcode of Life Database
BRUV	Baited Remote Underwater Video
CBD	Convention on Biological Diversity
CCRF	Code of Conduct for Responsible Fisheries
CITES	Convention on the International Trade in Endangered Species
CMS	Convention on Migratory Species
COI	Cytochrome c oxidase I
CPUE	Catch per unit effort
CR	Critically Endangered
DD	Data Deficient
DNA	Deoxyribonucleic Acid
EAD	Environment Agency Abu Dhabi
EEZ	Exclusive Economic Zone
EN	Endangered
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GCC	Gulf Cooperation Council
IOTC	Indian Ocean Tuna Commission
IPOA	International Plan of Action for the conservation and management of sharks
IRI	Index of Relative Importance
IUCN	International Union for Conservation of Nature and Natural Resources
IUU	Illegal Unreported Unmonitored
KAUST	King Abdullah University of Science and Technology
K2P	Kimura 2 Parameter

LC	Least Concern
MoEW	Ministry of Environment and Water
MoU	Memorandum of Understanding
ML	Maximum Likelihood
MP	Maximum Parsimony
MPA	Marine Protected Area
Nei	Not elsewhere included
NJ	Neighbor Joining
NMFS	National Marine Fisheries Service
NPOA	National Plan of Action
NT	Near Threatened
PCR	Polymerase Chain Reaction
RECOFI	Regional Commission for Fisheries
RFMO	Regional Fisheries Management Organization
ROPME	Regional Organization for the Protection of the Marine Environment
SAR	Shark Assessment Report
UAE	United Arab Emirates
UAEU	United Arab Emirates University
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNCLOS	United Nations Convention on the Law of the Sea
US	United States
USD	United States Dollar
VU	Vulnerable
YOY	Young of year

CHAPTER I
INTRODUCTION

1.1 Assessing the need for shark conservation and management: approaches to evaluating the shark fishery in the United Arab Emirates

1.1.1 An overview of elasmobranchs

Chondrichthyan fishes (class Chondrichthyes) are a distinct group of fish characterized by a cartilaginous skeleton. This group includes the elasmobranchs (subclass Elasmobranchii) comprising of sharks and batoids (skates, rays, guitarfishes and sawfishes), as well as the chimaeras (subclass Holocephalii). Species belonging to these subclasses are commonly referred to collectively as ‘sharks’ (Fowler *et al.* 2005). In this study, the term ‘shark’ refers to the subclass Elasmobranchii excluding the batoids; ‘elasmobranchs’ refers to both sharks and batoids; while the term ‘chondrichthyans’ refers to all sharks, batoids and chimaeras. Chondrichthyans represent a relatively small group of approximately 1,150 described species that have successfully functioned in a variety of aquatic environments for over 400 million years. New species are being discovered and described at a rapid rate and it is believed that over 1,200 species may actually exist (Naylor *et al.* 2012).

Concerns over the status and conservation of elasmobranch populations around the world have been raised at an international level. Elasmobranch vulnerability to directed fishing pressure and indirect losses due to bycatch are well established (Manire & Gruber 1990; Camhi *et al.* 1998; Stevens *et al.* 2000a; Baum *et al.* 2003). The effects of fishing comprise pressure from commercial, artisanal, subsistence and recreational fishing activities as well as shark control programs in several countries (Stevens *et al.* 2000a; Fowler *et al.* 2005). Furthermore, a wide range of anthropogenic activities has affected shark populations, both directly and indirectly, including habitat degradation and pollution (Camhi *et al.* 1998; Stevens *et al.* 2000a).

The K-selected life history strategies of most sharks, defined as longevity, slow growth, late maturity, long gestation, low reproductive rates and low natural mortality, result in a slow intrinsic rate of population increase and makes their recovery potential very low (Manire & Gruber 1990; Camhi *et al.* 1998; Stevens *et al.* 2000a; Otway *et al.* 2004; Shark Advisory Group & Lack 2004; NMFS 2005). It is important to note that different shark species exhibit considerable variations in life history parameters (Fowler *et al.* 2005). While many smaller species of sharks still require careful management, they are not as extreme in their life histories and are likely to have higher productivity as well as a better ability to withstand fishing pressure. However, for all sharks, there is a direct relationship between stock size and recruitment with population replenishment rates being extremely slow (Bonfil 2001). The combination of these factors means that shark stocks can be easily overfished. Therefore, once shark populations have been overexploited, the recovery process can take decades or longer. Understanding these biological characteristics is extremely important for shark fisheries monitoring and management.

Most species of sharks are apex predators and are considered to be at the top of marine food chains (Stevens *et al.* 2000a). Even though an extensive body of literature exists about the food habits of many species of sharks, little is known about the dynamic function they serve in their ecosystems (Fowler 2005). It is, however, believed that long term ecological effects of depleted shark populations are likely to be far-reaching and could have unexpected and tremendous consequences on ecosystems (Stevens *et al.* 2000a; Robbins *et al.* 2006; White & Kyne 2010) as well as unpredictable effects on the abundance of commercially important fish stocks (Stevens *et al.* 2000a; Watts 2003; Watts & Wu 2005). Sharks play an important role in controlling population size and species diversity of their prey (Cortes 1999). Because studies investigating quantitative dietary data show that sharks occupy relatively high trophic levels (Cortes 1999), ecological impacts of eliminating top predators have received much interest in recent years. While the exact consequences of removing apex predators remain uncertain, studies have shown that effects can include the release of mesopredator prey populations from predatory control (Lucifora *et al.* 2009); the induction of subsequent cascades of indirect trophic interactions likely to affect the whole marine community and the functioning of ecosystems (Myers 2007; Lucifora *et al.* 2009); and changes in the abundance, size structure and life history parameters of these species which could eventually lead to extinction (Stevens *et al.* 2000a).

1.1.2 Worldwide trends in shark exploitation

Even though sharks have been fished and utilized for centuries for their meat, fins, liver, skin, cartilage, jaws and teeth, shark fisheries have generally been undervalued and ignored (Fowler *et al.* 2005). This is mainly due to the uncertainty in the status of sharks as little quantitative evidence is available to highlight their decline (Baum *et al.* 2003). Indeed, there has been a lack of knowledge about the life-history limitations of most shark species and their vulnerability to overfishing (FAO 2005). Furthermore, knowledge of the basic biology, population dynamics and behavior of sharks is scarce, as are suitable models and fisheries data to analyze shark stocks (Fowler *et al.* 2005). However, abundant historical evidence also shows that commercial fisheries for sharks, which have steadily grown since the 1920s, have had severe impact on some shark populations, and major declines in stocks have been documented due to direct or incidental fishing (Baum *et al.* 2003). Indeed, many targeted shark fisheries have been associated with 'boom and bust' cycles (Lam & Sadovy de Mitcheson 2011). During the 1940s, several target fisheries developed in response to the market for Vitamin A from shark livers and then developed into targeted fisheries for meat, fins and other products. For example, catches from the North Atlantic porbeagle (*Lamna nasus)* fishery peaked at 11,000 metric ton (mt) in 1964 and then crashed to below 2,000 mt after about a decade (Compagno 1990). Furthermore, the Californian soupfin (*Galeorhinus galeus)* fishery, which reached a peak at 4,000 mt in 1939 to meet the demand for Vitamin A, suddenly collapsed (Compagno 1990; Stevens *et al.* 2000a).

Comprehensive global data on the decline of shark stocks are not readily available, but recent research has demonstrated that various shark populations around the world are showing drastic reductions. Many populations are now depleted and some species are considered threatened or critically endangered as a direct result of the rapid and largely unregulated growth of target and bycatch fisheries (Camhi *et al.* 1998; Shark Advisory Group & Lack 2004 (SAG and Lack); Watts & Wu 2005). Studies on trends in population abundance for the Northwestern Atlantic have shown that hammerhead sharks (specifically scalloped hammerheads, *Sphyrna lewini*), white sharks (*Carcharodon carcharias),* tiger sharks (*Galeocerdo cuvier*), thresher sharks (*Alopias* sp.) and coastal species of the genus *Carcharhinus,* have shown a decline of 89%, 79%, 65%, 80%, and 61% respectively since 1986 (Baum *et al.* 2003). In the Mediterranean Sea, five large predatory shark species have showed levels of decline ranging from 96 to 99.9% in the past two centuries (Ferretti *et al.* 2008). In the South China Sea, declines have been documented in shark biodiversity and catch numbers with a reduction from 109 to 18 species recorded over five decades (Lam & Sadovy de Mitcheson 2011). These trends show that overfishing is threatening large coastal and oceanic sharks throughout their range with substantial declines over short periods of time. With the current fishing pressure, it is likely the majority of shark populations will continue to decline (Worm *et al.* 2013). Finally, little information is available on the impact of recreational and sport fisheries for sharks around the world. However, in the United States (US), it is estimated that 8,000 mt of sharks were landed yearly between 1970 and 1986, while in 1996 approximately 5.4 million sharks were caught by anglers, of which 445,000 were retained (Camhi *et al.* 1998). A more recent study has shown that 2.7 million sharks were caught by recreational fishermen in 2011 (NMFS 2012) and, although 96% of these sharks were released, no information was provided on survival rates. However, in combination with commercial landings, these catches are likely to have contributed to a decline in sharks in the area. This decline is presumably further exacerbated by the depletion of their prey species as well as habitat loss and degradation due to coastal development and pollution (Camhi *et al.* 1998).

It is clear that the main reason for shark stock depletion is the rapid growth in the demand for their fins, currently being used for shark fin soup, an Asian delicacy

(Stevens *et al.* 2000a). This demand has led to an increase in catch efforts and global reported landings of elasmobranchs to the Food and Agriculture Organization (FAO) have been steadily increasing since the mid-1950s. According to FAO statistics, these reached a historical record of 900,151 mt in 2003, an increase of approximately 17% over the level recorded just a decade earlier (Lack & Sant 2006b; Lack & Sant 2011). However, since then, there has been a decline in global reported catches of almost 20% reaching 750,000 mt per year (Fischer *et al.* 2012). From 2000 to 2010, landings for sharks reported to the FAO declined by 2.3% from 392,000 to 383,236 mt (Worm *et al.* 2013). Recent shark mortality estimates based on published FAO data from Worm *et al.* (2013) suggest that in the year 2000, 99 million sharks were killed. This value is sensitive to various assumptions and variables, such as levels of illegal, unreported and unregulated (IUU) fishing estimates, which are computed and can range between 63 to 273 million sharks. Using the same variables for the year 2010, the total mortality of sharks was estimated between 97 and 267 million sharks.

Twenty six nations are considered to be major shark fishing entities and were responsible for 84% of the global shark catches reported between 2000 and 2009 (Lack & Sant 2006b; Fischer *et al.* 2012). The countries representing the top 20 nations group have remained relatively stable in the past two decades (Lack & Sant 2006a) with the highest elasmobranch catches reported from Indonesia (13% of world catches), India (9%) and Spain (7.3%), with over 60,000 mt per country per year and accounting for more than 35% of total reported catches (Lack & Sant 2011). Other major contributors include Taiwan (5.8%), Pakistan (3.9%), Mexico (4.1%), Argentina (4.3%), Sri Lanka (2.4%) and Iran (1.7%) (Lack & Sant 2006b; Lack & Sant 2011).

The exact volume of shark catches is notably higher than the FAO statistics (Worm *et al.* 2013). The high value of fins favors IUU fishing and leads to under-reporting, inaccurate record keeping, as well as vast quantities of sharks caught as bycatch that remain undocumented and unregulated (Lack & Sant 2006b). This is especially true since thousands of metric tons of elasmobranchs are believed to be discarded at sea, either in whole forms or with their fins removed. These discards are often unaccounted for in logbooks by individual countries. Actual catches including discards and bycatch may be up to double those recorded in the official statistics and probably close to 1.5 million mt (Bonfil 1994). Also, many countries do not have an effective or even an existing system of monitoring landings, bycatch, discards, or catches from recreational, subsistence and artisanal fisheries (Bonfil 1994). Therefore, little species-specific or fishery-specific data are available from areas with the highest catches and virtually nothing is known about the status of individual stocks (Bonfil 1994). This issue has been highlighted by analysis of trade records from commercial markets (Clarke *et al.* 2006b) and represents a challenge to the proper management and conservation of these species (Bonfil 1994; Barker & Schluessel 2005).

The biggest and fastest growing market for all shark fins is China although there are huge markets in Japan, Hong Kong, Singapore and Korea. Even though imports in Hong Kong have declined in recent years, it still currently handles one-half to two-thirds of the global trade in shark fins (Clarke *et al.* 2006b; Hareide *et al.* 2007). Traders receive fins from at least 85 countries and territories in poorly sorted shipments which are then re-sorted at auctions (Holmes *et al.* 2009). From 1998 to 2009, Spain, Indonesia, the United Arab Emirates (UAE), Taiwan and Japan comprised the top five countries exporting shark fins to Hong Kong from an estimated total number of sharks annually traded worldwide, ranging from 26 and 73 million (Clarke *et al.* 2006b; Hareide *et al.* 2007; Godin & Worm 2010). Furthermore, fishery independent estimates of global shark catch destined for the fin trade indicate that shark biomass in the fin trade is actually three to four times higher than the total shark catch quantities reported to FAO (Clarke *et al.* 2006b; Lack & Sant 2006b). However, little information is available on the species composition of these imports since there is a lack of accurate species identification and reporting. It is believed that the main groups of elasmobranchs taken in fisheries around the world are carcharhinids (requiem sharks) and sphyrnids (hammerheads). Furthermore, pelagic sharks such as the blue (*Prionace glauca*), oceanic whitetip (*Carcharhinus longimanus*), and silky sharks (*Carcharhinus falciformis)* represent a large by-catch of high seas longline fisheries that generally target tuna and billfish (Bonfil 1994). Bonfil (1994) estimated that 6.2 to 6.5 million of these species were taken every year around the world and were retained primarily for their highly valued fins.

1.1.3 International context and challenges for the assessment and management of shark fisheries

Until recently, low priority was afforded to the management of elasmobranch resources by fisheries scientists, managers and conservationists (FAO 2005). International concern over the sustainability of shark fisheries started to build in the late 1980s and 1990s as fisheries expanded globally in response to the lucrative trade in shark fins in southeast Asia (Bonfil 1994). In 1999, in response to concerns over the increase of shark fishing and the global decline in shark populations, the United Nations (UN) FAO Committee on Fisheries developed an International Plan of Action for the Conservation and Management of Sharks (IPOA) within the context and framework of the Code of Conduct for Responsible Fisheries (CCRF) (FAO 1999a). The aim of this plan of action was to identify measures needed to promote the long-term sustainable use of sharks as well as shark conservation and management across states with shark fisheries. As a voluntary instrument, it encouraged signatory nations to identify national, sub-regional and regional issues in order to produce a Shark Assessment Report (SAR) as well as develop and implement National Plans of Actions (NPOA) by February 2001 (FAO 2005; Fowler 2005). Progress towards the development and implementation of these NPOA has been slow especially from countries reporting the highest shark catches. In the past decade, FAO has received reports of shark catches from 143 countries (including European Union (EU) countries) of which 47 (33%) have developed an NPOA (Fischer *et al.* 2012). It's worth noting that 30 of these plans originated from countries or entities that reported fewer than 1% of shark catches between 2000 and 2009. Furthermore, only 17 of these NPOA's pertain to the 26 top shark-fishing countries responsible for 84% of the global shark catches (Fischer *et al.* 2012).

Even with the increased attention given to shark conservation, most shark fisheries around the world remain completely unmonitored, unregulated, and unmanaged (Camhi *et al.* 1998; Lam & Sadovy de Mitcheson 2011). Because sharks have generally been of low economic value and only make up a low proportion of the world fisheries catch, they have been a low priority for research and management funds

(Camhi *et al.* 1998). One of the problems facing the conservation of sharks is a traditionally negative perception of these animals coupled with negative media coverage (Manire & Gruber 1990; Camhi *et al.* 1998; Thompson 2000; Compagno 2002). Also, the large volume of incidental capture has led to a large and poorly documented mortality. The rise in the price of shark fins has increased the value of shark catches and has been an incentive to retain all captures. This has resulted in a very poorly documented global catch estimated to be at least twice the size of that reported (Bonfil 1994).

While the most comprehensive data source regarding global shark catches remains a compilation of fishery reports from different countries provided to the FAO, this information is often incomplete and inadequate (Compagno 1990; Bonfil 1994; Rose 1996). In general, reports by the FAO of shark catch volume are believed to be an underestimation (Fowler *et al.* 2002). Firstly, catch data and analyses are often grouped together as ‘elasmobranchs’ which results in three groups of catches, with overlapping reports in shark, skate, and ray, covering the actual volume of sharks caught. However, Bonfil (1994) noted that sharks constituted more than half of the total weight of elasmobranch catches from 1976 to 1991 in the lumped statistics. Secondly, the shark catch data do not include the group ‘sharks, skates and rays nei’. ‘Nei’ (‘not elsewhere included’) refers to catch data that cannot be attributed to a state or entity, or if the data are not available for appropriate separation into the three categories. This group however constitutes at least twice the volume reported under the shark category (FAO 2009a). Thirdly, only 15% of the FAO catch data are recorded on a species basis (Lack & Sant 2006b) which further reduces the accuracy and usefulness of existing reports. Finally, these data do not include mortalities due to bycatch and under reporting of catches, which can be substantial (Bonfil 1994).

The International Union for the Conservation of Nature and Natural Resources (IUCN) has evaluated the conservation status of many shark species. The Red List assessments of sharks currently categorizes 141 of them as ‘critically endangered’ (CR), ‘endangered’ (EN), ‘vulnerable’ (VU), or ‘near threatened’ (NT) (IUCN 2012; Worm *et al.* 2013). However, even though many shark species are currently classified as threatened, the exact status of these species is difficult to ascertain as many lack accurate data to allow for their assessment. This is mainly because any efforts to gain a better understanding of the status of various shark populations, and enhance the management of these species, are hampered by a variety of factors. The lack of regional or national basic taxonomic data, history and baseline data on species-specific abundances, biological data on life history characteristics, genetic research, data on fishing effort, as well as catches and discard at seas from directed and incidental fisheries, limit the development of management initiatives (Bonfil 1994; Camhi *et al.* 1998; FAO 2009b, 2009a). While some biological data have been collected from across the world, some aspects of the biology of sharks such as maximum sizes, size at birth, maturity and litter sizes, can vary considerably between regions making it essential to collect data locally and regionally (Compagno 2002). Furthermore, because a large proportion of threatened shark species are highly migratory, with some undertaking large scale movements across and around ocean basins, they are placed outside the responsibility of individual countries and, therefore, conservation efforts in one state can be undermined by actions in the waters of other states or on the high seas

(Stevens *et al.* 2000a). The lack of coordinated regional efforts for shark fisheries management, as well as regional or national mechanisms to collect data, is an impediment for undertaking stock assessments. Without a joint management system, which is difficult to implement while stocks remain poorly understood, it is complex to proceed (Bonfil 1997). Finally, the lack of capacity and funding resources necessary to collect this information and conduct stock assessments on the sustainability of current fishing practices is lacking in most countries (White & Kyne 2010).

1.2 Current status of fisheries in the UAE

1.2.1 Cultural context

Evidence from archaeological sites in the UAE, dating back over 7,000 years, suggests that there has always been a strong dependence on marine resources through fishing and pearl diving which are presently part of the cultural heritage of the country (Beech 2004b; EAD 2011a). Before the discovery of oil in the 1930s and the emergence of the oil-based economy in the early 1960s, the local culture was characterized by a simple subsistence lifestyle and traditionally comprised of the nomadic desert Bedouins working on oasis farms and the sea farers, who were involved in fishing, pearl diving and maritime trade (EAD 2011a). With the new oil sector, the pearl diving industry slowly disappeared and fisheries lost some of their economic importance (Carter 2005; Al Janahi 2008b; EAD 2011a). However, fishing remains the most important ‘renewable natural resource’ (Carpenter *et al.* 1997; Grandcourt 2012) as well as an important sector of the economy providing a source of income, employment, food security, and recreation for many of the inhabitants

(Sheppard *et al.* 2010). This is especially true for the more isolated coastal and island communities in the UAE for whom fisheries continue to have a meaningful cultural and socio-economic role (EAD 2011a).

1.2.2 Local fisheries and fish resources

Coastal populations in the region have increased dramatically since the discovery of oil and, therefore, the demand for fish has also seen an increase (Sheppard *et al.* 1992; Carpenter *et al.* 1997). During the 1970s, there was a clear interest by all countries in the region to develop their fishing industry in order to diversify their investments, and deal with the increasing demand for fish for both human consumption and as animal feed (Sivasubramaniam 1981). A review of regional fishery statistics from the past decade shows a continuing trend of increasing fishing effort (Valinassab *et al.* 2006) and an increase in reef fish yield (Grandcourt 2012). Between 1986 and 2007, an average of 181,972 mt of reef fish was landed in the Gulf ranging between a minimum of 117,984 mt in 1986 and a maximum of 231,012 mt in 1992 (Grandcourt 2012), a two-fold increase in six years.

In the past 15 years, the UAE has emerged as a regional market for fish and is also becoming a hub for fish exports to Gulf Cooperation Council (GCC) countries, the Middle East, Africa and Europe (Al Mousa *et al.* 2008). Records indicate that the average annual capture of marine fishes in the UAE was steadily increasing until 1999, reaching 117,608 mt, before a decline in catches was observed with quantities reaching 95,150 mt in 2003 (Earthtrends 2003). In 2007, the UAE landed the greatest quantity of reef fish compared to other Gulf countries with 68,680 mt comprised mainly of Lethrinidae (emperors), Serranidae (groupers), Carangidae (jacks) and Sparidae (sea breams) (Grandcourt 2012). Fisheries independent surveys of the UAE's demersal and small pelagic fish resources have shown major declines in fish abundance of both commercial and non-commercial species with biomass density estimates in 2003 at around 19% of recorded values from 1978 (Shallard & Associates 2003). It has been suggested that these reductions were mainly due to overexploitation (Sheppard *et al.* 1992; De Young 2006; Al Janahi 2008b) especially since a large proportion of the expatriate community originates from the Indian subcontinent and has a wide-ranging taste for seafood which has increased the market in terms of quantity and marketable species (Sheppard *et al.* 1992; Carpenter *et al.* 1997).

Sale *et al.* (2011) noted that there is a need to assess fisheries resources in the region as there is limited data on the status of various stocks with most catch data recorded to family levels rather than species levels. This hinders the ability of managers to develop appropriate assessments that could lead to effective management of fish stocks. Moreover, information on species composition, as well as catch and effort data, have been collected in some emirates of the UAE to lay a foundation for fisheries management initiatives. This has mostly consisted of surveys at major landing sites spread throughout the country. The Emirate of Abu Dhabi, through efforts from the Environmental Agency (EAD), has the longest standing database of survey results and produces annual statistical reports for landing sites in the Western region (Abu Dhabi waters) (Hartmann *et al.* 2010). Other emirates do not seem to have a centralized system but data are collected through the Ministry of Environment and Water (MoEW) for the remaining fishing provinces which include the Central region (Dubai, Sharjah, Umm Al Quwain and Ajman), the Northern region (Ras Al Khaimah) and the Eastern region (Fujeirah). Also, fishing regulations are weak, rarely enforced or are inconsistent among jurisdictions that share stocks (Grandcourt 2012). One viable solution for the protection of marine stocks has been the designation of marine protected areas, such as the Marawah Biosphere Reserve and the Al Yasat Protected Area in Abu Dhabi, where only artisanal fishermen using traditional gear are allowed to fish, and which also restricts the effects of most development activities (Sale *et al.* 2011). However, the use of coastal and offshore areas has still increased dramatically and this usage is not likely to subside in the near future.

1.2.3 Fishing industry in the UAE: gear and vessel characteristics

Regionally, four primary sectors of capture fisheries exist including recreational, speed-boat, dhow-based, and modern commercial fisheries, and are distinguished by the type of gear used in each sector (Carpenter *et al.* 1997; Beech 2004b; Grandcourt 2012). While there has been a steady improvement in fishing technology, fisheries in the UAE have remained artisanal utilizing a wide range of traditional fishing gears and technologies. Generally, the most common gear used is circular dome shaped fish traps made from galvanized wire called *gargoors* (EAD 2011a). However, a large variety of gears exists including gill nets (*Mansab*), drift nets (*Asharee*), barrier traps (*Hadrah*), hand lines (*Hadaq*) and longlines (*Manshala*) and are used based on the type of fishing vessel and target species (Carpenter *et al.* 1997). These fishing gears are usually used alone or in combination with other traditional gear. In depth information and descriptions of the various fishing gears, methods used, and target species for each have been published by Carpenter *et al.* (1997), Beech (2004b), and Grandcourt (2012).

The fishery is characterized by highly diverse catches and comparable to multi-species tropical fisheries (Hartmann *et al.* 2010; Grandcourt 2012). While it is described as ‘artisanal’ because of the traditional methods used, it operates on a scale that is indisputably commercial in nature (Grandcourt 2012). In UAE waters, fishing is only permitted for two types of vessels, wooden dhows or *lanshes* and fiberglass dories or *tarads*. Lanshes are traditionally built wooden dhows decked and powered by inboard diesel engines of 150 to 300 horsepower (HP) (Grandcourt 2012). This type of vessel is usually between 12 to 22 m in length and has more recently been constructed with a fiberglass reinforced plastic hull, while retaining its traditional form (Al-Ansi & Priede 1996). Fishing trips last between one and seven days, tending to be longer during the cooler months than in the summer, and fish is stored whole on ice in insulated cool boxes. The crew size varies from 4 to 8 persons. Typically, gear used on these boats consists of fishing traps but driftnets, gillnets, hook and line as well as trolling lines can be used (Carpenter *et al.* 1997). The operational range is up to 65 km from port although this depends on the vessel size and the size of the engines it is equipped with (**Appendix B**, **Plate 1.1.**).

Tarads are usually constructed with fiberglass and powered by one to two outboard engines of 50 to 250 HP each. Fishing trips vary depending on the type of gear used and the target species but are generally undertaken during the day or night. Because of the small size of the boat, measuring six to eight meters in length, fishing trips usually last between two to four hours and are limited to a maximum of 24 hours.

The number of crew varies from one to four persons (EAD 2011a). Fishing grounds are usually closer to their home ports due to limitations on the range tarads can travel; however, it is important to note that some tarads are equipped with two 250 HP engines, thus traveling long distances in a short amount of time (**App. B, Plate 1.2.**).

This artisanal fleet operates from various ports across the country and covers most of the UAE Gulf sector. There is no specific time for departure or arrival in port, but unloading is always dictated by the timings set for each landing site, usually prior to the opening of the markets, either in the early morning or late afternoon. Catches are sold at fish markets and landing sites and buyers are generally local traders or hotel and supermarket purchasers (Al Mousa *et al.* 2008). These operations are usually organized by fisheries cooperative societies that have been established in each emirate. These cooperatives have been set up by the government to deal with fishermen's needs, ensure their training, and increase awareness among both the fishermen and the general community of newly implemented laws and subsequent ministerial decrees (Al Janahi 2008a). Most landing sites, particularly ones in major cities, have facilities for landing, storing, auctioning, wholesaling and retailing the catch.

Local full-time fishermen are provided with incentives from the government by means of subsidized marine engines, motor repairs, and fishing gear to encourage participation in the fishing industry (De Young 2006; Al Janahi 2008b). Fishermen with other sources of income are also provided with similar benefits in order to improve their standard of living (Al Janahi 2008a). This strategy has been successful in increasing the number of fishermen and the number of licensed boats. Individuals engaged in fishing as full-time or part-time fishermen showed an increase from 3,955 in 1976 to 21,220 in 2008 (MoEW 2013). It is, however, important to note that these numbers reflect a combination of both local and expatriate fishermen. Of the 21,220 fishermen reported for 2008, only 6,101 were UAE citizens representing 28.7% of the total. The representation of locals in the total number of registered fishermen seems to be declining quickly with a drop from 43.8% of the total number of fishermen in 2005. This is mainly because many Emiratis are not solely dependent on income from fishing and are increasingly involved in other industries. Also, the total number of licensed fishing boats has been on the increase, from 1,065 vessels registered in 1976 to 6,054 in 2009 (Al Janahi 2008a). **Tables 1.1.** and **1.2. in App. A** illustrate the MoEW yearly data for licensed boats and registered fishermen respectively.

Finally, recreational fishing is a rapidly growing sector and, while it is suggested that total productivity and harvest pressure from this fishery is minimal compared to the commercial fisheries (Grandcourt 2012), data are not readily available to determine its impact. Fishing is mainly carried out from small motorboats based on the shore using hook and line, gargoors, and fly-fishing. Licensing of recreational fishermen was introduced between 2001 and 2003 and can be in the form of annual or weekly licenses available to both locals and expatriates over the age of 18. In 2006, Abu Dhabi reported a total of 4,396 annual license holders (EAD 2007).

1.2.4 Shark fishery and status of sharks in the UAE

Sharks have long been documented in the Arabian Gulf (Blegvad & Loppenthin 1944; Basson *et al.* 1977) with historical records mainly based on opportunistic information collected from market observations (Tourenq *et al.* 2007; Moore *et al.*

2010a), demersal fisheries surveys or research cruises in Iran, Qatar, Kuwait, the Arabian Gulf and Gulf of Oman (White & Barwani 1971; Gubanov & Schleib 1980; Sivasubramaniam 1981; Sivasubramaniam & Ibrahim 1982b; Kuronuma & Abe 1986; Bishop 2003; Valinassab *et al.* 2006; FAO 2009a), encounters with large and morphologically distinctive species (Bishop & Abdul-Ghaffar 1993), and extrapolations from species recorded in the Indian Ocean (Carpenter *et al.* 1997). These efforts yielded important faunistic lists and species catalogues which provided information on species distribution and their incidence in fisheries.

More recently, reviews of the status of elasmobranchs in the region as well as an updated annotated checklist of the shark species found in the Arabian Gulf have been published (Moore *et al.* 2010a; Moore 2012; Moore *et al.* 2012a; Moore *et al.* 2012b). Data from some of these publications are based on opportunistic surveys in Kuwait (April 2008 and 2009), Qatar (April 2009), and Abu Dhabi (April 2010), and therefore do not reflect changes in geographical and temporal trends that could occur within this body of water. However, even with limited survey efforts, a range of new species records for this body of water has been published including the description of the slender weasel shark (*Paragaleus randalli*) (Compagno *et al.* 1996), the slit eye shark (*Loxodon macrorhinus*) (Moore *et al.* 2010a), and the rediscovery of the smoothtooth blacktip shark (*Carcharhinus leiodon*), previously only known from a holotype collected over 100 years ago in Yemen (Moore *et al.* 2011).

Based on a review of the available literature and market surveys, the most recent detailed account confirms 26 species of sharks in the Arabian Gulf (Moore *et al.* 2012b). Although these are all limited observations, they possess a relative value as they remain the only species records and measures of abundance levels for sharks in the region. However, the current limited amount of directed research on shark diversity, distribution and biology in the region raises doubt about the completeness and accuracy of available checklists. There remains a general lack of knowledge on the exact number of shark species, the species composition and quantities of catches, and the amount of fishing effort directed towards this fishery. Furthermore, no studies have been conducted regionally to define shark stocks or collect data on life history characteristics, migration patterns, population dynamics and nursery grounds.

The exploitation of shark resources in the UAE can be traced back to more than 7,000 years (Beech 2004b). The limited literature indicates that sharks were traditionally captured using longlines (Beech 2004b), with large hooks attached to strong ropes and baited with the hind leg of a lamb to attract large sharks (Sivasubramaniam & Ibrahim 1984). This fishing method was popular among pearl divers wanting to remove large sharks from the vicinity of their dive site (Sivasubramaniam & Ibrahim 1984). Sharks caught were processed and utilized in various ways. The oil was used to coat the exposed area (above the water line) of dhow hulls to reduce the deterioration of timber and to achieve a shiny appearance. Meat was salted and dried for use during seasons or periods where the weather was unfavorable for fishing (White & Barwani 1971; Sivasubramaniam & Ibrahim 1984), while carcasses were used as fertilizers in date plantations (Saif Al Ghais, pers. comm.). Furthermore, sharks have traditionally been a constituent of the Emirati diet and recipes for shark cooking have been documented for local consumption (Gubanov & Schleib 1980). However, written records of shark fisheries in the UAE are generally scarce and although trade with other Asian countries date back to the pearl diving industry (Carter 2005), it remains unclear when shark fins were first exported to eastern Asia from the UAE. Reports from the region in the 1970s describe that although sharks were sometimes caught in large quantities, causing heavy damage to gillnets (Sivasubramaniam & Ibrahim 1984) and representing over 50% of catches and 500 to 600 kg in weight after one hour of trawling off Kuwait (Gubanov & Schleib 1980), they were considered non-commercial and non-marketable and typically discarded (Gubanov & Schleib 1980; Sivasubramaniam & Ibrahim 1984). Based on data from landing sites and information obtained from crew, Sivasubramaniam and Ibrahim (1984) estimated that up to 70% of all sharks caught annually from artisanal and commercial fisheries were discarded. Therefore, in the 1970s, sharks were one of the poorly priced commercial species group (Sivasubramaniam 1981) with only some species such as *Carcharias menisorrah* (=*Carcharhinus dussumieri*) valued as food (Gubanov & Schleib 1980) and hammerhead sharks (Sphyrnidae) marketable in limited quantities in the area (Sivasubramaniam 1981).

Anecdotal evidence shows that shark fisheries across the Arabian Gulf, which have been dominated by traditional artisanal fisheries, have in recent years increased in their size and geographical extent. Worldwide, it is now widely accepted that even small amounts of 'artisanal' fishing can have detrimental impacts on target fish populations (Pinnegar & Engelhard 2008). Furthermore, research from other locations around the world has demonstrated that many of these fisheries are not sustainable due to the K-selected life history traits of sharks and their low resilience to intense fishing pressures (Bonfil 1994; Stevens *et al.* 2000a). However, catch data from the shark fisheries in the region are not only scant but their nature fragmented and scattered, a barrier to the creation of viable management plans for the conservation of these species. In fact, while sharks are usually landed, it remains unclear whether there is a targeted fishery or if they are bycatch from other fisheries. However, it seems that these catches are essentially driven by the shark fin export market.

Capture production statistics for the UAE have been reported to the FAO since 1986 and remained relatively stable between 1986 and 1999 with an average between 1,300 and 1,950 mt per year (**Figure 1.1.**) (FAO 2012). These numbers increased from 2002 onwards and reached a maximum of 3,520 mt in 2005 but have been fluctuating since. These landing statistics are difficult to interpret since no distinction is made between sharks caught from the UAE's Arabian Gulf and Arabian Sea coastlines; neither is information provided on data collection methods, and no details are provided regarding the type of weight measurement provided (i.e. live weight or dressed weight), which does not provide a means of investigating the relationship between these statistics and the actual catches of sharks. However, while these catches remain modest, the increasing trend raises concerns about potential stock depletions in the near future unless appropriate and scientifically based management actions are implemented. Nationally, since the inception of the Fish Landings and Population Dynamics Project in 2001, the EAD has collected information on its shark and ray catches (**Figure 1.2.**). Data were collected from fish landing receipts issued by fisheries cooperatives in Abu Dhabi and from data recorded by enumerators (EAD 2011b). Data collected until 2004 pools together landings of sharks and rays, while from 2005 onwards quantities are solely based on shark landings and range from a

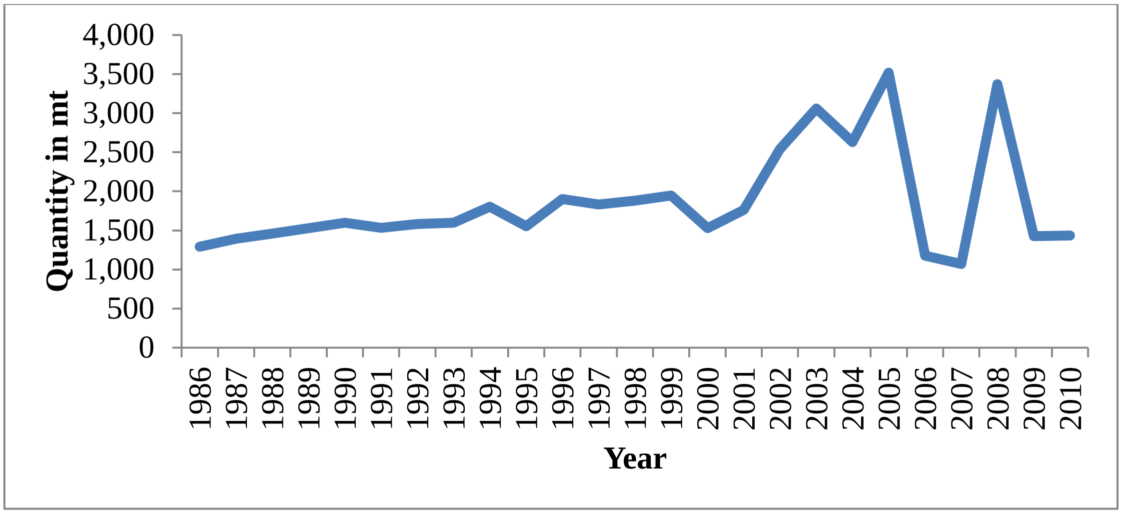

Figure 1.1. UAE capture production of sharks, rays, skates, etc. nei from 1986 to 2010 (FAO 2012).

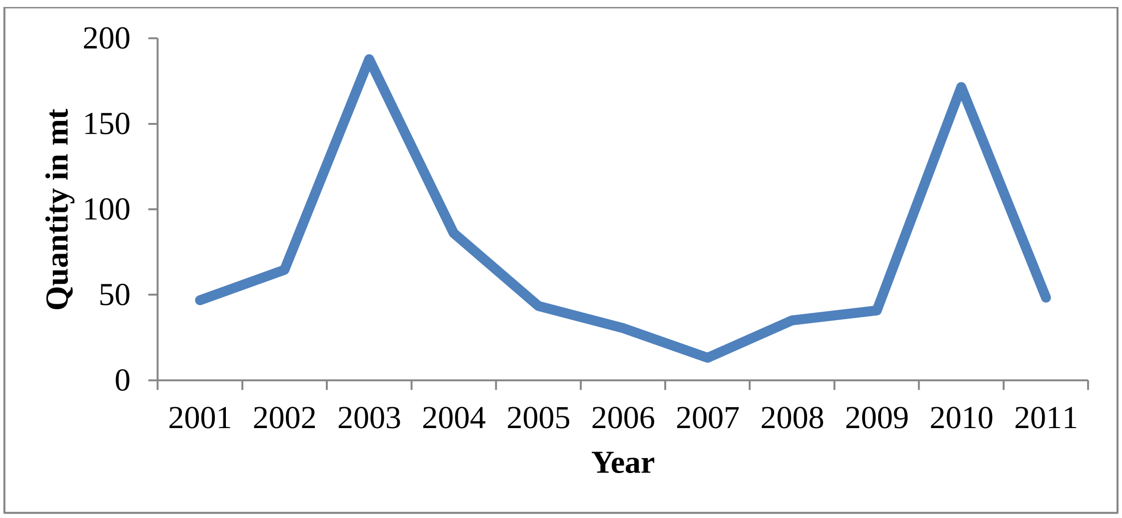

Figure 1.2. Abu Dhabi landing statistics for sharks and rays from 2001 to 2011 (EAD 2011b).

maximum of 187.8 mt in 2003 to a minimum of 13.2 mt in 2007 with an average of 69.8 mt during the period reported. When comparing the data from FAO's UAE capture production and Abu Dhabi landings, the only similar trend seems a decrease in catches in 2006 and 2007, a trend that is unexplainable without further data. However, it is important to note that although Abu Dhabi has the longest coastline in the UAE (EAD 2011a), fish quantities landed there only account for 7.6% of the total national catches (MoEW 2013) and this may explain why quantities reported seem low compared to the total reported for the UAE.

1.2.5 Management framework in the UAE

Despite international recognition of the vulnerability of sharks to overfishing (Stevens *et al.* 2000a; Watts & Wu 2005), there is still a lack of a concise overview of the current situation in the UAE. There is a scarcity of information on the impact the artisanal fishery has on sharks as well as an absence of reliable data available on shark catches from across the country. Furthermore, there is no established list of shark species found in UAE waters other than some confirmed sightings recorded within the Gulf during a survey conducted in 2002 by the EAD (Edwin Grandcourt, *pers. comm.)* and by Moore *et al.* (2012a) during a 10 day visit to the Abu Dhabi landing site in April 2010. While the UAE has been a signatory to the CCRF since 1999, there is still little information available on the status of the national shark fishery. The lack of detailed quantitative information on the locations and activities of the artisanal fishery, species-specific data, as well as basic life history information on targeted species hampers any attempts at regulating this fishery. Furthermore, the lack of adequate knowledge of shark stock compositions, volumes of landings and trade, abundance and distribution of species hinders the development of science-based measures to manage the shark fishery in the UAE. Without some benchmark of fisheries effort and catch composition, changes in relative abundance, and other potential impacts on exploited species are unlikely to be identified. It is therefore doubtful that any management will proceed and legislations implemented or enforced while stock assessments remain poorly understood.

All countries within the Gulf region share the same shark resources and yet they all have common problems in terms of their shark fishery. Gulf countries have limited control in the form of management measures to ensure the long-term sustainability of these species. While the biological and ecological traits of sharks have not been studied in this area, studies from other parts of the world confirm that sharks are very vulnerable to any human induced threats particularly the increase in commercial and recreational fisheries, the developing international trade in shark products, tourism and the aquarium trade (Environment Australia 2002). It is therefore increasingly important to quantify and characterize this fishery in order to gain a better understanding of exploitation rates and accurately assess populations. This is especially true since a collapse in shark stocks in the Gulf could have major consequences including jeopardizing fisheries that would result in significant economic and social costs.

Finally, various sources have reported that the UAE currently ranks amongst the top five largest shark fin exporting countries in the world to Hong Kong with approximately 400 to 500 mt of fins having been exported annually between 1998 and 2000 (Fowler *et al.* 2005; Hareide *et al.* 2007; WildAid 2007). The UAE, therefore, plays a crucial role in the international trade in shark fins and serves as an export hub for the Arabian and eastern African region (Fowler *et al.* 2005). With the increasing trend in shark catches, it is urgent that the UAE enlarges its capability to monitor, assess and manage the shark fishery.

1.2.6 International legislation

International laws and standards impose a responsibility on States and Regional Fisheries Management Organizations (RFMO) to manage shark stocks sustainably notwithstanding whether sharks are highly migratory or if they are taken as a target or by-catch species. An abundance of guidelines is available to assist in the management of shark species and there is a clear onus on coastal and fishing states to act individually and through RFMO’s. However, there is still a very low level of commitment to manage shark fisheries and few examples of effective and dedicated measures to ensure the conservation of shark species exist around the world.

Even though the IPOA sharks is a voluntary, non-binding legal instrument, it draws from a multitude of binding instruments. It was adopted to ensure the conservation and management of sharks and their long-term sustainable use by embracing the precautionary approach (FAO 1999a). It also calls on states to develop NPOA’s that describe the state of local shark stocks and populations, associated with fisheries as well as identify threats, research, monitoring and management needs for all sharks occurring in their waters. It urges states to cooperate regionally by developing regional plans of action and to cooperate through regional fisheries management organizations and other arrangements to ensure effective conservation and management of trans-boundary, straddling, highly migratory, and high seas stocks of sharks (FAO 1999a).

Some of the prevailing international and regional fisheries and wildlife instruments considered most relevant for the protection and conservation of shark resources, all ratified by the UAE (except for the Convention on Migratory Species) are listed below. The aim here is to place the IPOA into a bigger context and each instrument is highly relevant for the adoption of this plan. These have gradually been introduced to protect fisheries and provide a comprehensive basis for the development of appropriate management frameworks through a combination of fisheries, conservation and trade measures (Barker & Schluessel 2005). While developing these measures, the precautionary and ecosystem approaches have seldom been taken into account. Therefore, while some of them have been slowly introduced to protect sharks, many focus on fisheries management instead of protection (Barker & Schluessel 2005). On the other hand, wildlife tools have been more successful in the introduction of measures to protect sharks since they emphasize conservation. For improved management of threatened and commercially exploited species, it is crucial that managers and policy makers promote the utilization of all relevant management tools available since fisheries and wildlife agreements overlap significantly. They can therefore complement each other and provide managers with tools to reverse current population declines and promote sustainable use of various species more effectively (Fowler *et al.* 2002).

- The 1973 **Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)** is an intergovernmental treaty that aims to ensure that international trade in specimens of wild flora and fauna does not threaten their survival. The mechanism establishes the legal framework for the prevention of trade in endangered species and for the effective regulation of international trade in other species, which may become threatened, unless strictly regulated through a system of permits based on scientific and management findings. Appendix I lists species that are threatened with extinction and bans international trade in these species or their parts (except under exceptional circumstances). Trade in Appendix II species is subject to strict regulation and monitoring to ensure that it is not detrimental to the status of the listed species. Whale sharks (*Rhincodon typus*), basking sharks (*Cetorhinus maximus*), great white sharks (*Carcharodon carcharias*), porbeagle sharks (*L. nasus*), oceanic white tip sharks (*Carcharhinus longimanus*) and three species of hammerhead sharks (*Sphyrna mokarran, S. lewini* and *S. zygaena*) are now listed on this Appendix. The five species listed last were proposed in March 2013 at the CITES meeting in Bangkok, Thailand and Parties have 18 months from that date to prepare for the implementation of procedures to monitor trade in those species (CITES 1973).

- The 1979 **Convention on Migratory Species of Wild Animals (CMS)** aims to conserve species that migrate across national boundaries and/or international waters. The convention stipulates that Parties should promote cooperation and support research related to migratory species and endeavor to take immediate action for endangered migratory species. These species are listed in Appendix I and include the white shark and the basking shark. Parties are required to work to enforce strict protections for these animals, including a prohibition on take, as well as conserve or restore the habitats in which they live, mitigate obstacles to their migration, and control other factors that may endanger them. Appendix II contains species that need or would greatly benefit from international cooperation and also lists the previous species as well as whale sharks, longfin (*Isurus paucus*) and shortfin makos (*I. oxyrinchus*), porbeagle and northern hemisphere populations of spiny dogfish sharks (*Squalus acanthias*). Parties are required to conclude global or regional agreements on these species. A non-legally binding Memorandum of Understanding on the Conservation of Migratory Sharks (MoU sharks) was adopted in 2010 and focuses on increasing international cooperation to ensure action is taken to protect sharks listed on the Appendices (CMS 1979).

- The 1979 **Regional Organization for the Protection of Marine Environment (ROPME)** aims to coordinate efforts of its member states towards the protection of the water quality in the Arabian Gulf and abating the pollution caused by development activities (ESCWA 2007).
- The 1992 **Convention on Biological Diversity (CBD)** promotes the conservation of biological diversity and ensures the sustainable, fair and equitable use of its benefits. Parties are required to develop or adopt national strategies or policies for the conservation and sustainable use of biological diversity, to monitor components of this diversity that are important for conservation, and to identify and monitor activities with likely adverse impacts on the conservation and sustainable use of biodiversity. It also aims to establish a network of comprehensive, representative and effectively managed protected areas. Implementation is the individual responsibility of each Party and may be taken forward in varying ways in different States. It can therefore influence and drive

national fisheries conservation and management policies, including an obligation of Parties to prepare NPOA's for sharks (CBD 1992).

- The 1982 **United Nations Convention on the Law of the Sea (UNCLOS)** is a framework convention for managing the world's oceans and its resources. This instrument stipulates that coastal states have sovereign rights for the purpose of exploring and exploiting, conserving and managing fishery resources within their Exclusive Economic Zone (EEZ), to implement conservation measures that will avoid the over-exploitation of their living resources and ensure the restoration of species. In relation to sharks, a coastal state must ensure that species occurring within their EEZ are not endangered by overexploitation in the case of directed fisheries. Cooperation between states is required especially for the management of highly migratory species such as oceanic sharks that are listed under Annex I of UNCLOS. However, it does not impose a duty on the states to reach an agreement and if so, then each state shall manage the segment of the shark trans-boundary stock occurring within its EEZ (UNCLOS 1982).
- The 1992 **UN Conference on Environment and Development (UNCED) Agenda 21** is a non-binding and voluntary action plan related to sustainable development and includes provisions for integrated management of coastal areas, including EEZ's, marine environmental protection and conservation of marine living resources under national jurisdiction and in high seas (UNEP 1992).
- The 1993 **FAO Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas** elaborates responsibilities of flag states for their fishing vessels. This instrument

specifies measures necessary to ensure vessels flying their flags are not engaging in activities undermining the effectiveness of conservation measures (FAO 1995a).

- The 1995 **United Nations Agreement for the Implementation of the Provisions of the UNCLOS relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (UNFSA),** facilitates the implementation of UNCLOS provisions and obliges states to cooperate through RFMO's to conserve and manage fish stocks and establishes principles for high seas fishery resources conservation and management. This includes protecting marine biodiversity, minimizing pollution, monitoring catch of non-target species such as sharks and impacts on associated dependent species, particularly endangered ones. This instrument specifies the collection of scientific data and mandates that the precautionary approach to fisheries management and the ecosystem approach to the protection of marine biodiversity should be applied. The agreement requires coastal and fishing states to cooperate to ensure conservation and optimum utilization of oceanic shark species defined under UNCLOS including the sixgill (*Hexanchus griseus)*, basking, whale, thresher (Alopiidae spp.), requiem (Carcharinidae spp.), hammerhead (Sphyrnidae spp.) and mackerel sharks (Lamnidae spp.) (UN 1995).
- The 1999 **FAO Code of Conduct for Responsible Fisheries** complements the UNFSA and sets out principles and international standards of behavior for responsible fishing practices. It recommends new approaches to fisheries management, as well as social and economic considerations, in order to promote the conservation, management and development of all fisheries and provide

guidance in the formulation and implementation of further instruments in support of the objectives of the CCRF. Several provisions refer to the need to develop or use selective and environmentally-safe fishing gear and to minimize waste, catch of non-target species and impacts on associated or dependent species. Measures to conserve biodiversity, protect endangered species and allow depleted stocks to recover or be actively restored are to be adopted (FAO 1995b).

- The 1999 **Regional Commission for Fisheries (RECOFI)** was established through an agreement between Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and the UAE. This advisory body provides member countries with scientific and management advice aimed at promoting the development, conservation, management and best utilization of marine resources (FAO 1999b).
- The 2003 **Convention on the Conservation of Wildlife and their Natural Habitats in the Countries of the Gulf Cooperation Council** deals with the conservation of ecological systems and wildlife and focuses on some endangered species which are found or migrate among GCC countries. It recognizes that habitats need to be protected to preserve biodiversity in the region (GCC 2009).
- The 2008 **UN General Assembly Resolutions on Sustainable Fisheries (UNGA)** recognizes the need to promote long term conservation, management and sustainable use of shark populations given their vulnerability and the fact that some species are threatened with extinction. It reaffirms that data are still missing regarding sharks and that few countries have adopted an NPOA, calling upon states to urgently adopt measures to fully implement IPOA Sharks and regularly report on shark catches (UN 2008).

1.2.7 National legislation

The UAE is governed by a Federal system founded on the 2nd of December 1971. The union comprises seven Emirates (Abu Dhabi, Dubai, Sharjah, Ajman, Umm Al Quwain, Ras Al Khaimah and Fujeirah) and federal laws must be implemented by a competent authority at federal level or by different authorities in each emirate (Vine 2009; EAD 2011a). Although federal laws constitute the minimum requirement for implementation, each emirate has its own government and can develop and implement local laws more stringent than the federal ones. In the absence of such legislation, relevant international standards and environmental criteria can be adopted and utilized until new regulations are developed and approved (EAD 2011a).

In the UAE, legislation has been established for the protection and development of the marine environment in an attempt to regulate fisheries. This was first initiated with the implementation of Federal Laws 23 and 24. Furthermore, Ministerial Decree No. 542 (MoEW 2008) was issued in an effort to control the shark fishery and has emphasized the need for fundamental information on targeted species. Details of the specific laws pertaining to the conservation and management of the marine environment and sharks in the UAE are listed in **Table 1.3.**

Table 1.3. Federal Laws and legislations pertaining to fisheries and sharks in the UAE listed in yearly order (* date laws were entered into force) (Al Janahi 2008a; MoEW 2008).

Year	Law	Concerning	Description
1999 (2000*)	Federal Law 24	Protection and Development of the Environment	Specifies standards and regulations in accordance with regional and international conventions for the protection of the marine environment (environmental impact assessments, pollution, hazardous substances, natural reserves and protected areas, monitoring, licensing, penalties).
1999 (2001*)	Federal Law 23	Exploitation, Protection and Development of the Living Aquatic Resources in the State of the United Arab Emirates	Bans unlicensed fishing; regulates fishing gear, import and use of gear that is unlicensed; specifies fishing areas; prohibits the catch of fish of various sizes, species and during seasons; bans fishing of foreign fish in territorial waters; prohibits trawling, bottom setting nets, nylon and drift nets; prohibits fish exports without permits; records of all activities need to be provided to the ministry yearly; UAE nationals required on board.
2001	Ministerial decision 302	Executive bylaw of Federal Law 23	Fish exports only allowed with permits; re-exports need certificates of origin specifying the intended destination; quantities; types of fish; and value; forbids catching of fish just for their fins and the discards of sharks in fishing waters. Forbids all nylon nets and those with mesh sizes of less than 1.5x1.5 inches and gargoor openings of less than 2x2 inches.
2002 (2003*)	Federal Law 11	Regulating and Controlling the International Trade in Endangered Species of Wild Fauna and Flora	Implements and lays out all provisions and rules pertaining to CITES permitting with details on applications, import and export permits as well as the responsibilities of the management authority.
2003	Ministerial decree 261	Stop the new registration of speed and dhow fishing boats	Fishing licenses for both fiberglass boats and dhows are no longer issued unless boats have been inherited, resold or replaced and therefore require a license.
2008	Ministerial decree 542	Organizing measures for capturing sharks	Only dhows with shark fishing licenses allowed to fish for sharks; only hooks sizes 1 and 2 up to a maximum of 100 hooks; no fishing allowed between January 1st and April 30th; fishing allowed beyond 5 nm from coastline, 3 nm from islands, 1 nm from coral areas; prohibits catch of whale sharks and sawfishes; bans finning; fishermen need to cooperate with authorities to provide information about catch, species, catch locations; gear used; violators get license revoked for 4 months.
2011	Ministerial decree 216	Amendment of Ministerial decree 542 regarding organizing measures for capturing sharks	Reiterates Ministerial Decree 542 and is effective immediately.

1.3 Filling the gaps: the need for quality social, biological and ecological data

Sharks present a wide array of issues and challenges for management (Camhi *et al.* 1998). This is especially true when there is a lack of quality ecological and fisheries data that managers need in order to design more effective conservation measures (Schindler *et al.* 2002). To plan for the conservation of sharks, populations need to be monitored, fisheries and catches surveyed, socio-economic factors assessed and proper stock assessments undertaken (Martin 2005). Stock assessments are effective methods of evaluating the status of exploited populations and intend to characterize the commercial and recreational catch including landings and discards. They make use of various types of information to give managers advice regarding the status of a fishery as well as the potential outcomes of management actions. To complete stock assessments, an evaluation of each species and the available data on its life-history are necessary as this provides information on the natural potential of the population to sustain itself in the absence of fisheries (Godin & Worm 2010).

Developing scientific understanding of shark resources is crucial to better manage local, regional and even global shark fisheries (Barker & Schluessel 2005). Some of the basic information that needs to be collected includes data on shark reproductive characteristics (age at maturity, gestation period, average annual pups per female), growth rates and age structure, critical habitats at various life stages, relative abundance, feeding behavior, migration patterns and genetic population structure (Camhi *et al.* 1998). Furthermore, because of the importance of the international trade in shark fins as a motivation for the exploitation of many shark species, improved and accurate data on the volume of trade in sharks and their products are necessary to determine the relative importance of trade as a threat to shark species, trends in exploitation, and to examine the potential role of trade regulations as an additional measure for shark conservation (Camhi *et al.* 1998; FAO 2009a). However, since different species have varying natural capacities to respond to fishing pressure, any management and conservation effort requires reliable fishery information on shark catch and trade on a species-specific level (Abercrombie *et al.* 2005; Clarke *et al.* 2006a; Moura *et al.* 2008; Pinhal *et al.* 2008; Holmes *et al.* 2009). The inherent difficulty of accurately identifying shark species from external morphological features presents a challenge for monitoring elasmobranch landings as well the trade in shark products (Bonfil 1994; Holmes *et al.* 2009). The morphological characters used to differentiate between shark species are often subtle and there is generally little capacity in identification even when catches are monitored. This is why catch records are often grouped together in generic categories or into family groups e.g. hammerheads (Abercrombie *et al.* 2005; Ward *et al.* 2005; Holmes *et al.* 2009). Furthermore, there are substantial difficulties in the identification of processed shark carcasses and other marketed shark body parts, such as dried fins, to species levels (Ward *et al.* 2009). These identification difficulties greatly undermine species-specific conservation and management efforts (Hoelzel 2001; Shivji *et al.* 2002; Chapman *et al.* 2003; Mendonça *et al.* 2009; Zemlak *et al.* 2009).

In order to develop a taxonomic system that allows identification of various species, and solve these problems, which are crucial to conservation and management, scientists established a DNA barcoding system for animal life based on sequence diversity in the mitochondrial cytochrome *c* oxidase subunit 1 (COI) (Hebert *et al.*

2003b; Hajibabaei *et al.* 2005; Moura *et al.* 2008). A region of approximately 650 base-pairs (bp) was nominated as the 'barcode' region and scientists determined that this mitochondrial gene was sufficient to reliably place species into higher taxonomic categories promising a fast and accurate bio-identification system for animals (Hebert *et al.* 2003a; Hajibabaei *et al.* 2005). Effective universal primers with over 95% amplification across species have been developed using a bidirectional sequencing strategy (Hajibabaei *et al.* 2005; Holmes *et al.* 2009). Results have shown that species-level diagnoses can routinely be obtained through COI analysis proving that congeneric species of animals regularly possess a sequence divergence greater than 2% in their COI genes (Hebert *et al.* 2003b). While initial studies focused on a variety of species, this identification system was tested on fish including elasmobranchs and showed strong species-level resolution (Ward *et al.* 2005; Ward *et al.* 2008; Holmes *et al.* 2009; Mendonça *et al.* 2009; Zemlak *et al.* 2009). Some issues with this barcoding system exist, such as the inability to distinguish between several species of sharks, yet it has been recognized as a highly accurate method for discriminating between approximately 99% of chondrichthyans (Ward *et al.* 2008). Indeed, the use of two forward and two reverse primers in all four pairwise combination to amplify DNA barcodes have shown successful amplification of the COI gene (Ward *et al.* 2005). Currently, approximately 49% of all described species of elasmobranchs have been barcoded and information on sequences have been published into databases available to the public (Ward *et al.* 2008). Therefore, this barcoding methodology provides a good method to confirm field identification of shark species and supports the monitoring of catches and trade in various products.

1.4 Objectives of this study

The main objectives of this study arise from the need to establish an overview and baseline data of the present status of sharks in the UAE. It is the first research of its kind in the UAE, the most comprehensive study in the Gulf region, and serves as the first assessment of sharks in the UAE investigating the fishery, species composition, relative abundance and distribution, feeding ecology, and contributions to the international fin trade. The specific aims of this research project are to:

1. Interview a representative sample of fishermen involved in the artisanal shark fishery to document gear characteristics, catch locations, seasonality of catch, changes in catch levels, and fishery targets, in order to gain a comprehensive understanding of this industry.
2. Monitor catches at major landing sites and markets across the country in order to develop a list of confirmed shark species occurring along the Arabian Gulf coast of the UAE while providing an overview of the abundance, patterns of distribution, and biology of these species.
3. Undertake fishery dependent and independent surveys in order to assess the status of commercially important shark stocks in UAE waters by determining the volume, species composition, size composition and sex ratios of sharks found at landing sites and in nearshore waters.
4. Establish the distribution chain of shark products by monitoring the trade for catches from UAE waters and those imported from other countries in the region.

5. Gain an understanding of the role of the milk (*Rhizoprionodon acutus*) and the slit-eye (*Loxodon macrorhinus*), two commercially important species, in regulating the structure of the ecosystem in Gulf waters by studying their diet.
6. Disseminate results of this study in order to provide decision makers with solid foundations to develop and implement management plans for these species.

1.5 Thesis structure

This thesis is comprised of eight chapters, each structured to stand alone, with its own introduction, materials and methods, results, and discussion sections, building on the data collected from this study as a whole. However, to avoid unnecessary redundancy, a general materials and methods chapter was constructed providing a description of the general sites investigated and highlighting methodologies used for most of the studies in this thesis.

Chapter I provides a literature review with the background information needed to familiarize readers with necessary context for later chapters. An overview of chondrichthyans and their life history traits is provided, followed by information on the history of shark exploitation and trends in worldwide abundance and trade. The cultural and historical context for the shark fishery in the UAE is discussed as well as international, regional and national fisheries instruments and legislations for the protection and conservation of sharks.

Chapter II provides a general description of the Gulf region with details of its geographical boundaries and the environmental characteristics of the Arabian Gulf. It covers the general data collection methodologies used to undertake this study including the site selection process and analysis methods.

Chapter III covers the fishery in the UAE with an investigation based on interviews with fishermen from across the country, describing their local knowledge and experience. This provides a baseline of shark abundance and details on the shark fishery from a historical point of view. Furthermore, it describes the shark fishing process along with information on the retail use of sharks in the UAE.

Chapter IV provides results from market and landing site surveys, reveals the species of sharks found in UAE waters, their abundance, seasonality and distribution. It presents species-specific biological information on these species and summarizes results from a DNA barcoding study aimed at confirming their identification.

Chapter V outlines the results from fishery independent data based on a tagging study. Details are provided regarding fishing equipment used, locations, fishing effort and species of sharks caught.

Chapter VI documents the trade in shark products from the UAE. It also describes the species represented in the trade and their origin, and provides details from DNA barcoding undertaken to confirm species identification.

Chapter VII details the feeding ecology of two common species of sharks found in UAE landings: the milk shark, *R. acutus*, and the slit-eye shark, *L. macrorhinus*.

Chapter VIII summarizes key findings of this study and includes a discussion of their implications in terms of improved management and conservation of sharks. Future research is suggested based on information gaps determined from this study.

CHAPTER II
MATERIALS AND METHODS

2.1 The study area

2.1.1 General characteristics of the Arabian Gulf

The Arabian Gulf (hereafter referred to as 'the Gulf') is an epicontinental 'semi-enclosed' sea that covers an area of approximately 229,000 km^2 (Hamza & Munawar 2009). This basin lies in a subtropical zone with a hyper-arid climate (Carpenter *et al.* 1997) and stretches 1000 km in length from the Shatt al Arab waterway to the Strait of Hormuz, varying in width from 75 to 350 km (**Figure 2.1.**). This body of water opens into the Gulf of Oman through the Strait of Hormuz at its eastern end which is 56 km in width (Sale *et al.* 2011). The Gulf has an average depth of 35 m and gradually becomes deeper to 100 m as it approaches its entrance (Sheppard *et al.* 1992; Al Gahtani & Maslehuddin 2002; Nadim *et al.* 2008). This opening has the largest scale bathymetric changes while the remaining Gulf is stable and lacks a continental shelf edge. This basin is characterized by low hydrodynamic energy; relatively shallow depths; high evaporation rates, surface water temperatures and salinities; and minimal water exchange (Khan 2007). Its shallow nature allows strong benthic primary production and the Gulf is considered one of the most productive bodies of water in the world (Sheppard *et al.* 1992). Productivity is mostly sedimentary supporting highly productive habitats such as intertidal mudflats, seagrass, algal beds, mangrove forests and coral communities (Sheppard *et al.* 1992; Price 1993).

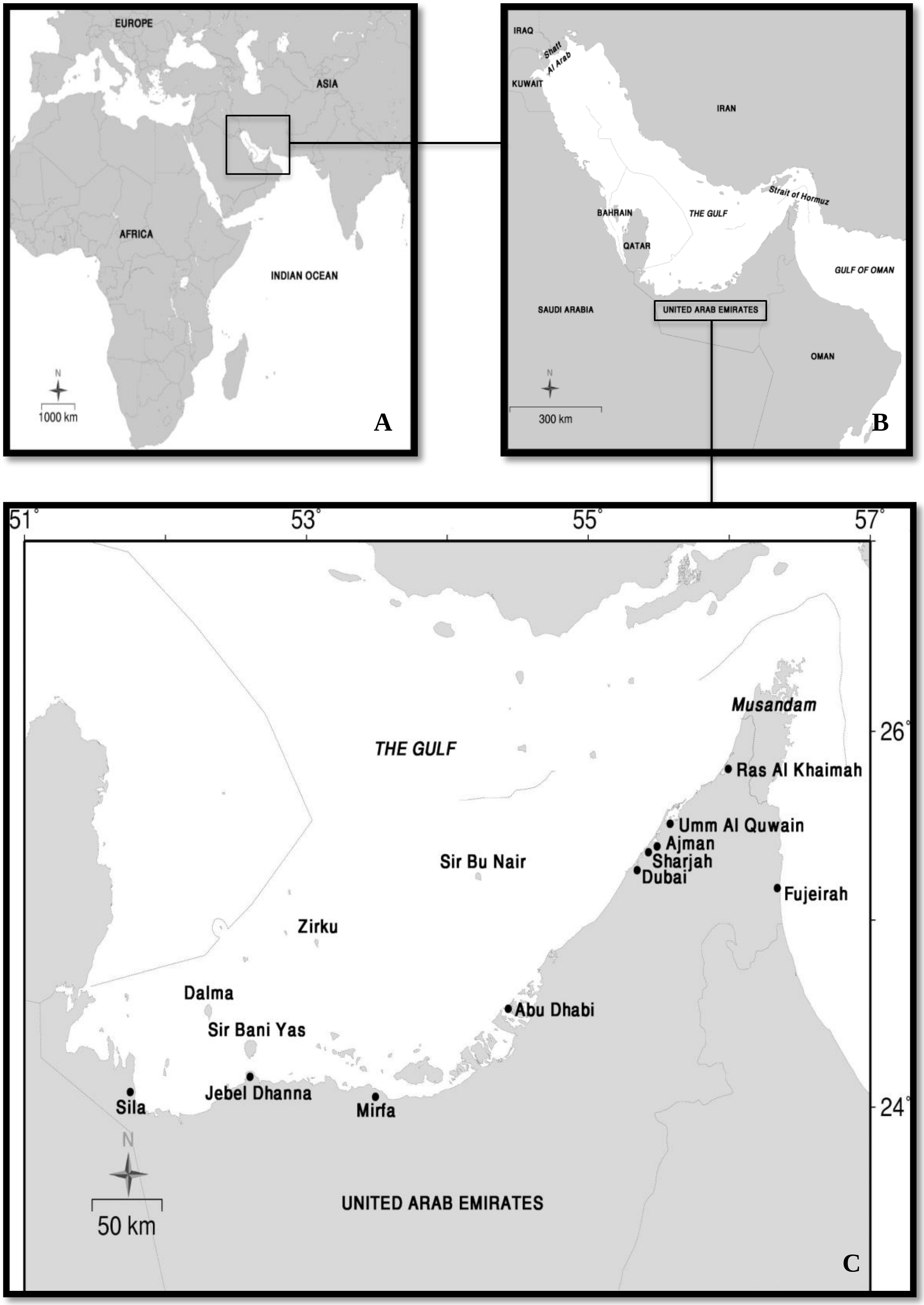

Figure 2.1. Location of the UAE relative to the world (A), the region (B), and map of the UAE depicting coastal areas along the Gulf and Gulf of Oman (C).

While the Indian Ocean coast exhibits environmental characteristics similar to other bodies of water, such as the Atlantic Ocean, the Gulf represents a highly extreme and harsh environment (Al Gahtani & Maslehuddin 2002). The region is renowned for its extreme heat and dryness that are mainly due to the coastal mountains separating the Arabian Peninsula from the sea. The surrounding arid land masses, and the lack of oceanic buffering, cause marked seasonal fluctuations with high summer heat, winter cold extremes, and low rainfall, resulting in some of the most remarkable effects seen in tropical areas (Carpenter *et al.* 1997).

Air temperatures in the region frequently reach around 0 °C in winter and 50 °C and above in summer (Sheppard *et al.* 1992; Carpenter *et al.* 1997). These climatic variations are strongly influenced by prevailing cold winds, the northern 'shamals', that can occur year around (Carpenter *et al.* 1997; Sheppard *et al.* 2010). These thermal winds, often caused by differences in the temperature of the land mass and the water, can be some of the strongest experienced in the Gulf.

Sea surface temperatures reflect these harsh conditions and fluctuate in near shore waters between 10 °C and 39 °C, a difference of 29 °C, and more moderately offshore between 18 °C and 36 °C (Carpenter *et al.* 1997). The rapid drop in seawater temperature of about 10 °C usually occurs between late November and December marking the transition between the warm and cold season. This usually coincides with the onset of the 'shamals' and lasts until April. During these winds, water temperatures in shallow areas can be reduced to as low as 4 °C off Qatar, 7 °C off Kuwait, and 14 °C in offshore waters of the Gulf. While many organisms in the area live at the limits of their physiological tolerance and are able to survive these extreme thermal variations, this dramatic drop in temperature limits the range of many important biotic groups and also results in extensive mortality of large parts of the nearshore tropical fauna (Carpenter *et al.* 1997).

The water enters this basin through the Strait of Hormuz at a normal oceanic salinity of 36.5 and 37 parts per thousand (ppt). However, salinity is influenced by the Gulf's arid climate and by the lack of fresh water input, limited to the Tigris, Euphrates and Karun rivers, which empty into the Shatt Al Arab waterway, as well as the Iranian Hendijan, Hileh and Mand rivers, which descend from the Zagros mountains (Sheppard *et al.* 1992; Beech 2004b). High summer temperatures and high evaporation rates lead to salinity levels that generally range between 37 and 44 ppt within the Gulf, with extreme values exceeding 60 ppt in some semi-enclosed coastal basins (Carpenter *et al.* 1997; Sheppard *et al.* 2010). The effects of freshwater runoff are mostly insignificant to the nearshore marine environment due to the low annual rainfall. These high salinities influence many localized biological communities leading to the formation of supra tidal flats, called 'sabkhas', as well as shallow areas that foster extensive algal mats.

Within the Gulf, high evaporation rates are due to high temperatures in the summer and dry alternating northeast and northwesterly winds in the winter. The evaporation rate is estimated to be 350 km^3 per year and exceeds the combined precipitation and fresh water input from the Shatt al Arab and the Iranian rivers (Sheppard *et al.* 1992; Carpenter *et al.* 1997). Therefore, the high loss of water is not compensated and the mean annual net evaporation rate is equivalent to the sea surface lowering at a rate of 140 to 500 cm per year. This creates a consistent density dependent reverse anti-clockwise flow from the Indian Ocean into the Gulf and the net water loss is replaced by surface inflow from the Gulf of Oman (Sheppard *et al.* 1992; Nadim *et al.* 2008).

The high evaporation rate, combined with the narrow opening of the Strait of Hormuz, has led to the formation of the saline, dense water found in the Gulf. The evaporation and low temperatures, as well as the increased density of seawater, drive important circulation patterns in the Gulf. The current flows into the Gulf along the Iranian coast and then flows around the water basin in a counter-clockwise direction (Sheppard *et al.* 1992; Reynolds 1993). Under the influence of the Coriolis force, this highly saline and dense water flows out the Gulf in the deepest part of the Strait of Hormuz below the inflowing fresher surface water. Circulation patterns based on modeling have shown that a complete turnover of waters in the Gulf is estimated to be around two to five years (Hunter 1986; Carpenter *et al.* 1997). Flushing time is estimated to be about three to five and a half years because of the effects of vertical mixing and other turbulent processes (Sheppard *et al.* 1992).

The Gulf is a highly stressed body of water due to its prevailing harsh environmental conditions and as a result of anthropogenic activities (Hamza & Munawar 2009). With eight bordering countries, including Iran, Iraq, Kuwait, Saudi Arabia, Bahrain, Qatar, the UAE and Oman, that have recently undergone rapid economic growth, the marine environment is changing rapidly. This is mainly due to substantial construction along shores and offshore regions, which are underpinned by its massive oil and gas industry, as well as by wealth from financial centers (Sheppard *et al.* 2010). Furthermore, it is a major shipping route and strategic location for many ports in the Middle East and South Asia especially for the global oil transport industry (Price 1993; Nadim *et al.* 2008; Sale *et al.* 2011). In fact, since the discovery of oil, the Gulf region has experienced a boom in economic activities and an unprecedented coastal development that has introduced a number of ecological stressors challenging its ecological integrity and sustainability (Sale *et al.* 2011). These stressors include pollution from the petrochemical industries, sewage treatment and desalination plants, habitat degradation from dredging and coastal reclamation as well as exploitation of natural resources from fishing and recreational activities (Sheppard *et al.* 1992; Hamza & Munawar 2009). While these activities have brought widespread prosperity to the region, they have also had a cumulative impact that affects the whole Gulf ecosystem.

2.1.2 Biodiversity in the Gulf

At the species level, the Gulf is considered biologically impoverished partly due to its young age but mostly because of harsh environmental conditions (Randall 1995; Bishop 2003; Sheppard *et al.* 2010). Unlike many of the world's oceans, which were formed several hundred million years ago, the Gulf is a relatively young sea dating back to approximately 3.5 million years with a marine history of approximately 15,000 years (Sheppard *et al.* 2010). This body of water only reached its current sea level during the Holocene period, around 6,000 years B.P., and the marine taxa that now exist in these waters are derived by the penetration of species from the Indian Ocean through the Strait of Hormuz (Price 1993; Beech 2004a). It is believed that most of the organisms living in the Gulf survive at the limits of their physiological tolerance due to its extreme environmental characteristics (Beech 2004a). The most extensive high-diverse marine environments in the Gulf are coral reefs and the coral dominated substrate of hard grounds, seagrass meadows and algal beds. Basson *et al.* (1977) reported low species richness for these waters and this was confirmed by most later research on benthic groups such as corals and echinoderms (Price & Coles 1992; Sheppard *et al.* 1992). On the other hand, the Gulf is also a recognized body of water for at least four species of endangered marine turtles, over ten species of cetaceans, the second largest population of dugongs in the world, as well as a large number of endemic and migratory birds (Hellyer & Aspinall 2005).

Although fisheries research in the Gulf and Gulf of Oman dates back to 1775 with the first Danish expedition involving Forsskål, relatively little is still know about the Gulf marine fauna (Beech 2004b). A number of studies using various methodologies have produced lists and books on the marine fishes of the Gulf. Beech (2004a) and Grandcourt (2012) provide a good summary of the various literature and species lists published by several countries in the region. Based on these publications, between 200 and up to 550 species, including reef associated fish, as well as sharks and rays, have been recorded from the Gulf (Krupp *et al.* 2000; Grandcourt 2012). When compared with the fish fauna documented in Oman, it is clear that the Gulf is limited in its fish biodiversity and low numbers of species are endemic to these waters (Randall 1995; Carpenter *et al.* 1997; Bishop 2003; Beech 2004b). However, the main problems that arise from the available literature are the many misidentifications found within them and the taxonomic changes that have occurred since their publication (Randall 1995; Beech 2004b; Grandcourt 2012). Furthermore, many of these accounts do not distinguish between locations where species were recorded and are based on historical records rather than actual specimens, which means that the distribution of many species remains poorly documented (Randall 1995; Bishop 2003). More recent publications including Randall (1995) and Carpenter *et al.* (1997) have summarized many of these reports and represent the most recent attempts to update the taxonomy and description of fishes in the region.

It appears there are regional variations in species richness throughout the Gulf with fewer species identified in western and southern areas while northern, eastern areas, as well as those of deeper waters closer to the Strait of Hormuz, are relatively richer in certain species (Price 1993; Beech 2004b). This is believed to be related to several factors including the bottom topography and sediment type of the Gulf (Beech 2004b). Basson *et al.* (1977) suggested that certain species associate themselves with different habitats and their occurrence within those ecosystems can vary seasonally. Highly productive ecosystems such as the intertidal mudflats, seagrass and algal beds, mangrove forests and coral reefs are supported within shallow areas and provide nursery, foraging, and breeding grounds for a number of marine species including mammals, sirenians, reptiles, teleost fish and elasmobranchs (Carpenter *et al.* 1997). Therefore, ecological gradients and controls have to be taken into consideration when investigating species distribution and abundance in the Gulf (Sheppard *et al.* 1992).

2.1.3 The United Arab Emirates

The UAE lies along the southeastern coast of the Gulf and extends across the Hajjar Mountains to the Gulf of Oman between the latitudes of 22° and 26° N and the longitudes of 51° and 57° E. The country's total area is approximately 82,880 km^2

with a coastline stretching to roughly 740 km including some 650 km of the western coast of the Gulf (Vine 2009). The Emirate of Abu Dhabi accounts for 87% of the country's total landmass while other emirates are significantly smaller. Its EEZ totals about 59,000 km^2 encompassing a large number of small islands in the Gulf, located a few hundred meters from shore to more than 150 km offshore (Al Abed & Hellyer 2001). The UAE has two separate coastal areas, including the sandy and low Gulf coast and the rocky and somewhat steep Gulf of Oman coast and, therefore, occupies a strategic location along the southern end of the Strait of Hormuz. The coast is characterized by a number of broad, sandy flats and lagoons, and is edged with barrier and fringing reefs. Most of the southern Gulf region has a bottom topography which is mostly flat, featureless, and dominated by soft sediments (Carpenter *et al.* 1997). The area between Qatar and the UAE is very shallow and only becomes deeper closer to the offshore islands. This offshore area is a barrier complex of islands and shallow areas that have fringing and patch reefs colonized by corals (EAD 2011b). Much of the shoreline consists of gently sloping beaches with a gradual blending of marine-terrestrial conditions sometimes extending over a number of kilometers.

The most productive and diverse aquatic habitats of the UAE occur within the sheltered waters along the coast and offshore islands. There, mangrove forests, seagrass beds, saltmarshes, macro-algal beds, mud flats, nutrient-rich shallows, and coral reefs occur, supporting a great variety of coastal and marine species (EAD 2011a). While the UAE is sparsely populated in some areas, some coastal regions are now under pressure because of the growing population. The latest census figures from 2005 show the UAE's population at 4.1 million compared to 2.4 million in 1995 while the estimated population for 2010 is at 8.2 million comprising of approximately 85% expatriates (National Bureau of Statistics 2012). This growth is concentrated in some urban areas such as Abu Dhabi Island and Dubai, and has brought with it a demand for various resources such as new infrastructure as well as fresh water and electricity, which is further increasing the human impact on the environment.

2.3 Sampling procedures

The main study area was the approximately 650 km of the Gulf coastline of the UAE. Fieldwork was principally conducted along this coast, except for the interviews detailed in **Chapter III**, which were conducted across the country. To avoid unnecessary repetition in several chapters, details of the data collection from market and landing site surveys, as well as genetic sampling methods, are provided below. The remaining methodologies are provided in each individual chapter.

2.3.1 Market and landing site surveys

From April to June 2010, several exploratory market and landing site visits were carried out to determine sites with the largest concentrations of shark catches. It was therefore decided that the focus of this study, would be the landing sites in the Western (Mina Zayed, Abu Dhabi), Central (Jubail fish market, Sharjah) and Northern (Maarid fish market, Ras Al Khaimah) regions. While several landing sites can be found within each region, these three locations are found along the coastline and vessels offload their catches directly at each site, which allowed some control in terms of accuracy of capture location. Vessels operating and offloading at these sites fish exclusively in Gulf waters and it was therefore possible to ensure that all species recorded were from the Gulf and not Arabian Sea waters. Furthermore, fishermen from nearby landing sites transport any large catches to these markets at the time of auction, which enabled a larger number of samples to be collected during each survey.

Fishermen in the UAE land their catches several times a day and therefore the survey was split into two components: landing-sites where data were recorded based on landings, and fish wholesale markets where fish landing at other times of the day could still be recorded. Landing site visits were made prior to the start of the main auction of the day, when the majority of catches were on display, and were at different times of the day, i.e. between 4:30 and 8:00 h in Abu Dhabi, 16:00 and 18:30 h in Sharjah, and 12:30 and 15:00 h in Ras Al Khaimah. Sharks found at landing sites were always caught from UAE Gulf waters while those found at the markets were sometimes transported from other Emirates or from Oman. Data were recorded on the origin of each shark and only those landed in UAE waters were considered for analysis in **Chapter IV**. All sharks originating from other locations, i.e. Oman, were included in the trade analysis in **Chapter VI**.

Data collection commenced at the start of October 2010 and was ongoing until the end of September 2012. Each site was visited twice a month on a rotational basis until January 2012, when visits were reduced to once a month. After plotting the cumulative number of species present at each market visit against the number of market visits, it was determined that, even with a reduction in sampling frequency, surveys would be sufficient to describe the species composition at landing sites (see **Chapter IV**, section **4.2**). Each visit lasted three to four hours depending on the quantities of sharks landed.

When sharks were found, specimens were identified to the lowest possible taxonomic level using keys from Compagno (2002), Last and Stevens (2009), and Carpenter *et al.* (1997). Due to the large number of sharks typically landed on each of the days surveyed, weight measurements could not be taken. Total length (stretched total length, L_T, from tip of snout to posterior tip of tail, with tail flexed down to midline) of each individual was measured to the nearest 1.0 mm using a soft tape along the side of the body following Compagno (1984), and sex was determined. For males, an external examination of the extent of calcification of the claspers determined the maturity stage: stage 1 (immature), possessing non-calcified claspers that are pliable; stage 2 (maturing), possessing partially calcified claspers with distal cartilage elements present but not fully developed; stage 3 (mature), possessing fully calcified claspers with distal terminal elements fully developed. The reproductive status of females was not assessed but gravid females were recorded based on visual observation of late term embryos. Those individuals, mainly from placentaly viviparous species, which possessed visible umbilical scars that slowly close during the first few months of life, were considered neonates or young of year (YOY).

Because trade in sharks between the Emirates does occur, sharks sampled were marked with cuts on their left gills, and visits to markets did not occur on consecutive days and weeks in order to avoid any chance of double-counting sharks. Species composition, sizes, and sex of catches originating from the three regions (western, central, northern) were opportunistically recorded in Dubai while conducting trade surveys (see **Chapter VI**) and were included in the analysis in **Chapter IV**.

Trade surveys described in **Chapter VI** were conducted at the Deira fish market in Dubai where sharks are auctioned daily from 17:00 to 20:00 h. Data were collected four times a month until January 2012 and then reduced to twice a month until September 2012. While on some days sharks were transported from other emirates to the Deira fish market, the large majority of the sharks and fins auctioned at this site originated from Oman. Sharks were typically offloaded from the trucks and, shortly after, the auctions and removal of the fins began. Due to the large number of sharks typically found at this site, measurements and biological data could not always be taken from all individuals between the offload time and the start of the fin removal process. When this was not possible, the number of each species and capture location was recorded or, if species were not identifiable because they were lacking key morphological characteristics (i.e. fins), then the number of individuals that were not sampled was noted. Sharks here were displayed on a platform and placed side by side for sale, making it difficult to move these large specimens and get accurate sizes. Measurements were therefore made over the curve of the body and may be slightly larger as a result of body curvature (ICES 2010). Furthermore, errors may have originated from the twisted and distorted shapes that sometimes resulted from transport procedures. All other data relevant to sex and maturity were recorded as described above.

Finally, the IUCN Red List Status of each shark species recorded at both market and landing sites for the UAE and from the traded species, was investigated to determine the relative risk of extinction of each species based on global assessments.

This provided baseline information on the conservation status of these species in other areas in the world.

2.3.2 Sampling for genetic analysis

Tissue samples from 5,797 shark specimens were collected at landing sites and markets from fresh and frozen animals as well as fresh or dried fin specimens caught in Gulf waters or transported from various areas in Oman. For all specimens, tissue was sampled only from the last left gill slit to avoid sampling the same specimen more than once. All specimens were morphologically identified and data were collected as described in Section **2.3.1**. Samples originating from fresh or dried fins could not be identified to species level and only information about their origin was recorded. All samples were immediately stored in eppendorf tubes, preserved in 95% ethanol, and taken to the laboratory for storage at -20°C until required for analyses.

A sub-sample of these DNA tissues (n=785) was barcoded for this project to confirm species identification. Laboratory analyses, including DNA extraction, polymerase chain reaction (PCR) and sequencing, were undertaken at the Molecular Biology Laboratory of the United Arab Emirates University (UAEU) and in collaboration with the King Abdullah University of Science and Technology (KAUST), Red Sea Research Center, in Saudi Arabia; the Nova Southeastern University, Guy Harvey Research Institute, in the US; and University of Guelph, Canadian Barcode of Life Network at the Biodiversity Institute of Ontario (BOLD), in Canada. Details of the various techniques utilized for analyses are presented in **Chapter IV** section **4.2** and **Chapter VI** section **6.2**.

CHAPTER III

THE SHARK FISHERY IN THE UAE: AN INTERVIEW BASED APPROACH TO ASSESS THE STATUS OF SHARKS

3.1 Introduction

In the past few decades, there has been recognition that wildlife conservation can no longer be solely based on biological data (Kellert 1985; Newhouse 1990; Mangel *et al.* 1996; McCool & Guthrie 2001; Riley *et al.* 2002). The use of social sciences in the development of appropriate management regimes is now strongly advocated (Mangel *et al.* 1996; Mehta & Kellert 1998; Zinn *et al.* 1998; Conforti & Cascelli de Azverdo 2003; Hunter & Rinner 2004; McCleery *et al.* 2006; Miller 2009) and many government agencies have a legal mandate to involve all stakeholders and consider their needs and aspirations in the decision making process (Bright & Manfredo 1997; Tarrant *et al.* 1997; Casey *et al.* 2005). Therefore, governments have begun to incorporate a 'human dimensions' study in natural resource management to determine and understand public attitudes toward various wildlife species or conservation initiatives (Bright & Manfredo 1997; Riley *et al.* 2002; Hunter & Rinner 2004).

Fisheries management has progressed and now requires a wide range of socio-economic and cultural information regarding fishermen and fishing communities (Silver & Campbell 2005). The human component of fisheries is formed by the behavioral processes of the fishermen, which is of vital importance for their conservation and sustainable use (Moore *et al.* 2010b). Coastal resource managers have understood that the relationship between people and their environment, particularly in coastal communities which rely on marine resources for their survival, are extremely complex. It is therefore critical to monitor the biological characteristics of the marine environment and the human interdependence in order to determine the sustainability of coastal ecosystems (Epps & Benbow 2007). In fact, the successful implementation of a long-term management strategy is only possible with the knowledge and specific management of social and economic standards of a community. Some crucial information needed for management can only be collected through cooperation from local fishermen and includes the economic, social and cultural values of a fishery, the methods of capture and use of marine resources, and an understanding of the interactions between fishermen and other stakeholders (Silver & Campbell 2005). Finally, understanding the attitudes and functions of individual fishermen allows comprehending the human impact on various resources and leads to the identification as well as resolution of some conservation problems.

Fishermen's knowledge and observations of their ecological systems and traditional knowledge learned from elders can be complementary and beneficial to other scientific investigations while being used as a preliminary stage of ecological studies (Poizat & Baran 1997; Miller 2009). This knowledge can assist managers and policy makers in making better-informed decisions to deal with multi-faceted issues by providing an overview of likely responses from communities and stakeholders to wildlife management initiatives and decisions (Miller 2009). This is especially true since fishermen can have knowledge of various species, their behavior, feeding, distribution and reproduction (Johannes *et al.* 2000). Even if fishermen do not actively target some species, it is assumed that they would have 'Local Ecological Knowledge' on the seasonal occurrence, abundance and distribution of species in the areas they fish, and would be able to identify population trends, since they have accumulated information over years or even generations while fishing for other species of fish (Dicken 2006). Therefore, the use of social science as an interdisciplinary approach to data collection allows characterizing gear use and fishing effort of artisanal fisheries, estimating bycatch (Silver & Campbell 2005; Moore *et al.* 2010b), identifying and assessing the status and history of unmonitored species (Lam & Sadovy de Mitcheson 2011), as well as describing rapidly occurring environmental threats and the establishment of conservation priorities (Silver & Campbell 2005).

In artisanal fisheries, consisting of thousands of fishermen with little or no management infrastructure, researchers have to rely on the knowledge of fishermen to better understand interactions with coastal ecosystems and fill information gaps (Moore *et al.* 2010b). Understanding the motivational factors that prompt a fishery is fundamental (Ormsby 2004) since the increased demand and pressure for fisheries resources are not always local in origin, but national or even international, and can result in the overexploitation of target species (Epps & Benbow 2007). While industrial shark fisheries are considered to harvest the greatest shark biomass, it has been suggested that artisanal shark fisheries should not be overlooked since their overall shark landings can also be considerable (Bonfil 1994; Barker & Schluessel 2005). Generally, artisanal fisheries are data poor in terms of boat registrations and numbers of fishermen and therefore national or global fisheries statistics may not provide an accurate illustration of the fishing capacity or activity (Moore *et al.* 2010b). Without accurate scientific data, researchers have to rely on the acquisition of local knowledge to better understand artisanal fisheries and their interactions with coastal ecosystems (Johannes *et al.* 2000; Moore *et al.* 2010b). In fact, evaluating a fishery through a retrospective approach by combining historical literature, anecdotal data and fishermen accounts, allows generation of a profile of relatively unknown fisheries (Cheung & Sadovy 2004; Lam & Sadovy de Mitcheson 2011). This informal data also allows the prevention of the 'shifting baseline syndrome' where scientists and fishermen believe that stock sizes and species composition that occur at the start of their own career are the baseline against which to determine change patterns and use them as reference points (Pauly 1995).

While there are limitations to social survey data, interviews can provide useful information in economic and social sciences when data are limited or difficult to collect by other means (Moore *et al.* 2010b; Rasalato *et al.* 2010; Humber *et al.* 2011). Therefore, a growing body of research has favored using local ecological knowledge over more expensive and time-consuming methods to obtain information on several temporal and spatial scales (Poizat & Baran 1997), and to characterize rapidly occurring environmental threats in order to establish conservation priorities (Moore *et al.* 2010b). Face to face interviews, which involves the administration of a survey in which the interviewer questions an interviewee using a structured set of questions, is a highly regarded method in social science (Moscardo & Ormsby 2004). These types of interviews are used routinely, usually obtain high response rates, and imply that less bias is introduced into the data (Singleton *et al.* 1993). Furthermore, the interviewer can ensure that respondents attempt to reply all questions, and that questions can be clarified so that informants understand what is being asked of them (Singleton *et al.*

1993). Finally, visual aids such as photographs or illustrations can be presented which provides an additional means of collecting information.

Because little information is available on the shark fishery in the UAE (refer to **Chapter I** Section **1.2.4**), including an absence of long-term data sets, increasing knowledge of the interactions between fishermen and sharks through anecdotal information from fishermen is crucial. As a result of more advanced fishing technology, and a greater number of vessels in the water, fishing effort along the coast of the UAE has continued to increase. Fisheries managers are now faced with the challenge of conserving targeted fish stocks while ensuring equitable resource allocation and sustained multiple use. Therefore, if the effects of fishing are to be managed successfully, it is clearly in the interest of conservation and fisheries agencies to identify and achieve an understanding of the social, economic and ecological implications of fishermen and their activities. Conventional methods alone cannot generate a picture of the shark resources of this region because of the lack of official data collected. Thus, studies using traditional knowledge to supplement scientific data are urgently needed to address changes in the status of sharks within UAE fisheries.

This chapter describes the artisanal shark fishery of the UAE based on data collected from fishermen knowledge. The objectives were to 1) record historical knowledge and current perceptions on the status of the shark fishery in the UAE; 2) gain an understanding of the nature of the interactions between fishermen and sharks; 3) survey the spatial distribution, patterns of fishing, preferences and targets of the artisanal shark fishery; 4) characterize gear use, catch seasonality and location, uses of sharks, and fishermen perception of sharks by using informal sources of information; 5) demonstrate any changes that may have occurred in shark abundance, catches, and body size over recent decades based on fishermen interviews; 6) provide managers with a greater insight into the needs and preferences of fishermen as well as areas where management controls may be most necessary, whilst building a database from which effective decisions can be made.

3.2 Materials and methods

3.2.1 Study design

A pilot survey of artisanal fishing sites along the eastern and western coast of the UAE was conducted in May 2010. The entire coastline was traveled by vehicle to ensure fishing camps were located. To obtain a representative picture of the shark fishery and to understand its recent history and the long-term historical trends in the status of sharks along the coast of the UAE, main fishing and landing sites across the country were selected as study areas. These sites were selected based on referrals from fishermen, government officials and the current literature. The data collection took place in June, July, and September 2010.

Opportunistic sampling was conducted near fishing ports, at landing sites, and fishermen 'majlis' (a meeting place where fishermen gather for social interactions) with people known to have participated or be still involved in the shark fishery. Since fishing is exclusively a male activity, all respondents were male. Selections were based on the presence of fishermen in these areas and informants were also asked to suggest other peers they believed had knowledge of sharks and shark fisheries.

3.2.2 Questionnaire design and content

The purpose of the survey instrument was to gain an understanding of the artisanal shark fishery in the UAE with an insight into the social, motivational and economic aspects behind it. Only semi-structured interviews were used because of insufficient baseline knowledge on the topic to structure questions for the survey. Although well-designed open-ended questions may provide data of equivalent precision to closed format ones, the latter generally result in less uncertainty, for both the respondent and the researcher (White *et al.* 2005). One-on-one interviews were preferred to avoid interference from other informants, but on one occasion group interviews were made (Fujeirah, Al Aquamiah, **Appendix B**, **Plate 3.1.**). Each interview required about 30 minutes to complete, but sometimes lasted as long as two hours since fishermen were allowed a certain degree of freedom to initiate new topics and provide additional information regarding the shark fishery. The approximate order of survey questions was followed but participants were allowed to bring up topics. Nearly 90% of fishermen approached agreed to participate in interviews. Refusal to participate was usually due to lack of sufficient time especially closer to Muslim prayer times.

Interviews were initiated by informing all potential respondents the affiliation of the interviewer, that this study formed part of a PhD project investigating sharks and the various species found in the Gulf, clarifying that their identity was not being recorded (unless they voluntarily provided their names), and by guaranteeing strict confidentiality. Interviews were conducted in Arabic based on a questionnaire of 47 semi-structured and unstructured questions previously tested and adjusted through pilot interviews with the same target population (a copy of the survey in English and

Arabic is presented in **App. C**). The survey was divided into four sections described as: Section (1) background information, with questions about age, fishing background, sources of income, time spent fishing, and position on boat; Section (2) vessel and fishing gear characteristics, with questions about the type of boat used, duration and seasonality of trips, main target species and fishing locations; Section (3) shark catches, with questions on species composition, top target species, local names of species, catch locations, description of catches and shark sizes over time, fishing practices, shark utilization and retail price of sharks and shark products; Section (4) perception and participation, with questions regarding their knowledge of shark legislation, opinion on shark conservation and their interest in getting involved in future management measures. This last section was developed to gauge knowledge of Ministerial Decree 542 dealing with sharks and other environmental legislations.

During the interview, a shark guide (Compagno *et al.* 2005) was used to clarify species identifications, since fishermen use local names for species and these differ between communities. Furthermore, illustrations of non-local shark species provided a test to the reliability of respondents' answers. Gear illustrations were also used to confirm types of gear used in the fishery and a map of the UAE coastline was provided to identify fishing grounds (Moore *et al.* 2010b). While the accuracy of locations highlighted by fishermen can be questioned, this provided a good overview of general areas fished. Notes on the behavior in responding to questions such as pauses or hesitations and other key points presented by the respondents were noted.

All interviews were stopped when the information and knowledge collected from different respondents converged (Beebe 2001). This occurred when the majority of topics and conversations began to be repeated and it was likely that little additional information was going to be gained about the fishery. Therefore, while the number of interviews conducted (n=126) is not a representative sample of the total fishermen population in the UAE, the study provided enough information to begin to understand the shark fishery from the perspective of the fishermen and to determine whether they had seen a trend in the abundance of sharks.

3.2.3 Data analysis

All interviews were translated to English and data was classified, coded and analyzed using SPSS (Statistical Package for Social Sciences) in order to undertake descriptive and statistical analyses. Firstly, data was summarized to provide a basic description of the sample and how they responded to individual question items. Secondly, cross-generational differences were first tested for significant deviations from normality using the Anderson-Darling test (Zar 2010). In all cases, a significant deviation was found ($p<0.05$) and therefore difference among the various age groups were tested using a one-way analysis of variance (ANOVA) with Tukey post-hoc comparisons of the six age groups (significance level at $p<0.05$).

3.3 Results

3.3.1 The fishermen

A total of 126 interviews were conducted in the Western (n=26), Central (n=50), Northern (n=22) and Eastern (n=28) regions of the UAE at 17 different fishing camps and locations (**App. A, Table 3.1.**). These locations varied from very small landing sites with basic structures (e.g. Sila) to locations where fisheries cooperatives were established and modern facilities were available, e.g. Jubail market in Sharjah. All interviewees were Emirati fishermen ranging in age from 20 to 79 years old (mean= 52.04 ± 13.02 S.D.) (**Figure 3.1.**). Fishermen were over-represented in the middle age groups (40-49 years old and 50 to 59 years old), accounting for 40.2% of the sample, and under-represented by those who indicated they were in the younger age groups (20 to 29 years old), who represented only 2.4% of the sample.

The fishermen stated they had learnt to fish between the time they were born and before they were 40 years old. Fishing was typically a family tradition with 89.7% of respondents coming from fishing families and having learnt their fishing skills from their fathers or close relatives. Respondents had acquired in-depth knowledge of Gulf waters and its marine resources with 47.6% of fishermen surveyed possessing over forty years fishing experience and 49.2% having between 20 and 39 years of experience (range from eight to 70 years of fishing experience, mean= 39.5 ± 13.93 S.D.) (**Figure 3.2.**). Almost half of the fishermen interviewed (n=56) had started fishing as children and before the age of 15.

The majority of these fishermen (58.7%) earned their living from other occupations, such as government or administrative jobs, but complemented their income from fishing. Fishing was the primary occupation for only 30.9% of the respondents with a further 10.3% of them involved in the fishing industry or retired (**Figure 3.3.**). The fishermen studied operated both dhows (27.8%) and tarads (72.2%) for their fishing activities while occupying various positions on the boat. The majority of respondents (63.5%) owned their boats while the remaining 36.5% worked as captains either on a family member's or a friend's vessel. While the traditional dhow is still operational, some fishermen stated that over the years, they have increasingly invested in tarads to reduce the amount of time at sea, access sites further offshore faster, and concurrently cover the expenses associated with their fishing activity.

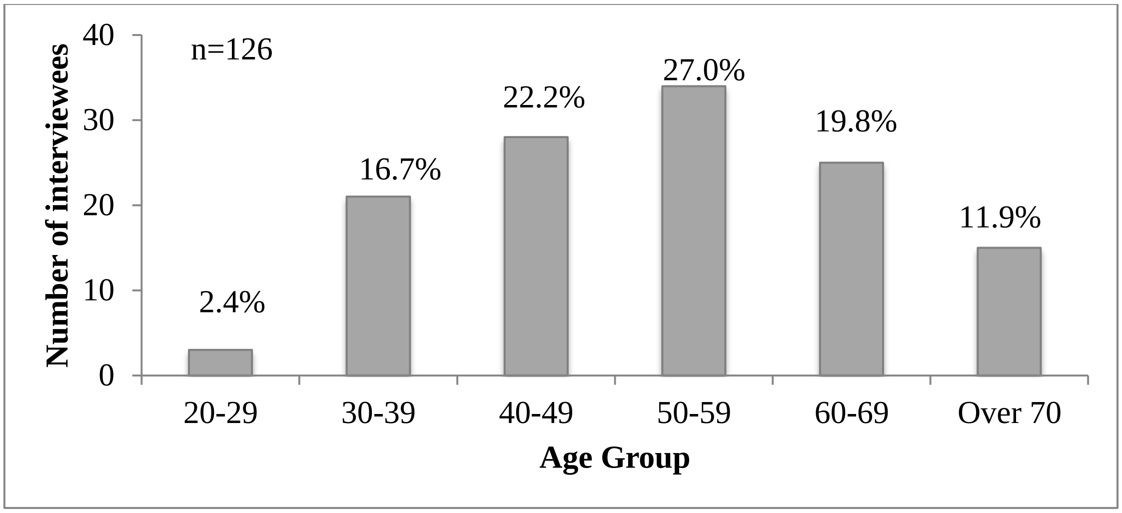

Figure 3.1. The age of interviewees showing the percentage of respondents in each age category.

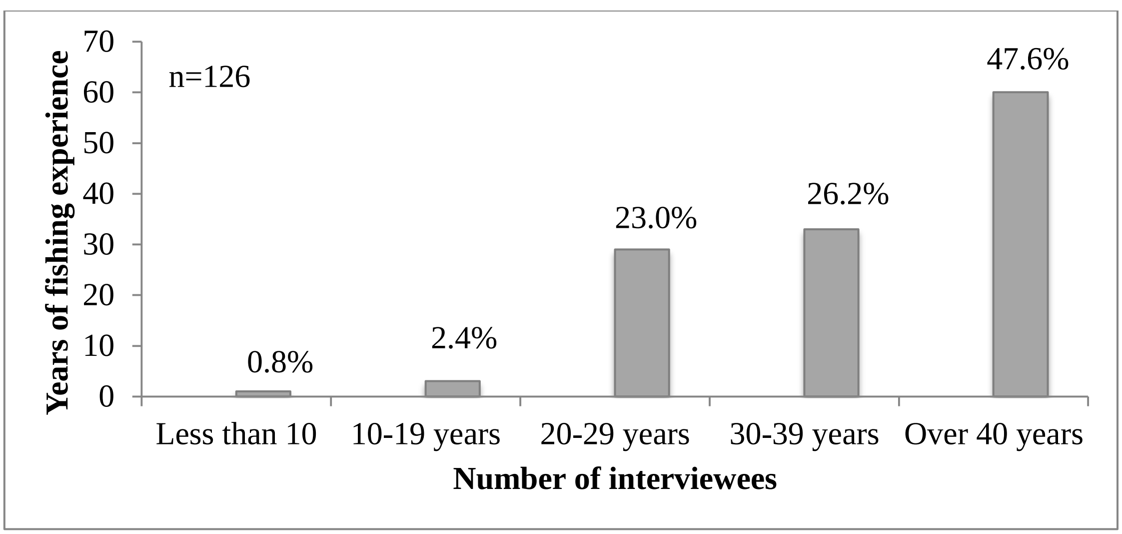

Figure 3.2. Interviewee years of fishing experience showing the percentage of respondents in each category.

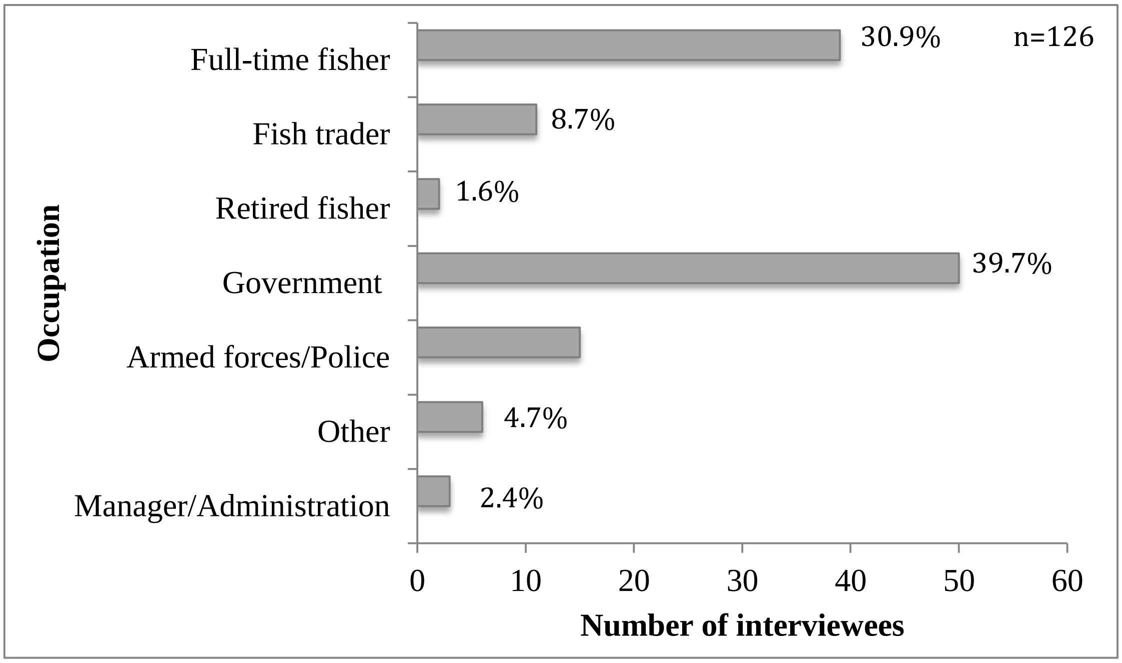

Figure 3.3. The occupation of interviewees showing the percentage of respondents in each occupational category.

3.3.2 Fishing gear and techniques

Dhows, ranging in size between 14 and 21 m, with inboard engines of up to 400 HP, spent between 24 hours and up to 10 days at sea with 40% of them fishing between three to five days. These vessels often covered areas up to 270 km from their port of departure. Tarads, ranging in size between six and 15 m, with mainly two outboard engines (91.2%) of 45 to 300 HP each, spent a couple of hours and up to a full day fishing on each trip with the majority averaging between six and 12 hours at sea (79.1%). These fishermen stated that they either spent time fishing in coastal areas or, if the weather allowed, would travel up to 130-185 km in all directions to find more productive fishing grounds. Dhow fishermen usually had anything between two to 15 workers and tarads between one to six workers, originating from the subcontinent (mainly India, Pakistan and Bangladesh), assisting them on the vessels.

However, some tarad fishermen mentioned they occasionally went out fishing on their own.

For all vessels, Abu Dhabi fishermen tended to target areas closer to the offshore islands of the Emirate and outside the established MPA's, but some travelled all the way to Sir Bu Nair Island and even to the offshore waters of Dubai. Dubai fishermen also travelled long distances ranging from the waters of Ras Al Khaimah to the western border of Abu Dhabi. Fishermen from Ajman, Sharjah, Umm Al Quwain, and Ras Al Khaimah stayed relatively close to the waters of their respective emirates but frequently travelled closer to the border with Iran and Oman (Musandam). All respondents stated they never left Gulf waters and limited their fishing to areas before the Omani border of the Musandam Peninsula. Similarly, fishermen in Fujeirah remained in waters of their emirate but spent more time out at sea in deep water locations up to 90 to 100 km offshore. When asked about locations where most sharks were caught, 85.7% of respondents stated they had no specific catch areas and that sharks could be fished in the general areas they visited. Only 10.3% of fishermen mentioned offshore deeper waters as appropriate locations for shark fishing, whereas 3.2% stated that waters around the islands of Sir Bu Nair, Al Yasat and Dalma were good locations. Maps used during interviews to collect spatial information on fishing patterns indicated that fishermen were mostly unable to interpret maps, or specify exact fishing locations or distances from the shore where they fished. However, results from all interviews combined (both oral descriptions and fishing locations highlighted on maps) clearly show that all waters within the Gulf are utilized (**Figure 3.4.**).

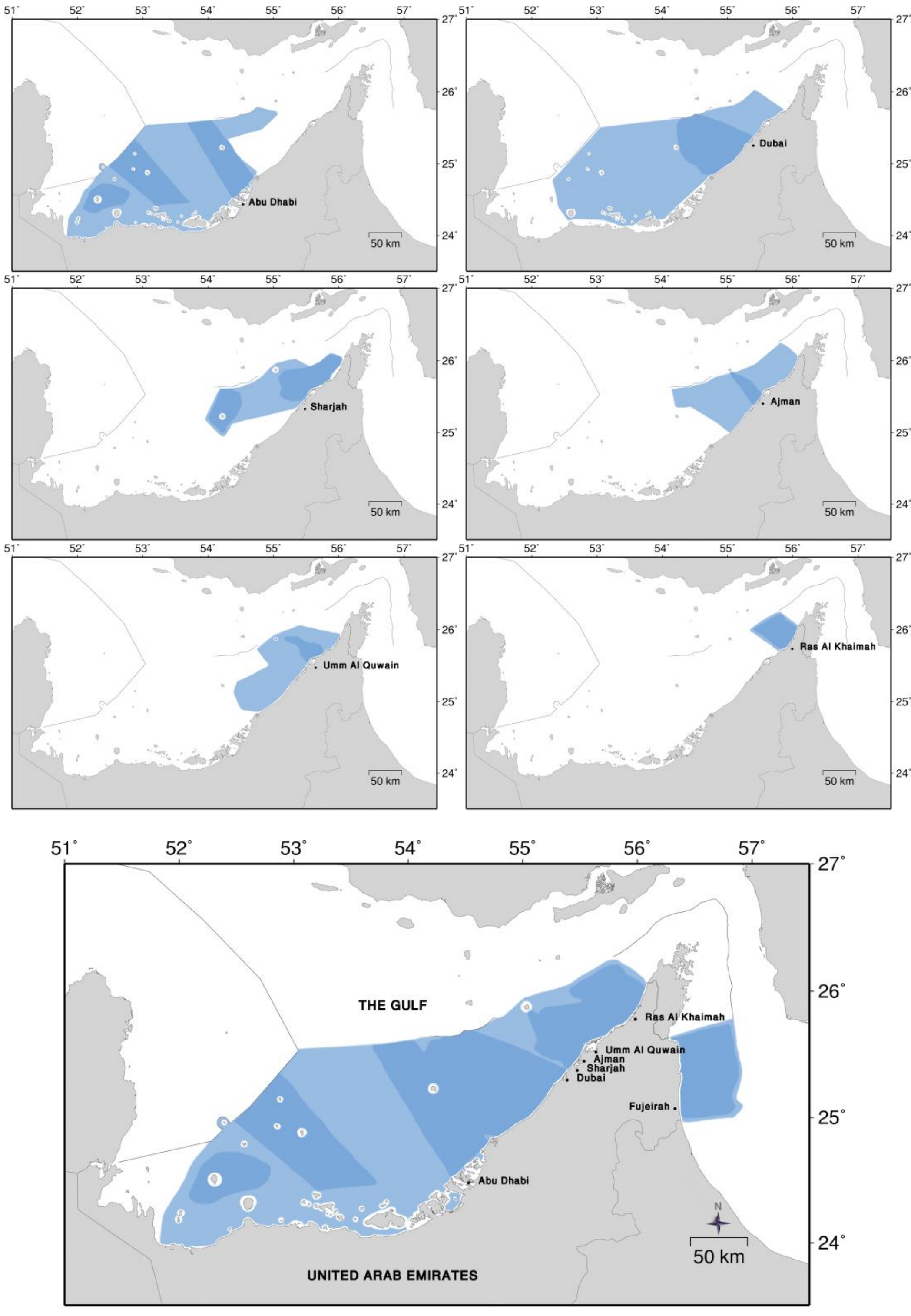

Figure 3.4. Approximate fishing grounds highlighted by fishermen from each emirate. Darker blue color represents intensively fished areas. The bottom map combines all information from other maps and data collected from Fujeirah. (MPAs not shown).

Fishermen used a multi-species, multi-gear approach as a response to the seasonal variability and fluctuating abundances of their various target species. According to respondents, 23.8% fished for all species and did not have a primary target. However, 54% of fishermen specifically targeted various species of Lethrinidae (Emperors), Scrombridae (Mackerels), and Serranidae (Groupers) as their main target species. The primary fishing gear cited for both types of vessels included drift nets and gill nets (53.2%), hand lines (30.1%), gargoors (9.5%), longlines (5.5%) and trolling (1.6%). However, fishermen used multiple gears on each trip and gargoors were the most cited gear (28.6%) used in combination with other equipment. Longlines were mainly used by dhows (17.1%) and only three fishermen operating tarads confirmed use of this gear. When asked about which gear catches the most sharks, respondents stated all sharks could be caught using hooks of various sizes (60.3%), nets (36.5%), and only 3.1% stated sharks could be caught with all gear types.

Fishermen believed small sharks (<1.5 m in length) could be caught using hooks of various sizes (54%) and nets (44.4%), while large sharks (>1.5 m in length) were mainly caught using hooks (78.6%) and sometimes in nets (20.6%). The largest quantities of sharks were believed to be caught using hooks of various sizes (66.6%), namely on longlines (48.4%), but a few fishermen mentioned the use of drum lines (anchored floating drum with a baited hook attached to it).

Hooks used were generally J-type hooks attached to monofilament for the hand lines or to rope, and sometimes chains, for the longlines (**App. B, Plate 3.2.**). Usually, there was no consensus on the type of bait to use when fishing in general or for catching sharks with 29 species of local fish reported. Furthermore, each fisherman had his own preference depending on the availability of fish on the boat.

3.3.3 Fishing periods and seasons

The fishing season extends throughout the year and 91.3% of the fishermen reported fishing all year long. In fact, 42.9% of fishermen stated they go out fishing every day if the weather permits. The average number of days spent at sea per month ranged between six and 30 days (mean= 21.03 ± 8.95 S.D.) and only 10.3% of respondents spent less than 10 days at sea each month. However, 7.1% of fishermen stated they spend less time at sea and go fishing at different times of the day during the hot summer months from June to September. Generally, dhow fishermen fished all day (57.1%) or in the early hours of the day between 6:00 and 12:00 h (42.8%) when out at sea. On the other hand, tarad fishermen had varying fishing schedules. Some fishermen (25.3%) stated they fished all day while others preferred fishing only during daytime from 12:00 to 18:00 h (27.5%), in evenings from 18:00 to 00:00 h (9.9%), overnight from 18:00 to 6:00 h (17.6%), or in mornings from 6:00 to 12:00 h (18.7%).

When asked about the best season to catch sharks, 81% of respondents reported that winter (December to February) and spring (March to May) were the high seasons for catching sharks with anything between one to 20 large sharks, and between 100 and up to 1000 small sharks, caught during one fishing trip. Catches reported were disproportionate among the fishermen using various gear but respondents agreed that the large number of small sharks were usually caught in nets. Large sharks were mainly caught on large hooks left soaking overnight.

The low season was reported as being the summer (June to August) by 75.4% of respondents with no shark catches or only up to 20 small sharks caught during a fishing trip. There was no general agreement as to the best times of the day to fish for sharks. However, 54% of respondents believed that the best time for shark fishing was either in the evenings or overnight from 18:00 to 6:00 h. The remaining 43% of respondents felt that sharks could be caught at any time of the day.

3.3.4 Shark diversity and utilization

When shown illustrations of the various species of sharks from around the world, fishermen were able to distinguish between the various families of sharks. However, respondents found it hard to differentiate between similar species and commented instead on their general appearance and distinct features they may have such as blacktips, heads in the shape of a hammer (hammerheads), stripes (for tiger sharks), and bottom dwellers (i.e. carpet sharks). Since knowledge of sharks, and the ability to distinguish between species, was low for all fishermen, species-specific information on catches was not possible to gather. Only 13.5% of fishermen stated there were over 10 shark species in UAE waters while others believed there were between six and 10 species (39.7%), less than five (31%), or didn't know (15.9%). Also, fishermen considered some elasmobranchs such as guitarfishes and sawfishes as sharks.

Fishermen had always fished for sharks (84.9%) and all respondents reported that they either targeted sharks (40.5%), took them incidentally as bycatch (26.2%), or both (33.3%). Sharks were mainly landed full (96.8%) and only 3.2% of fishermen stated they finned sharks at sea. Fishermen confirmed that in the past, sharks were also utilized when caught but that fins used to be of little importance. The meat was consumed fresh or dried, the eggs of species such as guitarfishes were eaten, the liver used for waterproofing dhows, while carcasses were retained and used as fertilizers. Some fishermen also stated that several species of sharks, including small carpet sharks and torpedo rays, were discarded both in the past and the present. Nowadays, respondents generally sold their catches (whole shark) at the local fish landing sites directly to middlemen known as shark traders that made daily buying trips from Dubai or Sharjah at the time of auctions and originating from India, Pakistan, China, Korea and Sri Lanka (88.9%). The remaining catches were sold directly to Fishermen Cooperative representatives or to buyers present at markets, especially in remote areas such as Sila in Abu Dhabi. These sharks were then transported to Dubai where they were re-auctioned and resold. Only 3.2% of respondents consumed their catches (usually those landing small sharks) while 43.6% stated they consumed most of the small sharks and sold the bigger catches, and 53.2% fully sold their catches. Fishermen declared that prices for sharks depended either on their sizes (65%), both sizes and species (23.8%), or on market values decided by the various traders (11.1%).

Small sharks were usually sold at landing sites for prices varying between AED 2 to AED 10 per kilo (kg) (USD 0.5 to 2.7 per kg) for each shark or as a bulk of up to AED 1,500 (USD 400) for approximately 100 sharks. Larger sharks could fetch prices between AED 150 (USD 40) and up to AED 3,000 (USD 810) per shark. Two dhow fishermen stated that one good shark-fishing day could bring them an additional income of up to AED 30,000 (USD 8,100) if large sharks were landed. The majority of fishermen (68.3%) admitted not knowing the price of shark fins since they sold their catches in full but were aware these were the most valuable body parts of the shark. The remaining fishermen were aware fins were usually dried or sold fresh at prices ranging from AED 300 to 4000 per *min* (about 4 kg) depending on the size of the fin and the species. Fishermen pointed to several species of sharks and batoids they targeted and considered most valuable. These included guitarfishes (27.8% of respondents), blacktip sharks (19%), hammerheads (13.5%) and sawfishes (14.3%).

3.3.5 Changes in shark stocks over time

Fishermen were asked whether they had observed changes in the numbers of sharks captured over the years. Respondents broadly agreed that sharks had decreased in their catches, size and abundance. Changes in catches were described by 82.5% of respondents, who also reported a significant decline for all shark species since they had begun fishing. Some fishermen also stated that species such as mako sharks (*Isurus oxyrinchus*) have disappeared from Gulf waters. Of these respondents, 70.7% declared overfishing and overexploitation of sharks as the main causes behind their lower catches. Some stated sharks were very difficult to catch nowadays, especially close to shore while others believed sharks were moving to deeper waters to 'escape' the rising numbers of fishermen targeting them. A majority of the fishermen (68.2%) agreed that sharks were smaller at capture than in the past, 28.6% had not seen a size difference, and 3.2% did not know. The predominant reason cited for these size changes was general overfishing (57%), yet 13.9% of the remaining respondents explained this was specifically due to overfishing of large sharks and because smaller sharks were not given the opportunity to grow before they were fished out.

Finally, fishermen were asked whether they thought sharks had increased, decreased, or remained the same in terms of abundance over the last 10 years, five years, and two years. A general decline in abundance was noted by 78.6% of all fishermen, while 11.9% believed populations had remained relatively constant or had increased (8.7%) in numbers. Those fishermen that had seen a decline in abundance started seeing a change at least 10 years before the time of the interviews (72.7%) and five years prior to the interviews (96%). When probed for more specific information regarding the start of the changes they have noted, 16.2% stated that they had started seeing a decline over 20 years ago and 40.4% believed it dated back to 15 years ago. Fishermen had many explanations and opinions for the causes of the observed changes. The majority (74.7%) of respondents attributed this decline to overfishing but other reasons stated included pollution, coastal development, weather changes and Iranians fishing in Gulf waters. **App. A, Table 3.2.** illustrates some quotes regarding the status of the shark fishery in the UAE.

3.3.6 Fishermen perceptions of sharks and their conservation

The majority of fishermen expressed concern about the status of the shark fishery in the UAE. Indeed, 76.2% of fishermen felt concerned about the future of sharks, 77.8% stated there should be regulations regarding the killing of sharks, and 76.2% thought sharks should be protected. Some of the reasons given for shark protection included ‘sharks bring with them other fish and clean the sea’, ‘they should be protected like other fish’, and to ‘maintain our heritage’. Respondents who disagreed with these statements tended to give responses stating that sharks ‘are too dangerous to protect', 'God will replenish shark stocks so there is no need for us to protect them', and 'it would not be fair if the UAE were the only country to protect sharks in the Gulf since other nations are allowed to fish for them'. Fishermen showed an understanding of national laws and regulations regarding the marine environment, specifically stipulations in Federal Laws 23 and 24 on fishing. They were able to specify the seasons where shark fishing was prohibited, that longlines were illegal and that only licensed dhows were permitted to capture sharks. However, only 36.5% of fishermen felt they were consulted by the government on fisheries decisions while 61.1% complained and felt excluded from the whole decision-making process. These respondents stated that they received their information regarding fishing regulations from the Fishermen Cooperatives and that even though workshops were sometimes held to gather their opinion, they were disappointed that decisions did not reflect their concerns. Finally, 75.4% of respondents indicated their willingness to be involved in government initiatives for the protection of sharks.

3.3.7 Cross-generational differences

Some cross-generational differences were tested to determine if there were differences in perceptions of the status of shark stocks in the UAE based on the various age groups. No significant differences were found when looking at differences in catches (ANOVA: $F_{5, 120} = 0.951$, $p > 0.05$), sizes of sharks (ANOVA: $F_{5, 120} = 1.441$, $p > 0.05$), and abundance (ANOVA: $F_{5, 120} = 1.540$, $p > 0.05$). However, a significant difference emerged when looking at the perception of the number of years since the start of shark declines. The number of years since the onset of the decline was significantly different across the six age groups (ANOVA: $F_{5, 120}$= 2.882, $p<0.05$). Post-hoc comparisons of the six groups indicated the ‘over 70 years’ group (Tukey: M=15.26, 95% C.I. [8.88, 21.64]) gave significantly longer times than the ‘20 to 29 years’ group (Tukey: M=1.66, 95% C.I. [-5.5, 8.83], p = 0.03) and the ‘30 to 39 years’ group (Tukey: M= 7.23, 95% C.I. [4.6, 9.86], p= 0.031). Older fishermen started seeing a difference in the abundance of sharks many years before younger fishermen. However, the general trend appeared to be that the majority of fishermen from all age groups have seen a decline in shark numbers since they began fishing in the area.

3.4 Discussion

The interviews were a rich source of information confirming the presence of a shark fishery in the UAE. The study provided insights into local fishermen perceptions and use of sharks, as well as a description of the geographical extent, size, vessel and gear characteristics, length of fishing season, target species and status of the artisanal shark fishery along the Gulf coast of the UAE. These data currently constitute the largest and only data set of its kind for the UAE and the broader region. While the lack of historical data precludes comparisons with the past status of the fishery and was insufficient to interpret the complex social, economic and cultural aspects of the shark fishery as relating to the lives of these fishermen, the data gathered provides a much needed baseline for future investigations into the shark fisheries of the region.

There are several areas that require more research attention to fully understand fishermen and their relationship with the marine environment in the UAE, but results from this study encourage consideration of ecological knowledge as an important source of information in a data poor area. While some information collected, including fishing locations, catch numbers and target species, were not accurate, this could be due to a combination of factors. Firstly, fishermen could genuinely not have been able to read maps and determine areas they usually fish or they were just reluctant to provide information regarding their preferred fishing spots. Secondly, data on catches could have been either overestimated for their target catch or underestimated for bycatch or protected species, presumably because fishermen may have had the perception that catch information supplied would eventually be used as a tool against them to place further restrictions and regulations on shark fishing (Moore *et al.* 2010b). Thirdly, the inability to identify sharks to a species-specific level and distinguish between different species could be due to low levels of knowledge about sharks in general, and to the similar appearance of many species, especially those from the Carcharhinidae family.

Reliable interview information requires access and trust with fishermen communities since information obtained depends on respondents' accuracy, a high degree of cooperation from fishermen and consistency in interpretation of questions (McCluskey & Lewison 2008). In this study, fishermen were welcoming, wanted to participate in the survey, and were willing to supply in depth information on the shark fishery. Furthermore, most of the information collected seemed to be corroborated by the majority of fishermen in interviews that were conducted privately. There is therefore no reason to doubt the reliability of the data and no evidence for under-reporting of fishing effort, local catches and processing activities.

As noted by Johannes *et al.* (2000), artisanal fishermen can accumulate invaluable knowledge over their fishing careers. The majority of fishermen in the UAE had accumulated over 35 years of fishing experience in the region and acquired knowledge of their target species both from their own fishing experience and undoubtedly due to the fact that a large number of them came from fishermen families and had, therefore, combined knowledge over generations. Findings suggest fishermen here are mostly a homogenous group possessing similar values, motivations, knowledge, preferences and levels of fishing experience. However, fisheries identified along the coast of the UAE were active year round, diverse, and highly opportunistic. All fishermen utilized either dhows and tarads, yet, their activities, effort level and fishing methods changed seasonally depending on the fisherman while a diversity of fish species, mainly teleosts, were targeted. Fishing effort could not be accurately quantified since it was difficult to ascertain which gear was used to catch sharks transported on trucks, and generally dhows and tarads could fish with variable numbers of hooks and nets for varying lengths of time. Therefore, future research will need to focus on gathering more specific data regarding the use of fishing equipment and time out at sea.

The nature of the fishery in the UAE was found to be similar to other fisheries in the region which have been described as small scale, multi-gear and multi-species with few industrial vessels in operation (Carpenter *et al.* 1997; Bonfil 2001; Mannini 2010). Furthermore, after Oman and Iran, the UAE is reported as having the largest number of registered vessels and fishermen in the RECOFI region (Mannini 2010) with similar numbers to those reported in Yemen for the Gulf of Aden fishery, i.e. up to 19,000 fishermen and 5,400 vessels (Bonfil 2001). Although further data needs to be collected on fishing effort, this implies that the fishery in the UAE is likely to have an impact on Gulf fish resources if exploitation levels are high. The type of fishing gear found here is also similar to that reported from other countries in the region (Carpenter *et al.* 1997) and was mainly characterized by nets, traps and hook and line. The only differences in the fishery characteristics for the region are likely to be due to the fishing grounds utilized, gear configurations and mechanization of vessels. For instance, while fishermen in Oman use similar vessels, they fish in waters that can reach 100 m in depth (Henderson *et al.* 2008) which would require gear modifications if fishermen were targeting demersal fish species. While similar in characteristics to each other, fisheries in the region are however different from others in the Indian Ocean which seem to operate on either much smaller or much larger scales. For instance, in Madagascar, artisanal fishermen mainly utilize small vessels with motors of less than 50 HP and fish in waters less than 100 m using mainly set gillnets of a variety of mesh sizes (Robinson & Sauer 2013). On the other hand, in Sri Lanka and the Seychelles, both artisanal and industrial fisheries exist utilizing a variety of equipment and using both inshore and offshore areas as fishing grounds (Joseph 1999; Nageon de Lestang 1999).

In this study, all fishermen confirmed that sharks have long been utilized in the UAE and meat had traditionally been consumed either fresh or dried forming an integral part of the local culture. Beech (2004b) had shown that this exploitation of shark resources by coastal communities in the UAE dated back to the 6-7th century since remains of shark vertebrae at several archeological sites were found to represent a dump of processed food. This seems to be a general historical trend in the region where sharks have formed the basis of many traditional food dishes in Kuwait (Gubanov & Schleib 1980), Qatar (Sivasubramaniam & Ibrahim 1984), and Oman (Henderson *et al.* 2006). However, even with a history of shark fisheries and the strong cultural dimension of sharks in the region, fishermen had little knowledge of different shark species and were unable to distinguish between them, hampering the collection of species-specific data. Generally, the reliability of information reported by fishermen is strongly dependent on the target taxa, which should be easily identifiable (Rasalato *et al.* 2010). It is clear from this study, especially through the use of shark illustrations during interviews, that fishermen were able to distinguish between, and recognize, several species of sharks. However, this was limited to family level identification and in many cases respondents could not differentiate between similar looking species such as the milk shark (*Rhizoprionodon acutus*) or the hardnose shark (*Carcharhinus macloti*). Fishermen did note that some species, including hammerheads and guitarfishes, yielded higher value fins and were therefore the most sought out to capture. Yet, because no accurate information could be collected regarding the various species, it was not possible to ascertain if changes in species composition had occurred. Furthermore, it was not possible to assess the scale and value of shark catches since fishermen recollection of the actual catches and their value was often vague. Further knowledge on the most targeted shark species would enable managers to estimate fishing pressure on each species and review current laws and regulations in relation to these types of sharks.

Although sharks were not the primary targets of the fisheries, they were targeted by a large number of fishermen. Unlike other areas in the world, where artisanal shark fisheries are still relied upon for subsistence and directly consumed in local markets (Bizzarro *et al.* 2009a), sharks landed across the UAE were typically caught to be sold whole directly to fin traders, providing a valuable source of additional income for most fishermen, especially those with other occupations. As has been recently documented in Oman (Henderson *et al.* 2007), fishermen here affirmed that sharks had only recently become commercially important with a shark fishery driven by the fin trade industry. Similarly, effort from a targeted artisanal shark fishery has increased over the past decades in northern Madagascar in response to this industry (Robinson & Sauer 2013). This economic incentive suggests that the artisanal fishery in the UAE could have a substantial impact on shark populations if shark resources are not managed appropriately. As seen in many countries, artisanal fisheries contribute to the majority catches and can have significant impacts on local ecosystems (McCluskey & Lewison 2008). Therefore, given the severe pressures sharks are facing around the world (Stevens *et al.* 2000a), the reported collapses of shark populations (Baum *et al.* 2003; Baum & Myers 2004; Dulvy *et al.* 2008; Ferretti *et al.* 2008), and their crucial role in marine ecosystems, research has highlighted that these fisheries need to be managed even at artisanal levels (Martin 2005; Robbins *et al.* 2006; Myers 2007).

The majority of fishermen also indicated a general decline in shark catches, abundance and sizes over the last two decades. Because baseline information is not available, these results should be interpreted cautiously. However, it seems that fishermen were not reporting responses that would have been deemed acceptable because of legality concerns, but rather a true reflection of the state of the current shark fishery. In fact, fishermen admitted to fishing for sharks on non-licensed dhows, tarads, using longlines, and capturing sharks even during the closed shark-fishing season without any fear of penalties. This could also be an indication that fishermen are aware of the limited enforcement of these laws and were, therefore, not concerned about their responses. Furthermore, fishermen stated that overfishing was the primary cause of these reductions. Long-term overfishing is recognized as one of the most severe anthropogenic disturbance for the collapse of coastal ecosystems especially when large predatory fishes are targeted (Bunce *et al.* 2008). Here, fishermen from all age groups noted these changes, which suggests that overexploitation has been ongoing for decades. The only cross-generational difference observed was the time the perceived change in these variables were noted between the '20-29 years', the '30-39 years' and the 'over 70' age groups. This could indicate that the change is happening so quickly that all age groups are experiencing it without time for a 'shifting environmental baseline syndrome' to develop. In fact, each generation of fishermen had adjusted to the increasing scarcity of fish, were witnessing a modified environment in the long term, and a change to what they perceived 'natural' at the start of their fishing career. This means that if conservation policies were put in place immediately, various age groups would not be expected to resist to these corrective policies as suggested by Bunce *et al.* (2008).

Although these data do not confirm that sharks are being overfished in the UAE, reports of declines by fishermen and the fact that fishers were moving to ever more distant fishing grounds to capture sharks are signs of overfishing and should be an alarm to the potential decline in shark populations in the region. Fishermen in the UAE were fishing in coastal areas if the fishing trip was short but it is clear from their responses and the areas highlighted on maps that all waters of the UAE are being utilized with some locations being used intensely. Other studies have shown that fishermen expanding fisheries to offshore areas are signs of overexploitation (Schaeffer 2004; Bunce *et al.* 2008). Lam and Sadovy de Mitcheson (2011), reported a similar trend in China with fishermen moving further offshore to fish and having to intensify their fishing effort to capture the same quantities of sharks. In their study, fishermen also gave overfishing as one of the reasons for the collapse of shark populations in southern Chinese waters. Actually, due to the decline of their shark catches, targeted fisheries for sharks had to turn to other fisheries since increasing fishing effort yielded similar or lower catches. Fishermen in the UAE also reported that some shark species found in the past did not appear to occur in the region anymore, suggesting possible cases of local extinction such as for mako shark (*I. oxyrinchus),* which is, however, still recorded from the Arabian Sea and Sea of Oman (Henderson *et al.* 2007). Since historical baselines for the UAE are missing, it is of vital importance to use records from these interviews as insights into changes that may have occurred and to evaluate the current state of the shark fishery. Other studies have used this type of interview data to determine the status of fisheries, which in turn has prompted resource managers to develop conservation strategies. For instance, older fishermen in the Gulf of California reported having experienced higher catches and larger-sized fish than younger fishermen (Saenz-Arroyo *et al.* 2005). Also, data comparing catches and sizes of groupers based on fishermen from Rodrigues Island in the Mauritius showed there had been a 75% decline in catches and a 83% reduction in sizes of fish across generations (Bunce *et al.* 2008). These perceptions were indicative of fishery decline and ecosystem impairment (Bunce *et al.* 2008). Based on these experiences, it is clear that without some form of immediate management strategy, there is a risk of further environmental degradation coupled with depletion or even extinction of shark species in UAE waters.

Generally, fishermen were aware of the laws governing the marine environment in the UAE as well as the regulations managing the shark fishery (refer to **Chapter I**, **Table 1.3.**). However, they were also aware that there was insufficient enforcement and that there was no need to alter their fishing behavior. On the other hand, most fishermen seemed to appreciate the value of sharks as a live resource and were keen on protecting them. Yet, respondents felt they did not have enough input in government decisions on fishing and wanted to be consulted for future management initiatives. If the future protection of the shark fishery is to be considered, managers need to acknowledge that people management is as important as resource management (Ormsby 2004). The local fishing community needs to be involved and fishermen's knowledge must be used to develop and implement conservation strategies (Saenz-Arroyo *et al.* 2005; Rasalato *et al.* 2010).

Additional research is clearly required before fishermen reactions and the effects on fishery stocks can be predicted with precision. Future data collection and follow up studies through surveys and interview techniques should build on previous work so that findings can be compared and changes can be illustrated while using the same interview format (Heyman & Granados-Dieseldorff 2012). Allowing fishers to participate will ensure they do not become increasingly dissatisfied with their experiences of participation and project outcomes, refuse opportunities to participate, provide falsified information, and defy enforcement or new regulations (Silver & Campbell 2005). As suggested by Silver and Campbell (2005), when research relies on information provided by local fishermen, these should be involved at all stages of the research initiative, from project to research formulation, data collection, policy formulation, implementation and monitoring. One solution could be engaging the community in data collection as has been done with turtle fisheries in Madagascar. Fishermen were trained to collect data and were involved in research which allowed the development of trusted relationships within the community (Humber *et al.* 2011). This is only likely to occur here if fishermen are trained in proper shark identification, since as has been documented from other fisheries in the region such as the Maldives (Anderson & Ahmed 1993), they were unable to distinguish between various species.

Finally, as suggested by Poizat and Baran (1997), collecting information on fishermen knowledge has proved useful during the initial development of this project by helping identify the best complementary science based approaches to understand the shark fishery and trade in sharks from the UAE. Because fishermen were not able to identify sharks to species level, it was clear that further information needed to be collected regarding the various species present in UAE waters and to determine catch levels. Furthermore, this section of the study also allowed building cooperative relationships between the principal investigator and the local fishermen, which facilitated the collection of biological samples, environmental information and observational data on sharks as part of the market surveys. The next chapter of this study provides empirical support that allows corroborating and validating the oral tradition acquired from fishermen knowledge.

CHAPTER IV

ASSESSING SPECIES COMPOSITION, ABUNDANCE, AND DISTRIBUTION OF SHARKS ALONG THE GULF COAST OF THE UAE: A FISHERY DEPENDENT APPROACH

4.1 Introduction

Artisanal fisheries represent a considerable portion of global shark landings (Bonfil 1994) and can greatly affect the abundance and size composition of these species (Pinnegar & Engelhard 2008). Baseline, species-specific information from these fisheries are essential for monitoring exploited populations and for the development of effective management plans (Henderson *et al.* 2007; Bizzarro *et al.* 2009b). Indeed, without some baseline of fisheries effort and catch composition, changes in relative abundance and other potential impacts on exploited species are unlikely to be identified (Bizzarro *et al.* 2009b).

To determine the status of a fishery, resource managers need to rely on several important factors including catch estimates for both target and bycatch species encountered in the fishery (FAO 2005). The amount of catch is among the most common reported measure of fisheries production (McCluskey & Lewison 2008). One of the primary goals of quantifying the volume of species of fish taken in commercial fishing activities is to obtain information on the status of harvested species, an important indicator of the sustainability of a fishery, and therefore acquire the data necessary to develop and monitor the implementation of fishery management plans (Martin 2005; FAO 2009a).

Fishery dependent data collection is one of the most resourceful tools available to managers and a key element in the effective management of fisheries (Simpfendorfer *et al.* 2011). This information can be relatively easy to collect at ports or landing sites and provides key data on the number of individuals harvested from various fishery dependent sources, including observers, logbooks, and dockside or shore side monitoring. It provides managers with reliable data on the species composition of individual fisheries, utilization rates and fishing practices, as well as allowing monitoring of quotas, estimating of fishing mortality, and calculating of catch per unit effort (CPUE) (Godin & Worm 2010). Furthermore, when the entire catch is brought back to landing sites for distribution or sale, these assessments allow identifying, quantifying, and gathering species-specific biological data, as well as collecting information on abundance and distribution. Such information is often used as a basis to establish management measures including the introduction of size limits of catch and seasonal closures.

Concerns about fish and shark overexploitation in UAE waters have highlighted the need for vital information on targeted species and have prompted the elaboration of federal laws and ministerial decrees specifically focusing on sharks. However, even with regulations in place, the UAE shark fishery has remained largely unmonitored and anecdotal evidence has indicated that shark populations are still impacted by fisheries. Furthermore, historical shark landings data are extremely limited and while the UAE submits capture production data to the FAO, these numbers are not species-specific and probably underestimated, which hampers management efforts. In fact, no overall assessment of the state of the artisanal shark fishery has been conducted and basic biological information is sparse for the majority of commercially exploited species. To improve understanding, conservation, and management of exploited shark populations on the UAE Gulf coast, research addressing taxonomy and life history traits of various species needs to be undertaken (Simpfendorfer *et al.* 2011).

It is important to note that accurate species specific identification of shark species is the most crucial, although challenging, aspect of fishery sampling and is an integral component of effective fishery management (White & Last 2012). Actually, accurate identification is a fundamental requirement that can no longer be overlooked since, without adequate resolution of taxonomy, conservation management strategies cannot be properly determined (White & Last 2012). For instance, the genus *Carcharhinus* (Family Carcharhinidae) includes a diverse group of sharks with morphologically similar species, often making accurate identification difficult, especially since ontogenetic changes can also lead to misidentification issues (White 2012). In many instances, molecular methods have therefore become an important identification tool to distinguish between closely related species (White & Last 2012). Hebert *et al.* (2003b) proposed the use of a single gene sequence, COI, to differentiate between such species and it was shown that in Australia, this 650 bp gene could provide discrimination of 99% of chondrichthyans as well as suggest potential cryptic speciation in a number of taxa (Ward *et al.* 2008). Furthermore, although there has been a large number of studies on the biological aspects of species from this family around the world, and despite historical literature showing that sharks from this family potentially dominate the shark landings in the region (Blegvad & Loppenthin 1944; Sivasubramaniam & Ibrahim 1982b; Carpenter *et al.* 1997; Valinassab *et al.* 2006), life history traits data of species from this genus have not been documented in the UAE. In fact, little biological information on sharks is available for the Gulf area in general, with recent published data focusing on other countries in the northwest region of this basin (Moore *et al.* 2010a; Moore *et al.* 2011; Moore *et al.* 2012a; Moore *et al.* 2012b). Biological attributes such as sizes, reproductive condition, and sex, in a multi-species fishery are vital to collect especially since different species of sharks have variations in their life-history characteristics. Aspects of the biology of wide-ranging species, such as maximum sizes, size at birth, maturity and litter sizes, often vary considerably between regions (Compagno et al 2005), and it is therefore fundamental to document these data at regional levels and in areas where species are being exploited (White 2007; Hall *et al.* 2012). Additionally, documenting size classes allows monitoring temporal shifts in catch sizes which can signal overfishing or changes in fishing practices (FAO 2009a).

The collection of fishery dependent data in the UAE could therefore provide crucial information on the composition of landings, allow a comprehensive list of species to be developed (Henderson et al., 2007), and identify the species that conservation management needs to consider as priority species (Simpfendorfer *et al.* 2011). Furthermore, it would allow the assessment of catches and enable future management plans to be developed based on long term scientific data. Therefore, the aims of this study were to improve understanding of exploited shark species along the Gulf coast of the UAE by 1) determining the species composition, diversity, and relative abundance of sharks at various locations across the UAE; 2) collecting baseline biological information including size composition, sex ratio, and where possible, reproductive status for the most abundant species in landings; 3) investigating temporal and spatial variability in catch composition; 4) validating the field identification of each species through a genetic analysis of a representative sample of individuals using the COI gene.

4.2 Materials and methods

4.2.1 Market and landing site data

To determine species composition, abundance and distribution of sharks along the Gulf coast of the UAE, market and landing site surveys were undertaken as described in **Chapter II** section **2.3.1**.

For all species, a summary of catches was provided based on the location, season of landings, and IUCN Red List status. An analysis of species richness was undertaken using Jaccard's similarity index to determine the percentage of species shared between locations. Seasons were defined as: spring (March–May), summer (June–August), autumn (September–November) and winter (December–February). While full seasons were sampled for both years, due to the limited timeframe of the project, the autumn season had reduced sampling and accounted only for two months in 2010 and one month in 2012.

For those species where less than 50 sample specimens were recorded ($n<49$), a summary of biological findings is given with information about quantities, sex, and sizes of individuals from each species. For all species with ≥50 measured individuals, the assumption of equal sex ratios (1:1) within the landings was tested using Chi-square analysis with Yate's correction for continuity with a p value of < 0.05

considered significant. Finally, for species with over 200 individuals recorded, length frequency distributions were produced and size at maturity graphs for males. Potential differences in the size composition of landed females and males were examined using non-parametric approaches (Mann-Whitney U tests).

4.2.2 Genetic analysis

To validate the identity of species originating from within the Gulf, a set of 130 tissue samples comprising of five samples from each species, when available, were analyzed. Genomic DNA was extracted at the UAE University, using the DNeasy Tissue Kit (Qiagen Inc., Valencia, CA, USA) and according to the manufacturer's instructions, from 25 mg of fresh tissue collected from whole specimens (refer to **Chapter II** section **2.3.2.** for details). Extracted DNA from each specimen was then checked on 0.8% TBE agarose gels containing ethidium bromide for DNA quality and concentration. PCR and sequencing were conducted at the Nova Southeastern University, US. An approximately 650 bp fragment from the COI gene was amplified by PCR using the individual primers Fish F1 (5'-TCAACCAACCACAAAGACATTGGCAC-3'), Fish F2 (5'-TCGACTAATCATAA AGATATCGGCAC-3'), Fish R1 (5'-TAGACTTCTGGGTGGCCAAAGAATCA-3'), and Fish R2 (5'-ACTTCAGGGTGACCGAAGAATCAGAA-3') (Ward *et al.* 2005).

Amplification reactions were performed in 50 μL, volumes, containing 1 μL of the extraction genomic DNA, 10 pmol of each primer (1.25 μL), 10X PCR buffer (5 μL) (Qiagen Inc.), 50 μM dNTPs mix (8 μL) (Illustra dNTP set, GE Healthcare), 1 unit (0.2 μL) of HotStar Taq DNA Polymerase kit (Qiagen Inc.) and 33.3 μL HPLC purified water (OmniSolv). The PCR thermal cycling employed was: 95°C initial denaturation for 15 min to activate the hot start DNA polymerase, followed by 35 cycles of 94°C for 1 min, 50°C for 1 minute, 72°C for 2 min, and a 2 min final extension step at 72°C. Amplifications were performed using BioRad iCycler thermal cycler. Amplified fragments were confirmed on 1.2% agarose gel (Seakem LE Agarose) stained with ethidium bromide and viewed on a Foto Spectrum Transilluminater (FotoDyne). All PCR reactions were cleaned with QIAquick PCR Purification Kit (Qiagen) and eluted in 30 μL of Buffer EB. For each sample, 10 μL of cleaned Cycle Sequencing reaction was loaded per well in a MicroAmp 96-Well Reaction Plate (Applied Biosystems, US) and sequencing was completed with the dye-labeled termination method (Big Dye Terminator v3.1, Cycle Sequencing Kit, Applied Biosystems) on a 3130xl Genetic Analyzer (Applied Biosystems) in either forward or reverse directions.

Sequences were inspected and cleaned of ambiguous bases by visualizing the corresponding chromatogram using the program Bioedit (Hall 1999). Species identifications were made using both the BOLD Identification Engine (www.boldsystems.org) and GenBank nucleotide database (www.ncbi.nlm.nih.ggoc/nucleotide). Both engines matched each uploaded sequence with others present in their databases and provided similarity or maximum identity percentages, respectively, with matching sequences.

All sequences were then aligned using Clustal XI software and trimmed to 417 bp in order to include as many species as possible in the analysis but without compromising the power of this analysis. Phylogenetic relationships among species were analyzed by constructing phylogenetic trees using three different methods: Neighbor-joining (NJ), Maximum Likelihood (ML), and Maximum Parsimony (MP). The Kimura two parameter (K2P) distance model (Kimura 1980) was considered and the NJ and MP trees were performed with bootstrap of 1000 replications (MEGA 4 software) (Tamura *et al.* 2007).

4.3 Results

4.3.1 Overall species composition and IUCN Red List status

A total of 12,478 individual sharks originating from UAE Gulf waters were recorded at the various landing sites between October 2010 and September 2012. During this period, 205 landing site and market visits were undertaken. After 150 visits, which confirmed 28 species of sharks from Gulf waters, the frequency of surveys was reduced as it was determined that extra market visits would not bring an increase in the species diversity encountered (**Figure 4.1.**). However, an additional two species were documented in 2012 increasing the number of confirmed species to 30 shark species consisting of nine families from three orders (**Table 4.1.**). The family Carcharhinidae was the most diverse with 18 species, followed by Hemigaleidae with three species, as well as Sphyrnidae and Hemiscyllidae with two species each.

All shark species recorded here as originating from UAE Gulf waters were found to have been assessed by the IUCN on a global level. Data from the IUCN Red List showed that almost half (46.7%) of the species found in these waters are classified as 'Near Threatened'. The remaining species have been assessed as 'Endangered', 'Vulnerable', 'Data Deficient' (DD), or 'Least Concern' (LC) with each category representing 6.7%, 30%, 6.7% and 10% of the total species respectively (**Figure 4.2.**). Therefore, 36.7% of the shark species confirmed in the Gulf faced a high risk of global extinction.

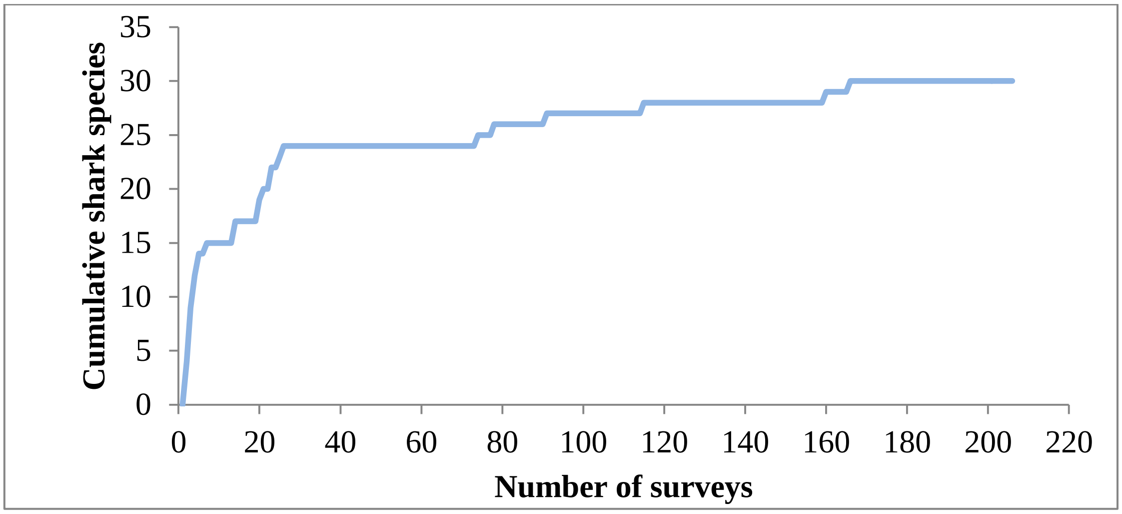

Figure 4.1. Cumulative shark species recorded from visits to all landing sites and markets from October 2010 to September 2012.

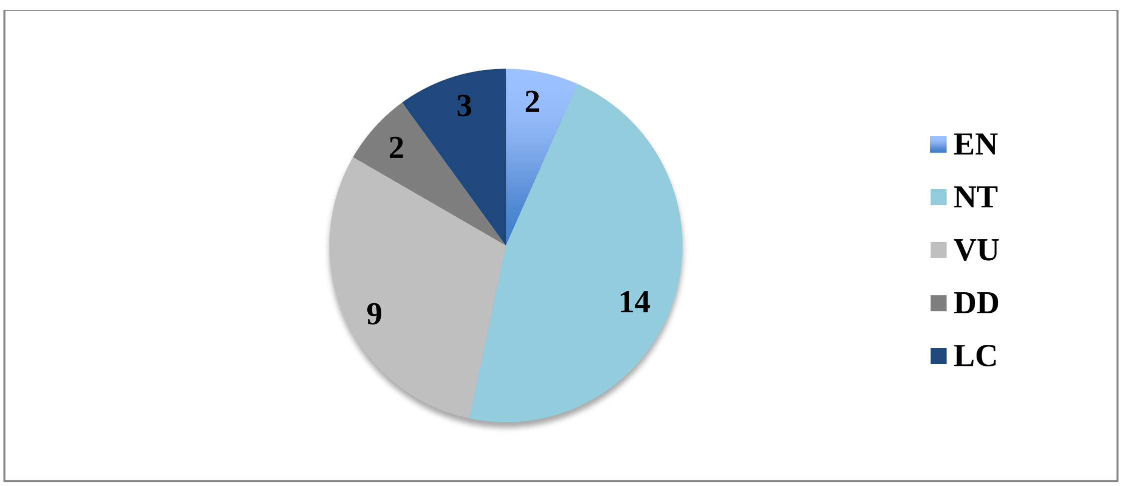

Figure 4.2. IUCN Red List status of the 30 shark species found in UAE waters. Values represent the number of shark species in each category (**EN** Endangered; **NT** Near Threatened; **VU** Vulnerable; **DD** Data Deficient; **LC** Least Concern). (IUCN, 2012).

Table 4.1. Taxonomic list of shark species recorded from UAE Gulf waters during landing surveys including FAO species code **(*** no FAO code assigned) and IUCN Red List Status with dates assessments were published (**EN** Endangered; **NT** Near Threatened; **VU** Vulnerable; **DD** Data Deficient; **LC** Least Concern).

Family	Species name	Common name	FAO code	IUCN status
Hemiscyllidae	*Chiloscyllium arabicum*	Arabian bamboo shark	ORA	NT (2009)
	Chiloscyllium griseum	Grey bamboo shark	ORR	NT (2003)
Ginglymostomatidae	*Nebrius ferrugineus*	Tawny nurse shark	ORZ	VU (2003)
Stegostomatidae	*Stegostoma fasciatum*	Zebra shark	OSF	VU (2003)
Rhincodontidae	*Rhincodon typus*	Whale shark	RHN	VU (2005)
Odontaspididae	*Carcharias taurus*	Sand tiger shark	CCT	VU (2009)
Triakidae	*Mustelus mosis*	Arabian smoothhound	MTM	DD (2009)
Hemigaleidae	*Chaenogaleus macrostoma*	Hooktooth shark	HCM	VU (2009)
	Hemipristis elongata	Snaggletooth shark	HEE	VU (2003)
	Paragaleus randalli	Slender weasel shark	PAR*	NT (2009)
Carcharhinidae	*Carcharhinus amblyrhynchoides*	Graceful shark	CCY	NT (2009)
	Carcharhinus amblyrhynchos	Grey Reef shark	AML	NT (2009)
	Carcharhinus amboinensis	Pigeye shark	CCF	DD (2009)
	Carcharhinus brevipinna	Spinner shark	CCB	NT (2009)
	Carcharhinus dussumieri	Whitecheek shark	CCD	NT (2003)
	Carcharhinus falciformis	Silky shark	FAL	NT (2009)
	Carcharhinus leiodon	Smoothtooth blacktip	CCJ	VU (2009)
	Carcharhinus leucas	Bull shark	CCE	NT (2009)
	Carcharhinus limbatus	Blacktip shark	CCL	NT (2009)
	Carcharhinus macloti	Hardnose shark	CCM	NT (2003)
	Carcharhinus melanopterus	Blacktip reef shark	BLR	NT (2009)
	Carcharhinus plumbeus	Sandbar shark	CCP	VU (2009)
	Carcharhinus sorrah	Spottail shark	CCQ	NT (2009)
	Galeocerdo cuvier	Tiger shark	TIG	NT (2009)
	Loxodon macrorhinus	Sliteye shark	CLD	LC (2003)
	Negaprion acutidens	Sharptooth lemon shark	NGA	VU (2003)
	Rhizoprionodon acutus	Milk shark	RHA	LC (2003)
	Rhizoprionodon oligolinx	Grey sharpnose shark	RHX	LC (2003)
Sphyrnidae	*Sphyrna lewini*	Scalloped hammerhead	SPL	EN (2007)
	Sphyrna mokarran	Great hammerhead	SPK	EN (2007)

Carcharhinids dominated landings in terms of numbers with 95.5% (n=11,922) of the total catch followed by the triakids consisting of only one species (*Mustelus mosis*) but accounting for 1.6% of the total catch. While the total number of species is relatively high, many of the species recorded were only found in small quantities and catches were dominated by a few species. The most abundant species was *Carcharhinus sorrah* (Müller & Henle, 1839), contributing 31.8% to the total number of all sharks, followed by *Rhizoprionodon acutus* (Rüppell, 1837) with 29.9% of the total. In terms of numbers, *Carcharhinus limbatus* (Valenciennes, 1839), *Loxodon macrorhinus* (Müller & Henle, 1839), *Carcharhinus dussumieri* (Valenciennes, in Müller & Henle, 1839), and *M. mosis* (Hemprich & Ehrenberg, 1899) were also relatively abundant, contributing 14.3%, 8.9%, 4.5% and 1.6% respectively, to the total number of sharks. The remaining 24 species confirmed comprised between 0.01% and 1.4% of the total catch numbers.

4.3.2 Species composition based on location and season

When considering the 30 shark species identified here, Sharjah was the most species rich region in terms of landings with a total of 26 species, followed closely by Dubai with 24 species. Ras Al Khaimah had 21 species while Abu Dhabi displayed the lowest species richness with a total of 19 species recorded. When comparing the similarity in the species composition between landing sites, the Jaccard's Index indicated that the degree of species overlap between region was moderately high with regions sharing anything between 60.7% and 80.7% of species (**Table 4.2.**). The highest similarity was between Ras Al Khaimah and Sharjah (80.7%) and Ras Al

Khaimah and Dubai (73%). The lowest J-values were found between Abu Dhabi and Sharjah (60%) indicating a low degree of species overlap between these two locations.

Table 4.2. Jaccard's similarity index values illustrating the degree of similarity in the species composition of the various landing sites.

	Abu Dhabi	Dubai	Sharjah	Ras Al Khaimah
Abu Dhabi	*	**0.65**	**0.60**	**0.66**
Dubai	*	*	**0.72**	**0.73**
Sharjah	*	*	*	**0.80**
Ras Al Khaimah	*	*	*	*

Even though sampling effort was consistent in each location and cross-seasonally, there was some degree of variability in the number of observed landings, between regions and across seasons (**Table 4.3.** and **4.4.**). Dubai landings were the lowest from all regions with 20.2% of the total catches, followed by Abu Dhabi with 22.5%. Sharjah and Ras Al Khaimah had the highest numbers of sharks landed with 28.7% and 28.5% respectively. When viewed from a regional perspective, the Central region, comprising of both the Dubai and Sharjah landing sites, contributed 49.5% of catches.

When landings were viewed seasonally, the number of species did not differ greatly between seasons with 25 species recorded in autumn, 24 in both winter and spring, and 23 in summer. However, the catch total varied with autumn yielding the highest numbers with 30.30% of the total captures, followed by spring (28%), winter (23.7%) and a significant decline in summer (17.8%). These numbers also varied

Table 4.3. Species composition and quantities recorded from 205 surveys in Abu Dhabi, Dubai, Sharjah, and Ras Al Khaimah, based on their location of origin.

Family/Species	Abu Dhabi	Dubai	Sharjah	Ras Al Khaimah	TOTAL
Hemiscyllidae					
C. arabicum	1	3	1	0	**5**
C. griseum	0	0	1	0	**1**
Ginglymostomatidae					
N. ferrugineus	0	0	2	0	**2**
Stegostomatidae					
S. fasciatum	0	5	4	0	**9**
Rhincodontidae					
R. typus	0	1	0	0	**1**
Odontaspididae					
C. taurus	1	0	0	0	**1**
Triakidae					
M. mosis	1	17	55	131	**204**
Hemigaleidae					
C. macrostoma	2	7	23	28	**60**
H. elongata	3	5	26	15	**49**
P. randalli	0	9	22	54	**85**
Carcharhinidae					
C. amblyrhynchoides	33	8	41	8	**90**
C. amblyrhynchos	0	4	3	1	**8**
C. amboinensis	61	16	42	8	**127**
C. brevipinna	8	33	17	8	**66**
C. dussumieri	136	63	212	150	**561**
C. falciformis	0	6	0	0	**6**
C. leiodon	1	2	0	0	**3**
C. leucas	93	44	18	12	**167**
C. limbatus	906	300	516	64	**1786**
C. macloti	0	60	11	102	**173**
C. melanopterus	10	15	10	3	**38**
C. plumbeus	1	0	6	6	**13**
C. sorrah	615	716	1460	1182	**3973**
G. cuvier	0	0	1	0	**1**
L. macrorhinus	8	320	88	704	**1120**
N. acutidens	30	3	7	1	**41**
R. acutus	818	870	989	1060	**3737**
R. oligolinx	0	0	1	11	**12**
Sphyrnidae					
S. lewini	0	7	2	6	**15**
S. mokarran	80	8	30	6	**124**
TOTAL	**2808**	**2522**	**3588**	**3560**	**12478**

Table 4.4. Seasonal and total catch composition of sharks landed throughout the project (n= number of individuals; % of shark landings).

Family/Species	Autumn		Winter		Spring		Summer		TOTAL	
	n	%	n	%	n	%	n	%	n	%
Hemiscyllidae										
C. arabicum	1	0.02	2	0.06	1	0.02	1	0.04	**5**	**0.04**
C. griseum	0	0.0	0	0.0	1	0.02	0	0.0	**1**	**0.01**
Ginglymostomatidae										
N. ferrugineus	0	0.0	1	0.03	0	0.0	1	0.04	**2**	**0.02**
Stegostomatidae										
S. fasciatum	1	0.02	0	0.0	7	0.2	1	0.04	**9**	**0.07**
Rhincodontidae										
R. typus	0	0.0	1	0.03	0	0.0	0	0.0	**1**	**0.01**
Odontaspididae										
C. taurus	0	0.0	0	0.0	1	0.02	0	0.0	**1**	**0.01**
Triakidae										
M. mosis	37	0.9	48	1.6	101	2.8	18	0.8	**204**	**1.63**
Hemigaleidae										
C. macrostoma	8	0.2	25	0.8	21	0.6	6	0.2	**60**	**0.48**
H. elongata	18	0.47	7	0.2	13	0.3	11	0.4	**49**	**0.39**
P. randalli	9	0.23	17	0.5	31	0.8	28	1.2	**85**	**0.68**
Carcharhinidae										
C. amblyrhynchoides	15	0.39	6	0.2	62	1.7	7	0.3	**90**	**0.72**
C. amblyrhynchos	3	0.07	0	0.0	0	0.0	5	0.2	**8**	**0.06**
C. amboinensis	19	0.5	32	1.0	61	1.7	15	0.6	**127**	**1.02**
C. brevipinna	6	0.15	12	0.4	36	1.0	12	0.5	**66**	**0.53**
C. dussumieri	187	4.94	189	6.3	96	2.7	86	3.8	**561**	**4.50**
C. falciformis	6	0.15	0	0.0	0	0.0	0	0.0	**6**	**0.05**
C. leiodon	2	0.05	1	0.03	0	0.0	0	0.0	**3**	**0.02**
C. leucas	19	0.5	62	2.0	68	1.9	18	0.8	**167**	**1.34**
C. limbatus	581	15.3	455	15.3	516	14.7	234	10.4	**1786**	**14.3**
C. macloti	73	1.93	42	1.4	43	1.2	15	0.6	**173**	**1.39**
C. melanopterus	8	0.2	5	0.1	9	0.2	16	0.7	**38**	**0.3**
C. plumbeus	4	0.1	5	0.1	1	0.02	3	0.1	**13**	**0.1**
C. sorrah	997	26.3	675	22.7	1179	33.7	1122	50.2	**3973**	**31.8**
G. cuvier	0	0.0	0	0.0	1	0.02	0	0.0	**1**	**0.01**
L. macrorhinus	415	10.9	235	7.9	270	7.7	200	8.9	**1120**	**8.98**
N. acutidens	19	0.5	4	0.1	11	0.3	7	0.3	**41**	**0.33**
R. acutus	131	3.46	1083	36.4	924	26.4	415	18.5	**3737**	**29.9**
R. oligolinx	4	0.1	8	0.2	0	0.0	0	0.0	**12**	**0.1**
Sphyrnidae										
S. lewini	8	0.2	1	0.03	4	0.1	2	0.08	**15**	**0.12**
S. mokarran	17	0.4	50	1.6	45	1.2	12	0.5	**124**	**0.99**
TOTAL	**3782**	**30.3**	**2968**	**23.7**	**3495**	**28.0**	**2233**	**17.8**	**12478**	**100**

when looking at the seasonal catch by landing site location. Abu Dhabi had the highest catches in autumn (37.9%), followed by winter (31.1%) and spring (25.9%), while barely any catches were recorded in summer (4%). In Dubai, catches were stable during autumn (30.9%) and spring (32%) but declined during winter (16.2%) and summer (20.7%). Landings in Sharjah were relatively stable across seasons although spring yielded the highest catches with 29% of the total, followed by summer (25.7%), winter (23.8%), and autumn (21.4%). Ras Al Khaimah also showed a different pattern with landings peaking in autumn (32.7%), followed by spring (27%), winter (23%), and summer (17.2%). When landings in Dubai and Sharjah were combined, Central region catches showed a similar pattern to Ras Al Khaimah with a peak in spring (30.2%), that was then followed by autumn (25.3%), summer (23.7%), and winter (20.7%) (**Figure 4.3.**).

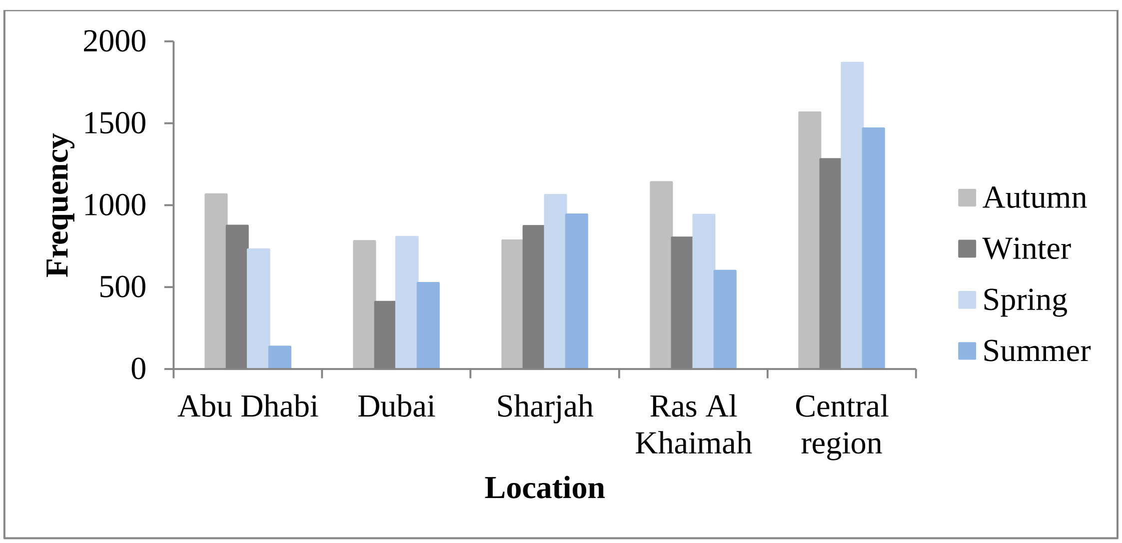

Figure 4.3. Seasonal shark landings recorded based the location of each landing site and showing the combination of catches from Dubai and Sharjah (Central region).

Overall species composition varied across locations and seasons. While six species dominated overall catches, when looking at regional occurrence and abundance of species, some variability was noted in the dominant species (**Figure 4.4.**). The most frequently observed species across the UAE were *C. sorrah* and *R. acutus. Carcharhinus sorrah*, was found at all landing sites with 36.7% of catches recorded in Sharjah, 29.7% in Ras Al Khaimah, 18% in Dubai, and 15.4% in Abu Dhabi, while *R. acutus* had 28.3% of catches recorded in Ras Al Khaimah, 26.4% in Sharjah, 23.2% in Dubai, and 21.8% in Abu Dhabi. Except for a difference in catches of *M. mosis* and *C. macloti* for Dubai and Sharjah, these two sites had a similar representation of their most abundant species and were therefore combined in the representation of catch composition (Central region). Interesting species occurrences included *M. mosis* accounting for a low proportion of catches in most locations (n=1 in Abu Dhabi) but common in Ras Al Khaimah, increasing its overall importance in the national catch composition; *C. macloti*, was absent in Abu Dhabi landings although recorded at all other locations across seasons with 58.9% of catches recorded in Ras Al Khaimah, 34.6% in Dubai, and 6.3% in Sharjah; *C. leucas* was present across seasons but catches were predominantly from Abu Dhabi (55.6%) where it was an abundant species, followed by Sharjah (28.8%), Dubai (16.7%) and Ras Al Khaimah (3.5%); *C. leiodon* was only found in Dubai and Abu Dhabi in autumn and winter; *C. falciformis* was in Dubai in autumn and not present at other landing sites or during other seasons; *R. oligolinx* was only recorded in Ras Al Khaimah (n=11) and Dubai (n=1) during autumn and winter; and *P. randalli*, *C. amblyrhynchos* and *S. lewini* were not recorded in Abu Dhabi but present at other sites.

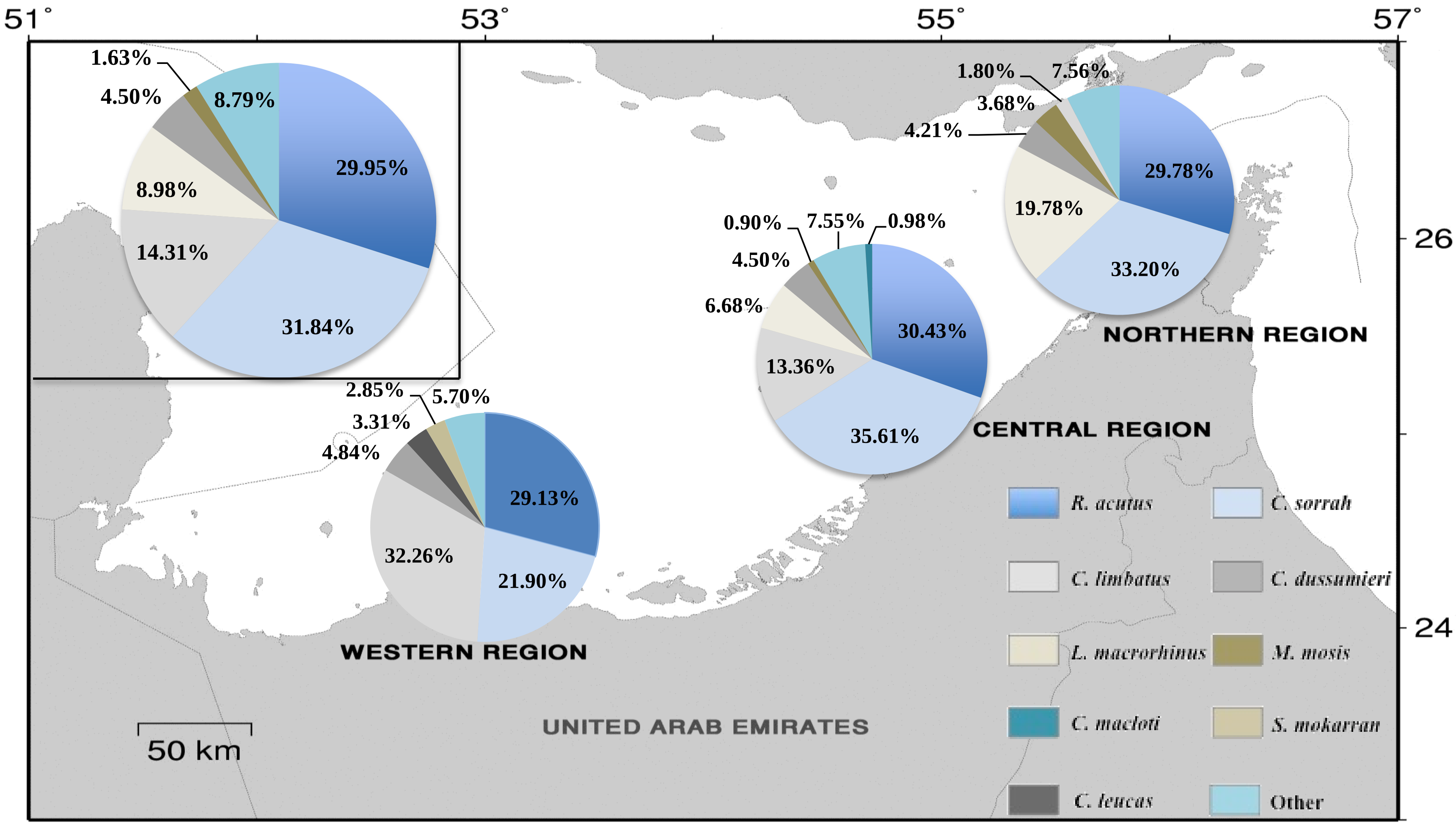

Figure 4.4. Relative catch composition (%) of the top six species for each of the three regions (Western, Central, Northern). Top left chart shows the overall species composition for the three regions combined.

4.3.3 Size distributions, sex ratios and seasonality of the most abundant species

- ***Carcharhinus sorrah***

A total of 3973 *C. sorrah* (Müller & Henle, 1839) were recorded, of which 2216 were females and 1757 were males. The landings contained significantly more females than males (X^2 (1, N=3973)= 52.796, $p<0.05$) with an overall sex ratio of 1.26:1. Sex ratios favored females through the sampling period remaining stable in spring (1.29:1) and summer (1.3:1), but dropping in autumn (1.06:1), and then increasing in winter (1.48:1). Catches of *C. sorrah* were highest during the spring (n=1179) and summer (n=1122) but declined during autumn (n=997) and winter (n=675).

Female sizes ranged from 437 to 1960 mm L_T (mean 1081.9 mm ± 283.2 S.D.), while males ranged from 439 to 1513 mm L_T (mean 952.3 mm ± 215.7 S.D.) (**Figure 4.5.**). There was a significant difference between the median size of females (1079.5 mm L_T) and males (910 mm L_T) *C. sorrah* (Mann-Whitney U-test, U=1389364.50, n=3973, $p<0.05$). While the lower limit of the size range was almost identical in both sexes, females reached a greater maximum length. Modal sizes for males were consistent, with a prominent mode at the 810-1009 mm L_T size class, but there was a decrease in the number of males represented in the 1210-1409 mm L_T size class and few males over those sizes were recorded. Instead, female modal sizes varied with prominent modes at the 810-1009 mm and 1210-1409 mm L_T size classes, and a substantial decrease in numbers in the 1010-1209 mm L_T size class was evident.

Ninety-two gravid females measuring 1102 to 1678 mm L_T were recorded throughout the year with 67.7% of them occurring during the spring season, especially during the month of May (n=45). Gravid females were also recorded in summer

(17.2%), autumn (5.3%) and winter (9.6%). Furthermore, a pattern was noted where the highest numbers of large females were recorded in the spring season, followed by summer and winter. The majority of gravid individuals were recorded in Abu Dhabi (45.6%) and Sharjah (40.2%).

Based on the size of the smallest mature individuals recorded, 48.8% of females and 32.4% of males were mature among landed specimens with both sexes maturing in the same size class, i.e.1010-1209 mm L_T. Immature males (n=909) with non-calcified claspers ranged in size between 439 to 964 mm L_T, males with partially calcified claspers (n=278) were between the sizes of 737 and 1220 mm L_T, and males with fully calcified claspers (n=570) ranged in sizes between 1048 to 1513 mm L_T (**Figure 4.6.**). Thus, maturity for males of this species seems to occur between these two sizes, i.e. 1048 mm and 1220 mm L_T.

Specimens with umbilical scars (n=523) measured 439 to 722 mm L_T. This indicates that the L_T birth of *C. sorrah* is likely to be between these two sizes or less than 439 mm L_T. These YOY were also recorded throughout the four seasons with 61.1% of them occurring in autumn, 6.6% in winter, 11.2% in spring, and 20.8% in summer (**Figure 4.7.**). Individuals with umbilical scars were recorded at all locations but were most prominent in Dubai (**Figure 4.8.**).

The largest number of individuals over 1210 mm L_T, particularly females, were recorded in Abu Dhabi and Sharjah while Ras Al Khaimah had few individuals over 1019 mm L_T. However, this species also dominated catches in both Sharjah and Ras Al Khaimah.

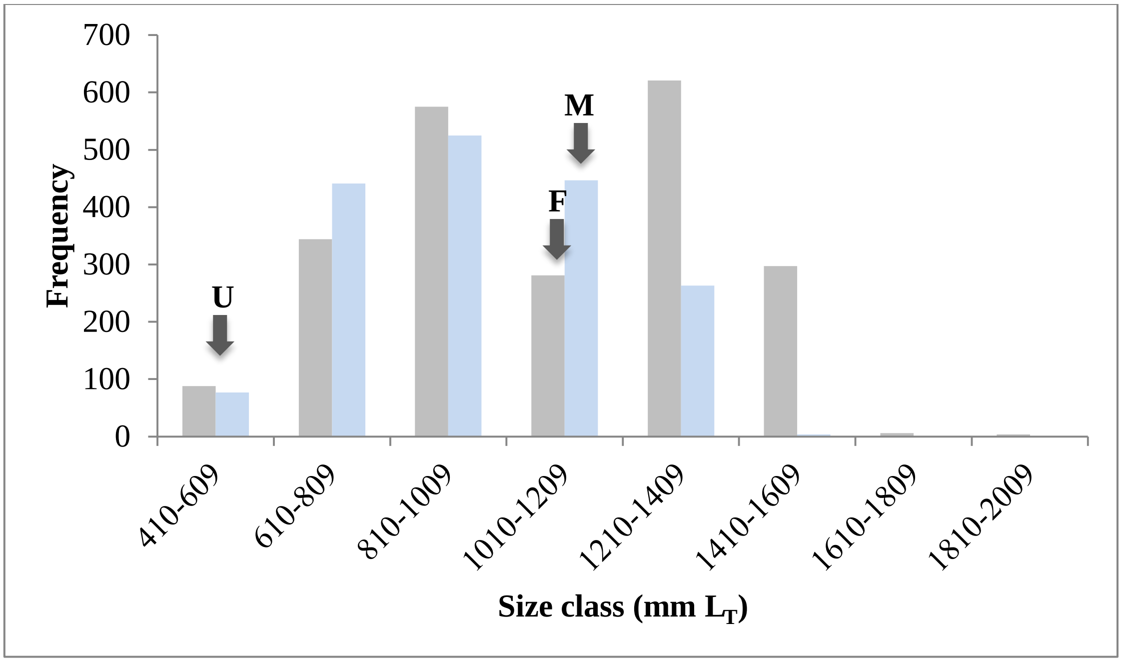

Figure 4.5. Size frequency distribution of female (■) and male (■) *C. sorrah*. Arrows represent sizes of the smallest individual with an umbilical scar (U), and male maturity (M), female maturity (F), based on the smallest mature individuals recorded.

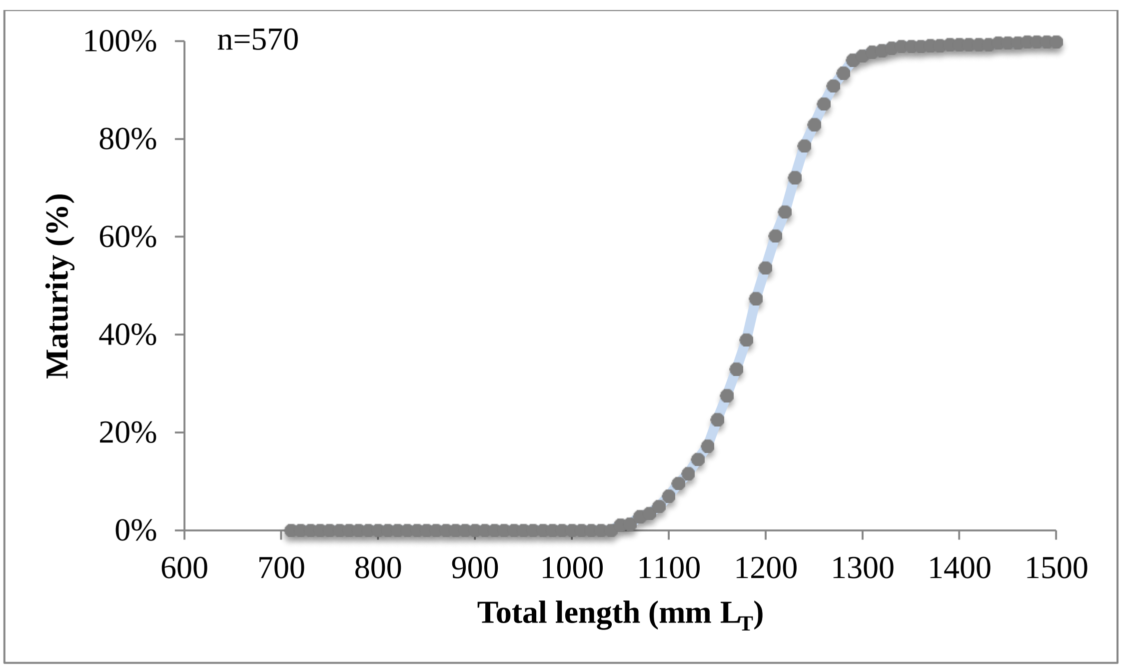

Figure 4.6. Percentage of mature male *C. sorrah* in each 100 mm length class, based on the presence of fully calcified claspers.

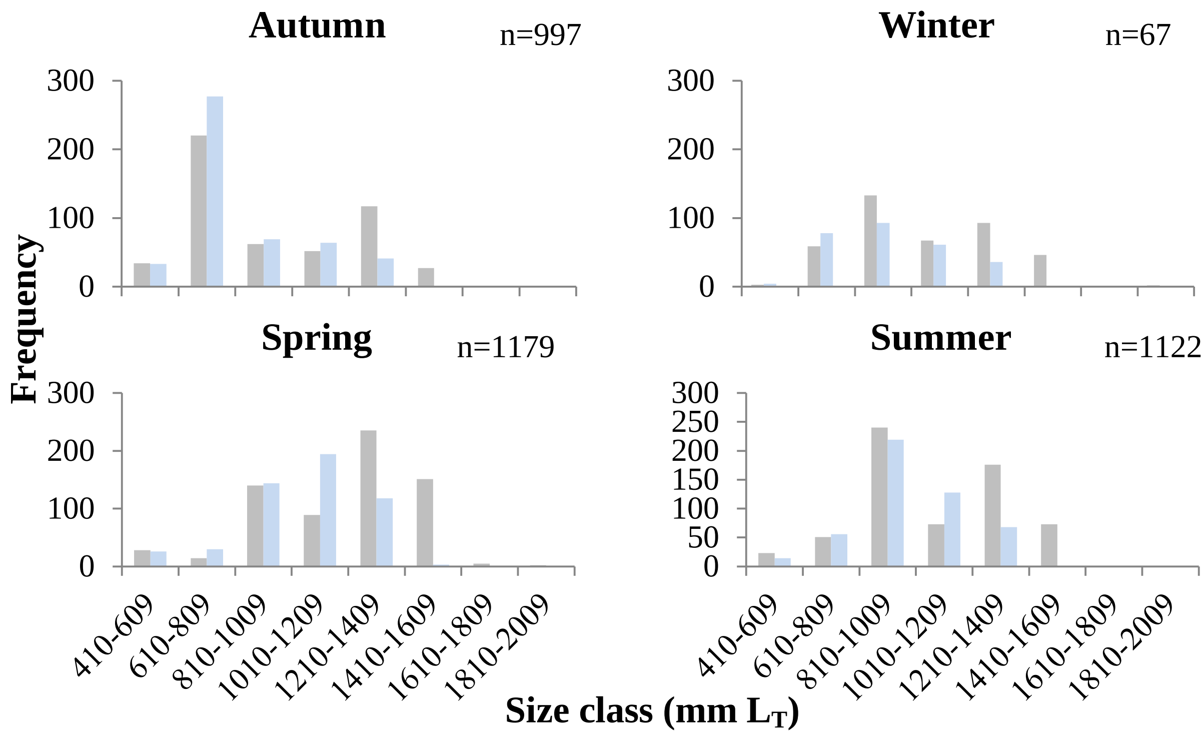

Figure 4.7. Seasonal size distribution of female (■) and male (■) *C. sorrah* at all landing sites.

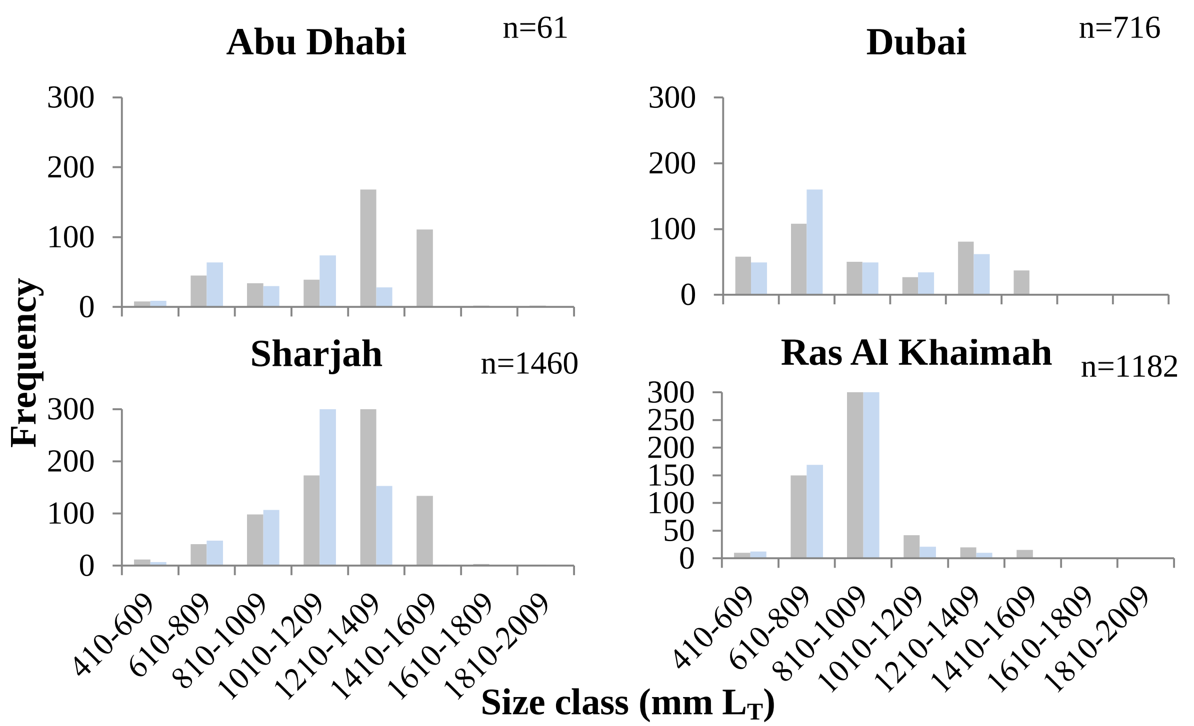

Figure 4.8. Size distribution of female (■) and male (■) *C. sorrah* based on landing site location.

- ***Rhizoprionodon acutus***

A total of 3737 *R. acutus* (Rüppell, 1837), comprising of 1903 females and 1834 males were recorded. The sex ratio of landings did not differ significantly from parity (X^2 (1, N=3737)= 1.237, $p>0.05$) and was overall 1.03:1 slightly in favor of females. Sex ratios remained similar in autumn (1.02:1), but changed in spring (1.46:1) and summer (1.34:1), while remaining in favor of females. However, males outnumbered females during winter months with a ratio of 1.39:1. *R. acutus* catches were highest during the autumn (n=1315) and winter (n=1083), declined in spring (n=924) and dropped significantly during summer (n=415).

Female sizes ranged from 372 to 981 mm L_T (mean 690 mm ± 105.2 S.D.) and males ranged from 375 to 888 mm L_T (mean 660 mm ± 85.2 S.D.). There was a significant difference between the median total length of female (702 mm L_T) and male (685 mm L_T) *R. acutus* (Mann-Whitney U-test, U=1414291.5, n=3737, $p<0.05$). The smaller individuals of both sexes were of similar sizes but females reached a greater maximum length (**Figure 4.9.**). Sizes for males and females varied but it was evident that the main modal size for males was the 610-709 mm L_T size class and larger individuals were not frequently landed.

Gravid females (n=225) were recorded with late term embryos throughout the year and ranged in size between 618 and 915 mm L_T. The majority was found during the spring (55.1%), particularly in March, but also in summer (17.3%), autumn (15.1%) and winter (12.9%). Spring and summer were also the seasons when the largest female specimens were recorded. The majority of gravid individuals were recorded in Ras Al Khaimah (52%) while 42.6% were landed in the Central region.

Based on the smallest mature specimens recorded, mature females (74.8%) and mature males (61.6%) dominated the captures. Mature females were recorded in the 610-709 mm L_T size class while males matured at smaller sizes (510-609 mm L_T size class). Immature males (n=375) with non-calcified claspers were between 375 and 639 mm L_T, males with partially calcified claspers (n=328) were between the sizes of 502 and 723 mm L_T, and males with fully calcified claspers (n=1131) ranged in sizes between 606 to 888 mm L_T. Thus, maturity for males of this species is likely to occur between these sizes, i.e. 606-723 mm L_T (**Figure 4.10.**). Males in the 810-909 mm L_T size classes and over were most common in Dubai but under-represented at other landing sites.

Specimens with umbilical scars (n=204) measured 372 to 503 mm L_T. This indicates that the L_T birth of *R. acutus* is likely to be between these two sizes or less than 372 mm L_T. Two embryos were also recorded measuring 285 and 346 mm L_T respectively. Young of year were recorded throughout the four seasons with 78.9% of them occurring in autumn, 5.4% in winter, 0.5% in spring and 15.2% in summer. **Figure 4.11.** shows that very few individuals in the 310-409 and 410-509 mm L_T sizes classes were recorded in winter and spring. Also, it was clear that for *R. acutus*, larger specimens were predominant during the winter, spring and summer months with smaller sizes represented during the autumn months. The smallest individuals, within the 310-409 mm L_T size class were only recorded from Dubai and were absent from other locations. However, size classes of 410-509 mm L_T and over were found at all other landing sites (**Figure 4.12.**).

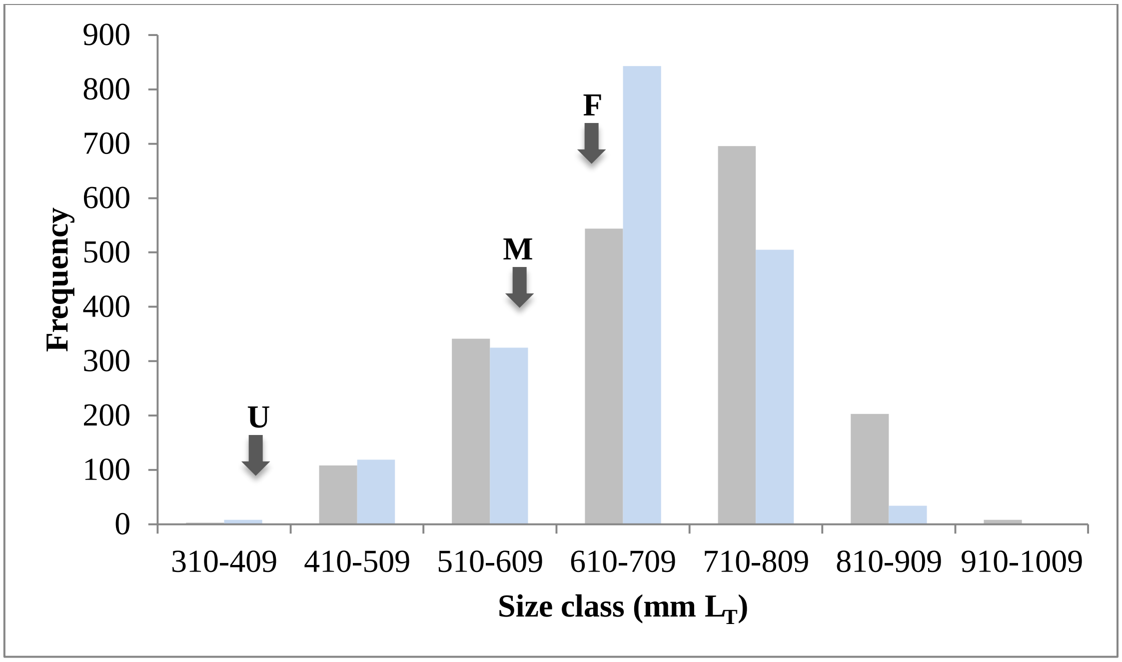

Figure 4.9. Size frequency distribution of female (■) and male (■) *R. acutus*. Arrows represent sizes of the smallest individual with an umbilical scar (U), and male maturity (M), female maturity (F), based on the smallest mature individuals recorded.

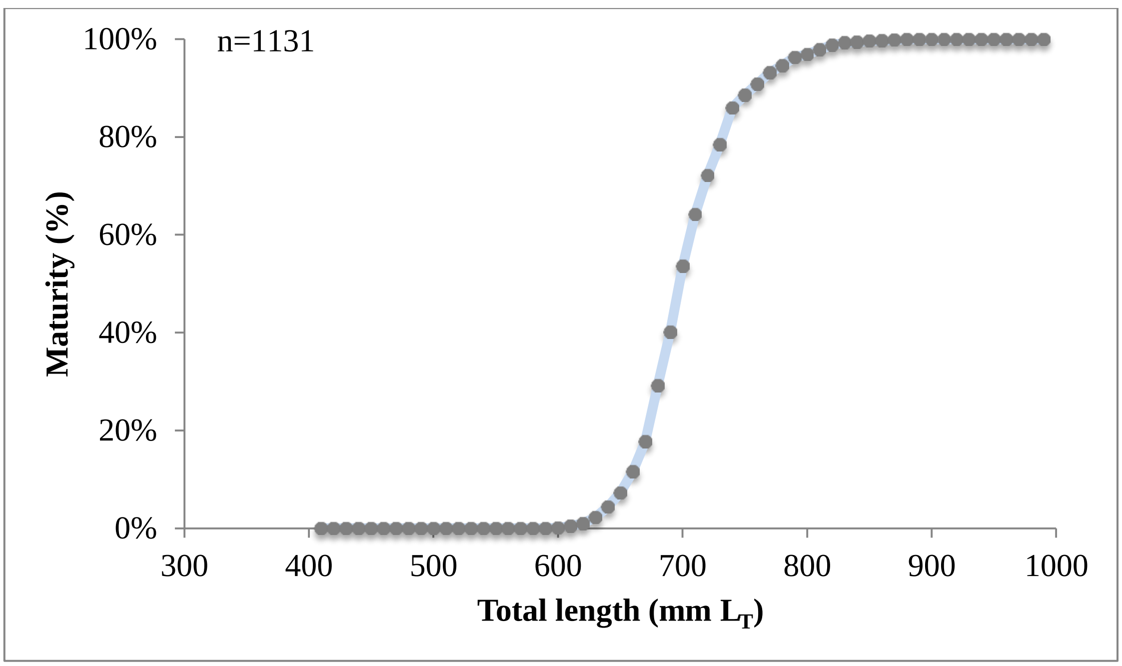

Figure 4.10. Percentage of mature male *R. acutus* in each 100 mm length class, based on the presence of fully calcified claspers.

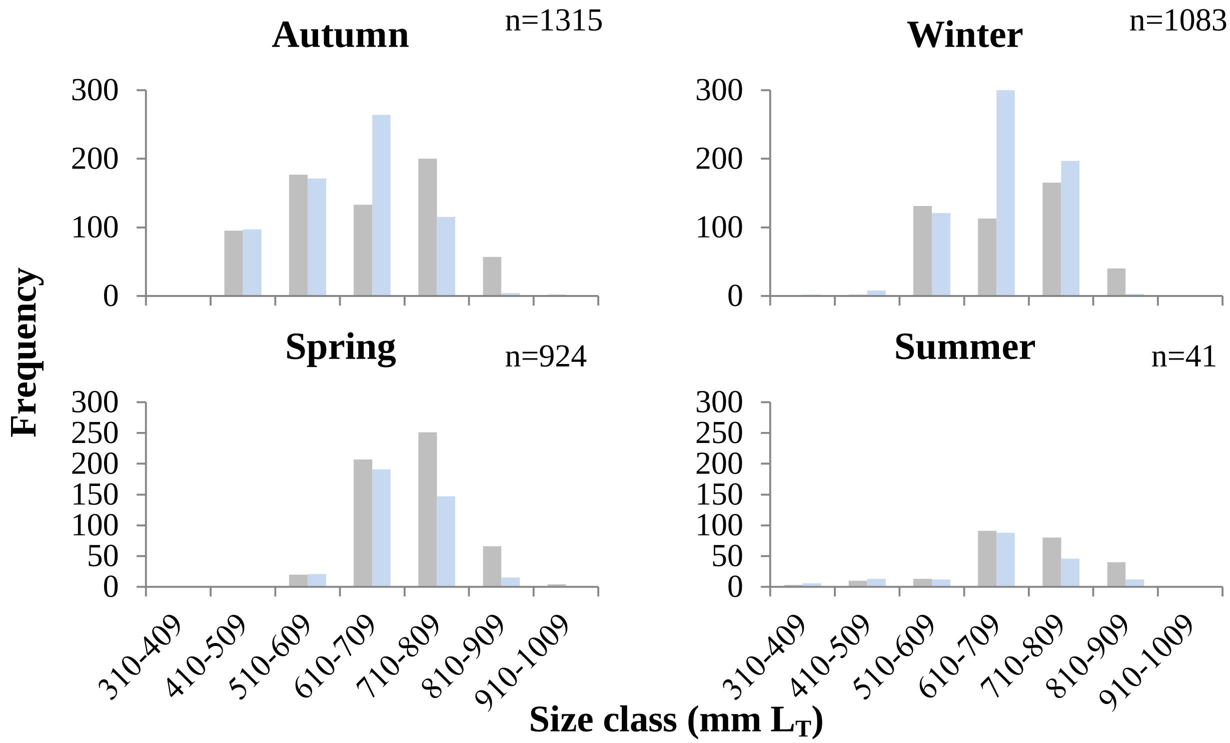

Figure 4.11. Seasonal size distribution of female (■) and male (■) *R. acutus* at all landing sites.

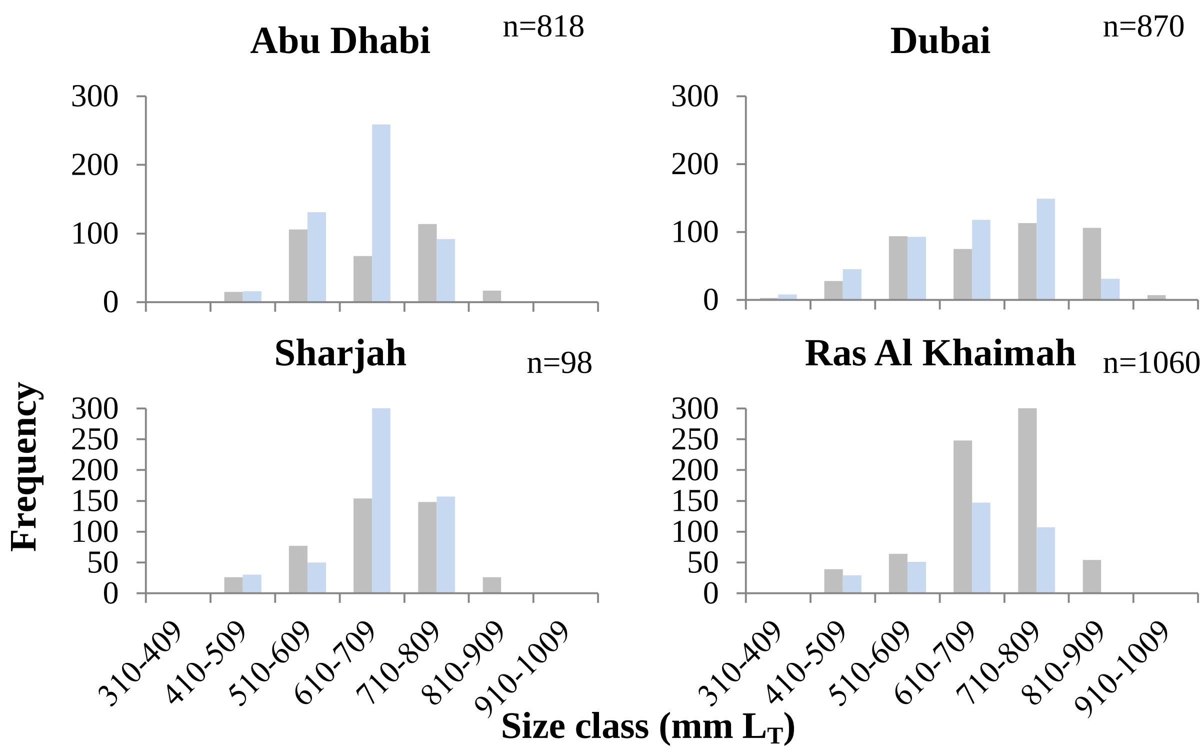

Figure 4.12. Size distribution of female (■) and male (■) *R. acutus* based on landing site location.

- ***Carcharhinus limbatus***

A total of 1786 *C. limbatus* (Valenciennes, 1839) were recorded, which included 898 females and 887 males. The sex ratio of landings did not differ significantly from parity (X^2 (1, N=1786)= 0.045, p>0.05) and was overall 1.01:1 in favor of females. The seasonal sex ratios alternated between sexes with males outnumbering females in winter (1.17:1) and spring (1.14:1), and females found in larger numbers in autumn (1.03:1) and especially in summer (1.85:1). Catches of this species remained stable across seasons but dropped by half during the summer months. Furthermore, catches of this species were significant in Abu Dhabi (n=906) and Sharjah (n=516) but less frequent in Dubai (n=300) and Ras Al Khaimah (n=64).

Female sizes ranged between 460 and 2620 mm L_T (mean 1442 mm ± 560 S.D.) and male sizes ranged from 416 to 2870 mm L_T (mean 1422.2 mm ± 551.5 S.D.). There was no significant difference between the median total length of female (1440 mm) and male (1461 mm) *C. limbatus* (Mann-Whitney U-test, U=390326, n=1786, p=0.466). The smallest individuals from both sexes were of similar sizes but the largest specimen of *C. limbatus* recorded was a male (**Figure 4.13.**).

Thirty-four gravid females with late term embryos were recorded and ranged in size between 1640 and 2532 mm L_T. The majority was found during the spring months (67.6%), especially March, but also in winter (29.4%) and autumn (2.9%). No pregnant females were documented during the summer months. Spring was also the season where the largest specimens were recorded for both males and females. These females were mostly found in Abu Dhabi and Sharjah (85.7%) where the individuals of the largest size classes were also recorded. Based on the size of the smallest mature specimens recorded, 40.6% of females and 31.4% of males were mature among landed individuals. Males were found to mature at a smaller size class than females (1210-1409 mm L_T). Immature males (n=455) with non-calcified claspers ranged in size between 416 to 1556 mm L_T, males with partially calcified claspers (n=154) were between the sizes of 1231 and 1957 mm L_T, and males with fully calcified claspers (n=279) ranged in sizes between 1407 to 2870 mm L_T. Thus, maturity for males of this species is likely to occur between these sizes, i.e. 1407-1957 (**Figure 4.14.**). A low number of male individuals was recorded during the summer months as well as in locations such as Ras Al Khaimah and Dubai throughout the sampling period.

Specimens with visible umbilical scars (n=54) measured 416 to 748 mm L_T. This indicates that the L_T birth of *C. limbatus* is likely to be between these two sizes or less than 416 mm L_T. These individuals were recorded throughout the four seasons with 62.7% of them occurring in autumn, 4.4% in winter, 14.1% in spring and 18.6% in summer. Modal sizes of 610-809 mm and 810-1009 mm L_T size classes were most prominent in summer and especially in autumn when larger size classes were under-represented (**Figure 4.15.**). Larger specimens were more prevalent during the winter, spring and summer months with smaller sizes represented during the autumn months. Individuals in the size classes less than 1010-1209 mm L_T size class were found at all landing sites especially in Dubai and Ras Al Khaimah which had few specimens larger than the 1210-1409 mm L_T size classes (**Figure 4.16.**).

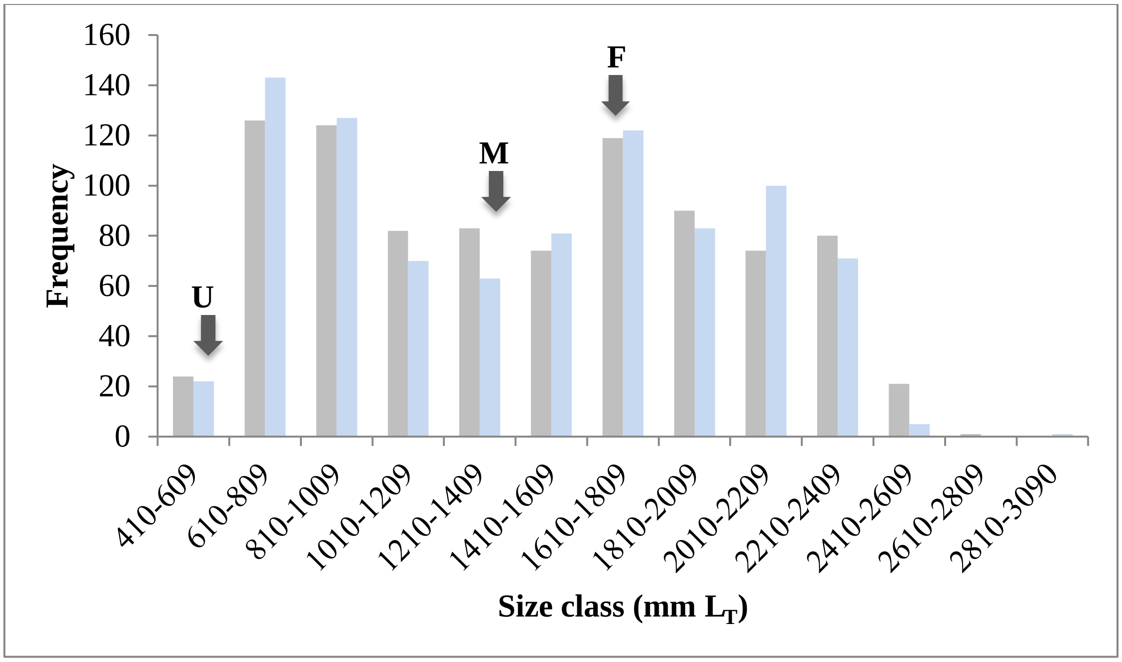

Figure 4.13. Size frequency distribution of female (■) and male (■) *C. limbatus*. Arrows represent sizes of the smallest individual with an umbilical scar (U), and male maturity (M), female maturity (F), based on the smallest mature individuals recorded.

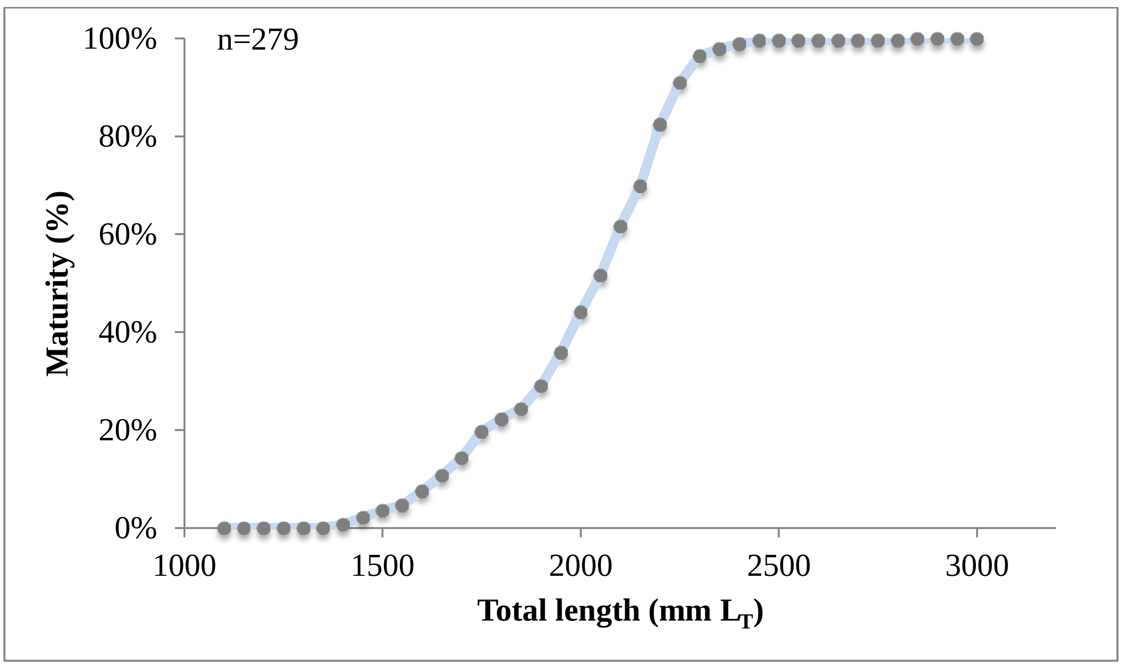

Figure 4.14. Percentage of mature male *C. limbatus* in each 500 mm length class, based on the presence of fully calcified claspers.

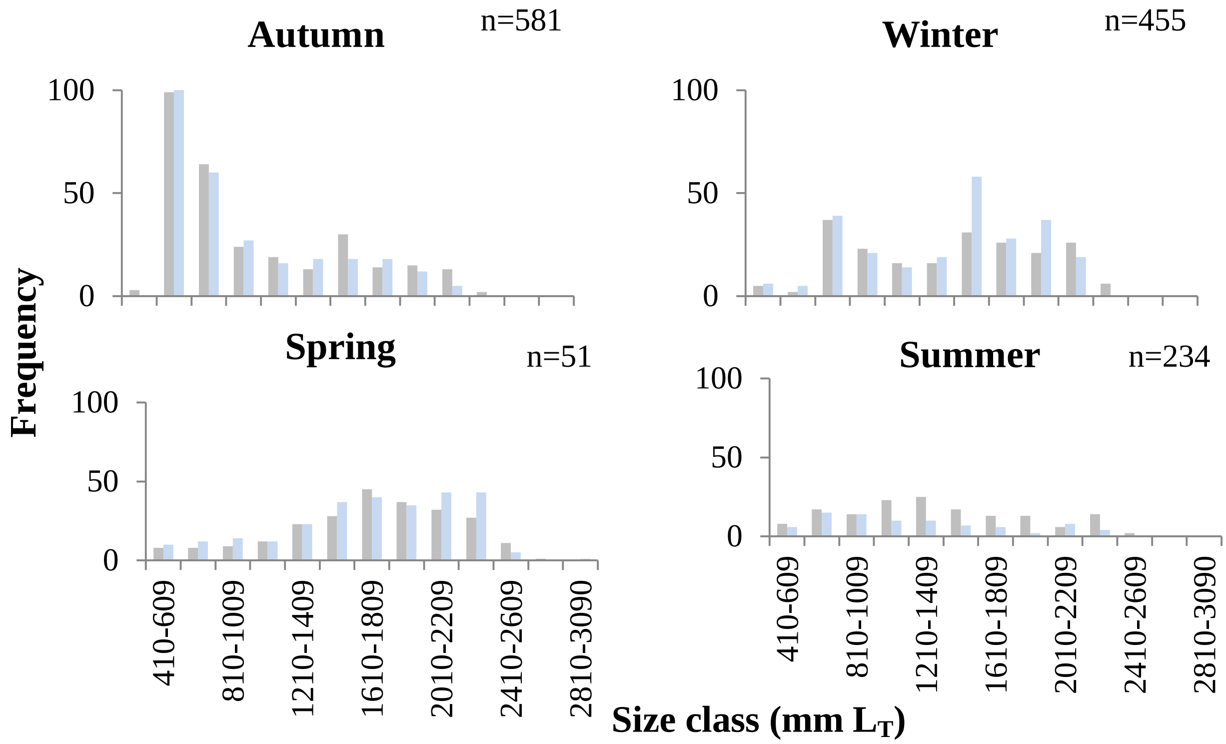

Figure 4.15. Seasonal size distribution of female (■) and male (■) *C. limbatus* at all landing sites.

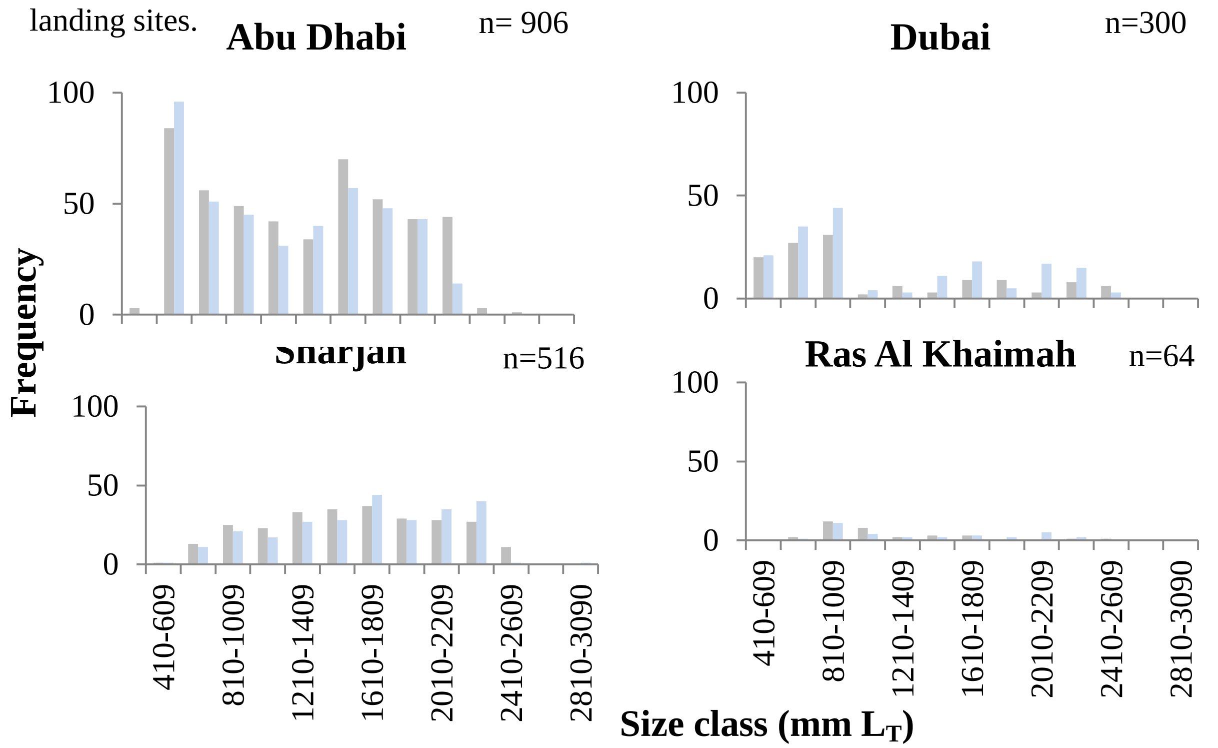

Figure 4.16. Size distribution of female (■) and male (■) *C. limbatus* based on landing site location.

- ***Loxodon macrorhinus***

A total of 1120 *L. macrorhinus* (Müller & Henle, 1839) were recorded, of which 488 were females and 632 were males. The landings contained significantly more males than females (X^2 (1, N=1120)= 18.258, $p<0.05$) with an overall sex ratio of 1.29:1 in favor of males. Sex ratios varied across seasons with females dominating the landings in winter (1.25:1) and spring (1.06:1), while males dominated in autumn (1.62:1) and summer (2.33:1). Catches of this species were stable across winter (n=235), spring (n=270), and summer (n=200), but almost doubled during the autumn months (n=415). Furthermore, the majority of catches were recorded in Ras Al Khaimah (62.8%), followed by Dubai (28.5%), and this species was not common in Abu Dhabi (0.7%) and Sharjah (7.8%).

Female sizes ranged from 472 to 882 mm L_T (mean 674.8 mm ± 80 S.D.) and males ranged from 469 to 901 mm L_T (mean 685.4 mm ± 68.7 S.D.). There was no significant difference between the median total length of female (682.5 mm L_T) and male (699 mm L_T) *L. macrorhinus* (Mann-Whitney U-test, U=144389, n=1120, p=0.067). While the lower limit of the size range was almost identical in both sexes, males reached a greater maximum length. Two distinct modal sizes were evident for males in the 650-699 mm and 700-749 mm L_T size classes and larger individuals were not common (**Figure 4.17.**).

Thirty-four gravid females measuring 701 to 824 mm L_T were recorded throughout the year with 35.3% of them occurring during the spring season, 50% in summer, 5.8% in autumn and 8.8% in winter. Spring and summer also represented the seasons when the larger size class females (over 750-799 mm L_T) were recorded although fewer females were recorded in summer in general (n=60). Larger males were present across seasons and locations. However, fewer females were recorded in Sharjah where instead the modal size class was for males in the 700-749 mm L_T. Individuals in size classes 700-749 mm L_T were most commonly landed in Dubai and Ras Al Khaimah. Based on the size of the smallest mature specimens recorded, 43.6% of females and 59.3% of males were mature among landed individuals. *Loxodon macrorhinus* individuals matured in different size classes with females maturing at larger sizes in the 700-749 mm L_T classes and males maturing in the 600-649 mm L_T size class. Immature males (n=74) with non-calcified claspers ranged in size between 469 to 608 mm L_T, males with partially calcified claspers (n=183) were between the sizes of 549 and 731 mm L_T, and males with fully calcified claspers (n=375) were between 645 to 901 mm L_T. Thus, maturity for males of this species likely occurs between these sizes, i.e. 645-731 mm L_T (**Figure 4.18.**). Males of all size classes were recorded across seasons, except in summer when larger individuals in the 650-699 mm L_T classes and larger were most abundant (**Figure 4.19.**).

Specimens with visible umbilical scars (n=17) measured 469 to 512 mm L_T. This indicates that the L_T birth of *L. macrorhinus* is likely to be between these two sizes or less than 469 mm L_T. These neonates were recorded in November (n=16) and August (n=1) suggesting that birth in this species is likely to occur during the late summer and autumn months. Also, the autumn and winter seasons seemed to have the largest numbers of individuals from size classes of 600-649 mm L_T and less. These were recorded at all landing sites except in Abu Dhabi where specimens were all over the 550-599 mm L_T size class (**Figure 4.20.**).

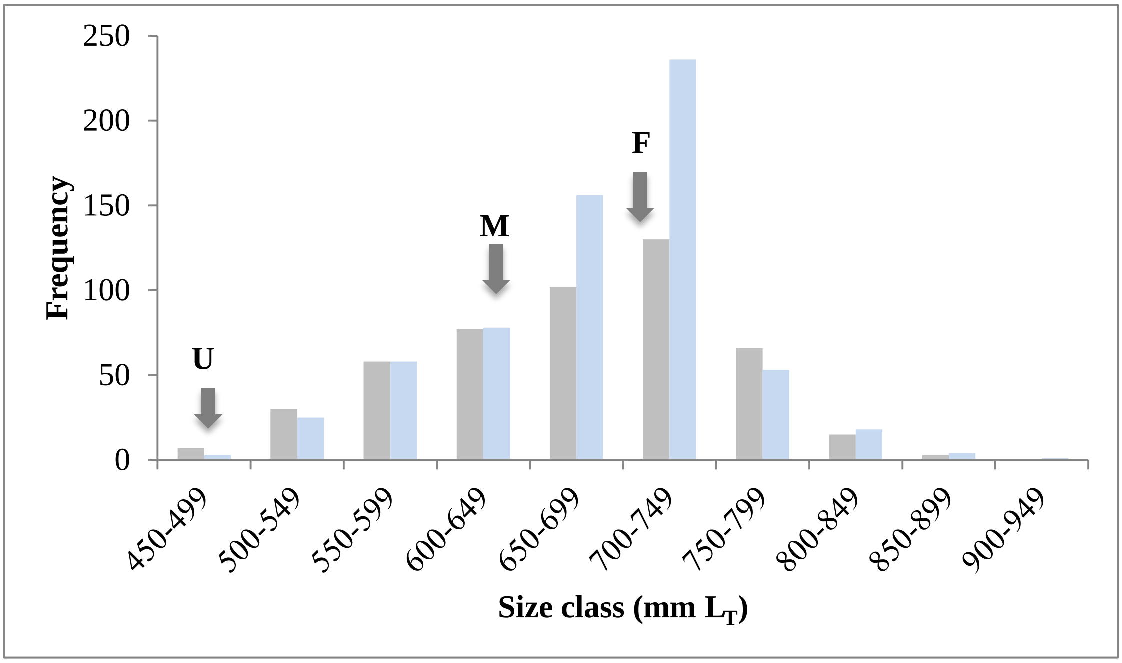

Figure 4.17. Size frequency distribution of female (■) and male (■) *L. macrorhinus*. Arrows represent sizes of the smallest individual with an umbilical scar (U), and male maturity (M), female maturity (F), based on the smallest mature individuals recorded.

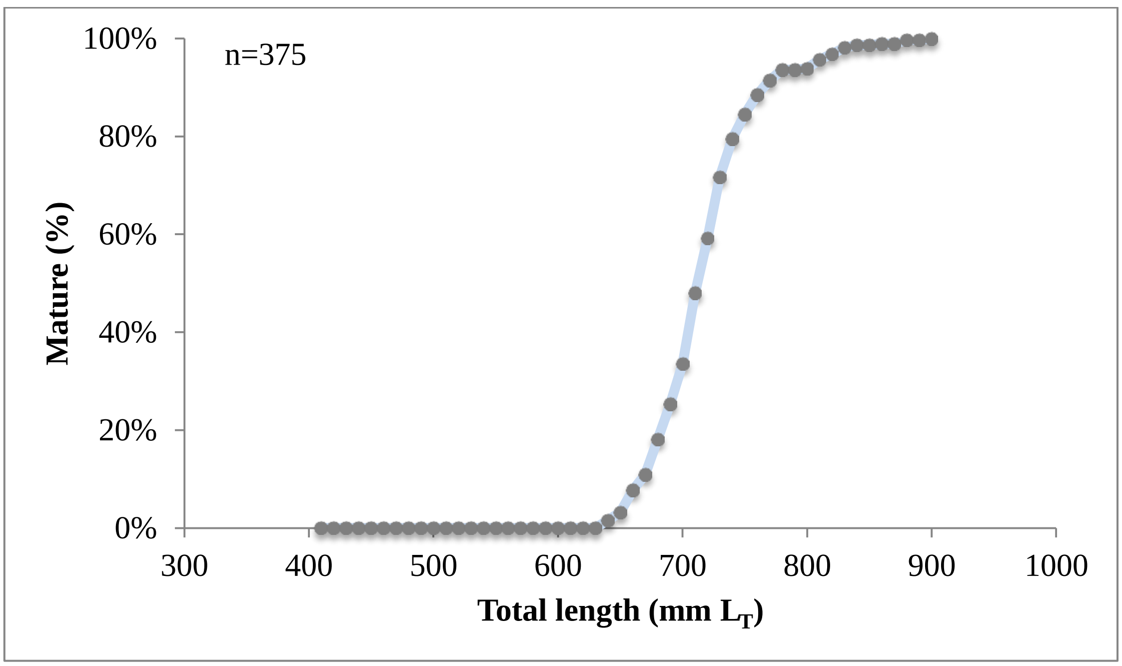

Figure 4.18. Percentage of mature male *L. macrorhinus* in each 100 mm length class, based on the presence of fully calcified claspers.

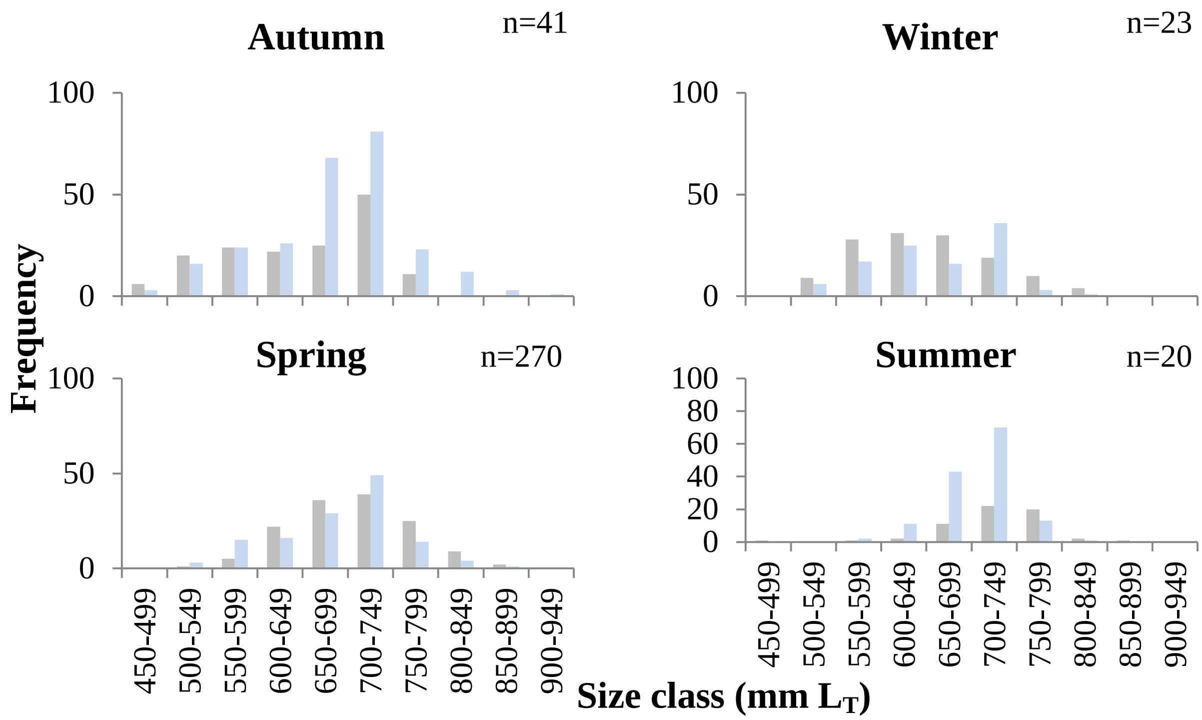

Figure 4.19. Seasonal size distribution of female (■) and male (■) *L. macrorhinus* at all landing sites.

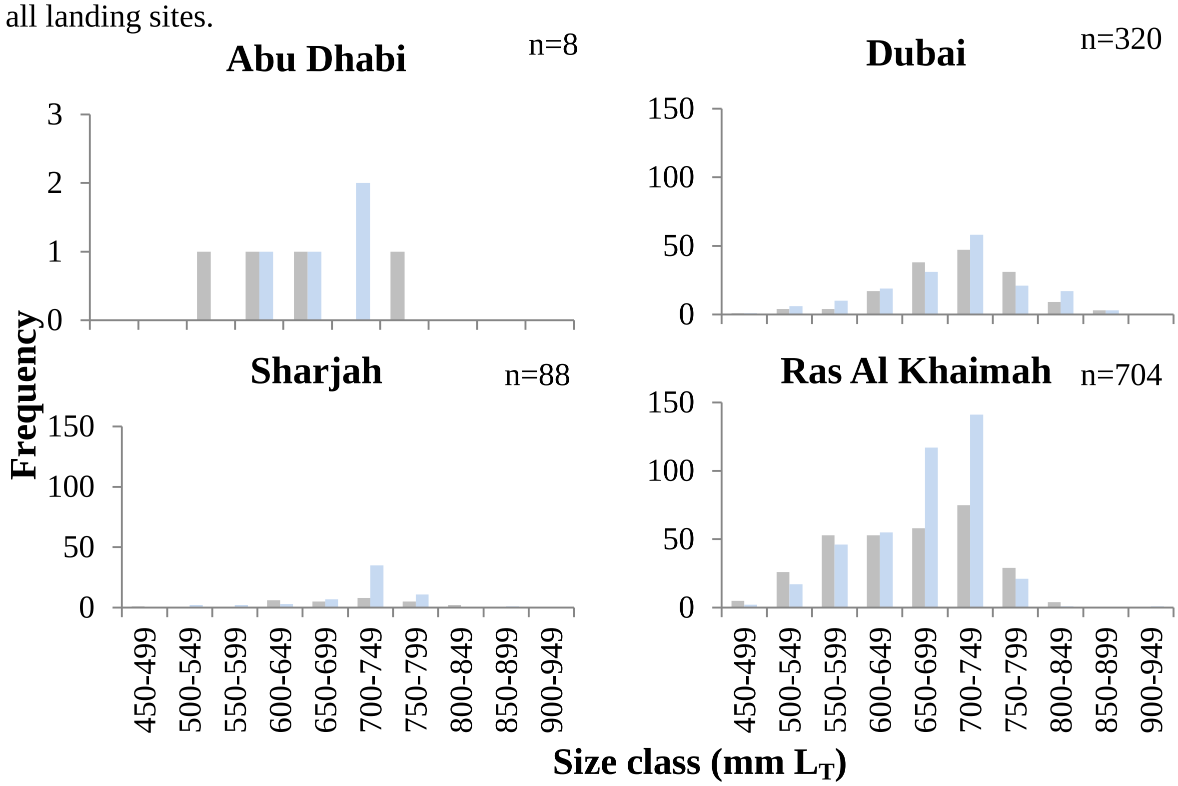

Figure 4.20. Size distribution of female (■) and male (■) *L. macrorhinus* based on landing site location.

- ***Carcharhinus dussumieri***

A total of 561 *C. dussumieri* (Valenciennes, in Müller & Henle, 1839), comprising of 210 females and 351 males were recorded. The landings contained significantly more males than females (X^2 (1, N=561)= 34.937, $p<0.05$) with an overall sex ratio of 1.67:1 in favor of males. Males outnumbered females throughout the seasons with sex ratios of 2.17:1 in autumn, 1.61:1 in winter, 1.66:1 in spring and 1.07:1 in summer. Catches of *C. dussumieri* remained stable in autumn (n=187) and winter (n=189) but dropped by half during the spring (n=96) and summer (n=86). Furthermore, catches of this species were significant in Abu Dhabi (n=136), Sharjah (n=212), and Ras Al Khaimah (n=150), but less frequent in Dubai (n=63).

Female sizes ranged from 369 to 989 mm L_T (mean 750.7 mm ± 117.4 S.D.) while males ranged from 362 to 921 mm L_T (mean 737.4 mm ± 80.1 S.D.). There was no significant difference between the median total length of female (730.5 mm L_T) and male (737 mm L_T) *C. dussumieri* (Mann-Whitney U-test, U=34704, n=561, p=0.247). The smaller individuals of both sexes were of similar sizes but females reached a greater maximum length (**Figure 4.21.**).

Gravid females (n=22) were recorded throughout the year and ranged in size between 815 and 989 mm L_T. The majority was found during the winter months (54.5%), but also in spring (31.8%), summer (9.1%), and autumn (4.5%). Based on the size of the smallest mature specimens recorded, 32.8% of females and 58.4% of males were mature among landed individuals. Males were found to mature at a smaller size class than females, 610-709 mm and 810-909 mm L_T, respectively. Immature males (n=25) possessing non-calcified claspers ranged in size between 362 to 638 mm L_T, males with partially calcified claspers (n=121) were between the sizes of 583 and 732 mm L_T, and males possessing fully calcified claspers (n=205) ranged in sizes between 678 to 921 mm L_T. Thus, maturity for males of this species is likely to occur between these sizes, i.e. 678 to 732 mm L_T (**Figure 4.22.**). Males also covered two main size classes in the 610-709 and 710-809 mm L_T size classes and therefore the vast majority of them were either maturing or fully mature. Males recorded in Sharjah and Ras Al Khaimah were the largest across locations in the 810-909 mm L_T size class and over, while large females were recorded at all sites. These large size classes for both sexes were recorded across the four seasons (**Figure 4.23.**).

Only two specimens with umbilical scars were recorded during the winter, measuring 362 and 369 mm L_T respectively. One embryo was also recorded measuring 379 mm L_T in February. All other specimens of this species were larger than 481 mm L_T and therefore an accurate L_T birth of *C. dussumieri* could not be determined but is likely to be close to the size of the YOY recorded. In general, across seasons and locations, few specimens below the 510-609 mm L_T size class were recorded. Winter was the only season where some YOY were found at the Dubai market, although size classes of 410-509 mm L_T were also recorded in Sharjah and Ras Al Khaimah in autumn and summer. Only specimens of 510-609 mm L_T and over were recorded in Abu Dhabi (**Figure 4.24.**).

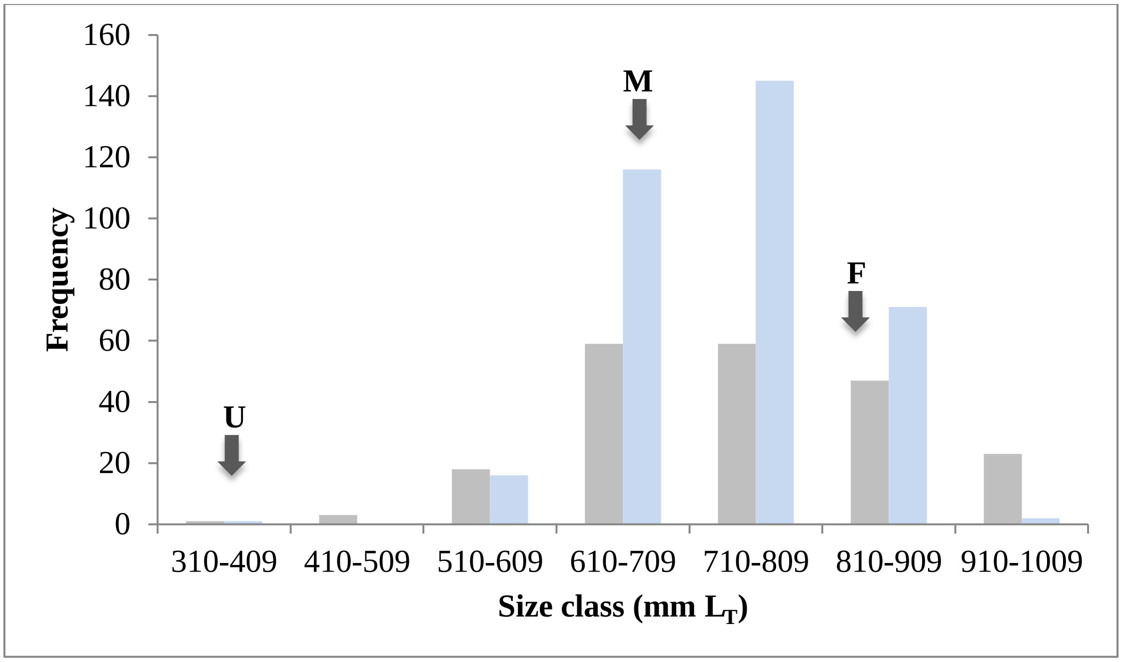

Figure 4.21. Size frequency distribution of female (■) and male (■) *C. dussumieri*. Arrows represent sizes of the smallest individual with an umbilical scar (U), and male maturity (M), female maturity (F), based on the smallest mature individuals recorded.

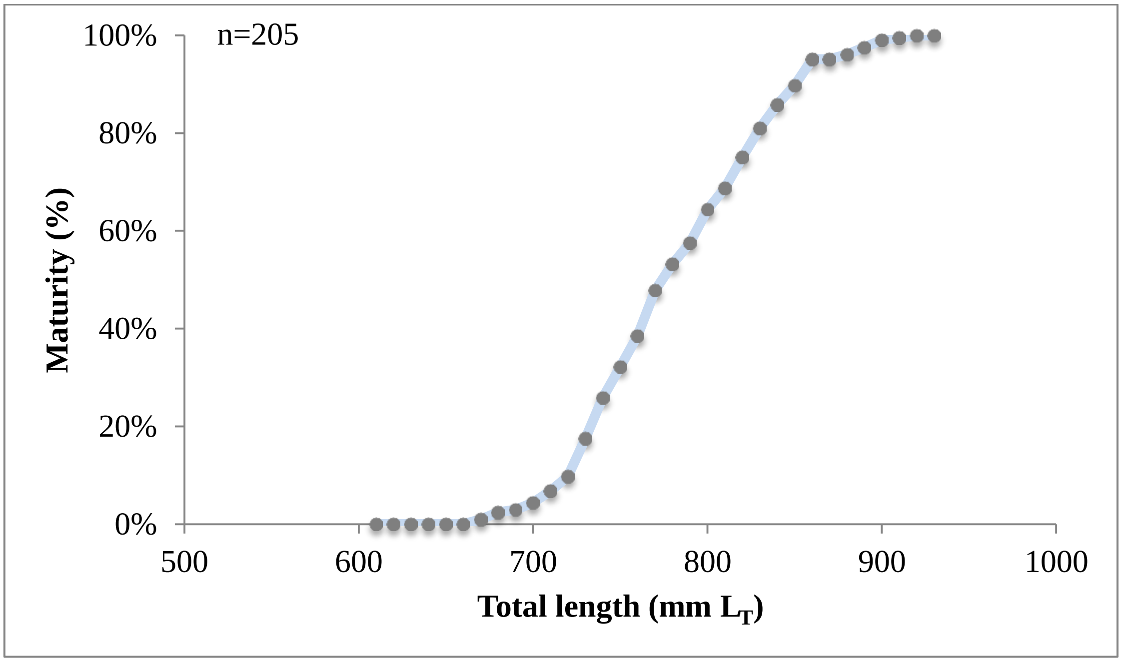

Figure 4.22. Percentage of mature male *C. dussumieri* in each 100 mm length class, based on the presence of fully calcified claspers.

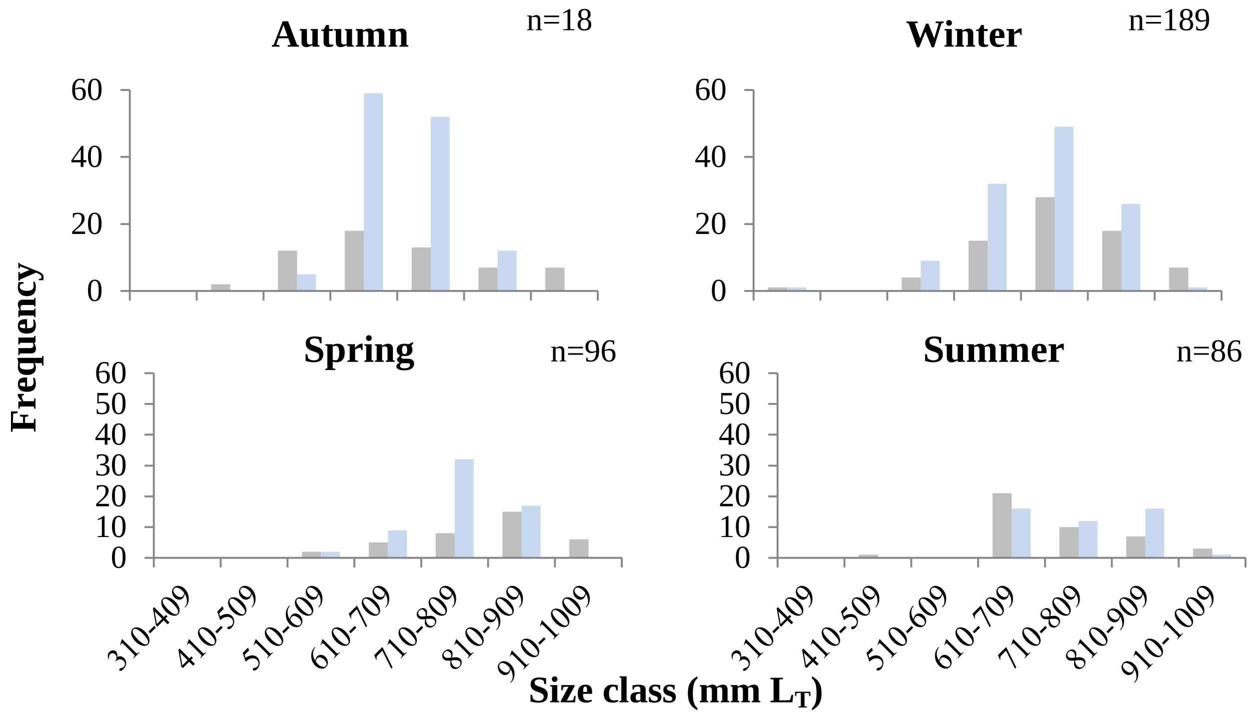

Figure 4.23. Seasonal size distribution of female (■) and male (■) *C. dussumieri* at all landing sites.

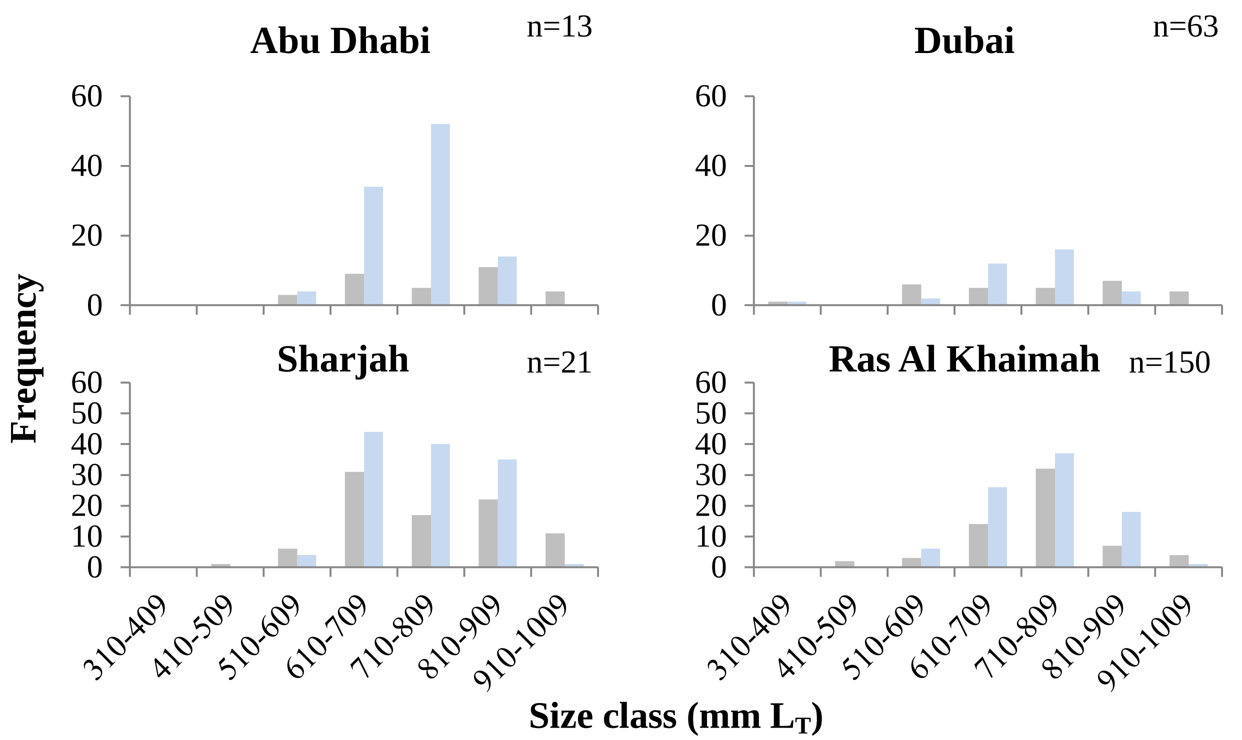

Figure 4.24. Size distribution of female (■) and male (■) *C. dussumieri* based on landing site location.

- ***Mustelus mosis***

A total of 204 *M. mosis* (Hemprich & Ehrenberg, 1899) were recorded, including 46 females. The landings contained significantly more males than females (X^2 (1, N=204)= 60.397, $p<0.05$) with an overall sex ratio of 3.43:1 in favor of males. There was a large disparity between males and females landed with males outnumbering females throughout the seasons with sex ratios of 2.08:1 in autumn, 2.43:1 in winter, and 5:1 in spring and summer. Catches of *M. mosis* were highest during the spring (n=101) but declined in summer (n=18) and were relatively stable in the autumn (n=37) and winter (n=48). Furthermore, catches were significant in Ras Al Khaimah (n=131), but less frequent at the Sharjah (n=55) and Dubai (n=17) landing sites. Only one female specimen measuring 837 mm L_T was recorded in Abu Dhabi during the spring.

Female sizes ranged between 569-1073 mm L_T (mean 791.7 mm ± 101 S.D.) and males sizes ranged between 582-913 mm L_T (mean 737.5 mm ± 38.6 S.D.). There was no significant difference between the median total length of female (781.5 mm L_T) and male (736 mm L_T) *M. mosis* (Mann-Whitney U-test, U=1058, n=204, p=0.501). The smallest individuals from both sexes were of similar sizes but the largest specimen of *M. mosis* recorded was a female (**Figure 4.25.**). The main modal sizes for males were the 700-749 mm and 750-799 mm L_T size class with very few individuals over those sizes. However, females recorded were represented in all size classes except the 950-999 mm L_T.

Five gravid females were recorded and ranged in size between 859 and 940 mm L_T. All these specimens were recorded during the spring season in Ras Al Khaimah (n=3), Dubai (n=1) and Sharjah (n=1). Furthermore, the largest female recorded (1073 mm L_T) was found in Ras Al Khaimah during the spring. However, while the largest females sizes were found during this season, spring and summer were also the times of the year where less females were recorded at all landing sites. Based on the size of the smallest mature specimens recorded, 28.2% of females and 74.1% of males were mature among landed individuals. Only one immature male was recorded (582 mm L_T), while 40 possessed partially calcified claspers with sizes ranging between 668 and 783 mm L_T, and 117 males possessed fully calcified claspers with sizes ranging between 704 to 913 mm L_T. Thus, maturity for males of this species is likely to occur between 704 mm and 783 mm L_T (**Figure 4.26.**). The smallest male specimens were recorded in Dubai in the 550-599 mm size class while specimens of larger sizes (650-699 mm to 900-949 mm L_T) were found in Ras Al Khaimah and Sharjah. However, males of all sizes were found across the four seasons (**Figure 4.27.**).

Furthermore, no specimens with visible umbilical scars were recorded and therefore size at birth for *M. mosis* could not be determined but is likely to be less than the size of the smallest individual found (569 mm L_T) and of the only immature male recorded (582 mm L_T). These small sizes were only recorded in autumn and spring at the Dubai and Ras Al Khaimah landing sites (**Figure 4.28.**).

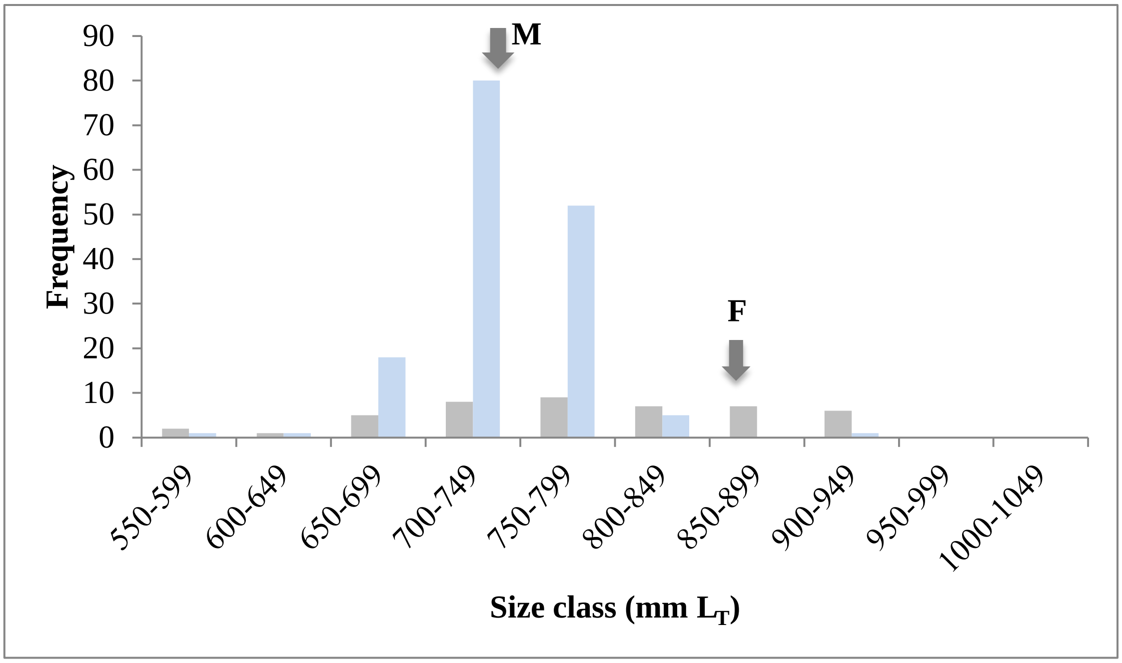

Figure 4.25. Size frequency distribution of female (■) and male (■) *M. mosis*. Arrows represent male maturity (M), and female maturity (F), based on the smallest mature individuals recorded.

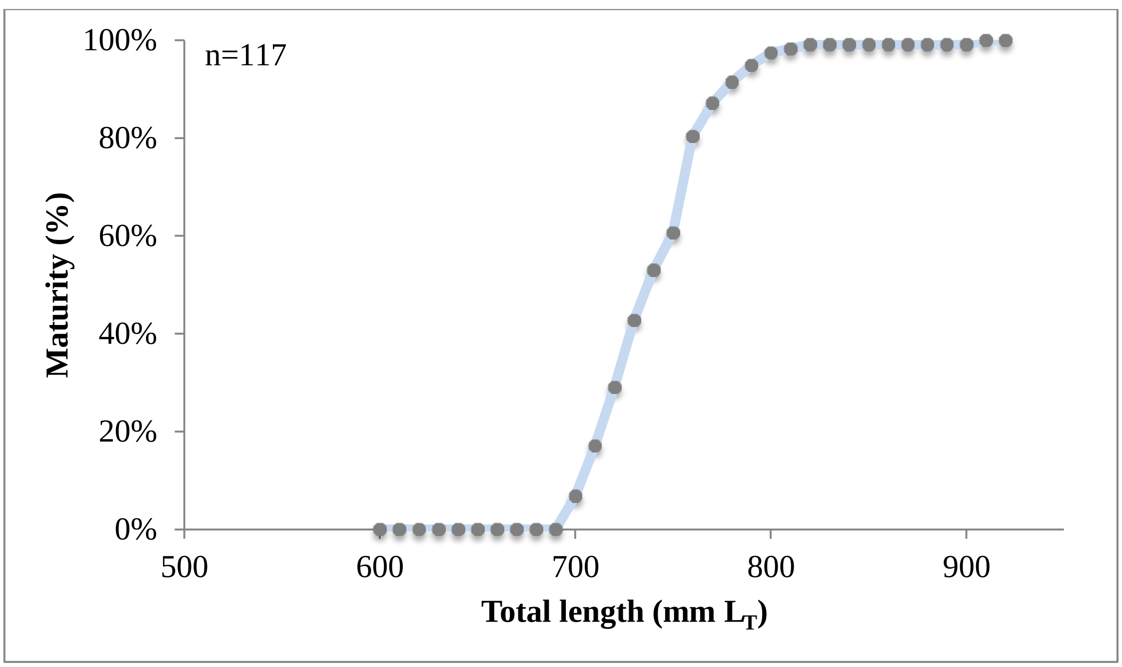

Figure 4.26. Percentage of mature male *M. mosis* in each 100 mm length class, based on the presence of fully calcified claspers.

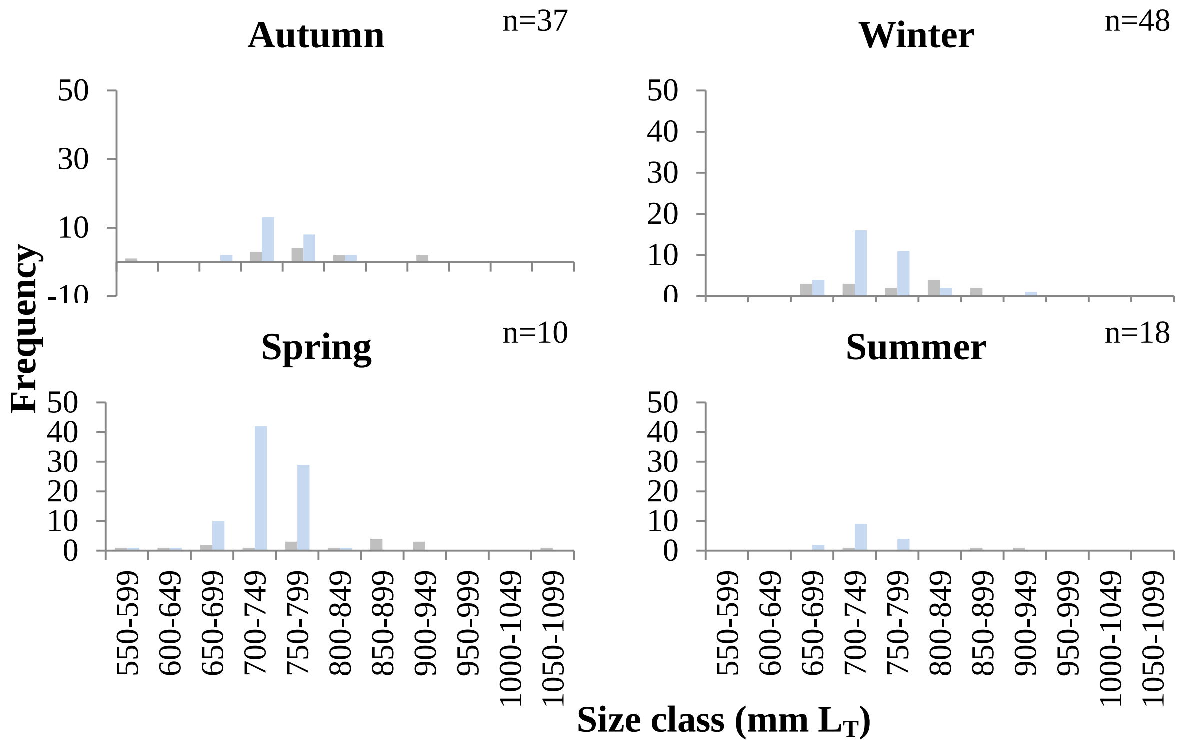

Figure 4.27. Seasonal size distribution of female (■) and male (■) *M. mosis* at all landing sites.

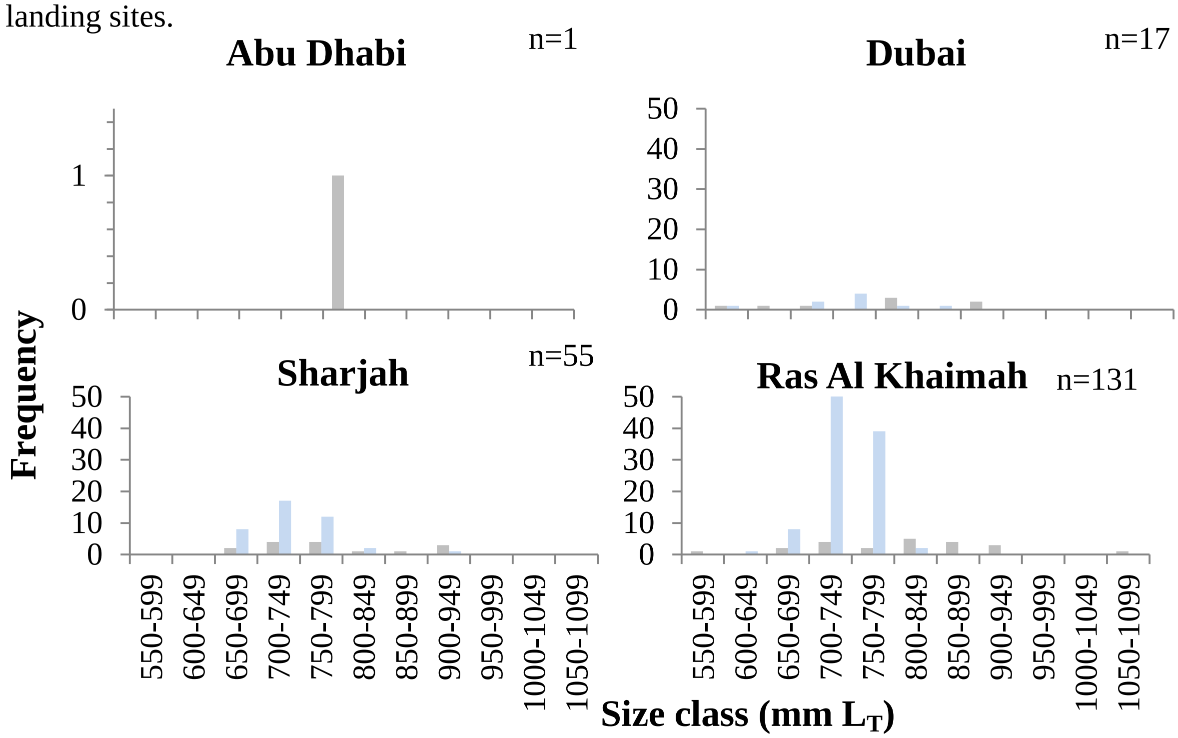

Figure 4.28. Size distribution of female (■) and male (■) *M. mosis* based on landing site location.

4.3.4 Size and sex composition of the remaining species

- ***Chiloscyllium arabicum***

Five *C. arabicum* (Gubanov, 1980) were recorded comprising one female (746 mm L_T) and four males (619 mm to 800 mm L_T). All males possessed fully calcified claspers indicating that males of this species likely mature at less than 619 mm L_T.

- ***Chiloscyllium griseum***

One mature male *C. griseum* (Müller & Henle, 1838) was recorded measuring 754 mm L_T in May 2011.

- ***Nebrius ferrugineus***

Two *N. ferrugineus* (Lesson, 1830) were recorded, comprising of one female (1395 mm L_T) and one male with fully calcified claspers (2191 mm L_T).

- ***Stegostoma fasciatum***

A total of nine *S. fasciatum* (Hermann, 1783) were recorded, of which five were females and four were males measuring from 1494 to 2110 mm L_T and 1835 to 1993 mm L_T respectively. One female measuring 1915 mm L_T was pregnant in May and all males possessed fully calcified claspers.

- ***Rhincodon typus***

One *R. typus* (Smith, 1828) was recorded in February 2012 in Dubai. This immature male measured 4452 mm L_T and possessed partially calcified claspers.

- ***Carcharias taurus***

The occurrence of a female specimen of *C. taurus* (Rafinesque, 1810) measuring 2560 mm L_T was confirmed through photographic evidence collected by fishermen on Dalma Island in Abu Dhabi.

- ***Chaenogaleus macrostoma***

A total of 60 *C. macrostoma* (Bleeker, 1852) were recorded comprising of 30 females and 30 males ranging in sizes from 514 to 934 mm L_T and 589 to 900 mm L_T respectively. The sex ratio of the landings did not differ significantly from parity (X^2 (1, N=60)= 0.016, p>0.05). Two gravid females of 832 and 841 mm L_T were recorded in the month of May. One male measuring 589 mm L_T possessed non-calcified claspers, four males (631-725 mm L_T) possessed partially calcified claspers, and all remaining males over 723 mm L_T possessed fully calcified claspers. Thus, male maturity for this species is likely to occur at ca.720-730 mm L_T.

- ***Hemipristis elongata***

A total of 49 *H. elongata* (Klunzinger, 1871) were recorded, of which 32 were females and 17 were males measuring 724 to 2560 mm L_T and 780 to 2052 mm L_T respectively. All males between 780 and 1226 mm L_T possessed partially calcified claspers, while males over 1311 mm L_T possessed fully calcified claspers suggesting that maturity in males of this species is likely to be occurring between 1226 mm and 1311 mm L_T.

- ***Paragaleus randalli***

A total of 85 *P. randalli* (Compagno, Krupp & Carpenter, 1996) were recorded, of which 25 were females and 55 were males. The landings contained significantly more males than females (X^2 (1, N=85)= 13.6, p<0.05). Females and males ranged in L_T from 665 to 848 mm and 616 to 809 mm respectively. Three pregnant females of 785, 801, 811 mm L_T were recorded in May. No immature males were found but five specimens ranging from 616 to 676 mm L_T possessed partially calcified claspers and the remaining 50 males were mature with fully calcified claspers (651 to 809 mm L_T). Maturity in males of this species is therefore likely to occur around 651-676 mm L_T.

- ***Carcharhinus amblyrhynchoides***

A total of 90 *C. amblyrhynchoides* (Whitley, 1934) comprising of 34 females and 56 males were recorded. The landings contained significantly more males than females (X^2 (1, N=90)= 4.9, $p<0.05$). The females and males measured in L_T from 865 to 2430 mm and 799 to 2334 mm, respectively. Two gravid females of 2043 and 2246 mm L_T with late term embryos were recorded in March. Eight males (799-1531 mm L_T) possessed non-calcified claspers, 13 males (1463-1774 mm L_T) possessed partially calcified claspers, and the remaining 35 males (1653-2334 mm L_T) possessed fully calcified claspers. Thus, it appears that males for this species are likely to attain maturity between 1653 and 1774 mm L_T.

- ***Carcharhinus amblyrhynchos***

A total of eight *C. amblyrhynchos* (Bleeker, 1856) were recorded, of which three were females and five were males measuring from 1080 mm to 1922 mm L_T and 1138 mm to 1805 mm L_T respectively. The smallest male (1138 mm L_T) possessed non-calcified claspers, one male (1352 mm L_T) possessed partially calcified claspers, and the remaining three males possessed fully calcified claspers (1627-1805 mm L_T). Therefore, an accurate size at maturity for males could not be determined, but is likely to be between 1352 mm and 1627 mm L_T.

- ***Carcharhinus amboinensis***

A total of 127 *C. amboinensis* (Müller & Henle, 1839) were recorded, of which 63 were females and 64 were males. The sex ratio of the landings did not differ significantly from parity (X^2 (1, N=127)= 0, p>0.05). The females and males ranged in L_T from 704 to 2586 and 642 to 2456 mm, respectively. One gravid female measuring 2546 mm L_T was recorded in May. Three female and six male specimens with visible umbilical scars measured 704 to 767 mm and 642 to 889 mm L_T, respectively. The smallest three neonates were found during the month of March (642, 659 and 704 mm L_T), five were found in May (763, 766, 767, 783, 866 mm L_T), and the largest YOY was recorded in August (889 mm L_T) indicating that the L_T at birth is likely to be less than 642 mm L_T and that birth is presumably occurring during the late spring and early summer months. Twenty-nine males were immature with non-calcified claspers (642-1970 mm L_T), 18 males had partially calcified claspers (1797-2173 mm L_T), while 17 males had fully calcified claspers (2150-2456 mm L_T). Thus, maturity for males of this species is likely to occur at L_T ca. 2150-2173 mm.

- ***Carcharhinus brevipinna***

A total of 66 *C. brevipinna* (Müller & Henle, 1839) were recorded, comprising of 34 females (561-2670 mm L_T) and 32 males (556-2391mm L_T). The sex ratio of landings did not differ significantly from parity (X^2 (1, N=66)= 0.015, p>0.05). Two gravid females measuring 2436 and 2602 mm L_T were recorded in February and May respectively. Two female and five male YOY specimens measured 602 to 794 mm and 556 to 828 mm L_T, respectively during the months of February (n=1), March (n=4), May (n=2), and July (n=1). Size at birth could not be estimated but is presumably close to or less than the L_T of the smallest individual, i.e. 556 mm. Seventeen males were immature with non-calcified claspers (556-1406 mm L_T), seven males had partially calcified claspers (1362-1822 mm L_T), while eight males had fully calcified claspers (1771-2391 mm L_T). Thus, maturity for males of this species is likely to occur at L_T ca. 1771-1822 mm.

- ***Carcharhinus falciformis***

A total of six *C. falciformis* (Müller & Henle, 1839) were recorded comprising of four females (757-1081 mm L_T) and two males possessing non-calcified claspers of 797 mm and 826 mm L_T respectively. Five of these specimens ranging from 757 mm to 832 mm L_T had visible umbilical scars. Size at birth could not be estimated but is likely to be close to or less than the L_T of the smallest individual, i.e. 757 mm.

- ***Carcharhinus leiodon***

A total of three *C. leiodon* (Garrick, 1985) were recorded. The one female and two males measured 531, 731 and 1372 mm L_T respectively. The female was recorded in December and had a visible umbilical scar which suggests that size at birth for this species is around 531 mm L_T or less, and parturition occurs during the winter months. The male measuring 731 mm L_T possessed non-calcified claspers whereas the 1372 mm L_T male had fully calcified claspers. Size at maturity could not be estimated but is presumably close to or less than the L_T of largest individual.

- ***Carcharhinus leucas***

A total of 167 *C. leucas* (Müller & Henle, 1839) were recorded, comprising of 90 females (688-2430 mm L_T) and 77 males (692-2977 mm L_T). The sex ratio of the landings did not differ significantly from parity (X^2 (1, N=167)= 0.862, p>0.05). One gravid female was recorded in December measuring 2190 mm L_T. Twenty six specimens with visible umbilical scars were recorded including 23 females (688-838 mm L_T) and 13 males (709-835 mm L_T) during the months of January (n=9), March (n=2), May (n=14), June (n=9) and August (n=2). Therefore, birth is presumably occurring at various times of the year with size at birth likely to be less than 688 mm L_T. All males less than 1633 mm L_T (n=32) possessed non-calcified claspers, 40 males ranging from 1638 to 2170 mm L_T possessed partially calcified claspers, and males over 2208 mm L_T possessed fully calcified claspers. Thus, maturity for males in this species is likely to be occurring sizes between 2170 and 2208 mm L_T.

- ***Carcharhinus macloti***

A total of 173 *C. macloti* (Müller & Henle, 1839) were recorded, of which 75 were females (518-971 mm L_T) and 98 were males (475-905 mm L_T). The sex ratio of landings did not differ significantly from parity (X^2 (1, N=173)= 2.797, p>0.05). Four females measuring 903, 910, 933 and 951 mm L_T were pregnant in May (n=2), June (n=1), and July (n=1), respectively. One of these females (951 mm L_T) had a female embryo measuring 447 mm L_T. Furthermore, two YOY males were recorded in June measuring 475 and 481 mm L_T, respectively. Thus, size at birth is likely to be between 447 and 481 mm L_T and birth is presumably occurring at this time of the year. All males (n=25) measuring less than 646 mm L_T possessed non-calcified claspers. Twenty nine males ranging in L_T from 648 to 779 mm possessed partially calcified claspers while 44 males over 746 mm L_T possessed fully calcified claspers. Therefore, maturity for males of this species is likely to occur between 746 and 779 mm L_T.

- ***Carcharhinus melanopterus***

A total of 38 *C. melanopterus* (Quoy & Gaimard, 1824) comprising 25 females (496-1523 mm L_T) and 13 males (522-1243 mm L_T) were recorded. Four females (1324-1468 mm L_T) were pregnant during the months of January, March, and April.

Eight neonates (496-607 mm L_T) were recorded in May, June, and July, thus size at birth is presumably close to or less than the L_T of the smallest individual, i.e. 496 mm L_T, with birth likely occurring at this time of the year for *C. melanopterus*. Eight males (522-920 mm L_T) were immature with non-calcified claspers, three possessed partially calcified claspers (1025-1061 mm L_T) and two had fully calcified claspers (1232-1243 mm L_T) which indicates that males of this species mature at ca. 1061-1232 mm L_T.

- ***Carcharhinus plumbeus***

A total of 13 *C. plumbeus* (Nardo, 1827) were recorded comprising of six females (1443-2393 mm L_T) and seven males (1589-1956 mm L_T). A single gravid female (1802 mm L_T) was recorded in May suggesting that size at maturity for females of this species is close to or less than this L_T. Males over 1712 mm L_T possessed fully-calcified claspers while one male (1589 mm L_T) possessed partially-calcified claspers suggesting that maturity for males of this species occurs between these two L_T. All individuals recorded were maturing or mature and no YOY specimens were recorded.

- ***Galeocerdo cuvier***

One immature male *G. cuvier* (Peron & Lesueur, 1822) possessing partially calcified claspers was recorded measuring 2073 mm L_T.

- ***Negaprion acutidens***

A total of 41 *N. acutidens* (Rüppell, 1837), comprising 18 females (882-2650 mm L_T) and 23 males (867-2440 mm L_T) were recorded. Two pregnant females were recorded measuring 2576 mm L_T and 2650 mm L_T in March and May 2011 respectively, thus females of this species are likely to be maturing at less than 2576 mm L_T. The largest males possessing non-calcified or partially calcified claspers were

1991 mm L_T and 2356 mm L_T respectively, whereas the only male possessing fully calcified claspers was 2440 mm L_T. Thus, an accurate size at maturity of males could not be determined, but is likely to be around the L_T of the only mature male.

- ***Rhizoprionodon oligolinx***

A total of 32 *R. oligolinx* (Springer, 1964) were recorded including 12 females and 20 males ranging in L_T between 552 to 907 mm and 577 to 785 mm, respectively. Two males possessed non-calcified claspers (577 and 594 mm L_T), one male possessed partially calcified claspers at 593 mm L_T, and the remaining 17 males possessed fully calcified claspers (609 mm to 785 mm L_T). Males of this species are therefore likely to be maturing between 593 mm and 609 mm L_T.

- ***Sphyrna lewini***

A total of 15 *S. lewini* (Griffith & Smith, 1834) were recorded, of which eight were females (475 to 3027 mm L_T) and seven were males (469 to 2543 mm L_T). The largest males possessing non-calcified or partially calcified claspers were 1078 mm and 1500 mm L_T respectively while the only male with fully calcified claspers measured 2543 mm L_T. Therefore, an accurate size at maturity for males could not be determined but is between the above two lengths. A single pregnant female showing evidence of late term embryos measured 3027 mm L_T. Also, three specimens were neonates measuring between 469 and 508 mm L_T, therefore the L_T at birth in this species is likely to be between these lengths. These were recorded in late July, August, and September, which could imply that birth is occurring in *S. lewini* at this time of the year.

- ***Sphyrna mokarran***

A total of 124 *S. mokarran* (Rüppell, 1837), comprising 69 females (815 to 3820 mm L_T) and 55 males (543 to 3058 mm L_T) were recorded. The sex ratio at landings did not differ significantly from parity (X^2 (1, N=124)= 1.362, p>0.05). Fourteen males ranging from 543 to 1970 mm L_T possessed non-calcified claspers, 29 males (1811-2678 mm L_T) possessed partially calcified claspers, and 12 males (2670-3058 mm L_T) possessed fully calcified claspers. This indicates that maturity in males of this species is likely to be occurring at ca. 2670-2678 mm L_T. Size at birth could not be estimated but one juvenile male recorded in August and measuring 543 mm L_T had a visible umbilical scar.

A summary of biological data collected from shark species confirmed from UAE Gulf waters, including size ranges and size at maturity for females and males, is provided in **App. A, Table 4.5.** along with similar information compiled from various published sources.

4.3.5 DNA barcoding

Of the 130 samples from 30 species identified in this study, the final data set comprised of 120 sequences from 29 species with sequence lengths varying from 485 to 637 bp. Ten samples were excluded from the analysis because three of them yielded ambiguous species identifications, and may therefore have been contaminated, while seven samples failed to provide good sequences, including the only sample of *C. griseum* collected from this study. All sequences were compared with those in BOLD and GenBank databases to confirm initial identification and results of matching sequences along with the amplicon size produced for each sample are provided in **App. A, Table 4.6.**

Genetic analysis unequivocally confirmed 24 species among the ones recorded in this study based on morphological characteristics. Of these, 12 sequences were the first available from the Gulf for the following species: *C. arabicum, N. ferrugineus, S. fasciatum, R. typus, C. taurus, C. amblyrhynchos, C. falciformis, C. melanopterus, C. plumbeus, N. acutidens, G. cuvier,* and *S. lewini.* However, taxonomic identification was ambiguous for five species and details are presented below.

- ***Chiloscyllium arabicum***

Only two samples were successfully barcoded. Although results from both BOLD and GenBank assigned this sequence to the *Chiloscyllium* genus, species resolution was not possible. The closest match was at 92.9% with *C. griseum* in BOLD and 93% with *C. hasselti* in the GenBank database.

- ***Rhizoprionodon oligolinx***

While these provided a 100% match with the same species in BOLD, the closest match in GenBank was 93% with *R. porosus*.

- ***Paragaleus randalli* and *C. macrostoma***

There was no consistency in the nomenclature of records in BOLD and GenBank for these two species. Most sequences in both databases for both species showed 100% similarity and 99% matches to both species simultaneously and to *P. tengi*.

- ***Carcharhinus limbatus* and *C. amblyrhynchoides***

Although sequences for *C. limbatus* had slightly different barcodes between them, they all matched the species in both databases. However, sequences from *C.*

amblyrhynchoides yielded ambiguous results and matched both *C. limbatus* and *C. amblyrhynchoides*.

4.3.6 Phylogenetic analysis

A similar tree topology was obtained with the three inference methods tested. Species were identified by well supported clusters, except for those species represented by a single sample (**App. A, Figure 4.29.**). In all trees, the specimens that from database matches could have been either *C. limbatus* or *C. amblyrhynchoides* were all assigned to one species based on their clustering. Some *P. randalli* and *C. macrostoma* samples clustered as one species, however, one *C. macrostoma* sample stood out as a separate species. Some of the differences between trees include:

- Neither ML or NJ trees reflected the separation between the Orectolobiform and Lamniform orders observed with the MP method, although they were clearly separated for the Carcharhiniformes.
- In the ML tree, species of the *Carcharhinus* genus cluster together; however, the remaining species from the Carcharhinidae family form their own clades and cluster together with species from the Hemigaleidae, Triakidae, and Sphyrnidae families.
- In the NJ tree, species cluster together in separate units and reflect their respective families and orders. Unlike the ML tree, Hemigaleidae species cluster together and reflect their separate family. However, Sphyrnidae and Triakidae species are still clustered closely with the Carcharhinidae.

- The MP tree provided the most conservative results. It did not support any family groupings but recognized Orectolobiformes and Lamniformes as separate orders. Furthermore, closely related and morphologically similar species such as *C. limbatus*, *C. amblyrhynchoides*, *C. leiodon* and *C. melanopterus* were clustered together into one clade. Similarly, specimens of *P. randalli* and *C. macrostoma* were clustered as one unit.

Although there are some differences in the classifications at the family and order levels, these trees provided similar outcomes in terms of relationships between species and therefore only results based on the NJ tree using the Kimura two-parameter model with bootstrap values are illustrated.

4.4 Discussion

This chapter details a two year study of shark catch composition at various landing sites across the Gulf coast of the UAE and greatly improves the current status of knowledge regarding the relative abundance, size distribution and biological aspects of most sharks exploited by the fishery. This market assessment is the first comprehensive study on shark species found in Gulf waters and has allowed an updated checklist of species in the area to be developed. It is however important to note that although much information has been gathered about the biology of the six most abundant species from UAE Gulf waters, data on these species and particularly from the remaining 24, are still incomplete and in some cases insufficient to allow for conclusions to be drawn regarding the local biological characteristics as well as the conservation status of each species. The data collected are, therefore, mostly an indication of the potential life-history characteristics of each species and a relative measure of the variability between them and other populations of the same species around the world. An overview of the likely reasons behind the variations recorded in this study are provided in the next sections as well as separate detailed accounts for each species with information on regional differences for maximum total length, size at maturity for males and females, as well as reproductive biology.

4.4.1 Species diversity and occurrence

Considering that the Gulf is regarded as a highly stressful environment for many species due its extreme environmental conditions (Carpenter *et al.* 1997), the total number of shark species recorded from this study can be considered high. Indeed, studies from the Red Sea, an enclosed body of water considered a marine biodiversity hotspot (Roberts *et al.* 2002), have only confirmed 29 species of sharks (Golani & Bogorodsky 2010; Spaet *et al.* 2011). Surveys conducted in Omani waters have documented 36 shark species from the Arabian Sea (Henderson *et al.* 2007; Henderson & Reeve 2011), while in the Maldives, 34 species have been reported (Anderson & Ahmed 1993). However, when compared with other countries in the region such as India which has documented 66 shark species (Raje *et al.* 2002), Sri Lanka with 61 species (Joseph 1999; Herath 2012), and Malaysia with 48 species (Ali *et al.* 1999), the Gulf has a significantly lower species richness. This could be due to a variety of reasons including the diversity of fishing gear used in other countries as well as the habitats that are exploited. In fact, countries bordering the Gulf are characterized by ‘artisanal’ fisheries limited to dhows and tarads using traditional gear (Carpenter *et al.*

1997), whereas other countries in the region utilize a diversity of fishing vessels that operate with a variety of gear at different depths (Ali *et al.* 1999; Joseph 1999). The limited bathymetry of the Gulf likely precludes deep water species such as the bramble shark, *Echinorhinus brucus,* that has been documented from Oman (Henderson *et al.* 2007; Javadzadeh *et al.* 2010; Henderson & Reeve 2011), or even small species commonly found in the Arabian Sea that favor deep waters such as the bigeye hound shark, *Iago omanensis* (Henderson *et al.* 2006), from inhabiting these waters. However, while it is known that deep water chondrichthyan fauna from around the world is highly biodiverse, it remains mostly undocumented (Kyne & Simpfendorfer 2007). Therefore, since the deepest waters in the Gulf are close to the Strait of Hormuz, where there is a lack of fisheries data and research, it is possible that shark species that have not been previously recorded for this body of water could be found.

The latest annotated checklist of shark species from the Gulf confirmed 26 species of sharks (Moore *et al.* 2012b). This study has elevated this number to 30 and confirmed the occurrence of species such as *C. griseum*, *N. ferrugineus*, *C. plumbeus* and *C. falciformis*, whose presence had previously been questioned. It is probable that most of the abundant shark species found in UAE Gulf waters have been documented through this study. Actually, the number of species encountered did not increase much after the first year of study and likely represents the actual species composition of the region. However, market surveys may have underestimated rare species, such as whale sharks, *R. typus,* which are often reported by the public particularly from sightings in marinas in Dubai and Abu Dhabi (David Robinson, *pers. comm*.). A ban on the fishing of whale sharks in the UAE has been in place since 2008 and while incidental bycatch of this species may still occur, they presumably go unreported or catches may not be retained. Furthermore, as noted from data collected though interviews with fishermen in this study (Refer to **Chapter III**), most carpet shark species such as *C. arabicum* and *S. fasciatum,* with low market value, are generally discarded at sea and therefore are presumably not accurately represented in landings. This could also be due to fishing practices and the positioning of fishing gear, which might preclude the capture of demersal or bottom associated species such as these. Finally, it is possible that other less abundant species or seasonal migrants would have been recorded if more frequent sampling was undertaken in remote areas where targeted shark fisheries are undertaken at smaller scales, i.e. Sila. For instance, the *C. taurus* record in this study was reported opportunistically when a fisherman showed the project investigator pictures of his catches (Jabado *et al.* 2013). Furthermore, a thresher shark sighting, *Alopias* sp., was reported by a diver at an offshore wreck in Dubai in August 2012 and was recognized based on its 'shark' appearance and its elongated tail (David Holdman, *pers. comm*.), a characteristic feature for this family of sharks (Compagno *et al.* 2005). While verification of this sighting is not possible, it is important to note that thresher sharks have previously been reported in the literature (Gubanov & Schleib 1980) and that remains of four caudal vertebrae belonging to thresher sharks were recorded from archeological sites off Dalma Island in Abu Dhabi (Beech 2004b). Furthermore, both the pelagic thresher, *Alopias pelagicus,* and the big eye thresher, *A. superciliosus,* are present in Omani waters (Henderson *et al.* 2007).

The most dominant species recorded in this study were *C. sorrah, R. acutus, C. limbatus, L. macrorhinus, C. dussumieri* and *M. mosis*. Other than *C. limbatus,* these species are relatively small sharks, generally measuring less than 1500 mm L_T, that commonly form large schools in inshore waters (Compagno *et al.* 2005; Last & Stevens 2009). Whereas not much is known about the behavior of *M. mosis*, it is also probable that it forms groups in inshore areas similarly to other species of triakids which are known to be abundant in coastal waters (Compagno *et al.* 2005). Likewise, *C. limbatus*, a larger shark reaching over 2500 mm L_T is known to prefer inshore areas and is commonly found in large surface schools (Compagno *et al.* 2005). This aggregating behavior and the preference for inshore waters could explain the particularly high abundance of these species in catches.

All species reported from Kuwait and Qatar landings were also present in UAE catches (Moore *et al.* 2012b). The lower number of species recorded in the northeastern Gulf surveys could be due to the limited temporal scale of the sampling which only occurred during the month of April. Indeed, even in the UAE, some species were only recorded at specific times of the year such as *C. falciformis* in the autumn months. Furthermore, the majority of species reported here were also documented from Omani landings except for both *Chiloscyllium* species, *N. ferrugineus* and *R. oligolinx* (Henderson & Reeve 2011). The absence of carpet sharks from Omani landings could also be due to fishermen discarding their catches at sea, especially if individuals captured were small, or at a low abundance. In fact, in this study, large specimens of *N. ferrugineus* have been documented originating from Oman while investigating the trade in sharks (Refer to **Chapter VI**). The reason behind the absence of *R. oligolinx* from catches in Oman remains unclear since it is considered an abundant inshore species across its range (Compagno *et al.* 2005).

Twenty six species of sharks were recorded in Sharjah while only 19 species were recorded in Abu Dhabi. These two sites had the lowest species overlap with only 60.7% similarity. These differences are unlikely to be due to fishing methods utilized since similar gears are used across the country. However, this could be explained by the variability of fishing grounds used by fishermen in these two emirates and the differences in habitats and environmental conditions that may be found in each area. Although Abu Dhabi waters include some offshore islands with deeper waters, most of the western inshore areas are characterized by shallow embayments with higher water temperatures and salinities (EAD 2011a). On the other hand, fishermen in Sharjah mostly utilize inshore and deeper waters towards the northern region of the UAE (Refer to **Chapter III**) which are supplied with oceanic water inflowing from the Arabian Sea (Price 1993). Studies have shown that within the Gulf, the richest areas for fish fauna are closer to the Strait of Hormuz where waters are deeper (Price 1993). The similarities in species recorded for Sharjah, Ras Al Khaimah and even Dubai are therefore likely to be due to the similar fishing grounds utilized.

While there were some seasonal variations in the numbers of species caught, the overall dominant species did not change throughout the sampling period. There seems to have been in shift in dominance between *C. sorrah* and *R. acutus* where *C. sorrah* was most common during the spring and summer months, while *R. acutus* contributed more to landings in the autumn and winter months. On the other hand, all other species were caught in lower numbers during the summer, which was the time of year that yielded the lowest number of catches at 17.8% of all landings. Studies on demersal fish species in the Gulf have shown a pattern where distribution and abundance vary seasonally and among habitat types (Basson *et al.* 1977; Shallard & Associates 2003). Grandcourt (2012) suggested this was likely due to the increased water temperatures during summer months and the reduced fishing activity at that time of the year. In fact, it is believed that the reduction of abundance of reef fish during the summer is a result of the movement of species to deeper and cooler waters (Shallard & Associates 2003). For sharks, some studies have shown that the most common species can change seasonally (Bizzarro *et al.* 2009b). Data from the artisanal shark fishery in Mexico showed that landings were highly seasonal and different between the regions studied and this was also attributed to the migratory behavior of various species of sharks (Castillo-Geniz *et al.* 1998). Similarly, catches in Oman showed marked differences between seasons and across survey sites which was also believed to be a result of the migration pattern of different shark species (Henderson *et al.* 2008). Also, differences in landings across seasons may be due to variable relative abundance of shark species in local waters. Because fishermen were found to be highly opportunistic, and most areas within UAE waters were utilized for fishing, the species composition of landings across seasons and locations probably reflected actual local relative abundance.

4.4.2 Size compositions

Species of the Carcharinidae family dominated landings in this study (95.5%). It has been shown that this family is very important in both commercial and artisanal fisheries across the world, and species within it mostly dominate catches in many tropical areas (Bonfil 1994; Castillo-Geniz *et al.* 1998; Compagno *et al.* 2005; Henderson *et al.* 2007; White 2007; Last & Stevens 2009). Biological parameters for the majority of species in this study showed significant variations when compared with published information from the Gulf, Oman, and other regions of the world. In general, within the carcharhinids, life history traits such as maximum size and length at maturity for females and males show considerable variations between populations of the same species across regions but also within the same stocks (Stevens & McLoughlin 1991; Compagno 2002; Lombardi-Carlson *et al.* 2003).

Similarly to what was found in this study, the market dominance of mostly small bodied sharks, from a limited number of species, has also been recorded from other areas. Data from Oman indicated that eight species dominated landings (Henderson *et al.* 2007); five species represented 64% of landings in the northeastern Gulf (Moore *et al.* 2012a); three species were dominant in Iran (FAO 2009a); 12 species were most abundant in Sri Lankan catches (Herath 2012); and five species comprised up to 90% of shark specimens recorded in Chinese markets (Lam & Sadovy de Mitcheson 2011). In this study, while some species of large bodied sharks were found in landings, they were either largely immature specimens, i.e. *C. limbatus*, or did not contribute substantially to fishery landings such as *C. brevipinna* and *S. mokarran*. Little information is available on whether larger sharks used to be more common, but fishermen have stated that shark sizes in the Gulf have been greatly reduced (Refer to **Chapter III**). Therefore, it is possible that many larger species have been overfished to some extent and that the fishery is now reliant on smaller sharks that dominate landings. It is important to note that individual species may have different levels of susceptibility and resilience to exploitation (Stevens *et al.* 2000a; Bonfil 2001). Small bodied carcharhinids, such as *R. acutus*, tend to grow fast, mature early, have short life spans and display aseasonal reproductive cycles (Wourms 1977; Stevens & McLoughlin 1991). In fact, Henderson *et al.* (2008) reported both female and male *R. acutus* in Oman reaching maturity at sizes corresponding to two and three years of age. On the other hand, larger sharks such as *C. brevipinna*, mature much later and exhibit slower growth rates while typically displaying seasonal breeding cycles and producing annual, biennial or triennial litters (Wourms 1977; Last & Stevens 2009). Therefore, the overall life-history traits of small shark species generally lead to a higher biological productivity making them less susceptible to fishing pressures which could explain their dominance at various markets. Musick *et al.* (1993) noted that in areas off southeastern Africa and in the northwest Atlantic, overexploitation of large sharks could have led to the proliferation of small bodied sharks. A declining trend in the number of large sharks and a shift in effort towards smaller individuals have also been documented from Mexico, China and Madagascar where the species composition of landings for the whole area have been impacted (McVean *et al.* 2006; Bizzarro *et al.* 2009b; Lam & Sadovy de Mitcheson 2011). Henderson *et al.* (2007) documented a shift in the species composition of the Omani shark fishery in just a few years where larger sharks such as *C. limbatus* and *S. lewini* were displaced by the smaller *L. macrorhinus* and *C. macloti*. A change in species composition and size ranges of fished sharks could have serious implications for the sustainability of a fishery. Furthermore, population studies of coastal shark species have indicated that even a slight increase in juvenile mortality can greatly reduce the sustainability of coastal shark fisheries (Cortes 1998). It is therefore important to monitor shark catches in the UAE to document any changes in the species and size compositions of sharks landed.

For most species in this study, size ranges of individuals were considerable and represented all life stages. Furthermore, for some species such as *C. sorrah*, *C. arabicum* and *P. randalli*, maximum sizes reported here were larger than previously documented. However, of concern was the high proportion of juveniles in the landings. According to the size data collected from the most abundant species, the majority of *C. sorrah*, *C. limbatus*, *C. dussumieri* and female *M. mosis* individuals were immature. The fishery in the UAE uses a combination of fishing gear, i.e. nets, hand lines and longlines, which allow the target of all sizes of sharks indiscriminately. Nets are likely to catch schooling juveniles sharks in large numbers since mesh sizes of 1.5 x 1.5 inches (about 380 mm) are allowed under Federal Law 23. These high numbers of immature individuals also likely indicate that many species are being exploited in their nursery areas and therefore being prevented from reaching maturity and consequently mating or producing young.

Variations in length at maturity for various species of sharks have been linked to water temperature (Menni & Lessa 1998) and it has been hypothesized that increased length at maturity occurs because animals at higher latitudes are required to store more energy during periods of low productivity and low water temperatures (Blackburn *et al.* 1999). However, no clear pattern emerged from this study to confirm these assumptions when comparing maximum sizes of species recorded in the UAE and other regions of the world. For example, size at maturity of male *C. sorrah* were highly variable and maturity in this study was reached at sizes smaller than those reported from the Maldives and Indonesia but larger than those reported from other areas of the Gulf at higher latitudes (Anderson & Ahmed 1993; White 2007; Moore *et* *al.* 2012a). Also, male *C. limbatus* reached maturity at sizes smaller than those reported at various latitudes including from Senegal, Indonesia, Brazil and other areas of the Gulf (Sadowsky 1967; Capape *et al.* 2004; White 2007; Moore *et al.* 2012a). Furthermore, in a survey of shark life history patterns evaluating 162 species, it was found that males matured at larger sizes only in 14.2% of cases (Cortes 2000). This was corroborated in this study where most males matured at sizes smaller than females. However, *C. limbatus* males seemed to mature at similar sizes to the females in the UAE. Because the maturity of females in this study was deduced based on the smallest mature female recorded, the sizes at maturity could be much smaller than those reported. This variability of growth rates and sizes at maturity highlights the need to individually ascertain the growth dynamics of each species in the UAE.

For the majority of species, gravid females, with late term embryos, were commonly recorded during the spring and/or the summer months (*C. sorrah, R. acutus, C. limbatus, L. macrorhinus, M. mosis, S. fasciatum, C macrostoma, P. randalli, C. amblyrhynchoides, C. amboinensis, C. brevipinna, C. macloti, C. melanopterus, C. plumbeus, N. acutidens*, and *S. lewini*). While clear seasonal patterns of reproduction could not be determined due to the limited sample size and lack of a detailed evaluation of female reproductive behavior, it is clear that this time of year is important for the breeding of many sharks species in the UAE. In fact, even though females of some species were found to be pregnant year round, there was also a peak in the presence of females with late term embryos in the spring for species such as *R. acutus* and *C. limbatus*. Concurrently, larger specimens from both sexes of most species were generally recorded in spring and summer while there was also a peak in the number of YOY individuals recorded in the summer and autumn. It has been hypothesized that an increase in water temperature could be the cue for the onset of the pupping season (Castro 1993). Water temperatures in the Gulf start rising in March and stay warm well into the autumn months (Sheppard *et al.* 1992). However, it remains unclear whether this peak in pregnant females and YOY specimens is due to changes in environmental conditions, to fishermen targeting areas where gravid females were commonly found, or whether in general, these individuals were found in nearshore regions, making them extremely vulnerable to exploitation.

A diversity of shark species use nearshore waters as nursery areas (Simpfendorfer & Milward 1993; Knip *et al.* 2012b). Simpfendorfer and Milward (1993) reported that juveniles of the Australian sharpnose shark, *Rhizoprionodon taylori*, *R. acutus*, *C. sorrah*, and the Australian blacktip shark, *C. tilstoni*, use Cleveland Bay in northeastern Australia at specific times of the year. Juvenile sharks from species like the lemon shark, *Negaprion brevirostris*, presumably also utilize these productive areas as shelter from predation and for foraging (Branstetter 1990). Furthermore, while male *C. sorrah* have been documented to undertake more extensive movements than females, potentially to look for mates, females mostly chose to remain in the same areas in which they gave birth (Simpfendorfer & Milward 1993). No information is available about the behavior of many of the species recorded here both from around the world or the Gulf, and therefore, these varying patterns across species and seasons warrant more research. It is clear, however, that landing pregnant females can be damaging for the long term sustainability of targeted populations and both pregnant and immature specimens of many species were recorded in this study. Therefore, further research is needed to determine areas potentially used as nursery grounds by various species and seasonal closure of these areas may be required to effectively manage and conserve these populations.

Finally, sexual segregation has been commonly reported in sharks (Klimley 1987; Sims 2005). For instance, *S. lewini* females tend to move to offshore waters at a smaller size than their male counterparts and form aggregations of medium-sized females (Klimley 1987). Sexual segregation was suggested for several shark species from this study where skewed sex ratios were noted. Overall sex ratios were in favor of females for *C. sorrah* while males outnumbered females for *L. macrorhinus*, *C. dussumieri*, *M. mosis*, *P. randalli*, and *C. amblyrhynchoides*. Furthermore, sex ratios changed across seasons for some of these species such as *C. limbatus* and *L. macrorhinus* where females outnumbered males during summer and autumn months. For many of these species, sexual segregation has not been previously observed in the region (i.e. *C. sorrah*) (Henderson *et al.* 2009; Moore *et al.* 2012a) or on the contrary have been observed from other studies but not in this one (i.e. *C. macrostoma*) (Moore *et al.* 2012a). For some species of sharks, skewed sex ratios could be associated with reproductive behaviors such as mating or pupping (Klimley 1987) or even for foraging (Sims *et al.* 2001). For instance, Knip *et al.* (2012a) found that females *C. sorrah* tended to use shallower habitat depths more frequently than males and that they had a preference for these areas during the winter months when water temperature was highest. Males, however, did not show any seasonal patterns for habitat preferences but had wider ranging movements than females (Knip *et al.* 2012a). In this study, females of this species were most common in the spring and summer while numbers were greatly reduced during the winter. However, no species-specific information is available about the behavior of sharks within the Gulf and, therefore, more research is warranted to gain a better understanding of these patterns.

4.4.3 Most abundant species

- ***Carcharhinus sorrah***

Carcharhinus sorrah is an abundant and widespread species in the region commonly found in catches off the Red Sea (Bonfil 2001), Oman (Henderson *et al.* 2007), Iran (FAO 2009a), and the southern Maldivian islands (Anderson & Ahmed 1993). It is also one the most commercially important species reported from Australia (Davenport & Stevens 1988; Last & Stevens 2009). In the Gulf, it appears to dominate landings in Kuwait, Qatar (Moore *et al.* 2012a) and the UAE (this study).

The maximum reported size for this species is 1600 mm L_T (Compagno 2002) and similar sizes have been documented from Oman at 1600 mm L_T (Henderson *et al.* 2009), and Indonesia at 1572 mm L_T (White 2007). These sizes are larger than those reported from the Maldives at 1220 mm L_T (Anderson & Ahmed 1993), and Australia at 1239 mm L_T (Davenport & Stevens 1988) and 1310 mm L_T (Harry *et al.* 2013), but smaller than the sizes from the Gulf at 1666 mm L_T (Moore *et al.* 2012a) and the largest individual recorded from this study at 1960 mm L_T. Compagno (2002) stated that sizes of 1980 and 2300 mm L_T have been previously reported but questioned their validity. The maximum size from this study confirms that *C. sorrah* can reach larger sizes and extends the maximum size for this species.

The maximum size for females was notably larger than that of males from all records in the Gulf (Moore *et al.* 2012a). Size at maturity for females was assessed based on the smallest gravid individual possessing late term embryos recorded at 1102 mm L_T. This is significantly smaller than the size of the smallest pregnant individual recorded from Indonesia at 1328 mm L_T, however an accurate size at maturity for females was not determined from that location (White 2007). On the other hand, a 1120 mm L_T female captured in the Maldives had ‘developing embryos’ (Anderson & Ahmed 1993), while embryos where visible in Australia from females measuring 1010 mm L_T and where maturity for females was reported between 929 and 951 mm L_T (Harry *et al.* 2013). Therefore, size at maturity of females in the UAE is likely to be more similar to these ranges. The majority of late term pregnant females were recorded in the spring and summer while the highest number of neonates were recorded in autumn. Since some gravid females were also recorded at other times of the year, a clear season could not be allocated for time of birth of this species and it is likely to occur all year round. However, it is evident that parturition mainly occurs during the autumn months for *C. sorrah* in UAE waters. Similarly, the time of year for birth in Indonesia was in September and October (White 2007), while it seems that in Australia parturition occurred slightly later, in December (Harry *et al.* 2013). However, this appears to fluctuate between regions as birth season has been reported from March to May in Bombay waters (Compagno 2002) and in spring in both Omani and South African waters (Bass *et al.* 1973; Henderson *et al.* 2008).

Size at maturity for males was similar to that for females and maturity occurred at 1048 mm L_T and over. Mature males were recorded at sizes of 1080 mm L_T and over in the Maldives (Anderson & Ahmed 1993). However, much smaller sizes at maturity were reported from Kuwait and Qatar where males were found to mature between 850 and 1100 mm L_T (Moore *et al.* 2012a) and from Australia at sizes ranging between 929 and 951 mm L_T (Harry *et al.* 2013).

In this study, the overall sex ratio favored females contrary to what was reported from Oman and Indonesia where the sex ratio was not significantly different (White 2007; Henderson *et al.* 2009). Therefore, the suggestion that sex ratios become more skewed as the species reaches its southern range limit (Stevens *et al.* 2000a) is not corroborated from data in this study or from reports from the Maldives where males outnumbered females (Anderson & Ahmed 1993).

Specimens considered to be YOY measured between 437 mm and 722 mm L_T which is smaller than the neonates of 522 mm L_T recorded in Indonesia (White 2007), 500 mm L_T from the Gulf (Moore *et al.* 2012a), and about 524 mm L_T in Australia (Harry *et al.* 2013). However, it is closer to the range of 450 to 600 mm L_T reported by Compagno (2002).

- ***Rhizoprionodon acutus***

A common and widely distributed species across its range, *R. acutus* has been reported to often dominate landings in areas where it occurs (Krishnamoorthi & Jagadis 1986; Stevens & McLoughlin 1991; Jayaprakash *et al.* 2002; Capape *et al.* 2006; Henderson *et al.* 2007; FAO 2009a; Moore *et al.* 2012a).

The maximum size reported for this species seems to vary between areas and has been documented at 1780 mm L_T (Compagno 2002), 980 mm L_T in Australia (Stevens & McLoughlin 1991), 1020 mm L_T in South Africa (Bass *et al.* 1975), 1080 mm L_T

off Madras in India (Krishnamoorthi & Jagadis 1986), 750 mm L_T off Cochin in India (Jayaprakash *et al.* 2002), 890 mm L_T from the Gulf (Moore *et al.* 2012a), 970 mm L_T in Oman (Henderson *et al.* 2009), 940 mm L_T in Indonesia (White 2007), and 1260 mm L_T in Senegal (Capape *et al.* 2006). The maximum size reported here is broadly similar to the lowest range of documented sizes at 981 mm L_T.

Minimum size at maturity for females in this study was 618 mm L_T or less. This size is smaller than that reported from Senegal at 890 mm L_T (Capape *et al.* 2006), Indonesia at 830 to 840 mm L_T (White 2007), South Africa at 700 to 800 mm L_T (Bass *et al.* 1975), India at 650 mm L_T (Krishnamoorthi & Jagadis 1986), northern Australia at 730 mm L_T (Stevens & McLoughlin 1991), but similar to reports from Oman where females matured between 620 and 740 mm L_T (Henderson *et al.* 2006). Pregnant females with late term embryos were recorded throughout the year but a peak was apparent during the spring, especially in March, when the largest female specimens were also recorded. On the other hand, the highest number of YOY were recorded in autumn which does not allow a determination of an exact time of year for parturition. This could indicate that females *R. acutus* are likely to breed throughout the year with a peak in autumn. Stevens and McLoughlin (1991) also reported that in northern Australia, females breed all year long while off the coast of South Africa, there seemed to be a clear breeding season between November and January each year (Bass *et al.* 1975). In India, females were also found to breed all year with no clear patterns (Appukuttan & Nair 1988). In Oman, post-partum females and neonates were also recorded throughout the year, with a peak during the spring season (Henderson *et al.* 2006). The time of year for parturition reported here is therefore later than that reported from Senegal where YOY specimens were mainly recorded between May and August with a peak in June (Capape *et al.* 2006) and from Oman and Iran where peak parturition were reported for spring and summer (Asadi 2001; Henderson *et al.* 2006).

Size at maturity for males in this study was recorded at 606 mm L_T from the smallest mature male measured. This is smaller than male maturity sizes reported from Indonesia at 770 to 790 mm L_T (White 2007), northern Australia at 730 to 800 mm L_T (Stevens & McLoughlin 1991), South Africa at 680 to 720 mm L_T (Bass *et al.* 1975), India at 650 mm L_T (Krishnamoorthi & Jagadis 1986), Senegal at 840 mm L_T (Capape *et al.* 2006), but similar to sizes reported from Oman at 630 to 710 mm L_T (Henderson *et al.* 2006) and slightly larger to the 540 to 680 mm L_T reported from the Gulf (Moore *et al.* 2012a).

Size at birth in this study ranged between 372 to 503 mm L_T based on YOY specimens. This was slightly higher than that reported from Indonesia at about 310 mm L_T (White 2007) and South Africa at 300 to 350 mm L_T (Bass *et al.* 1975), but closer to what was reported for Australia at sizes between 340 to 380 mm L_T (Stevens & McLoughlin 1991), India at 340 mm L_T (Appukuttan & Nair 1988), and Oman at about 370 mm L_T (Henderson *et al.* 2009). Neonate sizes from Senegal were slightly larger and ranged between 430 and 490 mm L_T but size at birth was estimated at 325 to 500 mm L_T (Capape *et al.* 2006).

The overall sex ratio in this study did not differ from parity but it was evident that females outnumbered males in spring and summer while males outnumbered females during the winter months. On the other hand, in India, females outnumbered males in winter landings in Cochin (Jayaprakash *et al.* 2002) while in Madras females outnumbered males in both winter and spring (Krishnamoorthi & Jagadis 1986). No differences between females and males were found in landings in Indonesia and Oman (White 2007; Henderson *et al.* 2009). However, in Senegal sex ratios were in favor of females (Capape *et al.* 2006), while males outnumbered females in both Kuwait and Qatar (Moore *et al.* 2012a) and off northern Australia (Stevens & McLoughlin 1991).

- ***Carcharhinus limbatus***

Not many historical records of *C. limbatus* are available in the region. This species was confirmed in a photograph by Randall (1986) and later documented in Kuwait by Moore *et al.* (2012b). It has only been documented by a few specimens in the Maldives (Anderson & Ahmed 1993), is not commonly found in catches from Kuwait and Qatar (Moore *et al.* 2012a), and yet similarly to what was found in this study, it represents one of the eight dominant species in Omani landings (Henderson *et al.* 2007).

Growth characteristics for this species seem to be highly variable between water basins. Generally, the maximum reported size for this species is approximately 2550 mm L_T (Compagno 2002) but larger sizes have been documented from Oman at 2640 mm L_T (Henderson *et al.* 2009), Yemen at 2800 mm L_T (Bonfil 2001), and the largest individual in this study measured 2870 mm L_T. These sizes are larger than those documented from Brazil at 2125 mm L_T (Sadowsky 1967), Indonesia at 2458 mm L_T (White 2007), Senegal at 2450 mm L_T (Capape *et al.* 2004), South Africa at 2470 mm L_T (Bass *et al.* 1973), the Gulf of Mexico at 1830 mm L_T (Killam & Parsons 1989), and even the Gulf at 2230 mm L_T (Moore *et al.* 2012a). Furthermore, while female specimens of this species seem to reach greater sizes than male individuals (Bass *et al.*

1973; Killam & Parsons 1989; Capape *et al.* 2004; White 2007; Henderson *et al.* 2009; Moore *et al.* 2012a), the largest individual collected from this study was a male.

Minimum size at maturity for females was assessed based on the smallest gravid individual recorded at 1640 mm L_T. This size is in accordance to the sizes at maturity reported for females in the Gulf between 1640 and 1840 mm L_T (Moore *et al.* 2012a), Indonesia at 1650 and 1800 mm L_T (White 2007), Brazil at 1580 mm L_T (Sadowsky 1967), Senegal at 1780 mm L_T (Capape *et al.* 2004) and Gulf of Mexico between 1580 to 1620 mm L_T (Killam & Parsons 1989). However, this is significantly smaller than sizes at maturity reported from South Africa at 1900 mm L_T (Bass *et al.* 1973). The majority of late term pregnant females were recorded in the spring, especially in March, as well as during winter. Although females outnumbered males during the summer months, no pregnant females were recorded during that time. On the other hand, neonates were recorded from the summer and the majority were recorded during the autumn months. This could imply that pregnant females migrate to unknown nursery areas to give birth during the summer months. Parturition may occur between the summer and autumn months which is in accordance with reports from Senegal where neonates were recorded between July and September (Capape *et al.* 2004).

Size at maturity for males was smaller than for females and maturity occurred at 1407 mm L_T for the smallest mature male specimen recorded. This size is similar to reports from Brazil where males matured at about 1486 mm L_T (Sadowsky 1967) but slightly larger than those from the Gulf of Mexico at 1330 to 1360 mm L_T (Killam & Parsons 1989). However, it was substantially smaller than maturity for males in other areas such as the Gulf at 1640 to 1840 mm L_T (Moore *et al.* 2012a), Senegal at 1670 mm L_T (Capape *et al.* 2004), Indonesia between 1830 and 1940 mm L_T, and South Africa at 1800 mm L_T (Bass *et al.* 1973).

Specimens with umbilical scars measured between 416 and 748 mm L_T and the smallest individual recorded in this study was smaller than neonates recorded from Indonesia, South Africa, Senegal, and the Gulf of Mexico where size at birth ranged between 550 and 660 mm L_T (Bass *et al.* 1973; Killam & Parsons 1989; Capape *et al.* 2004; White 2007). Furthermore, the smallest individuals reported for the Gulf measured 550 mm L_T (Moore *et al.* 2012a), and 610 to 650 mm L_T by Henderson *et al.* (2009) in Oman.

- ***Loxodon macrorhinus***

Limited information is available on the biological characteristics of *L. macrorhinus* (Gutteridge *et al.* 2013). This species has only been recently confirmed in the Gulf from specimens identified in Qatar (Moore *et al.* 2010a). Similarly to what has been reported in Oman, where this species was the third most abundant in catches (Henderson *et al.* 2007), and from the Maldives where it represented 70% of sharks caught in a research survey (Anderson & Ahmed 1993), this species dominated landings in the UAE. During the first year of study, Henderson *et al.* (2007) noted that *L. macrorhinus* was absent from landings from Al Batinah, Al Wusta and Musandam, but subsequently became the most abundant catch in Musandam. In this study, individuals were recorded from all landing sites and were most common in Ras Al Khaimah which is situated close to the Musandam Peninsula. However, they were rare in Abu Dhabi (n=8) and the high number of records, 155 individuals, reported by Moore *et al.* (2012a) from the Abu Dhabi site do not have information regarding their place of origin, and are likely to have been transported overland from other areas in the UAE or Oman for sale at the market (Refer to **Chapter VI)**.

The overall sex ratio of landings in the UAE was in favor of males, which was also reported from Abu Dhabi (Moore *et al.* 2012a), northern Australia (Stevens & McLoughlin 1991), eastern Australia (Gutteridge *et al.* 2013), Indonesia (White 2007), and the Maldives (Anderson & Ahmed 1993). On the other hand, a balanced sex ratio was reported from Oman (Henderson *et al.* 2009). However, sex ratios were variable across seasons here and females dominated landings in winter and spring similarly to what has been reported from the Maldives where most females were caught between November and February (Anderson & Ahmed 1993). These variations could be due to a number of factors including seasonal gear selection, fishing locations, movements of this species, as well as sexual and sex segregation (Anderson & Ahmed 1993).

The maximum sizes reported for this species across regions are highly variable and specimens measuring up to 940 mm L_T in the Maldives (Anderson & Ahmed 1993) and 989 mm L_T in Indonesia (White 2007) have been reported. On the other hand, in northern Australia and on the western coast in Hervey Bay, no specimens over 880 mm and 878 mm L_T respectively, were recorded (Stevens & McLoughlin 1991; Gutteridge *et al.* 2013). Maximum sizes reported from this study were slightly smaller than reports from other areas. However, females reached a maximum of 882 mm L_T which is a similar length to that reported by Moore *et al.* (2012a) at 840 mm L_T and from Oman at 870 mm L_T (Henderson *et al.* 2009).

Males in this study reached a maximum size of 901 mm L_T which was also smaller than the 974 mm L_T reported from Indonesia (White 2007), and 940 mm L_T in the Maldives (Anderson & Ahmed 1993), but larger than sizes reported from Oman at 850 mm L_T (Henderson *et al.* 2009), eastern Australia at 855 mm L_T (Gutteridge *et al.* 2013) as well as Qatar and Abu Dhabi at 790 mm L_T (Moore *et al.* 2012a). While Anderson and Ahmed (1993) reported that females tended to be larger than males in their catches, males from this study reached a greater maximum length.

In this study, the smallest gravid female collected measured 701 mm L_T. In northern Australia, pregnant females as small as 560 mm L_T were recorded (Stevens & McLoughlin 1991), yet the smallest pregnant female was 640 mm L_T in eastern Australia (Gutteridge *et al.* 2013) which is similar to the estimated size at maturity for females here. In other regions, larger sizes at maturity were reported with 850 mm L_T in South Africa (Bass *et al.* 1975) and 900 mm L_T in Indonesia (White 2007).

Size at maturity for males ranged between 645 to 901 mm L_T which is slightly larger than the sizes at maturity reported by Moore *et al.* (2012a) ranging between 610 and 710 mm L_T. However, it is closer to sizes reported in northern Australia where males were found to mature at about 640 mm L_T (Stevens & McLoughlin 1991) and smaller than sizes at maturity reported from Indonesia at 800 to 830 mm L_T (White 2007) and South Africa at 730 to 750 mm L_T (Bass *et al.* 1975)

Breeding appears to occur all year in northern Australia with a peak in parturition in October and November (Stevens & McLoughlin 1991) while in Indonesia this was reported from September and October (White 2007). Studies from India indicated that most gravid females were collected in July along the east coast while neonates were recorded in August from the west coast (Appukuttan & Nair 1988). Gravid females in this study were mostly recorded from late spring into summer and most specimens with umbilical scars were found from August to November. However, pregnant females with late term embryos were found throughout the year, and while the main breeding season may be from late summer till the end of autumn, it is likely that this species breeds year round. Pregnant sharks were also observed throughout the year in eastern Australia (Gutteridge *et al.* 2013).

Size at birth was estimated to be between 400 and 460 mm L_T in both Australia and South Africa (Bass *et al.* 1975; Stevens & McLoughlin 1991; Gutteridge *et al.* 2013) but was much larger at 540 to 550 mm L_T in Indonesia (White 2007). The smallest sizes reported from Oman were 450 mm and 460 mm L_T for females and males respectively, and 530 mm L_T in the Gulf (Moore *et al.* 2012a) but no indication on whether these were neonates or not is provided (Henderson *et al.* 2009). Sizes of YOY individuals in this study were between these ranges at 469 mm and 512 mm L_T.

- ***Carcharhinus dussumieri***

Reports of *C. dussumieri* suggest that this species is widespread and abundant in the Gulf (Blegvad & Loppenthin 1944; Basson *et al.* 1977; Gubanov & Schleib 1980; FAO 2009a; Moore *et al.* 2012b). In Kuwait, this species was the second most abundant in landings (Moore *et al.* 2012a), it represented one of the most abundant species in Iran (FAO 2009a), yet although it is also reported from Omani landings, it is not considered abundant (Henderson *et al.* 2007).

The maximum reported sizes for this species in this study were 989 mm L_T for females and 921 mm L_T for males. These sizes were smaller than previously reported from the Gulf where females reached 1000 mm L_T and males 960 mm L_T (Moore *et al.* 2012a). Female sizes were larger than those reported from Indonesia at 918 L_T (White

2007) and from northern Australia at 880 mm L_T (Stevens & McLoughlin 1991). On the other hand, male sizes were smaller than those reported from Indonesia at 937 mm L_T (White 2007) and from Australia at 870 mm L_T (Stevens & McLoughlin 1991).

Minimum size at maturity for females was assessed from the smallest gravid female recorded at 815 mm L_T. Pregnant females previously reported in the Gulf were of a similar size and ranged between 790 to 1007 mm L_T (Moore *et al.* 2012a), which is larger than those reported maturing at 700 mm L_T in northern Australia (Stevens & McLoughlin 1991) and at 640 mm L_T in Oman (Henderson *et al.* 2008).

Size at maturity for males in this study was between 678 mm and 921 mm L_T and was similar to the 670 mm L_T documented from Iran (Asadi 2001) and the 650 to 700 mm L_T from Oman (Henderson *et al.* 2008), but slightly larger than maturity sizes documented from elsewhere in the Gulf that ranged from 630 to 800 mm L_T (Moore *et al.* 2012a). Furthermore, this size at maturity for males was smaller than the size of 700 mm L_T from Australia and 750 mm L_T documented in Indonesia (Stevens & McLoughlin 1991; White 2007).

Gravid females were recorded throughout the year confirming that this species does not have a specific birthing season (Stevens & McLoughlin 1991; Asadi 2001; Compagno 2002; White 2007). There was however a peak in late term pregnant females during winter months and in spring which is a similar time of the year as that reported from October to April from Iran (Asadi 2001). Appukuttan and Nair (1988) also reported a peak parturition period in March and April for the Gulf of Mannar in India. While an accurate size at birth could not be determined due to the small sample size, the smallest individual with an umbilical scar measured 362 mm L_T. This size is similar to the size at birth reported from other studies where neonates were found at sizes between 380 to 400 mm L_T in northern Australia (Stevens & McLoughlin 1991) and 320 to 387 mm L_T in the Gulf (Asadi 2001; Moore *et al.* 2012a). Yet, this size was slightly larger than the 280 to 340 mm L_T reported from Indonesia (White 2007).

In this study, males outnumbered females across seasons which was similar to the findings reported from both Kuwait and Qatar (Moore *et al.* 2012a). On the other hand, surveys from Iran reported higher female catches (Asadi 2001), while no differences in sex ratios of landings were found in Indonesia (White 2007). This could be due to variations in fishing gear used or to sexual segregation in this species.

- ***Mustelus mosis***

This is the only *Mustelus* species in the region and while it has been reported from various publications (Blegvad & Loppenthin 1944; Basson *et al.* 1977; Gubanov & Schleib 1980), information regarding its biological traits remain scarce. Henderson *et al.* (2007) documented it from Omani landings but no information was provided on biological characteristics. Maximum sizes reported are up to 1500 mm L_T (Compagno 2002) but the maximum length recorded in this study was much smaller at 1073 mm L_T. Females here were much larger in size than those reported from the Gulf ranging between 630 and 830 mm L_T (Moore *et al.* 2012a). The maximum size for males of 913 mm L_T was also higher than the 840 mm L_T reported by Moore *et al.* (2012a).

Minimum size at maturity for females was determined to be less than the L_T of the smallest gravid female at 859 mm, which is likely to be similar to the 820 mm L_T for female maturity reported by Compagno (2002) and Henderson *et al.* (2008) in Oman. All pregnant females were reported from the spring which could indicate that parturition occurs at this time of the year for this species similarly to what was documented from Oman (Henderson *et al.* 2008). This is also the time of the year where the largest number and the smallest specimens of this species were found at landings. However, more samples are needed to confirm this finding. Males were mature at sizes between 704 and 913 mm L_T which are larger sizes than those reported by Compagno (2002) at 630 to 670 mm L_T, and by Moore *et al.* (2012a) at less than 650 mm L_T for Gulf specimens.

Similarly to landings in Kuwait (Moore *et al.* 2012a), males outnumbered females throughout the year here. Furthermore, as was reported by Moore *et al.* (2012a) for the Gulf and by Bonfil (2001) for the Red Sea, the majority of individuals recorded were mature. In fact, only one immature individual was recorded in this study.

4.4.4 Other species

- ***Chiloscyllium arabicum***

The largest *C. arabicum* recorded here was an 800 mm L_T male which is a larger maximum size than previously reported. In fact, Compagno (2002) stated that the maximum size was likely to be around 700 mm L_T, while Gubanov and Schleib (1980) and Moore *et al.* (2012a) reported a maximum L_T of 780 mm and 770 mm respectively for males in the Gulf. Therefore, this specimen extends the documented size range for males of this species. The female specimen (746 mm L_T) was also larger than the reported maximum L_T by Compagno (2002) and within the average found by Moore *et al.* (2012a). Also, maturity for males was reported at 620 mm L_T by Moore *et al.* (2012a) and is corroborated here where all males were mature at 619 mm L_T and over.

- ***Chiloscyllium griseum***

Although several authors have documented the occurrence of *C. griseum* in Gulf waters (Gubanov & Schleib 1980; Randall 1986), the one specimen recorded in this study validates records of *C. griseum* from Gulf waters. Compagno (2002) reported that this species reaches sizes of 770 mm L_T and over, which accords with the mature male specimen found here measuring 754 mm L_T.

- ***Nebrius ferrugineus***

N. ferrugineus has only been previously reported once in Kuwait when a two meter specimen was caught during a shrimp trawl (Bishop 2003). However, since no photographs or materials were retained (Moore *et al.* 2012b), the record has not been confirmed. This study confirms the presence of this species in Gulf waters with two specimens recorded. Compagno (2002) reported that males mature at about 2500 mm L_T, however, the male specimen recorded here possessed fully calcified claspers at a much smaller size (2191 mm L_T).

- ***Stegostoma fasciatum***

This species had previously been confirmed through photographic records in Bahrain (Randall 1986) and Kuwait (Gubanov & Schleib 1980). Compagno (2002) reported that females of this species mature between 1690 and 1710 mm L_T while males mature between 1470 and 1830 mm L_T. The one female in this study measuring 1915 mm L_T had late term embryos suggesting that females of this species reach maturity at sizes below this L_T while all males possessed fully calcified claspers indicating that males of this species are mature at sizes of 1835 mm L_T or less. Therefore, maturity sizes recorded in this study for both sexes were within the range described. The minimum and maximum sizes recorded ranging between 1494 and 2110 mm L_T were however significantly larger than sizes reported from the Maldives where specimens ranged between 1120 and 1800 mm L_T (Anderson & Ahmed 1993).

- ***Rhincodon typus***

Whale sharks, *R. typus*, have been historically recorded in the Gulf (Blegvad & Loppenthin 1944; Bishop & Abdul-Ghaffar 1993), and more recently, large aggregations have been documented in the offshore waters of Qatar (Robinson *et al.* 2013). The specimen documented here (4452 mm L_T) is smaller than the 6000 to 8000 mm L_T size range of those reported from Qatar. While only one individual was recorded from this study, it is likely that *R. typus* is more common in Gulf waters than previously believed and its relative absence from landings could be due to the protected status of this species.

- ***Carcharias taurus***

The occurrence of this specimen of *C. taurus* is the first documented record in UAE waters and the only reported catch since its last published occurrence in the Gulf (Krupp *et al.* 2000; Moore *et al.* 2007). Only three records have been historically reported with the last specimen caught in 1997 (Jabado *et al.* 2013). Size at maturity differs between geographic locations (Dicken 2006) but it is likely that this female specimen measuring 2560 mm L_T was mature based on a study by Gilmore *et al.* (1983) who documented females reaching maturity between 2200 and 2300 mm L_T.

- ***Chaenogaleus macrostoma***

Records of *C. macrostoma* are widely available from the region but little information is available regarding its biological characteristics. Henderson *et al.*

(2007) reported that this species was limited to landings in Musandam and not present along the rest of the Omani coast. Studies by Moore *et al.* (2012a) showed that catches of males outnumbered those of females in Kuwait while females outnumbered males in Qatar. In this study, no significant difference was found in the sex ratio of landings.

The maximum reported size for this species in the literature is 1000 mm L_T (Compagno 2002). Females here reached a maximum of 934 mm L_T while males were smaller with a maximum of 900 mm L_T. Females were slightly larger than those reported from the Gulf at a maximum of 920 mm L_T but males reached the same size (Moore *et al.* 2012a). The smallest pregnant female recorded measured 832 mm L_T and it is therefore assumed that they reach maturity at a smaller size. In Oman, females were found to be mature between 860 and 930 mm L_T but still immature at 700 mm L_T (Henderson *et al.* 2008). Also, a study off the Gulf of Mannar in India recorded gravid females ranging in sizes between 821 mm to 933 mm L_T (Appukuttan & Nair 1988). Male maturity from UAE waters is likely to occur at sizes between 720 and 730 mm L_T which is similar to the size of over 700 mm L_T reported from the Gulf (Moore *et al.* 2012a) but slightly larger than reported by Compagno (2002) at 680 mm L_T.

- ***Hemipristis elongata***

Only two previous specimens of *H. elongata*, both females, have been confirmed from the Gulf, in Kuwait (1170 mm L_T) and Qatar (1190 mm L_T) (Moore *et al.* 2010a). This study confirms they are not as uncommon as previously believed since 49 specimens were recorded from UAE waters. While also documented from Omani waters (Henderson *et al.* 2007), published information regarding its abundance was not available. However, four gravid females measuring between 1970 and 2310 mm

L_T were examined in summer and autumn (Henderson *et al.* 2008). In the Maldives, this shark also appears to be rare and only one specimen of approximately 1500 mm L_T has been documented (Anderson & Ahmed 1993). Compagno (2002) reported that the maximum size for this species is around 2300 and 2400 mm L_T with females maturing between 1700 and 2180 mm L_T, and males between 1200 and 1450 mm L_T. Stevens and McLoughlin (1991) reported maximum sizes of 1840 mm L_T for females and 1770 mm L_T for males in Australia. The maximum size recorded in this study is 2560 mm L_T which is higher than the maximum size reported by both studies. Furthermore, size at maturity for males from the Gulf also differed from published sizes. Here, males were found to be immature until 1226 mm L_T instead of 1060 mm L_T (Compagno 2002) and 1080 mm L_T (Stevens & McLoughlin 1991), while mature individuals measured over 1311 mm L_T.

- ***Paragaleus randalli***

Although reported from the Gulf as *Hypogaleus hyugaensis* by Randall (1986), it was later described as *P. randalli* by Compagno *et al.* (1996). Literature on this species is scarce but it has been documented from both the Gulf and the Gulf of Oman (Compagno *et al.* 1996; Henderson & Reeve 2011; Moore *et al.* 2012a; Moore *et al.* 2012b). In this study, maximum sizes were 848 mm and 890 mm L_T for females and males respectively which are larger than other lengths previously documented in other studies. For females, maximum sizes were 836 mm, 810 mm and 811 mm L_T for specimens collected from the Gulf, Oman and India respectively (Compagno *et al.* 1996; Henderson & Reeve 2011; Moore *et al.* 2012a). Maximum sizes for males were reported as 810 mm L_T from both the Gulf and Oman (Henderson & Reeve 2011; Moore *et al.* 2012a), and 719 mm L_T from Bahrain (Compagno *et al.* 1996).

No information was provided on size at maturity from Oman. In this study, the smallest pregnant female recorded was 785 mm L_T. Compagno *et al.* (1996) reported two pregnant females in their study measuring 706 mm L_T in Bahrain and 811 mm L_T in India. It is therefore probable that females reach maturity at sizes similar to those reported from Bahrain. Size at maturity for males in this study was recorded between 651 and 676 mm L_T which is slightly larger than the sizes at maturity reported from the Gulf ranging between 610 and 640 mm L_T (Moore *et al.* 2012a). Compagno *et al.* (1996) documented mature males measuring 690 mm, 702 mm, 623 mm and 715 mm L_T from Musandam, Bahrain, and Sri Lanka respectively, while one male measuring 615 mm L_T from India was still immature.

- ***Carcharhinus amblyrhynchoides***

This species had been previously reported in the Gulf (Carpenter *et al.* 1997) but only recently were actual specimens collected and confirmed from five individuals in Kuwait and three in Qatar (Moore *et al.* 2010a; Moore *et al.* 2012a). Records of *C. amblyrhynchoides* from this study are the first from UAE waters. The largest females (2430 mm L_T) and males (2334 mm L_T) recorded in this study were much larger than the maximum L_T of 1660 mm reported from Kuwait and Qatar (Moore *et al.* 2012a), 1670 mm L_T reported from the Gulf of Thailand (Garrick 1982), 1783 mm L_T for females from Indonesia (White 2007), and 1620 mm and 1610 mm L_T for females and males from northern Australia (Stevens & McLoughlin 1991). Size at maturity for females and males from both northern Australia (Stevens & McLoughlin 1991) and

India (Pillai & Parakkal 2000) were reported to be 1150 mm and 1040 to 1100 mm L_T, and 1150 and 1080 mm L_T, respectively. In this study, it was not possible to determine the size at which females reached maturity but sizes of gravid females with late term embryos ranged between 2043 and 2246 mm L_T, which was also a larger size than gravid females recorded in Indonesia ranging between 1595 to 1783 mm L_T (White 2007), and in northern Australia with an L_T of 1200 mm (Stevens & McLoughlin 1991). Male maturity was also at larger sizes than previously reported ranging between 1653 and 1774 mm L_T. It was not possible to compare sizes at maturity with males from Kuwait and Qatar since all specimens recorded there were less than 880 mm L_T and still immature (Moore *et al.* 2012a).

- ***Carcharhinus amblyrhynchos***

Only one previous record of *C. amblyrhynchos* was found for the Gulf from an underwater picture taken in Saudi Arabia (Basson *et al.* 1977; Moore *et al.* 2010a) which extended the range of this species reported by Compagno *et al.* (2005). Henderson *et al.* (2007) listed this species from Omani waters without details of abundance. The first record of this species from the Lakshadweep Sea in India has also been recently reported (Kumar *et al.* 2013). Bonfil (2001) stated that this was one of the most abundant species recorded in the Red Sea and the Gulf of Aden and it was also reported to be very common in Maldivian waters (Anderson & Ahmed 1993). However, only eight specimens were recorded in this study, which presumably indicates that this species is not very common in UAE waters.

The maximum L_T for females and males recorded in this study were 1922 mm and 1805 mm respectively. Female sizes were much smaller than those reported in

Indonesia which reached a maximum of 2320 mm L_T (White 2007), but closer to the maximum sizes reported from northern Australia (Stevens & McLoughlin 1991) and Hawaii (Wetherbee *et al.* 1997), which reached 1788 mm and 1900 mm L_T respectively. Maximum L_T for males was similar to those recorded in Indonesia at 1825 mm (White 2007) and in Hawaii at 1850 mm (Wetherbee *et al.* 1997).

Maturity for males in this study occurred at L_T between 1352 and 1627 mm which is similar to reports from northern Australia (Stevens & McLoughlin 1991), Indonesia (White 2007), and Hawaii (Wetherbee *et al.* 1997) where males matured at about 1300 to 1350 mm L_T, over 1300 mm L_T, and between 1200 and 1400 mm L_T, respectively. However, it is slightly larger than other sizes reported from the western Indian Ocean where males were found to mature at about 1100 and 1200 mm L_T (Stevens 1984). In Oman, a female and male specimen, both immature, were measured at 950 mm and 760 mm L_T, respectively (Henderson *et al.* 2008).

- ***Carcharhinus amboinensis***

The maximum reported sizes for *C. amboinensis* around the world are 2800 mm L_T (Compagno 2002) and all specimens recorded here were smaller. However, they were larger than other sizes reported from the Gulf at 2460 mm L_T for females and 2270 mm L_T for males (Moore *et al.* 2012a) and than those reported in northern Australia at 2430 mm and 2310 mm L_T for females and males respectively (Stevens & McLoughlin 1991). The only late term pregnant female documented here measured 2546 mm L_T. In Australia, females were reported to mature at about 2150 mm L_T (Stevens & McLoughlin 1991) while Compagno (2002) reported maturity to occur at sizes ranging from 1980 mm to 2230 mm L_T. The female here was recorded in spring which is also the time of year where two pregnant females were reported in Oman (Henderson *et al.* 2008), suggesting that if the species follows a defined breeding season, spring could be the main parturition season. Males in this study were found to mature at sizes between 2150 L_T and 2173 mm $L_{T,}$ a similar range to the one reported from the Gulf with males reaching maturity between 2060 mm and 2270 mm L_T (Moore *et al.* 2012a), and in Australia at 2080 mm L_T (Stevens & McLoughlin 1991).

Specimens with visible umbilical scars were recorded here measuring between 642 and 889 mm L_T which is a larger range than previously documented with size at birth believed to be between 710 and 720 mm L_T (Compagno 2002).

- ***Carcharhinus brevipinna***

Records of *C. brevipinna* are widely available from the Gulf (Basson *et al.* 1977; Gubanov & Schleib 1980; Randall 1986; Bishop 2003; Moore *et al.* 2012b). The maximum reported size for this species is 3040 mm L_T from the coast of Taiwan (Joung *et al.* 2005). Maximum sizes from this study were 2670 mm L_T for females and 2391 mm L_T for males which are smaller than reported for Taiwan, and also smaller than from Indonesia and Australia where sizes of 2936 mm L_T and 2760 mm L_T for females, and 2499 mm L_T and 2600 mm L_T for males were reported respectively (White 2007). However, specimens here are larger than those documented by Moore *et al.* (2012a) for the Gulf where females reached 2460 mm and males 2270 mm L_T.

In this study, the smallest gravid female with late term embryos measured 2436 mm L_T and it can therefore be assumed that they reach maturity at sizes smaller than that. Females are reported to generally mature between 1700 and 2000 mm L_T (Compagno 2002), however size at maturity seems to vary greatly between regions with ranges between 2100 and 2200 mm L_T in Taiwan (Joung *et al.* 2005), 2000 and 2100 mm L_T in South Africa (Bass *et al.* 1973) and around 1700 mm L_T in Brazil (Sadowsky 1967).

In contrast to studies in Brazil that reported males attaining maturity at around 1600 mm L_T (Sadowsky 1967), maturity for males in this study occurred at generally smaller sizes than reported elsewhere between 1771 and 1822 mm L_T. These lengths are smaller than those documented by Moore *et al.* (2012a) in the Gulf where males reached maturity at 2060 to 2270 mm L_T. They are also smaller than those documented in Indonesia, South Africa, Taiwan, and Australia, where males reached maturity at 1960 mm L_T and over, between 1800 and 2000 mm L_T, 2100 to 2200 mm L_T, and around 1950 mm L_T, respectively (Bass *et al.* 1973; Stevens & McLoughlin 1991; Joung *et al.* 2005; White 2007).

Specimens with visible umbilical scars recorded in this study were between 556 and 828 mm L_T. These sizes are slightly smaller but within the sizes of YOY individuals reported from Indonesia which measured between 625 and 880 mm L_T but where females also had litters ranging in sizes between 563 and 810 mm L_T (White 2007). They are also close to sizes reported from the Gulf with the smallest individuals recorded between 570 and 690 mm L_T (Moore *et al.* 2012a), from Oman between 610 and 740 mm L_T (Henderson *et al.* 2008), and those documented in Taiwan at 650 to 700 mm L_T (Joung *et al.* 2005; Moore *et al.* 2012a).

- ***Carcharhinus falciformis***

Although Compagno *et al.* (2005) included the Gulf in the distribution map of this species, no specimens have previously been reported for verification. This study therefore expands the known range of *C. falciformis* to this body of water. Only six specimens were recorded here and it is therefore assumed that this species is not abundant in Gulf waters. It was only recorded from Dubai during the month of September and thus could be a seasonal occurrence in these waters or just occurring in the deeper waters of the northeastern Gulf as suggested by Moore *et al.* (2012b). While it has not been documented along the Musandam Peninsula, it was commonly observed in Omani landings where it dominated landings in the Sharqyiah region (Henderson *et al.* 2007). This species was also abundant in Maldivian waters where it comprised nearly 70% of all sharks recorded from a longlining survey (Anderson & Ahmed 1993). The lengths reported here are much smaller and represented only one life stage of this species compared to previous investigations in other regions where all life stages were found in catches (Anderson & Ahmed 1993; Henderson *et al.* 2009; Hall *et al.* 2012), and is likely due to the limited sample size.

Based on maturity records from the southwestern Indian Ocean where females matured at 2161 mm L_T and males at 2390 mm L_T (Stevens 1984), and on reports from the northwestern Gulf of Mexico where females reached maturity at L_T greater than 2250 mm and males at 2100-2200 mm L_T (Branstetter 1987), all individuals recorded in this study were immature. The minimum sizes recorded (757 mm L_T for females and 797 mm L_T for males) are larger than the 710 and 740 mm L_T for females and males reported in Oman (Henderson *et al.* 2009), similar to the sizes reported from eastern Indonesia where L_T at birth for females ranged between 799 and 823 mm and between 794 to 830 mm L_T for males (Hall *et al.* 2012). However, they were smaller than minimum sizes reported in the Maldives (560 to 630 mm L_T) and in northern Australia where size ranges were 830 mm and 860 mm L_T for females and males respectively (Stevens & McLoughlin 1991; Anderson & Ahmed 1993). *C. falciformis* generally occur in both coastal and offshore waters with juveniles tending to stay closer to shore and moving into deeper waters as late juveniles (Compagno *et al.* 2005; Joung *et al.* 2008; Hall *et al.* 2012). It is therefore possible that individuals of this species use Gulf waters as they mature before moving to deeper waters off Oman.

- ***Carcharhinus leiodon***

This species had only been previously recorded from one specimen in Yemen and described by Garrick (1985). More recently, this species was re-described from 32 specimens collected in Kuwait (Moore *et al.* 2011; Moore *et al.* 2012a) and was also recorded from two specimens in Salalah, Oman (Henderson & Reeve 2011). This study expands the distribution of *C. leiodon* to UAE Gulf waters. The maximum size reported in this study was a male of 1372 mm L_T which is larger than the maximum reported for males in Kuwait at 1320 mm L_T (Moore *et al.* 2012a). Size at birth has not been previously reported in the literature but is likely to be close to the 531 mm L_T recorded in this study as the specimen had a visible umbilical scar. Henderson and Reeve (2011) reported a 580 mm L_T individual but did not specify if an umbilical scar was evident. All specimens were recorded in November and December, suggesting that this species is at least present in these waters during the winter months.

- ***Carcharhinus leucas***

The biological characteristics of *C. leucas* seem to vary broadly across regions (Compagno *et al.* 2005). The maximum sizes reported from this study are 2430 mm and 2977 mm L_T for females and males respectively, which are significantly smaller than the maximum sizes of 3400 mm L_T reported for this species across the world (Compagno 2002). However, these sizes are larger than those reported for both sexes in the Gulf at 1830 mm and 1580 mm L_T (Moore *et al.* 2012a). Females reported here are smaller than those found in the Gulf of Mexico at 2710 mm L_T (Cruz-Martinez *et al.* 2002), and those found in Indonesia at 2910 mm L_T (White 2007). However, male sizes were much larger in this study compared to 2450 mm L_T in the Gulf of Mexico (Cruz-Martinez *et al.* 2002) and 1970 mm L_T in Indonesia (White 2007).

The only gravid female with late term embryos found measured 2190 mm L_T. This length at maturity accords with reports from the Gulf of Mexico where females reached maturity at 2040 mm L_T (Cruz-Martinez *et al.* 2002). However, Compagno (2002) reported that females can reach maturity at sizes between 1800 and 2300 mm L_T. Males here reached maturity between sizes of 2170 and 2208 mm L_T. In Indonesia, size at maturity for males was estimated at sizes greater than 1970 mm L_T (White 2007) while in the Gulf of Mexico, it ranged between 1900 to 2000 mm L_T (Cruz-Martinez *et al.* 2002) indicating that males in the Gulf are maturing at larger sizes.

Specimens with visible umbilical scars were recorded in winter, spring and summer which likely indicates that females may give birth throughout the year in the Gulf, similarly to *C. leucas* in Nicaragua where a peak was also reported in the spring and early summer (Compagno 2002). Size of YOY specimens ranged between 688 mm L_T and 838 mm L_T which is within and slightly larger than the range of 560 mm to 810 mm L_T reported by Compagno (2002).

- ***Carcharhinus macloti***

Moore *et al.* (2010a) confirmed the presence of *C. macloti* in the Gulf from an adult male (830 mm L_T) collected in Kuwait. This species was commonly found in landings in Oman (Henderson *et al.* 2007) and dominated catches along with several other small shark species (Henderson *et al.* 2009). Similarly to observations made in Oman (Henderson *et al.* 2009), sex ratios in this study were balanced whereas reports from Bombay, India, indicated that catches consisted primarily of males (Compagno 2002), and in Australia, females dominated landings (Stevens & McLoughlin 1991).

Females and males in this study reached a maximum size of 971 mm and 905 mm L_T respectively. This is smaller than the maximum sizes reported from northern Australia with females and males reaching 1080 mm and 960 mm L_T respectively (Stevens & McLoughlin 1991). However, these lengths were larger than those documented from Kuwait, Oman and Indonesia, where females measured a maximum of 940 mm, 930 mm, and 800 mm L_T, while males were 830 mm, 840 mm, and 878 mm L_T, respectively (White 2007; Henderson *et al.* 2009; Moore *et al.* 2012a).

The smallest pregnant specimen with late term embryos that was recorded measured 903 mm L_T, however an accurate size at maturity could not be determined. Other studies show that females attain maturity at sizes between 700 and 800 mm L_T (Stevens & McLoughlin 1991; White & Cavanagh 2007). Males in this study were found to mature at approximately 746 mm L_T. Moore *et al.* (2012a) similarly reported that male specimens from Kuwait matured at sizes between 750 and 830 mm L_T. In Indonesia, size at maturity for males was estimated to be between 520 and 730 mm L_T

(White 2007), while in India males are reported to mature at about 690 mm L_T (Appukuttan & Nair 1988), which are smaller sizes than documented from the Gulf.

An embryo and the smallest specimens recorded with visible umbilical scars measured between 447 and 481 mm L_T suggesting that size at birth occurs between these two sizes. These are slightly larger sizes than reported from India at 329 mm and 432 mm L_T (Appukuttan & Nair 1988), but closer to those reported off Indonesia at 390 and 440 mm L_T (White 2007) and northern Australia at about 400 to 450 mm L_T (Stevens & McLoughlin 1991).

- ***Carcharhinus melanopterus***

Reports of *C. melanopterus* from the Gulf are widespread (Gubanov & Schleib 1980; Bishop 2003) but few specimens have been confirmed. Moore *et al.* (2012b) provided the first photographic evidence from the UAE and one specimen was collected in 2010 at the Abu Dhabi market. Moore *et al.* (2011) suggested that this species may be replaced by *C. leiodon* in shallow water habitats of the Gulf. However, in the UAE, *C. melanopterus* is common around many islands including Sir Bani Yas, Dalma and Sir Bu Nair (personal observation). Only 38 individuals from this species were recorded from this study and this number may not reflect the abundance of this species in UAE waters. This is likely due to the fact that *C. melanopterus* generally prefers shallow coastal and coral reef habitats (Stevens 1984) that can be found around the islands of the UAE but where fishing is prohibited within 5.5 km of the coastline.

This species is reported to attain sizes between 1600 and 1800 mm L_T but most individuals are generally smaller and range between 1400 and 1600 mm L_T (Stevens 1984; Compagno *et al.* 2005; White 2007). However, maximum sizes reported from

Cochin, India, indicated that females can reach 2200 mm and males 2300 mm L_T (Jayaprakash *et al.* 2002). The maximum size for females here was 1523 mm L_T, with males at 1243 mm L_T. Female sizes were larger than reported from Indonesia at 1420 mm L_T (White 2007), and Aldabra at 1400 mm L_T (Stevens 1984), but similar to those from Australia at 1540 mm L_T (Chin *et al.* 2013). The largest male was smaller in size than the maximum recorded in Aldabra at 1300 mm L_T (Stevens 1984), in Indonesia at 1309 mm L_T (White 2007) and in Australia at 1350 mm L_T (Chin *et al.* 2013).

In this study, males reached maturity at ca. 1061-1232 mm L_T. These sizes are in accordance with male maturity sizes recorded in Indonesia and Australia where all males over 1100 mm L_T and 1190 mm L_T, respectively, were found to be mature (White 2007; Chin *et al.* 2013). However, these sizes were larger than in Oman, Aldabra and India where males were found to be mature at about 910 to 1000 mm L_T, 1050 mm $L_{T,}$ and between 910 and 1000 mm L_T, respectively (Stevens 1984; Appukuttan & Nair 1988; Henderson *et al.* 2008). The smallest pregnant female with late term embryos measured 1324 mm L_T suggesting that maturity is reached close to that length or at a smaller size. Females have been reported to mature at about 960 to 1120 mm L_T in Oman (Henderson *et al.* 2008), 1100 mm L_T in Aldabra (Stevens 1984), and between 960 and 1120 mm L_T in India (Appukuttan & Nair 1988).

Eight specimens recorded in this study had visible umbilical scars and measured between 496 and 607 mm L_T. These sizes are similar to those previously reported in Aldabra, Indonesia, Australia and India at 500 mm, 500 to 540 mm, 572 to 613 mm, and 350 to 750 mm L_T, respectively (Stevens 1984; Jayaprakash *et al.* 2002; White 2007; Chin *et al.* 2013).

- ***Carcharhinus plumbeus***

While some reports for *C. plumbeus* in the Gulf exist (Gubanov & Schleib 1980; Moore *et al.* 2012b), no specimens have previously been documented in landings. The limited sample size collected from this study does not allow conclusions to be drawn about the biology of this species in this body of water. However, maximum sizes documented are 2393 mm L_T and 1956 mm L_T for females and males respectively. The lengths for females here are larger than those reported from the western Indian Ocean and Brazil which were 2080 mm L_T (Stevens & McLoughlin 1991; Hazin *et al.* 2007), as well as those from Indonesia at 2001 mm L_T (White 2007). On the other hand, the largest male recorded in this study was closer in length to those reported from Australia, Indonesia and Brazil at 2040 mm L_T, 2003 mm L_T, 1960 mm L_T, respectively (Stevens & McLoughlin 1991; Hazin *et al.* 2007; White 2007).

One gravid female with late term embryos measuring 1802 mm L_T was recorded suggesting that maturity for females is likely to occur at sizes smaller than this. Females captured in Brazil were already mature at 1085 mm L_T (Hazin *et al.* 2007) while in Australia the smallest mature female recorded was 1490 mm L_T (Stevens & McLoughlin 1991). Males were found to be mature at sizes between 1589 and 1712 mm L_T in this study which is smaller than sizes at maturity documented from Indonesia where males reached maturity at approximately 1830 mm L_T (White 2007). These sizes were much larger than sizes documented off northeastern Brazil at 1080 mm L_T (Hazin *et al.* 2007). However, this was close to the size at maturity for males documented from northern Australia at 1560 mm L_T (Stevens & McLoughlin 1991).

- ***Galeocerdo cuvier***

G. cuvier has been confirmed in the Gulf from several reports (Basson *et al.* 1977; Sivasubramaniam & Ibrahim 1982a; Bishop 2003) but no details of specimens have been documented other than a photograph from a 4000 mm L_T pregnant female on Jana Island in Saudi Arabia (Basson *et al.* 1977). Only one specimen was recorded here from a juvenile male in Sharjah (2073 mm L_T) and therefore biological data was not possible to collect for this species. Males are generally reported to mature at sizes between 2260-2900 mm LT (Stevens 1984; Compagno *et al.* 2005) but have also been documented maturing at sizes around 3000-3370 mm L_T in Indonesia (White 2007).

- ***Negaprion acutidens***

The only evidence of the occurrence of this species in the Gulf has been from a photograph in Saudi Arabia (Basson *et al.* 1977). Bass *et al.* (1975) reported having collected material from Iran, however no information was provided on whether the specimen was collected from the Gulf or the Gulf of Oman coast. Forty one individuals were collected during this study which suggests that this species is not as rare as previously believed (Moore *et al.* 2012b).

Maximum sizes reported in this study are 2650 mm for females and 2440 mm L_T for males. These sizes are similar to the 2400 mm L_T described by Stevens (1984) at Aldabra but smaller than the 3000 to 3100 mm L_T reported elsewhere (Bass *et al.* 1975; Compagno 2002). Stevens (1984) reported that maturity for both sexes was attained at 2200 mm L_T while Bass *et al.* (1975) documented a 2430 mm L_T mature male in Natal, South Africa. Furthermore, a 2490 mm L_T pregnant female was documented from the Maldives (Anderson & Ahmed 1993). Females in this study were already mature at 2576 mm L_T while males reached maturity between 2356 and 2440 mm L_T, similarly to reports from South Africa.

- ***Rhizoprionodon oligolinx***

Little information is available on the biology of *R. oligolinx* around the world. In a recent study in Kuwait and Qatar, this species represented 4.8% of the total catches (Moore *et al.* 2012a). In the gillnet fishery off Cochin in India, *R. oligolinx* formed 1.7 to 2.7% of sharks landed (Jayaprakash *et al.* 2002). However, only 32 individuals were found in UAE landings which indicates that it may not be as common in these waters.

The maximum sizes reported for this species are 700 mm L_T for females and 610 mm L_T for males (Compagno 2002). In this study, both sexes were much larger with females reaching 907 mm and males 785 mm L_T. These sizes are also larger than those reported by Moore *et al.* (2012a) who recorded females at a maximum of 850 mm L_T and males at 640 mm L_T. Finally, White (2007) reported smaller sizes with females reaching 650 mm L_T and males 520 mm L_T in Indonesia.

Size at maturity for males in this study ranged between 609 and 785 mm $L_{T,}$ which is larger than maturity sizes recorded from Kuwait and Qatar (Moore *et al.* 2012a), Indonesia (White & Cavanagh 2007), and India (Nair *et al.* 1974), where males were found to mature at sizes between 450 and 530 mm L_T, 433 and 451 mm L_T, and 290 to 380 mm $L_{T,}$ respectively.

- ***Sphyrna lewini***

Moore *et al.* (2012b) provided the first photographic evidence of this species in the Gulf since previous records had never been confirmed (Randall 1986; Carpenter *et al.* 1997). The only other sample collected for this species was a female specimen (870 mm L_T) from the Mina Zayed fish market in Abu Dhabi (Moore *et al.* 2012a). However, the origin of this last record is uncertain since the catch location of this specimen has not been provided, and because the Abu Dhabi fish market mainly sells sharks that originate from a variety of locations including Oman (refer to **Chapter VI**). Only 15 specimens were recorded in this study, which indicates that this species is likely to be uncommon in Gulf waters. On the other hand, *S. lewini* seems to be very common within the Arabian Sea where it comprised 6% of total landings documented in Oman for 2002 (Henderson *et al.* 2009) and 26 to 31% of the gill net fishery off Cochin in India (Jayaprakash *et al.* 2002).

Bonfil (2001) suggested that this species displays a relatively high degree of plasticity in biological parameters across the world. The largest female recorded in this study was pregnant and measured 3027 mm L_T which is within the maturity sizes recorded for this species from other parts of the world. Female *S. lewini* have been reported to mature at sizes of 2503 mm L_T in the western Indian Ocean (Stevens 1984), 2000 mm L_T in Australia (Stevens & Lyle 1989), 2300 mm L_T in the Maldives (Anderson & Ahmed 1993), and 2500 mm L_T in the Gulf of Mexico (Branstetter 1987). Immature males here were still recorded at 1500 mm L_T with the only mature male measuring 2443 mm L_T. Male maturity has been reported between these two lengths at around 1800 mm L_T (Branstetter 1987) and 1500 mm L_T (Stevens & Lyle 1989). The largest female recorded in this study (3027 mm L_T) was larger than the maximum length reported from Oman at 2810 mm L_T (Henderson *et al.* 2009). On the other hand, the maximum length of males recorded here and in Oman was similar at 2443 mm and 2450 mm L_T, respectively.

Three specimens recorded in this study were YOY and measured between 469 and 508 mm L_T. These sizes are similar to those previously reported in South Africa and Australia at 450 to 500 mm L_T (Bass *et al.* 1975; Stevens & Lyle 1989), but were larger than those reported from Oman at 310 mm L_T for females and 430 mm L_T for males. These were recorded from July to September which is earlier than the time of year (October to January) reported for birth in Australia (Stevens & Lyle 1989), but similar to reports from the Maldives where near term pregnant females were caught in September (Anderson & Ahmed 1993). While only three YOY individuals were recorded in this study, the majority of specimens recorded in Oman were small sized individuals in the 600-800 mm L_T size classes (Henderson *et al.* 2009) and between 400 and 900 mm L_T in India (Jayaprakash *et al.* 2002). While it is interesting to note that a wider range of sizes was found in the Gulf, the limited sample size here does not allow a comparison of the various life stages represented in landings.

- ***Sphyrna mokarran***

Although this species has been recorded in both the Gulf (Moore *et al.* 2012a; Moore *et al.* 2012b) and in Oman (Henderson *et al.* 2007), little information is available on its abundance in the region. Maximum sizes recorded in this study were 3820 mm L_T for females and 3058 mm L_T for males which were larger than those recorded from both Kuwait and Qatar at 2140 mm and 1370 mm L_T for females and males respectively (Moore *et al.* 2012a). Female maturity was not assessed for the Gulf as no late term pregnant females were recorded but it has been reported to occur at sizes between 2500 and 3000 mm L_T (Compagno 2002) or smaller at 2100 mm L_T in Australia (Stevens & Lyle 1989). Males in this study were found to mature at sizes between 2670 and 2678 mm $L_{T,}$ which is larger than the size at maturity for males in Australia found to be 2250 mm L_T (Stevens & Lyle 1989), and larger than the 2210 mm L_T from Oman (Henderson *et al.* 2008), but within the range of 2340 to 2690 mm L_T reported by Compagno (2002).

The one male YOY recorded in this study was found in August, the time of year where birth has been reported to occur in the northern Hemisphere (Compagno 2002). This specimen measured 543 mm L_T which is within the size at birth range of 500 to 700 mm L_T reported by Compagno (2002), and White *et al.* (2006) for *S. mokarran* in Indonesia. This is however smaller than size at birth recorded from northern Australia which was closer to 650 mm L_T (Stevens & Lyle 1989) and from the smallest individuals (720 mm L_T) previously recorded in the Gulf (Moore *et al.* 2012a).

4.4.5 Species identification

Morphological identifications in the field were confirmed through DNA analysis of the COI gene, a method which allows discrimination between species (Hebert *et al.* 2003b; Ward *et al.* 2005). In most cases, species were matched correctly in the databases, and when illustrated using an NJ tree, conspecific species clustered together. While the true phylogeny of sharks is unlikely to be recovered using this analytical method (Ward *et al.* 2005), generating a tree allowed relationships between species to be summarized and provided a representation of the various families and species of sharks harvested in the fishery here. However, some unresolved questions about specimen identification remain.

C. arabicum was not assigned to a species either in the BOLD or GenBank databases and this is likely due to the fact that a barcode for this species is simply not available for comparison. Therefore, the sequence was assigned to the closest match in BOLD which was the *Chiloscyllium* genus. Similarly, *R. oligolinx* could not be reliably matched against a sequence in GenBank, which may also indicate a lack of sequences for this species within the database. Some confusion arose when submitting the sequences for *P. randalli* and *C. macrostoma*. Sequences matched both species and *P. tengi*, a species that has not been recorded from the western Indian Ocean (Compagno *et al.* 2005). These misplaced sequences could be due to a variety of reasons including the possibility that these species share haplotypes, that there was misidentification in the field, mislabeling errors for the samples, or that species associated with sequences in the databases were misidentified (White & Last 2012).

Holmes *et al.* (2009) stated that the success of barcoding is dependent on low levels of sequence variation within species and much higher levels between species. Therefore, some closely related species may not be easily identifiable, despite being different morphologically. In this study, the *C. limbatus* and *C. amblyrhynchoides* species pair could not be convincingly differentiated. Ward *et al.* (2008) reported low divergence and low bootstrap values for them in their barcoding results while Moore *et al.* (2011) stated that the COI gene barely differentiated between them. In similar cases which were also reported for closely related species such as *C. plumbeus* and *C. altimus* (Ward *et al.* 2008; Moftah *et al.* 2011), the COI gene may not be suitable for discrimination between species and an additional marker with a higher rate of evolution has been proposed for further analysis (Ward *et al.* 2008). Moore *et al.*

(2012b) also suggested that further taxonomic investigations were required on *C. limbatus* and *C. amblyrhynchoides* based on his Gulf samples.

It has been advised that the development of a voucher collection is a necessity when undertaking genetic analysis in order to resolve questions about specimen identification (Ward *et al.* 2005). A collection could not be started in this study because of the limited resources available and the lack of storage facilities that are necessary when dealing with large animals such as sharks. Future work will necessitate the development of a voucher collection to ensure correct identifications are referenced within the barcode library (Ward *et al.* 2005). Only one study has focused on developing a specimen and barcode collection for fish species in the Gulf which included two shark species, *C. macrostoma* and *M. mosis* (Asgharian *et al.* 2011). Some shark specimens were also retained and barcoded (Moore *et al.* 2012b), but these seem to be distributed across various facilities around the world. Barcoding studies must be able to reference an accurate and well-defined taxonomy, while having access to a representative number of barcodes that have been taxonomically verified and submitted to the available databases. Therefore, it seems that to better understand the evolution of species within the Gulf, a centralized facility would be warranted.

4.4.6 Considerations for the management and conservation of sharks in the UAE

This study provided a profile of a substantial and previously undocumented shark fishery and the results are evidence of an urgent need for action. In fact, a number of species considered to be of global conservation concern were recorded in this study. The only species currently receiving some form of international protection is *R. typus* which is listed on CITES (Appendix 2) and therefore has its international trade limited to sustainable levels. Other species that were encountered during market surveys including *C. limbatus*, *C. dussumieri*, *C. falciformis*, *C. plumbeus*, *S. lewini*, and *S. mokarran* are listed under either 'Threatened' or 'Near threatened' categories. Because the assessments of IUCN Red List generally lack information from this region, accurate data need to be obtained locally to determine which species are most threatened here. While the data collected in this study do not allow a clear indication of the status of shark stocks in the UAE, by looking at changes in abundance and species composition, it provides a baseline which should prove beneficial for the effective monitoring and sustainable exploitation of targeted shark stocks.

Results indicate that there may be a depletion of larger sharks species in these waters with sharks landed either being small-bodied species or immature individuals of larger-bodied species. Furthermore, gravid females and early life stages were targeted which reduces the productivity, resilience and sustainability of targeted populations (Smith *et al.* 2008). Moreover, certain biological variables differed from those reported from the Gulf region and other parts of the world suggesting that many species could belong to separate regional or even local stocks. Finally, many species recorded were not abundant and therefore there is a lack of species-specific regional life-history data and quantitative mortality assessments.

Using the results of this study as a baseline, it is critical that additional research is conducted to determine changes in catch rates, species and size composition that may be occurring. This study is limited because effort information was not collected and, therefore, it was not possible to interpret changes in the number of catches based on fishing practices and gear, a critical aspect of effective fisheries management (McCluskey & Lewison 2008). Therefore, further studies are clearly required in the region to gather details on fishing practices as well as the distribution, biological parameters, movement, stock structure and population boundaries of sharks.

While some laws already exist for the management of sharks in the UAE, these should be re-examined in light of the data gathered from this study and before unmonitored catches further compromise the recovery of already-depleted stocks in the Gulf. Around the world, the conservation of sharks has been confounded by delayed responses of fishery restrictions, typically resulting in the implementation of management strategies following the overexploitation of targeted shark populations (Stevens *et al.* 2000a). This fishery should therefore be managed with a precautionary approach using the data provided here to support decisions in management strategies, especially for the less abundant and incidentally caught species which can become depleted long before changes in catches of dominant species are recorded (Camhi *et al.* 1998).

CHAPTER V

A FISHERY INDEPENDENT APPROACH TO DETERMINE SPECIES COMPOSITION, ABUNDANCE, AND DISTRIBUTION OF SHARKS IN NEARSHORE AREAS

5.1 Introduction

Tagging studies have been undertaken since the beginning of the 20th century as a standard technique in fisheries and marine biological programs across the world (Davies & Joubert 1967). These programs rely on tagging, releasing and recapturing individuals on multiple occasions while collecting a wide range of data according to the research focus (FAO 2005). While fisheries dependent data are crucial for monitoring shark stocks, in many cases, fishery independent data are preferred. This is mainly due to the fact that fishery independent data do not have the biases associated with information collected from commercial or recreational fishermen which are subjected to a variability of fishing gear and practices (Simpfendorfer *et al.* 2002).

It has been shown that tagging studies allow the study of populations; evaluate catch effort; determine catch mortality; investigate the status of fish stocks; provide valuable measures of relative abundance; establish migration, distribution and behavioral patterns; as well as provide valuable information on a wide variety of aspects of shark biology including sizes, growth rates, age, and sex ratios (Davies & Joubert 1967; Branstetter & Musick 1993; Kohler & Turner 2001; FAO 2005). These attributes have value in understanding basic species biology and in developing life-history models. For example, Ebert (1996) was able to collect biological data and determine movement patterns from seven gill sharks, *Notorynchus cepedianus*, tagged in the coastal waters of South Africa. Hueter *et al.* (2007) also used conventional tagging methods to collect life history information as well as investigate movements and migration patterns of small and large coastal sharks along the coast of Florida in the US. Furthermore, if the attributes of sampled populations are representative of the population as a whole, then results collected can be used to infer levels and expected effects of exploitation on species. In fact, long term data sets have the potential for detecting changes in abundance over time and therefore the status of some marine populations (Simpfendorfer *et al.* 2002; FAO 2005). For instance, Govender and Birnie (1997) derived mortality estimates for the dusky shark, *Carcharhinus obscurus*, based on their mark recapture study in South Africa. Also, tagging data from the northwest Atlantic showed that from the 1970s to the mid-1980s, the CPUE for large coastal sharks had declined by 60 to 80% suggesting that stocks for common species such as the sandbar, *C. plumbeus*, dusky, *C. obscurus*, sand tiger, *Carcharias taurus*, and tiger, *Galeocerdo cuvier*, had been overfished (Musick *et al.* 1993). Finally, Carlson and Brusher (1999) described declines in CPUE for juveniles of the Atlantic sharpnose, *Rhizoprionodon terraenovae*, finetooth, *C. isodon*, and spinner, *C. brevipinna*, sharks based on data from three years of longlining surveys.

Long term longlining surveys have become even more effective when incorporated as part of collaborative programs with recreational fishers by allowing to tag a large volume of fish each year (FAO 2005). This has also reduced the research costs involved for scientists, given fishers a sense of ownership to the project, and allowed the sampling of various areas simultaneously (Drake *et al.* 2005). Some disadvantages associated with these programs have also been reported including the quality of data that can be collected, since this depends on the level of tagging experience, and the overall precision of these data, as it is based on the commitment of individual fishermen to the tagging program (FAO 2005). However, even data from collaborative programs can help in gaining a better understanding of species that are not well documented. For instance, Dicken (2006) was able to derive data from records of two collaborative tagging programs in South Africa and assess spatial and temporal movement patterns of *C. taurus*. It was therefore possible to confirm the geographical extent and seasonal utilization of nursery areas by juveniles as well as investigate site fidelity, natal homing, and the reproductive migration of females.

Despite technological innovations, such as satellite tracking animals, acoustic telemetry, and the use of Baited Remote Underwater Videos (BRUVs), longlining surveys, using conventional tags, remain a key source of information on the status of many shark species (Kohler & Turner 2001). Longlining surveys are also the channel by which acoustic and satellite telemetry devices are deployed (Heithaus *et al.* 1997; Heupel *et al.* 2006; Chin *et al.* 2013). A study comparing results from longlining surveys and BRUVs within a restricted area of the Bahamas, showed that longlining was able to document species richness faster than BRUVs, allowed more accurate species identification, the documentation of sex differences, and provided more precise data on sizes (Brooks *et al.* 2011). While it is clear that longlining programs are unable to collect the same type of information as satellite tagging, they remain an effective means of collecting valuable information from data poor areas. Actually, combining information from techniques such as acoustic telemetry with catch rate data, has shown that scientific monitoring of a species can be greatly improved by the collection of accurate data on movement, residency and site fidelity patterns. A study investigating the habitat use of the nurse shark, *Ginglymostoma cirratum*, off Recife in northeastern Brazil, demonstrated that the use of acoustic monitoring was able to support the trends observed from longline CPUE's (Ferreira *et al.* 2013). However, the acoustic study provided additional and more precise data on seasonal movements and residency patterns for this species at the population level, showing behaviors which had not been previously documented. On the other hand, while these technological innovations can provide important additional data on species, they are largely costly and require previous knowledge of species in an area.

Little is known about the diversity, biology and conservation status of sharks inhabiting UAE Gulf waters. In this study, information on species composition and distribution has been solely based on data collected from the literature, fishermen interviews, and landing surveys. This has provided valuable information on the number of species found in UAE coastal waters, their size distributions, biological attributes, and seasonality. However, because all catch data were dependent on the gear utilized by fishermen, as well as their choice of fishing grounds, no information on distribution, population structure and movements was ascertained. In reality, different shark species may have had differences in their vulnerability to fishing techniques while bycatch species, that could have been discarded at sea, may not have been properly represented in the landings. Furthermore, the distribution of sharks in UAE waters is not understood because fishermen from various emirates use overlapping fishing grounds (Refer to **Chapter III**) but also because sharks are known to either remain in certain areas or move extensively (Knip *et al.* 2012a). The behavior, habitat use, and movement patterns of sharks does not only vary greatly depending on the species concerned but also based on the size, age and sex of the individuals (Wearmouth & Sims 2008; Knip *et al.* 2010; Speed *et al.* 2010). What is clear however, is that most species of sharks tend to use nearshore regions at some point in their life either as nursery grounds, for foraging, or as a permanent habitat (Cartamil 2009; Knip *et al.* 2012a). Simpfendorfer and Milward (1993) showed that milk shark, *R. acutus,* individuals were dependent on the various habitats that could be found in nearshore areas and therefore tended to utilize them throughout the year. Similarly, adult spottail sharks, *C. sorrah,* in Cleveland Bay, Australia, exhibited long term presence and high residency in nearshore areas (Knip *et al.* 2012a). On the other hand, *R. terraenovae*, was reported to move widely and show limited attachment to nearshore areas (Carlson *et al.* 2008). Juveniles and adults of the sandbar shark, *C. plumbeus*, have been shown to spatially segregate in western Australian waters (McAuley *et al.* 2007). Juvenile and adult bonnethead sharks, *Sphyrna tiburo*, tended to be residents of the Pine Island Sound estuary in Florida, but did not show site fidelity to specific areas within that region (Heupel *et al.* 2006). Males and females of the lesser spotted dogfish, *Scyliorhinus canicula*, used similar habitats but were segregated within them by sex (Sims 2005). Finally, Castro (1993) showed that nearshore areas in South Carolina were used by several large species of sharks including the blacktip, *C. limbatus*, *C. brevipinna*, and the scalloped hammerhead, *S. lewini,* as nursery areas because these habitats provided neonates with abundant food and protected them from predation by larger sharks. Because such variability in the behavior of different shark species exists, gaining an understanding of the characteristics of shark populations in terms of their size and age structure, abundance, tendency to segregate by age and sex, movement, as well as site attachment and fidelity, is crucial for the long term conservation of these species (Cortes 2007; Simpfendorfer *et al.* 2011). Furthermore, understanding the function of nearshore habitats and how each shark species, at various stages of their lives, utilize them is necessary to determine their importance in the management of the shark fishery.

A tagging study was therefore initiated to investigate these parameters within nearshore areas of the UAE. The aims of the study were to 1) independently assess shark species composition; 2) provide a preliminary evaluation of shark abundance and distribution, 3) examine the use of nearshore habitats by sharks, and 4) compare the biological, species composition, and distribution, data from landings with the information collected through this fishery independent approach.

5.2 Materials and methods

Fishery-independent longline surveys were generally carried out from small fiberglass diving boats, up to 10 m in length, powered by two 4 stroke outboard engines (150 HP each). Surveys were limited to Dubai and Abu Dhabi waters (**Figure 5.1.**) and conducted between February 2011 and March 2013. During surveys, a crew of two to four volunteers were on board to help the project investigator with line deployment, hauling and data collection. The position of the boat and lines was determined using a GPS (Garmin GPS 12XL), with error ranging between 15 and 100 meters. Date, time, and coordinates, were recorded before and after each deployment and haul to determine exact sampling locations and the total sampling time for each set. Any other relevant environmental information was also noted, such as tide, type of bottom substrate and water temperature.

Although there was a conscious attempt to cover different areas at various set intervals each month, geographical distribution and sampling intensity was limited by availability of funding, boats, local weather conditions (especially during summer and winter months when wind variations were high), and site accessibility. Surveys sites were therefore chosen at random within nearshore areas between Abu Dhabi and Dubai. Sampling was done during all tidal cycles, and at all times, including nights.

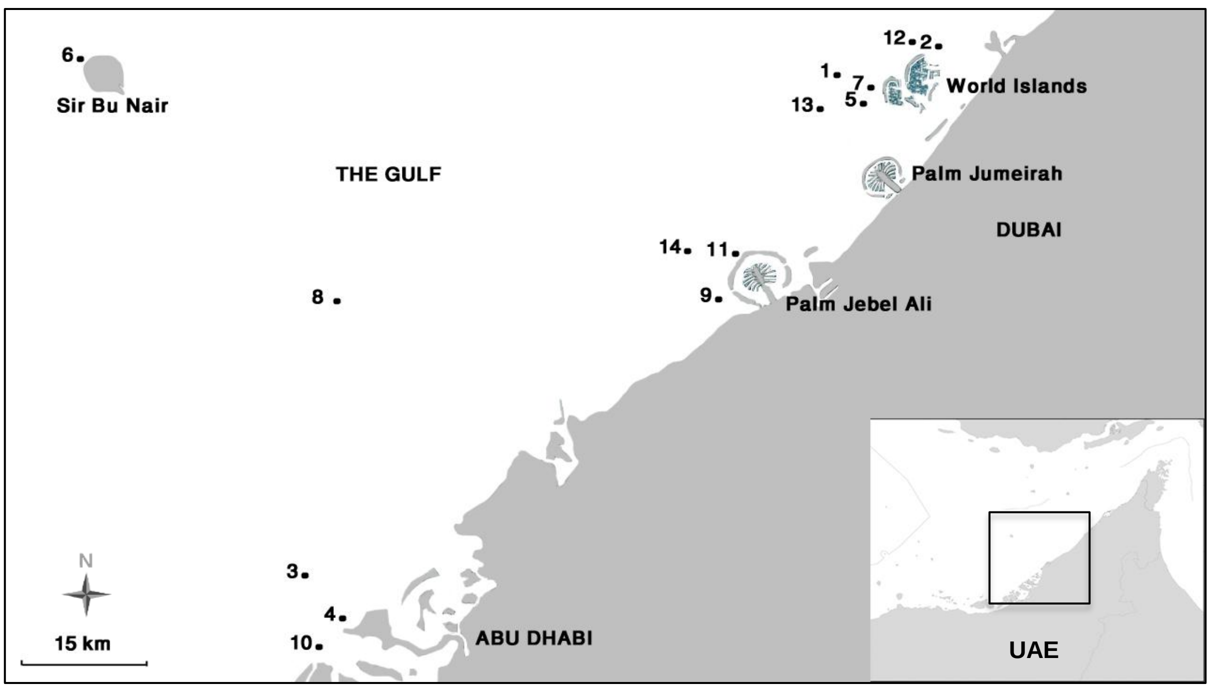

Figure 5.1. Location of longline sets along the coast of Dubai and Abu Dhabi. Each location has been assigned a site number (refer to **Appendix A, Table 5.1.** for exact locations). Inset on right illustrates these areas in relation to the coast of the UAE.

Demersal longlines were deployed at depths from seven and up to 22.5 m at the chosen sites. They comprised of a floatline rope of 7 mm black nylon, a 500 m kuralon rope mainline (hard twist twine 8 mm thick that sinks) with buoys and anchors at both ends (**App. A, Figure 5.2.**). Between 32 and 46 gangions, 2.5 m in length, were attached to the mainline. Each gangion was composed of a tuna clip, a 1.5 m snood line made of monofilament and connected by a swivel to a 1 m wire trace (1.8 mm metal trace with plastic cover), and the hook. These branchlines were spaced approximately at 10 m intervals along the mainline. For all sets, 30 circle hooks (Mustad 12/0 brand) were used while the remaining hooks were smaller (size 9/0 Eaglehawk saltwater hooks for billfish) to include smaller sharks and neonates in the catch. Hooks had different bait types randomly mixed between them and included sardines (*Sardinella longiceps*), Indian mackerel (*Rastrelliger kanagurta*), and kawa kawa (*Euthynnus affinis*), which represent common local species that could reliably be obtained throughout the study. Lines were set by hand from the bow of the boat and were typically soaked from two to six hours. During longer trips, these were checked every three hours to minimize impact on sharks, rebaited where needed, and reset. When sharks were caught, they were brought alongside the boat, identified to species level; measured (total length (L_T)); sexed and maturity stages for males determined; fin clips taken for genetic analysis; and each animal tagged with a conventional dart tag, as appropriate for the size of the shark, before removing the hook and releasing the shark (Kohler & Turner 2001). Furthermore, data tag type, tag number, capture location and release conditions (rated on a scale of 1 for excellent health to 5 for dead) were collected prior to release. Handling time at the vessel was three to eight minutes.

Four different tag types, stainless steel head dart tag (SSD), plastic tipped dart tags (PDA and PDS), and T-Bar anchor tag (TBA) were chosen to tag sharks during the surveys (**App. A, Figure 5.3.**). All dart tags were manufactured by Hallprint Pty Ltd (Australia) and comprised of a monofilament vinyl streamer attached to either a plastic barb (PDA, PDS, and TBA types) or a stainless steel pointed head (SSD). Tag applications were accomplished differently depending on the tag. The standard anchor T-Bar (TBA) tags were used for all sharks under 750 mm L_T and were applied using a 'Dennison Tagfast III" tagging gun. The two types of plastic tipped dart tags were used for sharks over 750 mm L_T and less than 1500 mm L_T (PDA and PDS) and applied using stainless steel applicator needles attached to dowell handles. Finally, stainless steel dart tags, made of 316S grade surgical steel, were used for sharks over 1500 mm L_T. All tags were directly anchored into the dorsal musculature at the base of the dorsal fin and placed at approximately a 45 degree angle, allowing the streamer to lie alongside the shark while it swims, and therefore minimizing hydrostatic drag (Dicken 2006). Once inserted, tags were gently pulled to ensure their secure attachment. Each tag had a unique number and an email address associated to this project printed on the streamer to facilitate capture reports. To encourage the reporting of tag recoveries, the study was described in detail to fishermen while tags were shown at landing sites.

For CPUE analysis of the longline sets, fishing effort in hook hours was calculated by multiplying the soak time (the length of time from when the first hook entered the water to when the last hook was retrieved) by the number of hooks set, before dividing the number of animals caught by the total hook hours.

5.3 Results

A total of 28 longline sets, comprising of 1,128 hooks and 101 hours of sampling, were completed in 14 trips to various nearshore areas off Dubai and Abu Dhabi (**Figure 5.1.** and **App. A, Table 5.1.**). Overall, 11 sharks from six species were captured including *R. acutus* (n=3), *C. limbatus* (n=3), *Chiloscyllium arabicum* (n=2), *C. sorrah* (n=1), *C. melanopterus* (n=1) and *C. plumbeus* (n=1). Data were collected from all sharks, however only nine individuals, actively swimming and energetic, were tagged. One *R. acutus,* and one *C. limbatus,* were found to be weak and were quickly unhooked and released after measurements and a DNA sample were collected.

Few sharks were tagged and none recaptured or reported during the program and as a result, the data were inadequate to investigate distribution, movement patterns, site fidelity and mortality rates. However, biological information was collected from each individual and is presented in **Table 5.2.**. The calculated CPUE was 0.000457 sharks per hook hour. *C. limbatus* and *R. acutus* were the most commonly encountered species, each representing 27.3% of the total catch. This was followed by *C. arabicum* with 18.2% of the catch while the remaining three species each comprised 9% of the catch. Furthermore, based on the life history data detailed in **Chapter IV**, all *C. sorrah*, *C. limbatus* and *R. acutus* individuals were immature while *C. melanopterus*, *C. plumbeus and C. arabicum* individuals were mature.

Table 5.2. Catch composition of shark species captured during longlining surveys from January 2011 to March 2013 with details on sex (F: female, M: male), size (mm L_T), tag type and number, location number (as illustrated in **Figure 5.1.**), time of capture (h), hook size, total number of shark per species and the percentage of the total catch. * indicates sharks deemed weak and not tagged.

Species	Sex	Size	Tag type	Tag #	Location number	Time captured	Hook	# of sharks	% total
C. sorrah	M	772	TBA	004	7	15.10	12/0	1	9%
C. arabicum	F M	633 652	TBA TBA	002 003	3 3	13.15 13.30	9/0 9/0	2	18.18%
C. limbatus	M F M	817 762 971	PDS PDS *	202 203 -	8 8 12	20.35 20.50 19.55	9/0 9/0 9/0	3	27.27%
C. melanopterus	F	1348	PDS	249	6	21.05	12/0	1	9%
R. acutus	M M F	558 534 532	TBA * TBA	013 - 014	9 9 9	14.48 15.10 15.13	9/0 9/0 9/0	3	27.27%
C. plumbeus	F	1801	PDS	301	12	18.05	12/0	1	9%
TOTAL								**11**	**100%**

5.4 Discussion

This tagging study was the first attempt at collecting fishery independent data in nearshore waters of the UAE. While the scope of this study had to be reduced due to limited funding, access to various sites, and availability of boats, it did provide an indication of shark abundance in nearshore waters. The CPUE calculated here is considerably lower than what has been documented in other studies from other regions of the world (Branstetter & Musick 1993; Simpfendorfer *et al.* 2002; Brooks *et al.* 2011; Hiraoka & Yokawa 2012; Chin *et al.* 2013). While this could indicate that sharks are overexploited in these waters, as was suggested by the fishermen interviewed in **Chapter III**, there was no baseline information with which to compare data from this study. Furthermore, lower tagging and recapture success is not always a reflection of low abundance (Kohler *et al.* 1998) and the status of shark populations should not always be solely based on abundance trend information but more on stock assessment models utilizing a variety of data types (Carlson *et al.* 2012). Therefore, many reasons could explain capturing sharks in low numbers and having low recapture and reporting rates.

Differences in gear characteristics have been shown to affect CPUE with monofilament gangions capturing more sharks than longlines made of steel and rope (Branstetter & Musick 1993). However, the design of the gear used in this study is unlikely to have affected CPUE rates as it was similar to gear configurations used in other studies that have had high catch rates (Simpfendorfer *et al.* 2002; Knip *et al.* 2012b, 2012a; Chin *et al.* 2013; Ferreira *et al.* 2013). Furthermore, the size of the hooks used were able to catch both small and large bodied sharks and presumably did not affect the catches. Additionally, soak times may have affected captures since lines were checked frequently. However, Morgan and Carlson (2010) stipulated that reduced soak times still allow to effectively catch targeted species but enable fishermen to release unwanted species alive. Therefore, gear selectivity is unlikely to have caused the low catch rates found in this study.

The time of day and locations chosen for tagging trips could have also affected catch rates. Kohler *et al.* (1998) suggested that some species can occur in offshore deep waters and would therefore not be present in the fishing area during the survey. In fact, species such as *C. sorrah* and the Australian black tip shark, *Carcharhinus* *tilstoni*, were found to have moved over 1000 km along the coast from their tagging locations (Stevens *et al.* 2000b). It is therefore possible that there was a lack of sharks in the areas sampled at those particular times. However, trips were conducted at all times of the day and night in order to allow for species with various diel patterns to be captured. This was done to ensure the sampling regime would not be affected by movement patterns of sharks since for example, some studies have shown that adult and juvenile *S. lewini* utilized small core areas during the day but ranged more widely at night (Klimley & Nelson 1984; Klimley *et al.* 1988). Similarly, other species such as the lemon shark, *Negaprion brevirostris* (Gruber *et al.* 1988), white tip reef sharks, *Triaenodon obesus* (Whitney *et al.* 2007), and gray reef sharks, *Carcharhinus amblyrhynchos* (McKibben & Nelson 1986), increased their movements at night. On the other hand, studies on species such on *S. tiburo* did not indicate consistent diel patterns in home range size (Heupel *et al.* 2006).

None of the sharks tagged in this study have been recaptured and none of the tags attached to sharks have been returned. This could have been due to the type of tag used which is an important variable in recapture rates (Dicken *et al.* 2006). In this study, several different dart tags were chosen because these tag types have been reported to be retained for long periods, with little biofouling or entanglements (in capture gear and vegetation) occurring when compared with other types of tags such as disk tags (Dicken *et al.* 2006). Furthermore, this variety of tags ensured that mortality was not induced in juvenile sharks as a result of using larger stainless steel tags (Dicken *et al.* 2006). The reporting rate here was not unusual since very few sharks were tagged and most tagging studies yield low return rates. Kohler *et al.*

(1998) reported that in a tagging study of blue sharks, *Prionace glauca*, undertaken for 30 years, only 5% of tags were recovered while Ferreira *et al.* (2013) reported a slightly higher rate of 8% for *G. cirratum* in Brazil. Several explanations have been provided for these low returns including post-release mortalities, large population sizes, dispersal, tag loss, and uncooperative fishermen (Kohler & Turner 2001). This could also have been the case in this study. Furthermore, there was no reward scheme associated with tag returns as has been implemented by the National Marine Fisheries Service (NMFS) in the US or by tagging programs in Canada, to encourage tag reports (Kohler *et al.* 1998; Kohler & Turner 2001; McFarlane & King 2003). Therefore, even if fishermen had recaptured a shark during the study period, they may not have been inclined to report it.

However, some biological information was derived from these surveys and corroborate some of the data collected in **Chapter IV**. While the sample size was too small to attempt to make any conclusions, some patterns were interesting to note. The two *C. arabicum* individuals were caught in shallow waters close to mangroves estuaries in Abu Dhabi which has been reported as a preferred habitat for this species by Compagno *et al.* (2005). Both male and female adult specimens were captured in the same set during the daytime at that time of year. This could imply that this species does not segregate by sex during the daytime. While this species could potentially be present at this site throughout the year with no specific movement patterns, the fact that both specimens were adults of different sexes could also imply that this area is being used as a mating ground. More research will need to be completed in order to gain better understanding of the behavior of this species.

The three *R. acutus* individuals were also caught on the same set during daytime. Both sexes were captured and males were deemed immature based on the level of calcification of their claspers. Data collected from landing sites in the UAE showed that males matured at sizes over 606 mm L_T while the smallest mature female was measured at 618 mm L_T. This maturity size for females was considerably larger than the 532 mm L_T caught in the longline survey, implying that this female specimen was immature. This may indicate that juveniles from both sexes are utilizing nearshore areas as potential nursery grounds and schooling together. Indeed, in Australia, juveniles of this species remained in shallow nearshore areas until they reached maturity (Simpfendorfer & Milward 1993; White & Potter 2004). However, this species could also be a permanent resident of this area since Davies and Joubert (1967) reported that off Durban, *R. acutus* were caught throughout the year within 8.8 km of the tagging location with no indication of a definite migration.

While all three *C. limbatus* individuals captured were slightly larger than the sizes recorded for YOY specimens from the landings, they were all under 1000 mm L_T indicating that they were also immature. Two of the specimens, a male and a female, were also captured on the same set implying that juveniles of both sexes in this species school together at this stage of their lives. In fact, Compagno *et al.* (2005) reported that individuals of this species often segregate together by age and sex. All these specimens were caught in areas that were relatively close to shore but within deeper waters that were not associated with specific habitats such as mangroves or seagrass beds. This is also what has been reported from other studies where *C. limbatus* YOY spent the first few months of their lives close to shore in nursery areas but then moved to slightly deeper waters as juveniles (Castro 1993; Heupel & Simpfendorfer 2002; Heupel *et al.* 2007).

Only one male *C. sorrah* was captured possessing non-calcified claspers and was within the size range documented from landings for immature individuals of this species. *Carcharhinus sorrah* have also been reported to occur mainly in coastal water habitats but can also be found in deeper waters (Compagno 2002). The *C. melanopterus* individual was captured off Sir Bu Nair Island in an area associated with coral reef habitats which has been reported as a preferred habitat for this species (Stevens 1984). Other female specimens of this species in this study were found to mature at sizes of 1324 mm L_T or less, and therefore this individual was also presumably mature. The *C. plumbeus* female captured was likely mature since it was of similar size to the 1802 mm L_T pregnant specimen recorded in landings. This species has been reported to occur near the bottom at around 20 to 55 m depths (Compagno *et al.* 2005). Since the capture of this specimen occurred at a depth of 17.5 m, this could indicate that it is more vulnerable to fishing at those depths since the longlines used were demersal. In fact, in Indonesia, this species was reported to be a known catch of demersal longline fisheries (White *et al.* 2006).

The species composition of catches reflected similar patterns to those recorded in the landing surveys with *R. acutus* and *C. limbatus* being among the most abundant species. However, *C. sorrah* was almost absent from catches here and while there is no clear explanation, it could simply be due to the fact that they were not present in the study area at the time of sampling or that other fishing gear such as nets may be more appropriate to catch these species. This could also explain why other abundant species such as *L. macrorhinus, C. dussumieri* and *M. mosis* were not captured. The catches of *C. arabicum* could indicate that they are in fact more abundant than suggested from the landing surveys but that fishermen either do discard them at sea or do not use their preferred habitats as fishing grounds. The *C. plumbeus* catch was unexpected since this species had only been represented by 13 specimens in the landing surveys. However, reports from other parts of the world have shown that this species is usually a significant component of coastal shark fisheries in areas where it occurs (Bass *et al.* 1973; McAuley *et al.* 2007; Last & Stevens 2009). *Carcharhinus plumbeus* had not been previously recorded from Dubai landings and this capture increases the number the species recorded in Dubai waters to 25.

It is clear that further research is needed to determine specific patterns of behavior and confirm biological attributes for sharks in UAE waters. To collect more fishery independent data, developing a collaborative tagging program, promoted to recreational or volunteer commercial fishermen, may be worthwhile and cost effective. This would allow public involvement as well as increase awareness and education on sharks and their conservation, especially if educational material is developed and distributed in the form of newsletters or through public presentations. In the US and South Africa, recovery rates were improved by properly advertising and publicizing tagging programs to a wide variety of audience and fishing sectors (Kohler *et al.* 1998; Dicken *et al.* 2006). Similarly, data on *G. cuvier* in the northwestern Atlantic would not have been possible to collect without the collaboration of scientists with fishermen who reported recaptures and provided species information (Natanson *et al.* 1999). Furthermore, developing collaborative tagging programs would allow extensive areas to be covered while large quantities of fish could be tagged (Kohler & Turner 2001; FAO 2005). Actually, the NMFS program was able to tag 142,868 sharks of more than 52 species from 1962 to 1997. Also, the use of dart tags comprising of a Plexiglas capsule containing a vinyl legend with return instructions (Kohler *et al.* 1998) printed in several languages including English, Arabic and Hindi, to represent the most common languages used in the Gulf, may be more effective in ensuring catch reports than tags with only English contact details.

Lastly, while it is not clear why catch rates in nearshore areas were so low in this study, overfishing should not be ruled out as a possibility. Declines in shark numbers have been reported from various areas of the Pacific, Atlantic and Mediterranean in recent years (Baum *et al.* 2003; Myers 2007; Ferretti *et al.* 2008; Lam & Sadovy de Mitcheson 2011) but also from localized tropical reef habitats in Australia (Robbins *et al.* 2006; Heupel *et al.* 2009). In this study, it is clear that shark populations are being exploited at high levels (Refer to **Chapter III** and **IV**) and therefore more research is warranted to better understand the status of shark stocks in these waters. It is especially important to identify nursery areas, since the majority of sharks caught are juveniles, and because these areas are often found in shallow coastal environments which are usually vulnerable to fisheries exploitation and other anthropogenic impacts. In fact, protecting and managing these areas is crucial for the conservation and sustainable management of sharks (Heupel & Simpfendorfer 2005; Heupel *et al.* 2007).

CHAPTER VI

QUANTIFYING AND CHARACTERIZING THE TRADE IN SHARKS AND SHARK PRODUCTS IN THE UAE THROUGH MARKET SURVEYS AND DNA BARCODING

6.1 Introduction

The vulnerability of sharks is directly linked to their K-selected life histories but also to the growing market for shark products which has been recognized as a major driver for the exploitation of many species (Stevens *et al.* 2000a; Clarke 2002; FAO 2009a; Worm *et al.* 2013). Among fishery commodities, shark products, including meat, fins, oil, skin, cartilage, and jaws, are highly diverse and versatile in both their usage and their value (Clarke 2004; Hareide *et al.* 2007).

The greatest quantity of international trade in shark products is in the form of fresh, chilled or frozen, unspecified shark meat (Clarke 2004). Rose (1996) reported that shark meat was becoming increasingly popular in many markets while anecdotal information from fishermen interviews has confirmed the growing market for shark meat around the world (Gilman *et al.* 2007). In some coastal fisheries, shark meat is a valuable source of protein and has been harvested for subsistence for over 5000 years (Rose 1996; Marshall & Barnett 1997; Joseph 1999; Vannuccini 1999). Also, meat is now in high demand in the EU, particularly in Spain and Italy, which imported 56% of global shark meat imports in 2005 (Hareide *et al.* 2007). On the other hand, shark meat is sometimes still considered low value compared to fins and is often discarded by some fisheries targeting tuna and swordfish who only retain fins in order to minimize the space taken by sharks in their vessel's storage compartments (Bonfil

1994; Hareide *et al.* 2007; Camhi *et al.* 2009). In contrast to the relatively low value of shark meat, shark fins, particularly those from coveted species, are among the world's most costly fishery products (Clarke 2002; Hareide *et al.* 2007). The demand for shark fins, and their high value, is a major driving force for shark mortality worldwide with estimates ranging between 26 to 73 million (Clarke *et al.* 2006b) and 63 to 273 million (Worm *et al.* 2013) sharks killed annually to supply the fin markets. Other shark derived products have a wide range of utilization with shark skin used to produce leather and sandpaper, and shark liver oil used in the textile and tanning industries, as a pharmaceutical product, in cosmetic ingredients, and as a lubricant (Vannuccini 1999). Furthermore, shark cartilage can be used in medicine, teeth as curios, and other discarded parts of the carcass as fishmeal and fertilizers (Rose 1996; Vannuccini 1999). However, these products are not likely to be driving shark catches as their usage is highly variable and appears to fluctuate over time with substantial declines having been reported in their trade (Clarke 2004).

The biggest and fastest growing market for shark fins is China, although there are huge markets in Japan, Hong Kong, Singapore and Korea (Vannuccini 1999). Reports indicate that Hong Kong serves as a transit point for mainland China, with 90-95% of dried raw fins and 97-98% of 'salted or in brine' raw fins imports, being redistributed back to the mainland (Clarke 2002). Furthermore, for decades, Hong Kong has been the center of the world trade in shark fins handling anything between 50% and 85% of global shark fin imports (Clarke 2004). Between 1996 and 2000, 85 to 110 countries or territories exported their shark fins to Hong Kong (Clarke 2002). Data from Hong Kong for the adjusted imported quantity (dried versus frozen) of shark fins from 1998 to 2002 show the main suppliers of shark fins as Spain, Taiwan, Indonesia and the UAE (Clarke 2004). However, little information is available on the actual origin of these fins and the species from which they originated (Clarke *et al.* 2006a).

One of the key problems with the management of sharks, is the incomplete and sometimes inaccurate reports of catches to the FAO (Rose 1996). Because shark fisheries have generally been considered to contribute minimally to the overall fishery production of various countries, data on the volume, species composition of catches, as well as exploitation levels of each species, have not been collected (Rose 1996). Furthermore, shark products that are considered of low value such as skins, leather, and oil, are rarely reported by trade entities, or are often combined into a single category, making their contribution to the trade difficult to assess (Rose 1996; Hareide *et al.* 2007). While many countries have agreed to utilize a harmonized system of codes to record imports and exports of shark products, the commodity categories used are not taxonomically segregated and since trade and capture production figures are not species specific for the majority of countries, sharks are generally aggregated into various categories with other marine species (Rose 1996; Clarke 2004). According to data compiled by the FAO from 2006, only about 30% of the world shark catches were reported at the species or genus level while another 13% were reported at the family level (FAO 2009a). Therefore, catches and capture production quantities are likely to be higher than those reported to FAO and analysis of shark product trade can only be undertaken for generic shark products (Clarke 2004). Furthermore, Clarke *et al.* (2006b) stated that the estimated 26 to 73 million sharks believed to be traded annually represent a shark biomass three to four times higher than the catch reported to FAO capture production statistics. This could largely be due to IUU fishing, further complicating the ability of various nations to properly monitor the status of their shark resources (FAO 2009a). It is, therefore, probable that world shark stocks are actually facing much heavier fishing pressures than FAO data indicate (Clarke *et al.* 2006b).

There are growing concerns with regards to the ability of shark populations to sustain the fishing pressures driven by market demand in parallel with trade growth (Camhi *et al.* 1998; Baum *et al.* 2003; Baum & Myers 2004; Clarke *et al.* 2007). As a result, in the last decade, multiple laws and regulations have been developed and implemented to regulate the harvest and trade in shark products. However, many of these measures contain loopholes and suffer from poor enforcement (Biery & Pauly 2012). Therefore, there is an urgent need to better understand the magnitude, global distribution, and species composition of shark fisheries in order to develop improved management strategies. However, data on the species composition of the shark fin trade remain limited to one quantitative study of the Hong Kong auction trade (Clarke *et al.* 2006a) and some qualitative information based on interviews with traders (Rose 1996; Clarke 2002). Therefore, trade studies are necessary to assess and better understand exploitation levels and the status of shark stocks around the world (Clarke *et al.* 2006b; Hareide *et al.* 2007; FAO 2009a).

In the UAE, one of the top exporters of shark fins to Hong Kong (Clarke 2004), much of the trade in sharks and shark products remains unregulated with little information available regarding the species and quantities involved. Since different species have varying natural capacities to respond to fishing pressure, any management and conservation efforts require reliable information on shark catch and trade on a species-specific level (Abercrombie *et al.* 2005; Clarke *et al.* 2006a; Moura *et al.* 2008; Pinhal *et al.* 2008; Holmes *et al.* 2009). Various methodologies for characterizing the fin trade are now available and include market surveys as well as genetic methods. Indeed, using molecular techniques to identify shark species from specimens that are morphologically difficult to identify, or from various body, parts has become an accepted technique (Shivji et al., 2002; Ward et al., 2005; Clarke et al., 2006; Ward et al., 2008; Holmes et al., 2009). Because the UAE plays such an important role in the global trade in shark fins, a study was needed to quantify and characterize the shark products traded. Therefore, the aims of this study were to 1) investigate the national and international trade dynamics of various shark products; 2) assess the species composition, exploitation levels, and origins of sharks involved in the trade; 3) confirm field identifications by barcoding a subsample of species found at the survey site; 4) assess the conservation status of species affected by the trade.

6.2 Materials and methods

6.2.1 Market surveys

Details of data collection are presented in **Chapter II** section **2.3.1**.

For all species involved in the trade, a summary of biological findings with quantities, IUCN Red List status, sizes of specimens for each species, and sex ratios is presented. For those species with ≥50 measured individuals, the assumption of equal sex ratios (1:1) within the landings was tested using Chi-square analysis with Yate's correction for continuity ($p < 0.05$). Although calculations could not be done for females, the proportion of immature males represented in the trade was calculated.

6.2.2 Trade records, market observations, and trader interviews

A comprehensive review of the available literature regarding the trade in shark fins and shark products from the UAE was conducted. It was not possible to obtain information regarding the trade from governmental institutions. Therefore, to estimate the UAE's contribution to the global trade in shark products, available trade records were collated from two sources, the FAO and the Hong Kong Census and Statistics Department. Using Fishstat J and the FAO Global Fisheries Commodities and Trade dataset (1976-2009) (FAO 2012), all types of shark commodities were selected for exports, imports, and re-exports from the UAE. Trade statistics from Hong Kong included imports of shark fins from the UAE, based on the country of origin using three codes from the harmonized system: 'shark fin with cartilage, dried' (0305 5950), 'shark fin without cartilage, dried' (0305 5960), and 'shark fin with cartilage, salted or in brine' (0305 6930) for the years 1998 to 2011. For calculations that include the 'shark fin with cartilage, salted or in brine' category, a factor of 1 kg = 0.25 kg dried fins was used to normalize the data for water content (Clarke 2002). Data extracted were used to determine quantities of shark fins exported and imported from/to the UAE and quantities of shark fins imported from the UAE into Hong Kong.

The trade dynamics of various shark products were investigated through market observations and informal, unstructured, trader interviews at the study site. Interviews were generally conducted before or after the start of the auctions during each survey trip, and respondents were mainly the same four to ten traders found on site. While they were all forthcoming with their answers and cooperative at the start of the study, with some interviews having been saved on a voice recorder, traders progressively became more cautious and suspicious making it difficult to gather information. In fact, while a good working relationship had been built by the principal investigator with the traders, it became gradually impossible to visit fin processing areas and get individuals to participate in interviews. Furthermore, some traders avoided displaying fins on some days because they were aware of scrutiny from the media and market visitors. Respondents were also concerned that information provided would be disclosed to government authorities, leading to monitoring of the trade. This change in behavior was largely due to organizations across the UAE promoting shark conservation through the media, while advocating a ban on the trade of all shark products.

6.2.3 Genetic analysis

In order to validate the identity of species originating from Oman, a set of 655 tissue samples from 27 shark species were genetically tested in collaboration with several international institutions.

- **KAUST**

A total of 182 tissue samples originating from Omani transshipments were sent to KAUST for genetic analyses. Three species were represented in these samples including the great, *Sphyrna mokarran*, scalloped, *S. lewini*, and smooth, *S. zygaena*, hammerheads.

DNA was extracted using the Machery-Nagel Genomic DNA from tissue (Bethlehem, PA, USA) extraction kit following the manufacturers' instructions. Total amplification volumes for PCR reactions were 25 μL, and contained 2 μL of the template DNA, 2 μL of the primer mix (10 pmol/μL), 12.5 μL of the Qiagen Master

Mix (Qiagen Inc.), and 8.5 μL of ultrapure water. Initial amplifications used the primer combination FishF1 and FishR1 (refer to **Chapter IV** for primer sequences), which amplified the barcode region for the majority of samples. When this failed to produce a PCR product, primers FishF2 and FishR2 were used, and if the PCR was still unsuccessful, primer combination FishF1 and HCO2198 (5'-TAAACTTCAGGGTGACCAAAAAATCA-3') (Folmer *et al.* 1994) was used. The PCR thermal cycling employed was: 95°C initial heating for 15 min to activate the hot start DNA polymerase, followed by 35 cycles of 94°C for 30 seconds, 58°C for 1 minute, 72°C for 1 min, and a 10 min final extension step at 72°C. Amplifications were performed using Veriti 96-well thermal cyclers (Applied Biosystems).

PCR products were visualized on 0.8% TBE agarose gels containing ethidium bromide for DNA quality and concentration, viewed on a GelDoc-It Imager (UVP, Mitsubishi), and purified using the Exonuclease I method (ExoSap, USB, Cleveland, OH, US). Sequencing was performed using the primer FishF1 with the dye-labeled termination method (BigDye Terminator v3.1, Applied Biosystems, Inc., Foster City, CA) in an Applied Biosystems 3730 XL genetic analyzer. All sequences were sequenced in forward and reverse directions.

- **Barcode of Life Initiative (BOLD)**

A total of 473 tissue samples (including 11 fin samples) originating from Omani transshipments were sent to the University of Guelph for analyses. Twenty six species were represented in these samples.

DNA was extracted using the standard glass fiber-based system (Ivanova *et al.* 2006). Total amplification reaction volumes were 12 μl, and contained 6.25 μl of 10%

trehalose, 2.0 μl ultrapure water, 1.25 μl of 10xPCR buffer for Platinum Taq (200 mM Tris–HCl, pH 8.4, 500 mM KCl) (Invitrogen, Inc, Foster City, CA, USA), 0.625 μl of 50 mM $MgCl_2$, 0.125 μl each primer (10 μM), 0.0625 μl dNTP mix (10 mM), 0.06 μl Platinum Taq Polymerase (Invitrogen, Carlsbad, USA), and 0.5-2.0 ml DNA template. The forward and reverse primer cocktail pair C_VF1LFt1 and C_VR1LRt1 (Ivanova *et al.* 2007) appended with M13 tails (5′-TGTAAAACGACGGCCAGT-3′ and 5′-CAGGAAACAGCTATGAC-3’) (Messing 1983) were used as PCR primers.

PCR amplification was conducted on an Eppendorf Mastercycler gradient thermal cycler (Brinkmann Instruments, Inc., Westbury, NY, USA). The PCR thermal cycling employed was: 2 min at 95°C; 35 cycles of 30 s at 94°C, 30 s at 52°C, and 1 min at 72°C; followed by 10 min at 72°C. PCR products were labeled using the BigDye Terminator v3.1 Cycle Sequencing Kit (Applied Biosystems, Foster City, USA) and sequencing performed on an ABI 3730x1 DNA Analyzer (Applied Biosystems, Inc.).

For all samples, species identifications were made using both the BOLD Identification Engine (www.boldsystems.org) and GenBank nucleotide database (www.ncbi.nlm.nih.ggoc/nucleotide). Both engines matched each uploaded sequence with others present in their databases and provided similarity or maximum identity percentages, respectively, with matching sequences.

6.3 Results

6.3.1 Market surveys and observations

At least 37 species of sharks were found to be traded across the UAE for both national and international markets. The biological information and details of the 30 shark species traded nationally are provided in **Chapter IV**. All other shark specimens found at the Dubai survey site originated from Oman and included 33 species of sharks regularly traded through the UAE. The trade in shark products consisted mainly of fins and meat. Jaws and teeth were infrequently sold to tourists in Dubai while the market for cartilage was largely non-existent. Liver oil was sometimes traded locally for dhow proofing but was not a regular occurrence and most shark carcasses were discarded after the fins and the meat had been removed. The distribution methods varied according to the size of the sharks landed, type of product, and its end use. **Figure 6.1.** illustrates the distribution chain for sharks from the UAE and Oman.

Nationally, sharks were auctioned along with other fish catches daily (**Appendix B, Plate 6.1.**). All small bodied sharks were initially auctioned at their respective landing sites. Retailers from fish stalls at adjacent markets and various restaurants and hotels purchased sharks which were then displayed as whole sharks for domestic consumption. Sharks were sold at local markets under the name of 'jarjur' and retailed at prices between AED 10 and 20 per kg (USD 2.5 to 6 per kg) depending on the location (**App. B, Plate 6.2.**). When sharks remained unsold for several days, fins were removed and either dried at the markets or transported to Dubai for drying and then resale. Shark meat was either discarded or processed. The largest quantities of shark meat were sold at the Dubai market stalls and were rarely marketed at other sites. In most cases, if processed, shark carcasses (without the fins and heads) were cut into small cubes, salted and dried, before being packaged into plastic bags and sold locally (**App. B, Plate 6.3.**). In Dubai, skins were occasionally removed and dried at the local market.

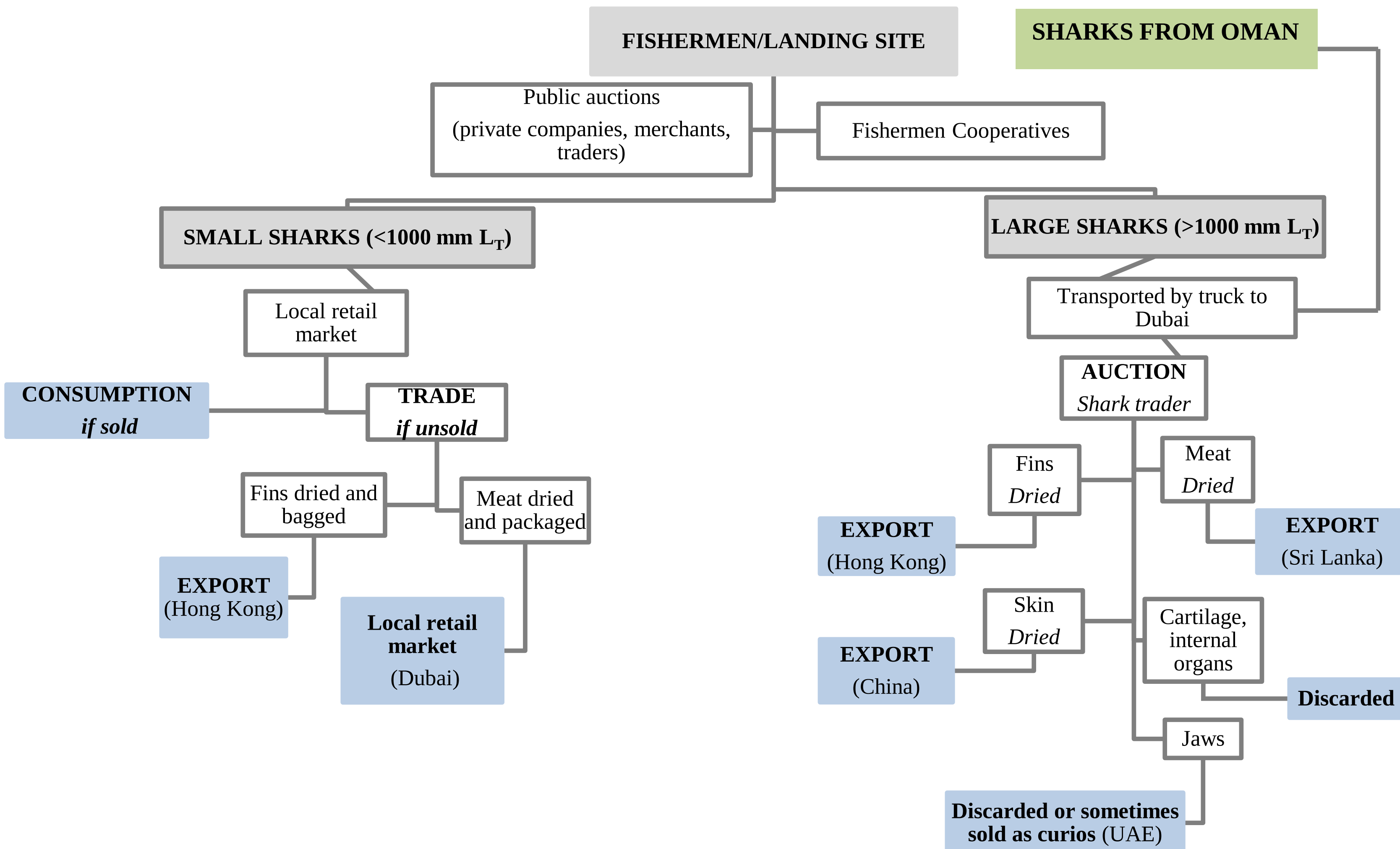

Figure 6.1. Distribution chain for sharks landed whole in the UAE and imported from Oman based on information collection from the traders. Boxes in blue indicate the final destination of each product.

Large bodied sharks were rarely sold domestically. If they were found at markets, they were usually filleted and sold at AED 15 per kg (USD 4 per kg). All other large sharks were either taken to processing facilities or transported to Dubai in trucks and kept frozen until they were displayed and auctioned at the Deira market. In Abu Dhabi, all large bodied sharks landed at the Mina Zayed site were exclusively sold to one trader who arrived daily by truck from Ajman (**App. B, Plate 6.4.**). Those landed in Sharjah were either immediately auctioned off at the Jubail landing site and taken for processing (**App. B, Plate 6.5.**), or transported to Dubai by traders wanting to get a better price. Large sharks were rarely landed in Ras Al Khaimah and, therefore, all auctioning was directly done on site with most sharks sold at the local market in Maarid. If large sharks were captured, fishermen would contact traders, who collected and transported them directly to facilities in the area for processing.

All other sharks found at markets in the UAE originated from Oman. Of these, small bodied sharks were frequently found in Abu Dhabi and Dubai but were absent from Sharjah and Ras Al Khaimah which only sold their respective catches. These sharks were usually transported to these destinations along with other fish products imported from Oman. However, all large bodied sharks were exclusively traded in Dubai. These were transported daily in refrigerated trucks for sale to local traders from various locations along the Omani coast, i.e. Sohar, Shinas, Muscat, Sur, Masirah Island, Mahoot, Dugum, Salalah. On arrival in Dubai, sharks and fins (without their respective carcasses) were offloaded at the back of the market (**App. B, Plate 6.6.**). Whole sharks were always displayed based on their location of origin and their sizes in front of the trucks transporting them. Fins were usually in fresh form with pectoral fins displayed in sets, caudal (whole tail) and first dorsal fins separately, and pelvic and second dorsal fins in mixed piles containing different species (**App. B, Plate 6.7.**). On some occasions, large quantities of dried fins packed in gunny sacks of large or small fins, were also sorted and weighed at the site (**App. B, Plate 6.8.**). Furthermore, on rare occurrences trucks full of dried shark skins were transported to Dubai for sale (**App. B, Plate 6.9.**). Auctions took place daily after the evening prayer and sharks were sold in bulk based on their display. For instance, if a truck had offloaded a large quantity of both large and small sharks, an auction was done for the large bodied ones and another for the smaller ones. Also, fins and meat were auctioned off separately. Prices varied widely depending on the species and sizes of the sharks traded on a particular day. On some days, the price of 20 large sharks (over 2 m each) could reach AED 20,000 (USD 5,500) while on other days, prices could be as low as AED 8,000 (USD 2,200). All auctions were conducted in Hindi and it was therefore not possible to collect accurate data on price ranges. After this process was completed, all fins were immediately removed on site by middle men (crude or straight cut with meat remaining on the fins) and placed in bags for the traders (**App. B, Plate 6.10.**). Shark meat was not generally processed at this site. Once all fins were removed, carcasses were either reloaded onto trucks or transported on carts to various areas where the meat was processed and the remaining body parts discarded. Processing sites, for drying fins and meat, were generally located in other emirates, i.e. Ajman, Umm Al Quwain, Ras Al Khaimah.

During the sampling period, only sharks originating from Oman where found to be traded in Deira, Dubai. A total of 12,069 individuals were recorded from 33 shark species. Of these, 6,334 were measured, sexed, and identified to species level, while 5,735 were not measured and biological characteristics could not be recorded (of which 396 had fins attached and species level identification was possible) (**Table 6.1.** and **6.2.**). The Carcharinidae family represented 74.9% of all sharks traded from Oman, followed by Sphyrnidae (9.3%), Lamnidae (9%) and Alopiidae (5.9%). The most common species, comprising 64.9% of the traded species, were *C. sorrah* (23.2% of all traded specimens), *Carcharhinus limbatus* (9.5%), *Isurus oxyrinchus* (9%), *C. falciformis* (8%), *C. brevipinna* (7.8%), and *Rhizoprionodon acutus* (7.3%). Other species that were important in the trade included *S. lewini*, *C. leucas*, *Alopias pelagicus,* and *C. plumbeus* with each representing over 3% of the trade. However, the remaining 23 species each consisted of less than 3% of the total species traded.

In some cases, significant differences in the sex ratios of traded species were evident. Females largely outnumbered males in specimens of *A. pelagicus, I. oxyrinchus, C. brevipinna, C. sorrah, S. zygaena* and *S. lewini,* while ratios were in favor of males for *C. leucas*, *C. limbatus, R. acutus* and *Prionace glauca*. Furthermore, immature male individuals from nine species including *C. altimus, I. oxyrinchus, C. amboinensis, C. falciformis, C. leucas, C. plumbeus, R. acutus, S. lewini* and *S. zygaena* dominated catches.

Some species were found to be seasonal in the trade and specific to some locations. For instance, the five individuals of *C. amblyrhynchos* were all transported from Khasab during the months of April, May and July. All but one *P. glauca* and one *A. superciliosus* specimens were from Salalah (one from Masirah Island respectively for each species), and were only encountered during August, September,

Table 6.1. Total number (n) and percentage of total (%) of species recorded from Oman with their IUCN Red List status (including fins confirmed as originating from those species (n=21) and individuals of species not measured) (**EN** Endangered; **NT** Near Threatened; **VU** Vulnerable; **DD** Data Deficient; **LC** Least Concern).

Family	Species name	Common name	n	%	IUCN
Ginglymostomatidae	*Nebrius ferrugineus*	Tawny Nurse shark	13	0.19	VU (2003)
Stegostomatidae	*Stegostoma fasciatum*	Zebra shark	4	0.06	VU (2003)
Rhincodontidae	*Rhincodon typus*	Whale shark	2	0.03	VU (2005)
Alopiidae	*Alopias pelagicus*	Pelagic thresher	246	3.65	VU (2009)
	Alopias superciliosus	Bigeye thresher	156	2.31	VU (2009)
Lamnidae	*Isurus oxyrinchus*	Shortfin mako	607	9.01	VU (2009)
Triakidae	*Mustelus mosis*	Arabian Smoothhound	26	0.39	DD (2009)
Hemigaleidae	*Chaenogaleus macrostoma*	Hooktooth shark	2	0.03	VU (2009)
	Hemipristis elongata	Snaggletooth shark	11	0.16	VU (2003)
	Paragaleus randalli	Slender Weasel shark	1	0.01	NT (2009)
Carcharhinidae	*Carcharhinus altimus*	Bignose shark	132	1.96	DD (2009)
	Carcharhinus amblyrhynchoides	Graceful shark	20	0.3	NT (2009)
	Carcharhinus amblyrhynchos	Grey Reef shark	5	0.07	NT (2009)
	Carcharhinus amboinensis	Pigeye shark	127	1.88	DD (2009)
	Carcharhinus brevipinna	Spinner shark	530	7.86	NT (2009)
	Carcharhinus dussumieri	Whitecheek shark	9	0.13	NT (2003)
	Carcharhinus falciformis	Silky shark	539	8.0	NT (2009)
	Carcharhinus leiodon	Smoothtooth Blacktip	19	0.28	VU (2009)
	Carcharhinus leucas	Bull shark	348	5.16	NT (2009)
	Carcharhinus limbatus	Blacktip shark	640	9.5	NT (2009)
	Carcharhinus longimanus	Oceanic White tip	30	0.45	VU (2006)
	Carcharhinus macloti	Hardnose shark	12	0.18	NT (2003)
	Carcharhinus melanopterus	Blacktip Reef shark	42	0.62	NT (2009)
	Carcharhinus plumbeus	Sandbar shark	214	3.18	VU (2009)
	Carcharhinus sorrah	Spottail shark	1567	23.25	NT (2009)
	Galeocerdo cuvier	Tiger shark	39	0.58	NT (2009)
	Loxodon macrorhinus	Sliteye shark	168	2.49	LC (2003)
	Negaprion acutidens	Sharptooth Lemon shark	41	0.61	VU (2003)
	Prionace glauca	Blue shark	76	1.13	NT (2009)
	Rhizoprionodon acutus	Milk shark	495	7.34	LC (2003)
Sphyrnidae	*Sphyrna lewini*	Scalloped Hammerhead	365	5.42	EN (2007)
	Sphyrna mokarran	Great Hammerhead	79	1.17	EN (2007)
	Sphyrna zygaena	Smooth Hammerhead	186	2.76	VU (2005)
TOTAL			**6751**		

Table 6.2. Summary of biological traits by sex for all species originating from Oman with quantities recorded for each sex, minimum and maximum sizes (mm L_T), means, size at maturity (based on the smallest pregnant female), sex ratios (*indicates sex ratios that are significantly different at p=0.05) and proportion of immature males.

Species name	Sex (n)	Min size	Max size	Mean (± S.D.)	Size at maturity	Sex ratio (F:M)	% immature
N. ferrugineus	F 10	124	2970	2457.9 (511.1)	-	3.33:1	-
	M 3	218	2866	2475.3 (352.7)	2866		-
S. fasciatum	F 2	199	1996	1993.5 (3.5)	-	2:1	-
	M 1	-	1882	-	1882		-
R. typus	F 0	-	-	-	-	0:1	-
	M 1	-	2900	-	-		-
A. pelagicus	F 105	1437	3497	2518.9 (558.2)	3290	1.45:1*	-
	M 72	1274	3486	2496.5 (538.1)	1720		49%
A. superciliosus	F 60	122	3635	2769.3 (642.1)	3476	1.25:1	-
	M 48	157	3331	2780.9 (411)	2526		6%
I. oxyrinchus	F 275	120	3690	1865.4 (360)	3690	1.27:1*	-
	M 216	119	3024	1755.1 (339.1)	1750		67%
M. mosis	F 19	418	990	659.9 (161.7)	990	2.71:1	-
	M 7	522	843	664.8 (117.8)	768		-
C. macrostoma	F 1	-	716	-	-	1:1	-
	M 1	-	846	-	846		-
H. elongata	F 7	133	2815	2188.4 (469.9)	2815	1.75:1	-
	M 4	119	2055	1656.2 (351.7)	1670		-
P. randalli	F 1	-	795	-	-	1:0	-
	M 0	-	-	-	-		-
C. altimus	F 52	929	2673	1487.6 (399.1)	2610	1.01:1	-
	M 51	921	2523	1452.4 (369.7)	2523		96%
C. amblyrhynchoides	F 9	503	2490	1264.1 (740)	-	1:1.22	-
	M 11	482	2512	1584.7 (859.6)	2152		-
C. amblyrhynchos	F 0	-	-	-	-	0:5	-
	M 5	138	1883	1629.4 (190.6)	1386		-
C. amboinensis	F 66	123	2783	2224.4 (293.1)	2450	1.13:1	-
	M 58	109	3185	2211.6 (275.7)	2110		62%
C. brevipinna	F 295	564	3770	2404.8 (490.9)	2395	1.26:1*	-
	M 233	650	2881	2136.1 (448)	1770		24%
C. dussumieri	F 1	-	666	-	-	1:8	-
	M 8	365	837	725.6 (155.1)	740		-
C. falciformis	F 245	795	2891	1857.3 (399.1)	2294	1:1.11	-
	M 272	824	2690	1824.2 (377.2)	2195		86%

Table 6.2. *Continued*

Species name	Sex (n)	Min size	Max size	Mean (± S.D.)	Size at maturity	Sex ratio (F:M)	% immature
C. leiodon	F 12	106	1648	1457.5 (179.9)	-	1.71:1	-
	M 7	144	1549	1499.8 (331.5)	1441		-
C. leucas	F 147	641	4090	2314.9 (633.4)	2352	1:1.35*	-
	M 199	509	3390	2237.9 (544.6)	2028		54%
C. limbatus	F 278	422	3290	2119.7 (671.5)	2353	1:1.24*	-
	M 345	331	3332	2128.6 (544.6)	1505		28%
C. longimanus	F 16	165	3100	2484.1 (375.7)	-	2:1	-
	M 8	160	2250	1901.2 (240.4)	2220		-
C. macloti	F 5	716	913	824.4 (87.6)	913	1:1.4	-
	M 7	715	912	808.1 (66.1)	758		-
C. melanopterus	F 23	578	1590	1328.1 (±243.2)	1413	1.21:1	-
	M 19	103	1475	1271.6 (108.6)	1138		-
C. plumbeus	F 96	875	2420	1333.3 (351.7)	1815	1:1.23	-
	M 118	795	2105	1358.4 (356.8)	1725		83%
C. sorrah	F 794	435	1883	1339 (277.6)	1240	1.11:1*	-
	M 711	420	1610	1103.2 (222.7)	1015		41%
G. cuvier	F 25	131	3320	1771.9 (472.7)	-	2.08:1	-
	M 12	100	3770	1992.7 (691.3)	377		-
L. macrorhinus	F 92	334	935	787.7 (116.4)	851	1.21:1	-
	M 76	492	914	6982.2 (82.9)	648		41%
N. acutidens	F 21	161	2770	2363.1 (358.7)	2616	1.1:1	-
	M 19	152	2840	2280 (401.3)	2070		-
P. glauca	F 9	229	3254	2703 (±332.9)	3039	1:7.24*	-
	M 65	187	3453	2725.7 (2842)	2247		2%
R. acutus	F 219	342	982	657.9 (166.3)	681	1:1.26*	-
	M 276	375	870	650.6 (136.8)	618		52%
S. lewini	F 222	445	3414	2155.8 (823.3)	2432	1.68:1*	-
	M 132	478	3553	1679.3 (647.3)	2005		63%
S. mokarran	F 35	608	4440	2147.8 (778.2)	3165	1:1.17	-
	M 41	955	3910	2462.6 (714.5)	2305		37%
S. zygaena	F 110	554	3550	2215.6 (615.8)	3136	1.96:1*	-
	M 56	528	2880	1831.8 (448.4)	2440		98%

and early October. On the other hand, while *A. pelagicus* and *I. oxyrinchus* were also predominantly found in August, September and October, some specimens were also traded in January, April, May and June. *C. falciformis* individuals were largely found in June, August, September and October. *S. mokarran* were all transported from

Salalah mainly during the month of October. *S. zygaena* were also mostly traded from August to October but originated from various locations. *S. lewini* were found throughout the year but a peak in catches was evident in June and July, with mainly pregnant females arriving from Mahoot and Masirah Island. Finally, *G. cuvier* individuals were only traded from January to April but arrived from various locations. All sharks recorded in the trade were found to have been assessed by the IUCN. According to the IUCN Red List assessments, 39.3% of sharks were considered Near Threatened, 6% Least Concern, while 9% were Data Deficient and therefore there was not enough information available to evaluate their status. Also, 39.3% were considered Vulnerable and 6% were listed as Endangered, which indicated that 45.3% of species found at the Dubai market from Oman faced a high risk of global extinction (**Figure 6.2.**).

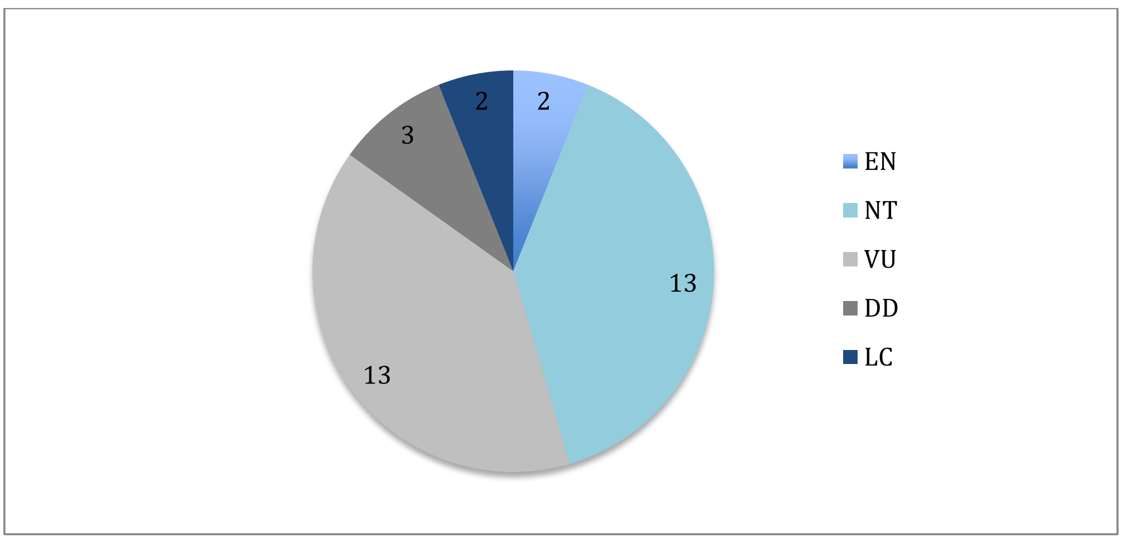

Figure 6.2. IUCN Red List status of the 33 shark species originating from Oman. Values represent the number of shark species in each category (**EN** Endangered; **NT** Near Threatened; **VU** Vulnerable; **DD** Data Deficient; **LC** Least Concern). (IUCN, 2012).

6.3.2 Interviews with traders

According to one of the traders, only four to five shark trading companies were established in Dubai, each employing up to ten staff. Acquiring a trade license for the business and fish exports was considered an easy process that did not involve a costly investment. However, competition was believed to be fierce and trading in shark products was perceived as a risky business since exporters from Oman needed to be paid before traders could secure product exports from the UAE. While respondents suggested that prices could fluctuate depending on the demand, the general trend in recent years had been falling prices and diminishing profits. This was attributed to the recent economic crisis and a reduction in demand from Hong Kong.

Overseas buyers frequently visited Dubai (especially from Hong Kong) to inspect products and build relationships with sellers. Trade was undertaken with a number of overseas importers since products were sold to those offering the best prices. Formal contracts were not signed and the trade was undertaken on an ad-hoc basis. Respondents stated that there was a need to establish and maintain good and stable working relationships with these buyers, and thus shark products were sometimes sold at a loss to avoid local competitors taking over the business. One respondent stated he also traded fins that originated from Iran and other neighboring countries.

The trade in large shark fins was considered the most lucrative business for all respondents. These were the most profitable and fins from small bodied sharks, meat and skin were only marketed for additional income. None of the shark fins auctioned in Dubai were redistributed to restaurants or hotels and all contributed to the trade. Prices for fresh and dried fins varied greatly and depended both on the species auctioned and on the demand. Sharks with ‘white fins’ (i.e. from hammerheads) were considered of the highest quality, and, therefore, the most expensive, followed by sharks with ‘black fins’ (i.e. *C. brevipinna* and many carcharhinids). One large fresh fin could sell for AED 60 (USD 17) while fins from smaller sharks could sell for prices between AED 20 and 40 (USD 6 to 11), depending on the species. Once dried, fins from small sharks could be sold for AED 60 per kg (USD 17 per kg). Most respondents mentioned that the dorsal, pectorals and lower caudal fins were the most valuable. Some species such as carpet sharks and the whale shark were not considered valuable. Actually, one whale shark captured off the coast of the UAE measuring 4452 mm L_T was auctioned whole in Dubai for AED 500 (USD 135). Traders said that both the fins and the meat were not very marketable for this species.

Traders believed the trade in shark meat was becoming more profitable since large quantities of meat could be sold with higher profit margins. They mentioned the profit margin for fins was only 5% after drying. However, meat was auctioned at approximately AED 6 per kg (USD 1.7 per kg) but could resell at prices up to AED 40 per kg (USD 11 per kg) after drying. The biggest market for shark meat was Sri Lanka and, unless meat was sold locally (usually in small quantities directly at the market or to restaurants and hotels), everything was exported. Furthermore, traders were not concerned about the rotting sharks frequently offloaded and stated that the meat could still be dried and sold. Skins imported from Oman were already dry and traders affirmed that these were exported directly to China. When asked about the use of the skin, none of them were able to clearly describe its usage and believed it was a food item consumed in Asia or processed and used as leather.

When asked about shark conservation, traders were aware of recent national initiatives by non-governmental organizations to push for monitoring of the trade in shark products, as it was well documented in the media. Many were concerned about potential impacts on their business and were becoming careful when displaying sharks and particularly fresh fins at the auction site. When asked about their reactions if measures were implemented to curb the trade, most traders mentioned they would either change their business or move to Yemen where the trade was booming.

6.3.3 Literature review and trade records

A review of the literature provided limited insight into the trade of shark products originating from the UAE. Rose (1996) reported that Somalia exported most of its shark fins through Dubai, which were then exported to Hong Kong or Singapore (Vannuccini 1999). Marshall and Barnett (1997) also reported that Somalia exported most of its dried shark fins through Dubai. Middlemen transported fins to Boraso and Berbera in Somalia, where they were purchased and either exported to Dubai directly or through Djibouti. Up to 10 mt of shark fins were exported between January and July 1996. Also, they stated that Arab fish trawlers used to bring their fins to Zanzibar but were now also exporting their products through Dubai. These shipments were generally transported to the UAE by boat, but were sometimes flown out, before being re-exported mainly to Singapore and Hong Kong. Ali *et al.* (2001) also reported that shark fins from Somalia destined for the Asian market were exported through Dubai with an average 8 to 10 mt of dried fins yearly. Hanfee (2001) confirmed that 20 mt of frozen shark meat, mainly from whale sharks, was sold to the UAE in 1994.

Furthermore, from 1995 to 1999, the UAE was among major markets for dried shark fins from India, importing 6 mt yearly (Raje *et al.* 2002). South Korea traded small volumes of frozen shark meat with the UAE from 1988 to 1994 (Rose 1996) and Thailand imported fins from here in 1996 (Vannuccini 1999). Clarke (2002) stated that the UAE likely served as a transshipment point for shark fins from Africa and hypothesized that it was not a domestic producer of shark fins. Interviews with traders in Zanzibar revealed that the trade in fins between North Africa and eastern Asia had been taken over by the UAE since the late 1990s and that this trend, along with decreasing shark populations, had driven some traders out of business (Schaeffer 2004). Hareide *et al.* (2007) reported that most imports from the UAE into Hong Kong included fins originating from several east African and Arabian states but did not provide quantities or information on species and countries. An FAO country report from Iran described an illegal trade of dried shark fins undertaken by fishermen directly with traders in the UAE with prices of fins ranging between USD 4 and 40 per kg depending on fin sizes (FAO 2009a). Finally, various reports have shown that the UAE exported between 400 to 500 mt of shark fins yearly to Hong Kong between 1998 and 2000 (Fowler *et al.* 2005; Hareide *et al.* 2007; WildAid 2007).

Data collated from the FAO are presented in **App. A, Table 6.3.** Only data from 1995 onwards were available for analysis. From 1995 to 2009, neither the UAE nor FAO had quantities or estimates reported for dried fin imports and re-exports. All exports of dried 'salted' fins were FAO estimates ranging from 0 mt in 1995 and reaching a peak at 539 mt in 2005. This estimate has remained relatively stable in the past decade ranging between 400 and 539 mt per year. Quantities of both 'frozen' and ‘salted or in brine’ fins were nil for exports and reported by the UAE as negligible in 2006. For the ‘sharks nei, fresh or chilled’ commodity, except in 2009 where the UAE declared exports at 98 mt, all values were FAO estimates varying between 2 mt in 1995 and 25 mt in 2004. Imports in this category have been declared since 2002 and reached a peak in 2005 at 253 mt but dropped again to 28 mt in 2009. Re-exports were also negligible but have been declared since 2002 and have ranged between 2 mt in 2002 with a peak at 80 mt in 2008. The ‘shark nei, frozen’ commodity had values either reported by the UAE or FAO estimates. The largest quantity reported for exports from the UAE was 35 mt in 2009. Imports were estimated by the FAO at 181 mt in 1995 but in later years were reported by the UAE at 103 mt for 2002 and 1 mt in 2009. Re-exports were declared at a minimum of 1 mt in 2007 reaching 38 mt in 2005 and declining to nil in 2008.

Data from Hong Kong are presented in **App. A, Figure 6.3.** (Anon 2012). Trade data for the country of origin indicated that Hong Kong mainly imported ‘dried shark fins with cartilage’ from the UAE with quantities ranging between a minimum of 355 mt in 2001 to a maximum of 538 mt in 2002. The average quantities for the 14 years of data available were 449 mt per year. There seemed to have been a downward trend in recent years with quantities reaching 386 mt in 2011. Since 2008, data have been available for imports of ‘dried fins without cartilage’, which have ranged between a minimum of 23 mt in 2008 to 78 mt in 2010. Finally, ‘fins with cartilage, salted or in brine, have only been reported from 2007 at 3 mt and from 2011 at 515 kg. When adjusted for water contents, these values were notably smaller and indicated that the UAE exported quantities of 805 kg of this commodity in 2007 and 129 kg in 2011.

6.3.4 Species identification through genetic analysis

Barcoding was successful for 77.2% of samples analyzed and confirmed the field identification of 26 species present in the trade (**App. A, Table 6.4.**). Of the 182 samples sent to KAUST for analysis, four of the *S. lewini* samples returned ambiguous results with misidentifications when matched in the databases and two failed to provide any sequences. Of the 473 samples sent for analysis to BOLD, 330 samples yielded good quality sequences that could be used to identify species. However, 90 samples failed to provide any sequences; 15 provided low quality sequences that were too short and thus not usable for species identifications; and 38 sequences matched species different than those identified at the survey site suggesting contamination either in the field or during transportation, since species identified at the survey site as *A. superciliosus* matched *S. zygaena* in BOLD, or similarly *C. leiodon* returned matches with *I. oxyrinchus*, species distinguishable morphologically and unlikely to have been confused in the field. The sequences from the analysis of 11 fins did not flag additional species and included three *C. amboinensis*, one *C. falciformis*, one *I. oxyrinchus*, one *C. brevipinna*, and one *N. acutidens*.

6.4 Discussion

The findings reported here confirm that a substantial trade in shark products is occurring in the UAE and is fuelled by international demand. While field data collected were limited to sharks originating from the UAE and Oman, the study provided a comprehensive overview on the utilization of various shark products, trade links from the UAE, and details of the species composition of the Omani trade. These species-specific trade estimates provide a step towards evaluating whether exploitation rates for particular species can be sustained.

Trade records showed that fins have been exported to Hong Kong for decades now; however little information was available regarding the trade in shark meat and other products such as skin. Although further research needs to be undertaken to determine if fresh fins transported from Oman originated from sharks processed at landing sites or finned at sea, what was clear, is that all sharks were fully utilized when possible and the practice of finning was minimal and even non-existent in the UAE. Small bodied sharks were usually consumed domestically while fins and meat from larger species were traded internationally (Rose 1996; Hanfee 1997; Marshall & Barnett 1997; Vannuccini 1999; Henderson *et al.* 2008). As noted by Rose (1996), shark meat from small bodied individuals can easily be marketed for human consumption due to the low levels of mercury and urea in their flesh and the ease of processing. On the other hand, Camhi *et al.* (1998) reported that even though shark meat was consumed locally in some regions of the world, this product had generally been of low value for export markets. Yet, Clarke (2004) and Hareide *et al.* (2007) suggested there may be an expanding market for frozen shark meat in mainland China with trade statistics showing a significant increase in imports in the past decade. In China, while the focus of shark processing plants has remained on fins, the target has shifted to all body parts, invluding fins from both small and large bodied sharks, to sustain the involvement of smaller plants in this business (Li *et al.* 2012). It is unclear if the trade in shark meat in the UAE is a relatively new market strategy having been developed because the global market for meat has been expanding. However, traders stated that trade in shark meat was becoming increasingly profitable for them and both the meat from small and large bodied sharks were utilized.

Rose (1996) stated that meat exports were limited because of the difficulty associated with having to process the meat immediately after capturing sharks. This is mainly because large sharks have high levels of urea and tend to spoil and produce an unpleasant odor very quickly unless the carcass is quickly chilled or frozen, making the product unacceptable to consumers. Sharks traded here were often frozen on trucks during transport but the strong smell of ammonia was noticeable during auctions when sharks were displayed in the heat. However, traders were not concerned with these odors and confirmed that the meat could still be sold after drying. According to the respondents, the main market for shark meat from the UAE was Sri Lanka but these exports could not be quantified as trade records were not available. This, however, seems plausible since there is a high demand for shark meat in Sri Lanka for consumption (Fischer *et al.* 2012) as it is a significant component of the local diet and provides much of the needed protein requirements for the poorer communities (WildAid 2007). Dried meat is also exported to Sri Lanka from other countries in the region such as India (Hanfee 1997, 2001) as well as the Maldives, who reportedly exported an estimated 304 mt of dried shark meat annually in the 1990s (Anderson & Ahmed 1993). Furthermore, records from Indonesia show that salted and dried meat were also mainly exported to Bangladesh and Sri Lanka, but no quantities were provided (Lack & Sant 2012). Yet, considering that Indonesia is one of the top shark fishing nations in the world, it is likely that these exports were substantial. Dried shark meat that was packaged and retailed for domestic consumption in the UAE was unlikely to be marketed for Emiratis as they prefer fresh meat from small bodied sharks (Gubanov & Schleib 1980). However, it is likely that the market for this product was due to the large number of Indian expatriates living here. Indeed, shark meat is known to be very popular in India and consumed in dried form along many areas of the coast (Hanfee 1997).

Little information was collected regarding the trade in skins other than the fact that it was exported directly to China. Rose (1996) reported that the market for skins is limited because they need to be processed immediately in order to preserve the quality, making it difficult to process both skins and meat simultaneously. Skin was also an important component of trade in China both for export and for trade with processing factories (Li *et al.* 2012). Traders here suggested that skin may be used for both leather and domestic consumption at its export destination in China. This is corroborated in the literature where skin is supposed to be used as leather or sandpaper (Vannuccini 1999; WildAid 2007) and is commonly consumed in some Chinese provinces, where it is fried as a snack or even cooked with soup (Lam 2009).

An interesting note from this study is that there was no demand for whale sharks products and, when captured, specimens were auctioned at very low prices. Even traders mentioned they had little value for them. Whether this was due to the protected status of whale sharks in the UAE and its CITES listing is unclear. Reports from other countries indicate that this species is valuable and in demand in many markets. Li *et al.* (2012) noted there was high demand and competition to trade in whale shark fins in China as they were some of the most expensive products. Similarly, Hong Kong traders declared that whale sharks were a valuable species for their business (Clarke

2002). In Taiwan, whale shark meat had high retail prices between USD 12 and 17 per kg (Clarke 2004). In India, all parts of this species are utilized from the cartilage to the leather and all products fetched high prices at the market with a set of four fins retailing at prices between USD 330 and 1,100 in 2000 (Hanfee 2001). In these reports, no information was provided regarding the sizes of the whales sharks preferred and, according to what Clarke (2004) suggested, this species could be valuable as trophies for display when specimens have large fins while smaller fins are of low value. Vannuccini (1999) also mentioned that fisheries targeting whale sharks were very small and existed mainly in India, the Philippines and Taiwan but that this species had limited commercial importance elsewhere.

Traders confirmed that the most lucrative business was the trade in large fins. Indeed, large bodied sharks were almost exclusively destined for the fin trade and were not retailed locally. Similarly to what was noted by Rose (1996) and Vannuccini (1999), traders here reported that fins from large sharks and 'white' fins from species such as hammerheads were the most valuable, followed by 'black' fins. Furthermore, at the time of auction, the most valuable fins were displayed in sets (dorsal, pectoral and caudal fins) which is reported to be the best method to get a better market price for them. While auctions mainly consisted of local traders, informants here noted that buyers from other countries, particularly Hong Kong, frequently visited the UAE to inspect products and build trading relationships. Clarke (2002) also reported that traders in Hong Kong sent staff overseas to secure supplies and arrange for the processing of various products. Informants here suggested that competition was fierce and therefore, there was a need to maintain good relationships with customers abroad.

Literature records have suggested that the UAE is a transshipment point for shark products and mostly shark fins from North African countries and other neighboring countries (Marshall & Barnett 1997; Ali *et al.* 2001; Hanfee 2001; Clarke 2002; Schaeffer 2004; Hareide *et al.* 2007). It does appear that for decades now, the UAE has served as an export destination for dried fins originating from Somalia (Rose 1996; Marshall & Barnett 1997; Ali *et al.* 2001) and from India (Raje *et al.* 2002). Furthermore, shark meat was exported to the UAE from Korea (small volumes) (Rose 1996) and India (Hanfee 2001). However, the reported quantities seem noticeably low, when considering that the UAE has been exporting between 400 and 539 mt per year of mainly dried shark fins as well as other sharks products to Hong Kong since 1995 (Fowler *et al.* 2005; Hareide *et al.* 2007; WildAid 2007; Anon 2012; FAO 2012), implying there is a large gap in our understanding of trade dynamics.

FAO capture production data for the UAE averaged at less than 3,000 mt per year from 1986 to 2010 (refer to **Chapter I**). Furthermore, the only data currently accessible from Abu Dhabi indicate that landings of whole sharks peaked of 187.8 mt in 2003. With Abu Dhabi fish landings representing a mere 7.6% of fish landings in the UAE (MoEW 2013), it is likely that capture production to the FAO is underreported. Fowler *et al.* (2002) suggested that many country reports were in fact 'guess-timates' and did not reflect the true level of catches. Results from **Chapter IV** indicate there is substantial shark fishery in the UAE; however, as suggested by Clarke (2002), it is unlikely that the UAE produces up to 500 mt of dried fins yearly from its fishery. Yet, the UAE did not report any imports or re-exports of dried fin products to the FAO between 1995 and 2009, suggesting that FAO estimates of exports were from domestic production or from other country reports. Therefore, further research is needed to determine the biomass of sharks by species landed in the UAE and what percentage could potentially contribute to the trade after processing.

Only shark products from the UAE and Oman, consisting primarily of fins and meat, were found at the Dubai survey site and it remains unclear what proportion of shark products traded from the UAE were represented at this particular location. While some traders mentioned they sometimes received products from Iran, they were not willing to provide further details regarding the trade in products from other countries. One report from Iran suggested that dried fins are shipped to the UAE, yet no information on the quantities traded was provided (FAO 2009a). Marshall and Barnett (1997) also reported that fin shipments from Somalia were generally transported to the UAE by boat. It is therefore likely that the Deira site is limited to the trade in shark products that are transported overland from Oman while products from other countries presumably arrive into the various ports or airports of the UAE. Assuming that shark products are reported, surveys of ports and an examination of bill of lading and air waybill records from the UAE may provide a better understanding of the type of products traded (i.e. meat (dried or frozen) or fins (dried or 'salted or in brine')), quantities, and countries of consignment for shark products. This is also likely to provide information on re-export quantities, as well as methods of transportation, from the UAE to Hong Kong since generally 67% of shark fins are imported to Hong Kong by sea and 15% by air (Clarke 2004).

Data from both FAO and Hong Kong indicated that the UAE mainly exports 'dried fins with cartilage' with negligible amounts of 'frozen' and 'salted or in brine' fins. However, FAO data also showed that in some years, the UAE imported substantial amounts of either ‘sharks nei, frozen’ (253 mt in 2005) and ‘sharks nei, fresh or chilled’ products (103 mt in 2002), implying that the UAE may also serve as a processing destination for various products before they are re-exported. The majority of imports from Oman recorded in this study were also in the form of whole sharks and fresh fins, with traders confirming that these products would need to be processed before being re-exported. Also, data from Hong Kong for the ‘frozen’ and ‘salted or in brine’ fins categories indicated that quantities of less than 1 mt of these commodities were imported from the UAE. On the other hand, the UAE could also be exporting products to countries other than Hong Kong. Clarke (2004) suggested that Hong Kong trade may only represent 50% of the global trade in fins. Furthermore, Vannuccini (1999) reported that Thailand and Singapore imported shark fins from the UAE. Therefore, other countries in Asia may be trading with the UAE in various products and more research is needed to determine the extent of this trade. Access to processing facilities here may allow a better understanding of trade dynamics both in terms of the processing capabilities in the UAE and on a species specific basis. Clarke *et al.* (2006a) were able to characterize the species composition of fins traded in Hong Kong by collecting samples from dried fins and using molecular techniques to confirm species identification. DNA barcoding was used in this study to confirm the species identifications of sharks originating from Oman. Similarly to what has been found in other studies, barcoding proved to be a successful method of identifying species (Hebert *et al.* 2003a; Moura *et al.* 2008; Ward *et al.* 2009; Asgharian *et al.* 2011). In fact, the 22.75% of samples that failed to barcode were probably due to contamination from the transport of multiple shark and fish species mixed on top of each other in trucks. Visits to processing facilities may allow a wider range of species to be sampled, in a 'cleaner' environment, and further genetic work to be undertaken. However, the sensitive nature of collecting samples and the inability to access processing sites limited the scope of this study. This was mainly because traders were becoming suspicious of the attention they were attracting during auctions. While they allowed the principal investigator to collect data from sharks displayed, many were not willing to collaborate in terms of supplying detailed information on the trade. There are indications that the media attention that shark conservation issues have been receiving is affecting cooperation from traders in other parts of the world as well. For instance, in China, shark processing companies refused to provide data on shark landings and rejected attempts at being interviewed by journalists for fear of a ban that would affect their livelihoods (Li *et al.* 2012). Also, although Clarke *et al.* (2006a) were able to characterize the composition and proportion of species in the trade by obtaining samples from traders in Hong Kong, traders limited the number of fins that could be sampled. Furthermore, when interviews were conducted, many informants were also wary of the attention they were getting.

The 37 species found to be traded in this study (Refer **to Chapter IV** for the list of shark species originating from the UAE) likely represent the minimum number of shark species traded from here since products from other species could also have been imported from various countries at different sites. It is also important to note that while this study has provided comprehensive information for species originating from UAE Gulf waters, results from Oman need to be interpreted with caution. It seems that while the UAE is an important destination for Omani products, some Omani traders process shark products on site and export dried shark fins directly to several Asian countries bypassing the UAE (Henderson *et al.* 2008). Reports on the fishery sector from Oman indicated that in 2005, 27% of the total quantity of fish was exported to the GCC market, particularly to Dubai, while the remaining catches were directly exported to the EU and Asian markets (ESCWA 2007). No information was available on the species-specific details of these exports but it is clear that the UAE only receives a fraction of Omani fish catches and, presumably, shark landings. Furthermore, similarly to what was found here, there is domestic consumption of sharks in Oman (Henderson *et al.* 2008) and therefore levels of exploitation for many species are likely to be significantly higher than what is reported from this study.

The species composition of sharks traded from Oman was different than the species represented in a survey of shark fin auction trade in Hong Kong (Clarke *et al.* 2006a). In their study, 34 to 45% of the shark fin trade comprised 14 species whereas six species represented 65% of the total species originating from Oman. The large quantities of *C. sorrah, R. acutus, C. falciformis* and *C. limbatus,* recorded here are presumably just a reflection of their high abundance in Omani waters. Still, several species recorded in high quantities in Hong Kong also comprised a high proportion of the trade from Oman. For instance, three species of hammerheads, *S. lewini*, *S. mokarran*, and *S. zygaena*, represented 9.3% of the Omani trade and 5.9% of the trade in Hong Kong. Two species of thresher sharks were reported here, *A. pelagicus* and *A. superciliosus*, and represented 5.9% of all species while three species of threshers (including the common thresher, *A. vulpinus*) comprised 2.3% of the total in Hong

Kong. The mako shark, *I. oxyrinchus*, represented 9% of the total species from Oman and 2.7% of fins in Hong Kong. Finally, the blue shark, *P. glauca*, comprised the majority of fins found in Hong Kong at 17.3% of all fins but only 1.1% of the total from Oman. While the quantities of these species represented in the trade from Oman and Hong Kong are different, many of the dominant species were similar and as suggested by Clarke *et al.* (2006a), their prevalence in the trade may reflect their relative abundance in fisheries, a preferential demand for their fins in the trade, or a combination of these factors. In fact, traders in the UAE and from other parts of the world have confirmed that fins from hammerheads are highly priced and this is likely to be the cause of their high representation in the fin trade. Furthermore, mako sharks are regarded for their meat which is recognized for its high quality and is in demand in many parts of the world (Rose 1996). However, contrary to what has been reported from other areas where *P. glauca* is the most widespread and abundant shark species (Bonfil 1994; Clarke *et al.* 2006a; Hareide *et al.* 2007), it was not one of the dominant species traded in this study. Many of the existing trade reports were conducted over a decade ago and while it is possible that a reduction of catches could be attributable to improved management of shark stocks in some areas, it could also reflect a decline in stocks due to overfishing (Lam 2009). Data from the northwest Atlantic suggested significant declines in the abundance of *P. glauca* (Simpfendorfer *et al.* 2002; Baum *et al.* 2003). Furthermore, this species was not recorded at landings in Oman in over four years of regular surveys (Henderson *et al.* 2007; Henderson & Reeve 2011). Reports from Oman have indicated that many fish stocks from the coastal fisheries have been overexploited due to the inadequate management of fish resources (ESCWA 2007) and therefore, although no data were available on the abundance of *P. glauca* there, the low numbers reported here could indicate that stocks of this species may have been reduced.

Based on global IUCN Red List assessments, over half of the species recorded here were found to be at global risk of extinction and it is highly probable that a number of other species threatened on a global scale would also be recorded if further studies were undertaken. Of the species recorded from Oman, the majority represented pelagic and/or highly migratory species, such as the three species of hammerheads, *Sphyrna* sp., the two species of threshers, *Alopias* sp., the oceanic white tip, *C. longimanus*, and the mako shark, *I. oxyrinchus*, that usually inhabit deeper waters (Compagno *et al.* 2005). However, Henderson *et al.* (2008) reported that most Omani fishing activity was undertaken in waters less than 100 m in depth. Therefore, the fact that many pelagic species recorded here frequently move to shallow waters over continental and insular shelves to forage, breed, or partake in social behaviors (Compagno *et al.* 2005; Dulvy *et al.* 2008) could explain their occurrence in the trade. For instance, although *S. lewini* individuals were traded throughout the year, females outnumbered males during the sampling period and with a peak in pregnant females in July and August. Sexual segregation in this species is well documented (Klimley 1987; Sims 2005) and this could indicate that fishermen are targeting areas where females aggregate for breeding. Furthermore, based on data from catches in the Kwazulu-Natal shark nets, *I. oxyrinchus* has been reported to move inshore from deeper waters in South Africa (Cliff *et al.* 1990), which could indicate that they are captured in Oman during their inshore migrations. Indeed, one of the most common threats for these migratory species is that breeding or migrating aggregations are specifically targeted by fisheries increasing their susceptibility to fishing pressure (IUCN 2007).

Due to the limited state of knowledge on many of these migratory species, it is difficult to determine the global status of their stocks. However, it is assumed that due to their low productivity, they have a limited capacity to withstand high mortalities and intense exploitation from fisheries (Cortes 1998; Stevens *et al.* 2000a; Dulvy *et al.* 2008). Furthermore, regional variations in the intensity of fishing mortality on each of these species affects the ability to determine their global threatened status. IUCN Red List Assessments are determined based on the quality and quantity of data available regarding each species from different regions (Dulvy *et al.* 2008). These data are limited from this region and all assessments for species that are listed as VU or NT such as *C. longimanus*, *A. superciliosus*, and *C. falciformis* are based on data from other parts of the world. Since none of the species found in the trade have been assessed regionally, it is critical to monitor them, collect regional data on their exploitation rates, and determine priorities for conservation. For instance, fishermen in the UAE stated that *I. oxyrinchus* had disappeared from Gulf waters (refer to **Chapter III**) and this species was not found during any of the landing site surveys across the country (refer to **Chapter IV**). However, this species was a substantial component of the trade from Oman and it is clear that exploitation rates need to be assessed regionally. In fact, little information is available regarding the biology and fishery for this species around the world but it is reported to have low productivity (Campana *et al.* 2005). Baum *et al.* (2003) reported that the mako shark population in the North

Atlantic had declined by 40% from 1986 to 2000. Also, in Canada, the median size of this species in the commercial catch was found to have declined since 1998 suggesting a loss of larger sharks due to growth overfishing. In this study, 67% of males captured were immature while the mean size of females was 1865.4 mm L_T. Although there could be differences in the sizes at maturity for females across different ocean basins, the reported range for maturity is between 2750 and 2900 mm L_T (Compagno *et al.* 2005), which is substantially larger than the majority of female specimens reported here suggesting that many of the females traded were also immature. Other species that were present at the study site in large quantities included the hammerheads. These three species are targets or bycatch species in a wide variety of fisheries throughout their range and are listed as 'Endangered' on the IUCN Red List because substantial population declines are suspected to have occurred in many areas as a result of fishing (Baum *et al.* 2003; Dudley & Simpfendorfer 2006; Myers 2007; Ferretti *et al.* 2008). Shark fin traders have indicated that these species obtain a premium in the trade due to their fin characteristics, and therefore pressure on them is likely to continue without some conservation intervention (Abercrombie *et al.* 2005). Indeed, Lack and Sant (2009) showed an 80% increase in global reported catch of hammerheads between 2000 and 2007. Therefore, identifying which species are most susceptible and most impacted by exploitation is a critical step to determine priorities for research and management (Shark Advisory Group & Lack 2004). In order to manage these species, it has been suggested that sharks should be ranked according to their life history traits and their ability to sustain high mortality levels especially in countries exporting large quantities of shark products (Barker & Schluessel 2005).

Because these species can cover vast distances, with some crossing entire ocean basins in their seasonal migration, it is crucial they are managed through regional cooperation in order to be able to implement effective management plans. However, even if the UAE were to regulate trade in these species, and if Oman were to ban the fishing of some species, these measures may have a limited impact on protected populations. This is particularly true since some of the largest shark fishing countries in the world fish in the Arabian Sea. Lack and Sant (2009) reported that from 1980 to 2007, India, Iran (only from 2000 to 2007), Pakistan and Sri Lanka were amongst the top shark catching countries in the world, landing from 2000 to 2010 a yearly average of 75,222 mt, 13,000 mt, 30,351 mt and 18,476 mt respectively (Fischer *et al.* 2012). What is perhaps more worrying for shark populations in the region was that between 2003 and 2005, all these fishing nations reported declining trends in catches of sharks and fish. For instance, in Iran, approximately 48% of the total fish landed comes from waters outside the Gulf in the Oman Sea and a downward trend in catches was noted, even though there has been an increase in fishing effort (FAO 2009a). This declining trend in landings has been attributed to environmental changes and pressures from overfishing (Esmaeili 2006; Valinassab *et al.* 2006; Esmaeili 2009). In Sri Lanka, sharks are ranked second after tuna in terms of the quantities of fish landed (Joseph 1999). India was reported to be the world's highest chondrichthyan fishery in 1997, with 16.6% of the world catches (Vannuccini 1999), but reports show that both catches and the sizes of captured sharks have declined (Hanfee 1997; Fischer *et al.* 2012). The fishery in Pakistan collapsed in 1983 (Bonfil 1994) but steadily increased again during the 1990s and the country ranked as the third top fishing country for sharks in 1997 (Vannuccini 1999). However, during the last decade, shark catches have dropped from about 50,000 mt to 10,000 mt (Fischer *et al.* 2012). Similarly, in Sri Lanka catches dropped significantly in 2004 from over 30,000 mt to less than 10,000 mt (Fischer *et al.* 2012). All these declining trends point to overfishing and overexploitation of shark resources. Furthermore, by 2012, none of these countries had developed an NPOA for sharks (Fischer *et al.* 2012). While these countries have some national fisheries legislations in place, sharks do not seem to feature as a priority. All the above countries, as well as Oman, are signatories to the Indian Ocean Tuna Commission (IOTC) which prohibits shark finning and the landing of all species of thresher sharks (*Alopias* sp.). Yet, finning has not been banned in India and data indicate that thresher sharks were one of the dominant species in national shark catches representing 23.9% of the total landings (Fischer *et al.* 2012). It remains unclear which measures have been nationally adopted in Pakistan, Iran and Sri Lanka. While Iran reports that the capture of thresher sharks is banned, there is no ban on shark finning. Sri Lanka has a finning ban and yet there is a limited capacity to enforce regulations and species-specific identifications remain a challenge (Fischer *et al.* 2012). No shark finning ban has been declared in Pakistan and reports indicate there is limited management of fisheries as well as a lack of capacity to undertake research and enforce legislations (Fischer *et al.* 2012). Finally, while Oman has a ban on finning in place, it is clear from this study that it does not enforce the ban on thresher shark catches. Furthermore, the transport of fresh fins with no corresponding carcasses suggests that finning may still be taking place, although in limited quantities.

To conclude, results from this trade survey have provided much needed information regarding products and species traded from the UAE and Oman as well as highlighted gaps in our knowledge. It is clear that further research is needed in order to better understand trade dynamics but the information here can be used as a first step to developing new management tools for the conservation of many species. Many conservation groups in the UAE have been campaigning for a complete ban on the trade of shark products. However, while traders in this study confirmed they were concerned about the potential impact of management measures on their business, many suggested they would just take their business elsewhere (i.e. Yemen) if bans were instated. Indeed, Yemen has been reported as one of the top countries for shark catches (Lack & Sant 2009) and a major exporter of shark fins to Hong Kong (Fowler *et al.* 2005). Similarly, traders in Hong Kong mentioned they would change their supply routes if regulations were put in place (Clarke 2002). Also, in China, informants stated they would not stop the trade in shark products if a ban were to be placed and would likely continue trading by developing a black market (Li *et al.* 2012). Therefore, bans on the trade in shark products are not likely to halt the current pressure faced by many species, especially since as Clarke *et al.* (2007) suggest, the demand for shark fins is not likely to relent in the near future. Instead, effective management needs to focus on sustainability (Worm *et al.* 2013), as well as collecting accurate fisheries and trade data in order to have good estimates of exploitation levels (Clarke *et al.* 2006b) to make sound recommendations on fishing limits (Hareide *et al.* 2007; FAO 2009a). The fact that boundaries of many shark populations are difficult to define and span across the jurisdictions of many countries highlights the need for actions to be taken, not only on a national basis but also at regional and international levels. These measures need to include the implementation and enforcement of finning bans as well as science-based and precautionary catch limits (Dulvy *et al.* 2008) with stringent controls on exploitation rates (Worm *et al.* 2013). Furthermore, because many species of sharks aggregate by age, sex and reproductive state, fishing can deplete large segments of specific age classes, and therefore fishing measures to regulate targeting of these aggregations may need to be implemented by designating critical habitats (i.e. nursery, pupping and mating grounds) protected from exploitation (Barker & Schluessel 2005; Worm *et al.* 2013).

CHAPTER VII

THE DIET OF TWO COMMERCIALLY IMPORTANT SHARK SPECIES, THE MILK SHARK (*Rhizoprionodon acutus*) AND SLIT-EYE SHARK (*Loxodon macrorhinus*)

7.1 Introduction

As apex predators, sharks are important components of the marine fauna and their life history can influence the ecology and structure of regional communities (Cortes 1999; Gelsleichter *et al.* 1999; Stevens *et al.* 2000a). To gain a better understanding of the trophic relationships occurring in these environments, information on the dietary composition of sharks is essential (Cortes 1999). Knowledge of food habits and feeding behavior allows us to determine the effect sharks have on other organisms through predation and competition. Specifically, this information can be used in the management of shark fisheries, by determining the energy needs of sharks and how changing biological and physical conditions in the marine environment, from both natural processes as well as anthropogenic influences, can affect them (Cortes 1997; Wetherbee & Cortes 2004). Furthermore, it provides scientists and resource managers with information on how changes in shark abundance may affect populations of their prey and their competitors (Bethea *et al.* 2004), or even the role of sharks in the predation of commercially important species (Cortes 1999). Finally, understanding the links between predator and prey contributes to a better assessment of the role and function of the components of marine ecosystems and the structure of marine food webs (Ellis 2003; Bethea *et al.* 2004; Braccini 2008). Despite this, our knowledge of prey consumption dynamics and food processing in most shark species remains limited (Wetherbee & Cortes 2004).

Information on the prey of individual predators is usually provided through an analysis of stomach contents (Hyslop 1980; Smale & Cliff 1998). Studies investigating the diets of various shark species have indicated that although they may forage on a relatively similar wide range of prey, the proportions of prey items can vary significantly both within conspecifics and interspecifics. Ontogenetic dietary shifts, as well as sexual differences (Klimley 1987; Simpfendorfer *et al.* 2001b), have been reported from many species who may segregate at different life stages (Simpfendorfer *et al.* 2001b; Wetherbee & Cortes 2004; White *et al.* 2004; McElroy *et al.* 2006; Saidi *et al.* 2009). Indeed, ontogenetic diet shifts are a widespread phenomenon among many species of animals and are generally attributed to increased chances of encountering a diversity of prey as well as to changes in body size among individuals which affects food acquisition (Lowe *et al.* 1996; Lucifora *et al.* 2009). Furthermore, it is assumed that changes in dietary composition that accompany growth reflect an increased ability of sharks to consume larger preys such as teleosts and cephalopods (Lowe *et al.* 1996). Geographical differences in the diet of sharks have also been documented (Joyce *et al.* 2002; Bethea *et al.* 2007; Ellis & Musick 2007; Saidi *et al.* 2009), which are likely due to prey availability and opportunism. Also, it has been recognized that elasmobranchs may partition their environment, or the resources within, in order to reduce the intensity of interspecific or intraspecific competition, facilitating their ability to coexist (Wetherbee & Cortes 2004; White *et al.* 2004). For instance, the sandbar shark, *Carcharhinus plumbeus*, varies its diet seasonally increasing its consumption of crustaceans between fall and winter (McElroy *et al.* 2006). These differences were attributed to changes in prey availability or seasonal movements of prey or predator. Because many factors can affect feeding habits, it is crucial to collect data locally to gain a better understanding of the dynamics between sharks and other components of the marine ecosystem.

Catch data from landing sites in the UAE show that two of the main species targeted by the commercial fishery are the milk-shark, *Rhizoprionodon acutus*, and the slit-eye shark, *Loxodon macrorhinus* (**Refer to Chapter IV**). While these species are among the most abundant sharks, there are concerns that fishing is over-exploiting their stocks and it is therefore crucial to collect data on their life-history, population status and diet. Although both *R. acutus* and *L. macrorhinus* are believed to be highly resilient to fishing pressures, given their K-selected life history traits, intensive exploitation can affect their populations. Understanding the feeding patterns of these species is therefore necessary in order to assess their influence on Gulf marine ecosystems. This is especially true since both species are considered tertiary consumers with trophic levels between 4.1 and 4.2 for *R. acutus* (Cortes 1999; Ba *et al.* 2013) and of 3.9 for *L. macrorhinus* (Cortes 1999) suggesting that overfishing may lead to significant changes in the habitats they occupy and within the communities they feed on (Stevens *et al.* 2000a). Although both these species have a wide distribution around the world, there is a paucity of information on their feeding habits and diet preferences from both this region and globally.

The milk shark is the most widely distributed species of the *Rhizoprionodon* genus, and can be found from the eastern Atlantic, the Indo-west Pacific and the

Mediterranean (Compagno *et al.* 2005). It is considered a coastal species frequently found off sandy beaches but can occur in depths up to 200 m. This species is also typically found in areas containing seagrass meadows (White *et al.* 2004). Furthermore, similarly to what was found in this study, *R. acutus* is one of the most commonly landed coastal shark in many fisheries across the world (Devadoss *et al.* 1989; Capape *et al.* 2006; Henderson *et al.* 2007; White 2007; FAO 2009a; Moore *et al.* 2012a). Some research has suggested that it usually feeds on small teleost fish, crustaceans and cephalopods (Bass *et al.* 1975). Appukuttan and Nair (1988) reported that on the southeast coast of India, the diet of this species consisted of a variety of fish among which silverbellies (Gerreidae) dominated. Cephalopods and crustaceans were also found in the stomachs, however, no species specific information or quantities were provided on prey items. Data from Cochin, India, showed that *R. acutus* food items included whitebaits (40%), juvenile threadfin breams (21%) (Nemipteridae), Carangidae such as *Decapterus russelli* (20%), crustaceans including *Parapenaeopsis stylifera* (5%), cephalopods such as *Sepiella* spp. (6%) and squids (8%). Stevens and McLoughlin (1991) found that fish occurred in 93.3% of *R. acutus* stomachs in the Timor and Arafura Sea off northern Australia. Furthermore, crustaceans were found in 10.4% of stomachs while 18.9% consisted of cephalopods. Simpfendorfer and Milward (1993) reported that the five most common groups in the diet of *R. acutus* in Cleveland Bay, Australia were unidentified fish (80%), Clupeidae (20%), Leiognathidae (12%), Engraulidae (8%) and Penaidae (8%). White *et al.* (2004) also reported the occurrence of teleosts, crustaceans and cephalopods in the diet of this species. Finally, Ba *et al.* (2013) documented similar prey items and suggested sexual, ontogenetic and geographical differences in feeding habits.

The slit-eye shark is also considered a wide ranging species that can be found throughout the Indo-west Pacific and generally inhabiting inshore areas with clear waters in depths up to 80 m (Compagno *et al.* 2005). Furthermore, *L. macrorhinus* has been reported as a relatively important catch in some fisheries around the world (Stevens & McLoughlin 1991; Anderson & Ahmed 1993; Henderson *et al.* 2007; White 2007). However, limited research has been conducted on the biology of this species (Gutteridge *et al.* 2013) and only a few studies have provided information on its diet. Appukuttan and Nair (1988) reported that on the east and west coasts of India, the diet of this species consisted mainly of small bony fishes, cephalopods and crustaceans for specimens ranging in sizes between 441 and 880 mm L_T. However, no species specific information or quantities were provided regarding prey items. Stevens and McLoughlin (1991) undertook the only quantitative study and found that fish occurred in 76.3% of *L. macrorhinus* stomachs in northern Australia. Furthermore, crustaceans were found in 60.4% of stomachs while 18.8% of prey items consisted of cephalopods. In Hervey Bay, eastern Australia, teleost fish dominated the diet of this species with an index of relative importance (IRI) of 79.5% followed by crustaceans (15.6%) and cephalopods (5%) (Gutteridge *et al.* 2013).

Due to the lack of data on the diet of these species from Gulf waters and their prevalence in commercial landings in the UAE, it was deemed important to gain a better understanding of their role in the local marine ecosystem. The objectives of this study were therefore to 1) describe the dietary composition of *R. acutus* and *L.*

macrorhinus from UAE Gulf waters, 2) compare the information collected here with results from diet studies of these species from other regions of the world.

7.2 Methods

Specimens were collected between January and May 2012 from landing sites in Abu Dhabi, Dubai and Ras Al Khaimah. Sharks were stored on ice and transported back to the laboratory at the UAEU for immediate processing. Data were collected on sex, maturity levels for both sexes, and total length (L_T) was measured to the nearest 1.0 mm. Maturity for males was assessed as described in **Chapter II**. Female maturity was assessed by examining the state of the ovary, the uterus and the oviducal glands (Henderson *et al.* 2008). Immature females had filiform uteri with small to slightly enlarged ovaries and non-differentiated or small sizes oocytes. Mature females were either gravid or had a developed ovary, enlarged oviducal glands and developed uteri. All sharks were checked for hook marks to record the capture method and therefore determine if any of the stomach contents were bait items.

Stomachs were excised and emptied onto a 1 mm mesh sized sieve which was fine enough to retain eye lenses and otoliths. Contents were washed lightly to remove unidentifiable slimy residue and facilitate identification. Each item was then separated, counted, and identified to the lowest possible taxon by use of keys and field guides specific to the region (Randall 1995; Carpenter *et al.* 1997). Specimens of each prey type were measured (L_T in mm) and when digested or partial teleost prey could not be measured directly, body depth was measured before items were blotted dry and weighed individually on a digital balance to the nearest 0.001 g. After weighing, the contents of each stomach were placed in a labeled jar containing 70% ethanol and archived.

Identification of specimens was only possible when prey items were not fully digested. Otoliths and cephalopod beaks found in stomachs were not identifiable due to a lack of reference collections in the UAE. However, the number of fish in each stomach was estimated based on the number of otoliths pairs found. Furthermore, the number of cephalopods was estimated based on the quantities of upper and lower beaks found. If identification failed, the prey item was included in the category 'unidentified' for that type of prey (i.e. shrimp, teleost). Prey items were grouped into the following five categories to facilitate diet comparisons and eliminate biases associated with comparisons based on variable levels of prey identification (Cortes 1997): teleost fish; cephalopods (squids and octopuses); crustaceans (decapod crustaceans including shrimps, crabs and lobsters); invertebrates (other invertebrates except for cephalopods and crustaceans); and 'other' (any other prey items such as plants or coral).

Only stomachs containing prey items were utilized for calculations and analyses. To allow for comparison with other dietary studies, the diet of each species was quantified using three indices including percent by frequency of occurrence (%F), calculated as the number of stomachs containing a prey type divided by the total number of stomachs containing food; percent by number (%N), calculated as the number of individuals in each prey type divided by the total number of prey items in the stomachs; and percent by weight (%W), calculated as the total weight of each prey type divided by the total weight of prey items in the stomachs (Hyslop 1980). Finally, a fourth index, the Index of Relative Importance (IRI), used to determine the importance of each prey, was calculated as:

$$IRI = \% F * (\%N + \%W)$$

The IRI values for each prey type were then converted to a percentage (%IRI) to facilitate comparisons between prey items (Cortes 1997) and was also computed for the five major prey categories. Generally, it is recommended that a cumulative prey curve is constructed for each species in order to determine if an adequate number of stomachs have been collected to accurately describe diets (Cortes 1997). One was not constructed in this study as it became clear early on that the advanced digestion state of many prey items would not allow an accurate determination of prey items found in stomachs. Finally, data from other studies investigating the diet of these species were examined for comparisons with results from this study.

7.3 Results

Rhizoprionodon acutus

Stomachs from 57 *R. acutus* specimens ranging from 509 to 875 mm L_T, and comprising of 30 females and 27 males were examined (**Figure 7.1.**). The majority of females were mature (73.3%, n=22) comprising of eight pregnant specimens (603-875 mm L_T) while eight individuals were immature (509-667 mm L_T). Males with non-calcified claspers comprised 29.6% of all individuals (517-610 mm L_T) while 25.9% had partially calcified claspers (574-683 mm L_T) and 44.4% possessed fully calcified claspers (613-714 mm L_T).

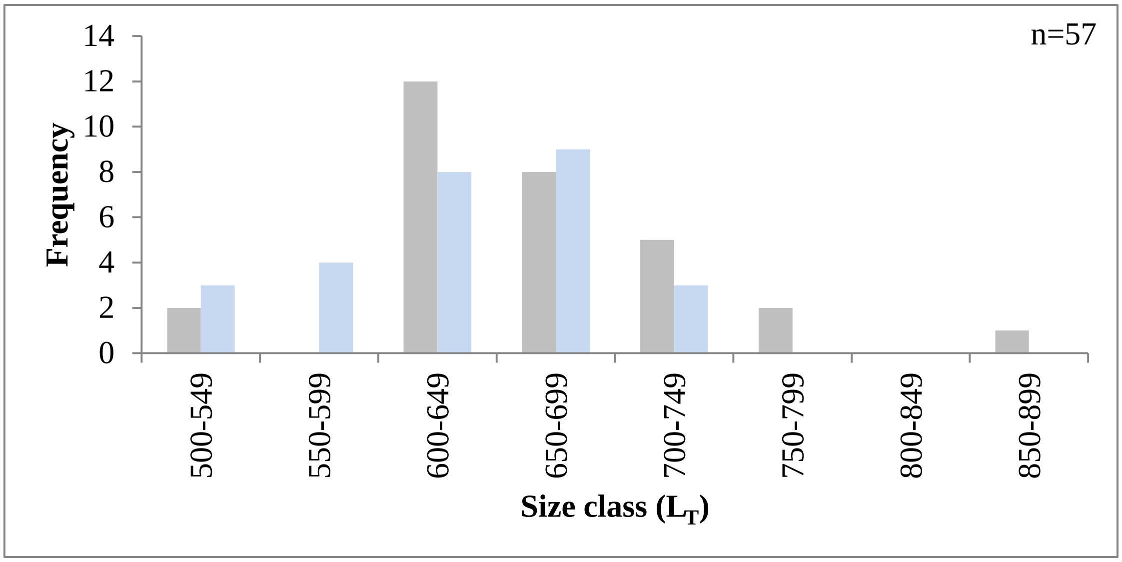

Figure 7.1. Size distribution of female (■) and male (■) *R. acutus* sampled for stomach content analysis.

None of the sharks dissected had hook marks and were probably captured in nets. The majority of stomachs contained prey items (66.6%, n=38) with the highest percentage of empty stomachs represented by mature females (68.4%). Average stomach weight for all stomachs was 35.05 g and 42.49 g for stomachs containing food.

Identifiable prey items were from seven families of teleost fish, one family of cephalopods, and nine species (**Table 7.1.**). The most commonly occurring families were the Engraulidae (anchovies), Gerreidae (mojarras) and Carangidae (jacks). Although the Engraulidae were the most numerous (28%), the Gerreidae occurred more frequently (18.4%) and were the most important in terms of weight (36.3%). The Lutjanidae (snappers) were low in terms of numbers (0.8%) and occurrence (2.6%) but important in terms of weight (17.8%). Prey items of little importance included cephalopods (0.5%), crustaceans (0.1%), and invertebrates (0.01%).

Table 7.1 Diet composition of *R. acutus* (n=38) and *L. macrorhinus* (n=48) from UAE waters expressed by percent frequency (%F), percent number (N%), percent weight (%W), Index of Relative Importance (IRI), and IRI expressed on a percent basis (%IRI). Unid.: Unidentifiable. No entries indicate prey not present in diet; *indicates that IRI and %IRI are expressed at the family instead of the prey level.

Dietary categories	*Rhizoprionodon acutus*					*Loxodon macrorhinus*				
Prey items	%F	%N	%W	IRI	%IRI	%F	%N	%W	IRI	%IRI
Teleosts	**86.8**	**68.8**	**99.41**	**14607**	**99.3**	**89.58**	**75.78**	**38.24**	**10213**	**84.06**
Carangidae	5.26	1.6	4.61	3266.4	72.86	-	-	-	-	-
Alepes djedaba	*2.63*	*0.8*	*3.93*	*12.4*	*0.19*	-	-	-	-	-
Selaroides leptolepis	*2.63*	*0.8*	*0.68*	*3.89*	*0.05*	-	-	-	-	-
Clupeidae	5.26	1.6	6.12	40.6	0.90	-	-	-	-	-
Sardinella longiceps	*5.26*	*1.6*	*6.12*	*40.6*	*0.62*	-	-	-	-	-
Engraulidae	10.5	28	3.73	334.1*	7.45*	41.67	35.16	16.75	2163*	69.58*
Gerreidae	18.4	5.6	36.35	772.7	17.23	-	-	-	-	-
Gerres longirostris	*13.1*	*4*	*31.02*	*460.8*	*7.07*	-	-	-	-	-
Gerres filamentosus	*2.63*	*0.8*	*2.74*	*9.31*	*0.14*	-	-	-	-	-
Gerres sp.	*2.63*	*0.8*	*2.59*	*8.91*	*0.13*	-	-	-	-	-
Lethrinidae	2.63	0.8	4.06	12.78	0.28	-	-	-	-	-
Lethrinus nebulosus	*2.63*	*0.8*	*4.06*	*12.78*	*0.19*	-	-	-	-	-
Lutjanidae	2.63	0.8	17.8	48.9	1.09	-	-	-	-	-
Lutjanus lutjanus	*2.63*	*0.8*	*17.8*	*48.9*	*0.75*	-	-	-	-	-
Mugilidae	2.63	0.8	1.13	5.07	0.11	-	-	-	-	-
Liza sp.	*2.63*	*0.8*	*1.13*	*5.07*	*0.07*	-	-	-	-	-
Fish unid.	71.0	52	25.62	5514.9	84.62	81.25	40.63	21.49	5047.2	59.27
Crustaceans	**7.89**	**2.4**	**0.02**	**19.09**	**0.12**	**37.5**	**15.63**	**11.07**	**1001.2**	**8.24**
Penaeidae	-	-	-	-	-	35.42	14.4	10.06	863.5	27.78
Parapenaeopsis stylifera	-	-	-	-	-	*2.08*	*0.26*	*1.1*	*2.82*	*0.03*
Penaeus sp.	-	-	-	-	-	*2.08*	*0.78*	*0.52*	*2.7*	*0.03*
Shrimp unid.	7.89	2.4	0.02	19.09	0.29	31.25	13.54	8.43	686.5	8.06
Portunidae	-	-	-	-	-	2.08	0.26	0.63	1.85	0.05
Portunus pelagicus	-	-	-	-	-	*2.08*	*0.26*	*0.63*	*1.85*	*0.02*
Ocypodidae	-	-	-	-	-	2.08	0.26	0.22	0.99*	0.03*
Palinuridae	-	-	-	-	-	4.17	0.52	0.17	2.919	0.09
Panulirus versicolor	-	-	-	-	-	4.17	0.52	0.17	2.919	0.03
Cephalopods	**13.1**	**5.6**	**0.51**	**80.4**	**0.54**	**22.92**	**7.03**	**27.02**	**780.4**	**6.42**
Sepiidae	2.63	0.8	0.02	2.15*	0.04*	4.17	0.78	3.31	17*	0.54*
Loliginidae	-	-	-	-	-	2.08	0.26	4.42	9.73	0.31
Loligo duvauceli	-	-	-	-	-	*2.08*	*0.26*	*4.42*	*9.73*	*0.11*
Beak with flesh unid.	7.89	4.8	0.48	41.6	0.63	20.83	5.99	19.29	526.5	6.18
Invertebrate	**2.63**	**0.8**	**0.06**	**2.26**	**0.01**	**4.17**	**0.52**	**0.03**	**0.12**	**<0.01**
Gastropod unid.	2.63	0.8	0.06	2.26	0.03	4.17	0.52	0.03	2.25	0.02
Other	**-**	**-**	**-**	**-**	**-**	**6.25**	**1.04**	**23.64**	**154.2**	**1.26**
Phascolosomatidae	-	-	-	-	-	2.08	0.26	23.12	48.6*	1.56*
Parasite unid.	-	-	-	-	-	2.08	0.26	0.04	0.62	<0.01
Faviidae	-	-	-	-	-	2.08	0.26	0.06	0.66*	0.02*
Rock	-	-	-	-	-	2.08	0.26	0.41	0.85	0.01

Among identified teleosts, *Gerres longirostris* and *Lutjanus lutjanus* contributed most to the weight primarily because of the sizes of the fish found in the stomachs measuring from 101 to 151 mm L_T and 241 mm L_T for each species respectively. Unidentified teleosts comprised the bulk of the observed prey items in terms of frequency of occurrence (71%) and relative importance (84.6%).

Of the identified species, teleosts were either representative of pelagic or demersal species while all other categories were representative of benthic organisms. Pelagic fish included the Clupeidae, Engraulidae and Carangidae (which can also be demersal but no identification was possible at the species level) while families of demersal fish included the Gerreidae, Lethrinidae, Lutjanidae and Mugilidae.

Results of the dietary composition for *R. acutus* from other studies are provided in **Table 7.2**.

Loxodon macrorhinus

Stomachs from 53 *L. macrorhinus* individuals measuring between 517 to 714 mm L_T were examined. The sample comprised of 37 females and 16 males (**Figure 7.2.**). Females ranging in sizes between 560 and 751 mm L_T were mature (78.3%) with 14 pregnant individuals, while those between 582 and 882 mm L_T were immature (21.6%). Males with non-calcified claspers comprised 18.7% of all individuals (560-640 mm L_T) while 43.7% had partially calcified claspers (633-711 mm L_T) and 37.5% possessed fully calcified claspers (690-834 mm L_T). Thirteen of the sharks dissected had hook marks along their mouths and jaws. However, upon examination of the stomach contents, which included small pieces of shrimps and cephalopod beaks, none of the prey items found were considered to be bait. The majority of stomachs contained prey items (90.5%, n=48) with the highest percentage of empty stomachs represented by mature females (80%). Average stomach weight for all stomachs was 21.35 g and 22.14 g for stomachs containing prey items.

Table 7.2. Diet of the milk shark, *R. acutus*, from other studies as categories of different prey items including teleosts, cephalopods, crustaceans, mollusks and invertebrates. Where available, information is provided on percentage contribution of each category to the overall frequency (%F), number (%N), dry weight (%) and index of relative importance (%IRI). Data are provided on the size range of samples (mm L_T), the total number of samples (n) and the number of stomach with prey items.

Prey categories	Northern Australia[1]	Eastern Australia[2]	North-eastern Australia[3]	North-eastern Australia[4]		Senegal[5]	Central west Australia[6]	
	%F	%F	% dry weight	% dry weight*	% dry weight**	%IRI	%F	%N
Teleosts	93.3	100	79.1	90.7	59.3	98.75%	63.3	69
Cephalopods	18.9		7.5	0.05	17.6	0.5	10.7	10.3
Crustaceans	10.4	8	13.3	8.6	19.9	0.63	-	-
Mollusks	1.2	-	-	-			21.4	20.7
Invertebrates	-	-	-	-		0.03	17.9	-
Other	0.6	-	0.1	0.6	3.1	0.08	-	-
Size range (mm L_T)	350-980	About 360 to 750	300-880	380-720	330-750	440-1130	<590 to 890	
Number of stomachs with food	164	50	106	130	64	577	28	
Total n	**315**	**146**	**142**	**-**	**77**	**3600**	**59**	

[1] (Stevens & McLoughlin 1991); [2] (Simpfendorfer & Milward 1993); [3] (Salini *et al.* 1990); [4] (Salini *et al.* 1992) * indicates estuary specimens, ** indicates nearshore specimens; [5] (Ba *et al.* 2013); [6] (White & Potter 2004).

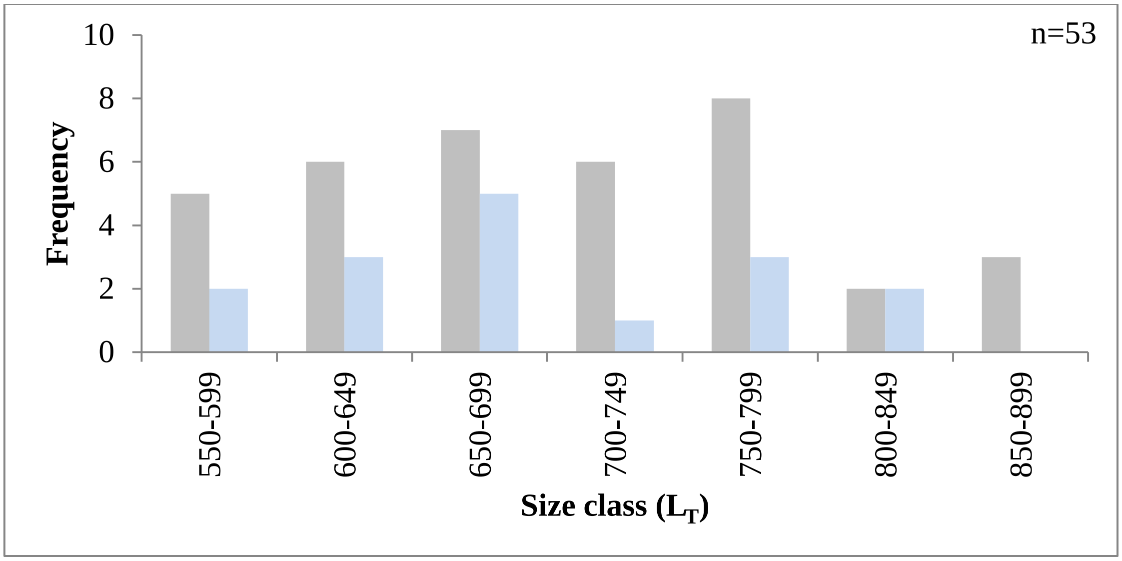

Figure 7.2 Size distribution of female (■) and male (■) *L. macrorhinus* sampled for stomach content analysis.

A total of seven different families (one teleost, four crustacean, two cephalopod) and four species could be positively identified. When grouping food items into one of the five categories, teleosts were the main prey observed in stomachs, followed by crustaceans and cephalopods. The most frequently occurring families were Engraulidae (41.6%) and Penaeidae (35.4%) and were also the most important prey items at 69.5% and 27.8% respectively. However, both engraulids and penaieds were much less important in terms of weight at 16.7% and 10.1% respectively. Other important prey items included cephalopods (6.4%) with unidentifiable beaks frequently occurring (20.8%). Unidentified teleosts comprised the bulk of the observed prey items in terms of frequency (81.2%) and weight (40.6%). Prey items of little importance were mainly invertebrates (<0.01) and all other prey items (1.2%). The 'other' category had a higher index of importance mainly because of the weight (31.1 g) and size (197 mm L_T) of the Phascolosomatidae identified but this item was only found in one stomach. Of the identified species, the only teleost family identified was pelagic while all other categories were representative of benthic organisms.

Results of the dietary composition for *L. macrorhinus* from other studies are provided in **Table 7.3**.

Table 7.3. Diet of the slit-eye shark, *L. macrorhinus,* from other studies as categories of different prey items including teleosts, cephalopods, crustaceans, mollusks and invertebrates. Where available, information is provided on percentage contribution of each category to the overall frequency (%F), number (%N), weight (%W) and index of relative importance (%IRI). Data are provided on the size range of samples (mm L_T), the total number of samples (n) and the number of stomach with prey items.

Prey categories	Northern Australia[1]	Eastern Australia[2]			
	%F	%F	%N	%W	%IRI
Teleosts	76.3	62.2	48.7	65.8	79.5
Cephalopods	18.8	17.8	11.5	13.6	5
Crustaceans	60.4	61.1	39.1	20	15.6
Mollusks	1	-	-	-	-
Invertebrates	1.4	1.1	0.7	0.6	<0.1
Size range (mm L_T)	400-880	571-878			
Number of stomachs with food	207	90			
Total n	**258**	**139**			

[1] (Stevens & McLoughlin 1991); [2] (Gutteridge *et al.* 2013).

7.4 Discussion

This study represents the first attempt to characterize and quantify the diet of two commercially important shark species, *R. acutus* and *L. macrorhinus,* in the Gulf. While the diets of both species were dominated by small teleosts, results clearly indicated that *R. acutus* fed on an abundance of fish species but limited numbers of crustaceans and cephalopods. On the other hand, *L. macrorhinus* seemed to have a preference for one species in terms of teleosts and fed on a wider variety of crustaceans and cephalopods. While the sample size in this study is limited and therefore data should be interpreted with caution, it appears there is little overlap in the diets of these two species. This suggests that these species may either be using different habitats or are selective in their prey items.

The published literature on the diet of *L. macrorhinus* was limited but available reports suggested that this species consumed mainly teleosts although crustaceans (including shrimps and crabs) and cephalopods frequently occurred in its diet (Appukuttan & Nair 1988; Stevens & McLoughlin 1991; Gutteridge *et al.* 2013). Gutteridge *et al.* (2013) noted that this species mainly fed on pelagic fish species and opportunistically consumed large quantities of demersal species. On the other hand, Stevens and McLoughlin (1991) reported that *L. macrorhinus* fed primarily on demersal teleost species in Northern Australia. In this study, the slit-eye shark fed largely on Engraulidae, a pelagic species. The fact that this family of fish comprised the most important proportion across the five indices calculated for all categories of identified prey items, and was more important in the diet than unidentified teleosts, could indicate that *L. macrorhinus* is selective in its feeding habits. Other shark species have been shown to be highly selective in their feeding behavior. For instance, the whiskery shark, *Furgaleus macki*, was found to be highly selective and showed a preference for octopuses inhabiting rocky reef areas (Simpfendorfer *et al.* 2001a). Further investigations are warranted regarding the feeding preferences of *L. macrorhinus* since the degree of feeding specialization can have important implications on a species if changes in abundance in its preferred prey were to occur (Simpfendorfer *et al.* 2001a). Furthermore, this species has been reported to have an affinity for clear waters (Gutteridge *et al.* 2013) making it further susceptible to any anthropogenic activities such as coastal development in the form of dredging and reclamation projects as well as desalination plants.

A larger number of studies have focused on the dietary preferences of *R. acutus* and have confirmed that this species feeds mainly on teleosts. Ba *et al.* (2013) reported this species as a specialized teleost feeder in Senegal mainly consuming pelagic species. However, some demersal teleosts were also documented in their study and it was suggested that this could be due to vertical movements allowing this species to interact with a wider range of fauna. Similarly, Salini *et al.* (1990) categorized *R. acutus* as a pelagic feeder off North-eastern Australia since it consumed a majority of pelagic teleosts. On the other hand, Stevens and McLoughlin (1991) reported that it fed on mainly demersal species in Northern Australia. Data from this study showed that *R. acutus* fed on both demersal (i.e. Gerreidae, Lethrinidae, Lutjanidae and Mugilidae) and pelagic species (Clupeidae, Engraulidae and Carangidae). It has been noted that *R. acutus* can have different feeding behaviors depending on the catch location of specimens (Salini *et al.* 1992). Individuals captured nearshore had 19.9% of their stomach comprising of crustaceans compared to those captured in estuaries (8.6%) and offshore (13.3%). Similarly, another small bodied shark, the white cheek shark, *Carcharhinus dussumieri*, was found to feed exclusively on crustaceans in nearshore waters (100%) but significantly less in offshore (38.5%) and estuary (33.8%) waters where its diet included teleost fishes at 52.5% and 64.8% of dry weight respectively. Although no information on species abundance between capture locations was available from Senegal, variations in the diet of the milk shark were also reported (Ba *et al.* 2013). Geographic differences in diets have been documented for many species of sharks including the sandbar shark, *C. plumbeus* (Ellis 2003), the tiger shark, *Galeocerdo cuvier* (Simpfendorfer *et al.* 2001b), and the bonnethead shark, *Sphyrna tiburo* (Bethea *et al.* 2007). This could explain some of the differences found in feeding preferences and type of species (demersal, pelagic, or both) consumed by both *R. acutus* and *L. macrorhinus* in this study and other localities around the world. In this study, it was not possible to determine the origin of sharks but they were presumably captured in both nearshore or offshore waters depending on the areas utilized by fishermen. Therefore, patterns of geographical or habitat differences could not be noted.

The large number of prey species that were confirmed from this study would suggest that *R. acutus* may be opportunistic in these waters. This species has been shown to prey on a variety of teleost species across its range (Salini *et al.* 1990; Stevens & McLoughlin 1991; Simpfendorfer & Milward 1993; White & Potter 2004; Ba *et al.* 2013). Many of the families and species identified in this study formed an important part of the diet of *R. acutus* in other areas. Stevens and McLoughlin (1991) reported teleosts that included clupeids (*Sardinella* sp.) and carangids (*Selaroides leptolepis*). Similarly, Simpfendorfer and Milward (1993) found clupeids and engraulids in the stomachs they examined. In Senegal, the three most important families represented were Clupeidae (especially *Sardinella* sp.), Carangidae and Mugilidae (Ba *et al.* 2013) and in western Australia clupeids and mugilids were important prey items (White & Potter 2004). The occurrence of these species in the stomachs of *R. acutus* both from this study and other studies could indicate a preference and selectivity for them. However, diversity in prey items within shark diets have previously been reported and it has been suggested that these are due to the types of habitats, species composition and prey availability within the areas frequented by the sharks (Salini *et al.* 1992; Simpfendorfer 1992; Lowe *et al.* 1996; Bethea *et al.* 2004). While quantitative data are not available on the abundance of fish species across UAE Gulf waters, data from the EAD indicate that the most abundant and commercially important species in terms of weight in Abu Dhabi waters are from the Scrombridae (mackerels), Serranidae (groupers), Carangidae and Lethrinidae families (EAD 2011b). While these are probably more a reflection of market demand in the UAE, they also provide a measure of abundance for species in these waters. The fact that most of these species were not found in the stomach contents of *R. acutus* could signify that they may be difficult to capture or too big to consume for a small-bodied shark (Simpfendorfer 1998). To get a better understanding of the prey selectivity in this body of water, further research will need to be undertaken to gather data on the abundance of teleost and other marine fauna.

While this study provides some important information on the diet of these two species, it is likely that the sample size was not adequate to provide a thorough analysis. Studies have shown that the number of samples required to reach a cumulative curve can vary greatly within and between species. Ba *et al.* (2013) reached a stable cumulative prey curve at 175 specimens for *R. acutus* in Senegal, while Bethea *et al.* (2004) reported that 201 stomachs of the Atlantic sharpnose, *Rhizoprionodon terraenovae*, and 109 stomachs of finetooth shark, *Carcharhinus isodon*, were not enough to reach an asymptote. It is therefore probable that further sampling would have provided a more accurate assessment of the importance of less frequently occurring species. Furthermore, the low proportion of identifiable prey also contributed to the difficulties in providing a thorough assessment of diets. On the other hand, the proportion of specimens with empty stomachs in this study was lower than what has previously been reported from other studies for both these species and other sharks. For *L. macrorhinus*, Gutteridge *et al.* (2013) found that 35.3% of specimens had empty stomachs while Stevens and McLoughlin (1991) indicated that 19.8% of individuals had no prey items in their stomachs. Of the 3600 specimens of *R. acutus* collected in Senegal, only 16.03% contained food (Ba *et al.* 2013). Simpfendorfer (1998) reported that 59% of stomachs from the Australian sharpnose shark, *Rhizoprionodon taylori*, were found to be empty while Joyce *et al.* (2002) stated that 51% of porbeagle stomachs, *Lamna nasus*, were empty. It has been suggested that the large number of empty stomachs that can be found in a study can be due to sampling gear that can be selective towards individuals attracted by bait (Cortes 1997; Gelsleichter *et al.* 1999; Joyce *et al.* 2002). The relatively high numbers of stomachs with prey items in this study are presumably due to the fact that most of these sharks were captured in nets since they had no hook marks. The 13 *L. macrorhinus* that had hook marks all had prey items in their stomachs. As suggested by Gelsleichter *et al.* (1999) for the smooth dogfish, *Mustelus canis*, this could indicate that *L. macrorhinus* eats frequently and/or that gastric evacuation is slow in comparison to its feeding frequency.

Finally, as was reported by Ba *et al.* (2013), *R. acutus* shows variations in its feeding habits based on sex, size and location. White and Potter (2004) as well as Simpfendorfer and Milward (1993) reported that although teleosts dominated the diets of all size classes, juveniles consumed larger quantities of crustaceans and cephalopods. It is likely that *L. macrorhinus* would also show variations in feeding habits if further research was undertaken. Therefore, while this study has provided a baseline characterization of the diets of *R. acutus* and *L. macrorhinus* from UAE Gulf waters, further data from a larger sample are required to provide an accurate assessment of feeding habits. Future studies should focus on collecting data on prey items at a lower taxonomic level (genus or species) and investigating possible ontogenetic shifts in diet as well as variations based on sex and habitats. This is especially important since, as two of the most abundant species in UAE Gulf waters, future changes in their abundance are likely to impact the dynamics of its important prey resources and a good understanding of these trophic interactions are needed for fisheries management.

CHAPTER VIII

GENERAL DISCUSSION: TOWARDS CONSERVATION OF SHARKS IN THE UAE

8.1 Summary and concluding remarks

This study was the first attempt at investigating the fishery and trade in sharks in the UAE while simultaneously providing information on various aspects of the ecology of several shark species found in Gulf waters. By integrating a variety of research tools such as fishermen interviews, landing site and trade surveys, a tagging program, and stomach content analysis, it has provided both fishery dependent and fishery independent data that have greatly expanded the current state of knowledge on the local shark fishery and shark species inhabiting UAE Gulf waters.

Interviews with fishermen allowed the first description of the geographical extent, size, gear characteristics and target species of the artisanal shark fishery. Results showed that the fishery was highly opportunistic and varied considerably in fishing behavior. The existence of a targeted shark fishery fuelled by the shark fin trade was confirmed indicating that this fishery is likely to have a substantial impact on shark populations. In fact, fishermen confirmed that the status of sharks had changed in recent years and that they were witnessing noticeable declines in catches, abundance and average sizes of sharks in UAE Gulf waters. Although limited data were obtained from fishermen regarding the variety of shark species, the 24 month landing sites and market surveys provided details of shark catches across the country. This significantly improved the current status of knowledge regarding the species composition, relative abundance and size distribution of sharks exploited by the fishery in the UAE. The 30 species of sharks recorded here, confirmed both through morphological traits and genetic analysis, indicated that shark biodiversity in the Gulf was relatively high and comparable to other countries in the region when considering that deep water species are precluded from inhabiting these waters. Within the time frame of the study, four species including the grey bamboo shark, *Chiloscyllium griseum*, tawny nurse shark, *Nebrius ferrugineus,* silky shark, *Carcharhinus falciformis,* and sandbar shark, *Carcharhinus plumbeus,* were confirmed in these waters for the first time. As has been previously documented for most shark species (Compagno 1984), the biological data collected here, including maximum sizes and size at maturity, varied between species and in comparison to the same species in other parts of the world. This suggests that further research needs to be undertaken, both nationally and regionally, to gain a better understanding of these differences and of the status of the various species on a local level. Specifically, the acquisition of additional life-history data on those species that dominate the catches, i.e. *Carcharhinus sorrah, Rhizoprionodon acutus, Carcharhinus limbatus, Loxodon macrorhinus, Carcharhinus dussumieri, Mustelus mosis,* is urgently required and emphasized by the fact that these six species represented over 90% of catches in UAE Gulf waters. Also, obtaining accurate life history data from this region is particularly important since analysis of the size at maturity for many species indicated that a considerable number of the specimens captured were either immature individuals or gravid females, a worrying sign when considering the conservation of these resources. Furthermore, the fishery independent study that was used to try and gather a reliable estimate of population size and mortality indicated that nearshore habitats in Dubai and Abu Dhabi had a low abundance of sharks. This finding was in line with data provided from fishermen who indicated they needed to travel further offshore to capture sharks. The feeding study undertaken here provided an overview of the diet of two commercially important species, the milk shark, *R. acutus*, and the slit-eye shark, *L. macrorhinus*. However, it is evident that further studies need to also focus on collecting information on the diet of targeted species to enhance our understanding of ecological interactions and the potential effects of declining shark populations on the various ecosystems in the Gulf. This is especially true since although the ecological role of many of these species remains poorly understood, sharks are likely to play an important role in structuring marine communities in UAE waters through predation. Finally, the trade survey conducted was the first attempt at quantifying and characterizing the trade in shark products in the UAE and the broader region. The prevalent trade in both shark meat and fins, indicated that demand was not likely to be curbed and that this trade would likely continue in years to come. While information was limited to the trade in shark products originating from the UAE and Oman, results indicated that the majority of species encountered were listed by the IUCN Red List as facing high risks of extinction globally. Since no information on stock structure is available, it is important that work be undertaken to determine the extent to which these species are part of stocks shared with other countries in the region and how the trade is affecting their survival.

While there is no baseline information with which to compare the results obtained in this study, all the data indicate that there is a high level of pressure on shark populations in UAE Gulf waters. In view of the life history traits and the possible detrimental impacts of fishing on many shark species in the UAE, the precautionary approach to the management of these resources is warranted. This is especially true since no stock assessments are currently available and some stocks may have already been depleted to below safe biological limits. Indeed, some populations may take decades to recover even with tough conservation measures in place (Simpfendorfer 2000; Ward-Paige *et al.* 2012). However, while few population recoveries of shark populations have been observed around the world (Ward-Paige *et al.* 2012), marine mammal populations, that also have similar life-history traits and have faced similar population declines, have shown marked recovery due to strong national and international management measures (Lotze & Worm 2009). Therefore, some of these conservation successes could provide guidance and hope for rebuilding shark stocks (Ward-Paige *et al.* 2012). Using the data gathered from this study as a baseline, building on the current legislation in the UAE, strengthening enforcement of the existing regulations, and developing and formulating new appropriate management strategies for a sustainable shark fishery, is now possible and can improve the management and conservation of shark resources in the UAE.

8.2 Recommendations and future research directions

The following recommendations are based on guidelines from various NPOA's that have been developed and are being implemented in countries such as the United Kingdom, Canada, Australia, Japan and the Seychelles (Fowler *et al.* 2004; Shark Advisory Group & Lack 2004; Anon 2007; Nevill *et al.* 2007; Anon 2009). Based on results from this study, the most important and relevant components of each of these

NPOA's have been adapted to the situation in the UAE. Recommendations are provided under four categories: 'conservation and management measures', 'data collection and handling', 'research' and 'education and awareness'. The list of actions proposed is not exhaustive but provides a strong base with which to initiate measures for the management and conservation of shark stocks in the UAE. It is important to note that actions in some categories can be fully dependent on the completion of other actions that may be listed in different categories. Furthermore, because this list is meant to provide an indication of actions needed rather than a complete plan of action, levels of priorities, information on the responsibility for the implementation of each action, and information on the various stakeholders to be involved in each action, have not been provided.

8.2.1 Conservation and management measures

The development of appropriate management actions is crucial for rebuilding threatened populations of sharks and sustaining associated fisheries. Based on the results from this study, there is a need to:

- Assess current management arrangements for shark fishing and determine if these are consistent with a precautionary approach and for achieving ecological sustainability of shark species;
- Improve and plan monitoring and enforcement of local fisheries regulations;
- Introduce precautionary management measures to prevent targeted fisheries for stocks considered at risk of global extinction in other parts of the world;

- Take action to protect and minimize threats to habitats determined as critical for the survival of shark species;
- Introduce minimum and maximum landing sizes for specific species of sharks as well as limits to catches of certain species;
- Initiate actions to ensure effective bycatch reduction methods are developed and introduced into the shark fishery;
- Ensure effective communication and consultation mechanisms are established between all stakeholders;
- Establish cooperative research and management initiatives for trans-boundary, straddling, highly migratory and high seas shark stocks;
- Ensure species listed on CITES are monitored in the trade of shark products;
- Develop a NPOA and actively promote the implementation and development of such plans in the region to improve regional management of shark stocks.

8.2.2 Data collection and handling

Data regarding the shark fishery in the UAE are limited and hampered by lack of species-specific data on landings. Therefore there is a need to:

- Produce identification guides with standardized terminology to enable fishermen and observers to identify target, bycatch and legally protected species (in Arabic, Hindi and English);
- Develop and implement a fishery monitoring program specific to sharks to provide accurate, species-specific, and independent third party verification of

fish landings with dockside monitoring, at sea observer coverage, quota monitoring systems and electronic vessel monitoring systems;

- Establish a commercial log book program where fishermen are required to complete the log for each day fished including details of catch and landing data;
- Develop standardized data collection methods along with a protocol that facilitates data gathering and management, summarization, efficient data extraction and exchange between relevant agencies while securing confidentiality and intellectual property rights;
- Create databases where all data collected are secure and which have automated internal verification and validation checks;
- Assess the availability of UAE export and import data for shark products.

8.2.3 Research

In order to gain a better understanding of the status of sharks in UAE waters, key research programs will need to be developed that will:

- Focus on identifying the biological stock structure of sharks in UAE waters as well as their status, distribution (temporal and spatial), biology and ecology;
- Initiate stock assessments for target and non-target shark species;
- Undertake a fishery independent research program that will allow the development of accurate abundance indices;
- Investigate the potential use of DNA identification kits in the field to identify shark species;

- Identify critical habitats to the survival of shark species including aggregation areas and breeding as well as pupping grounds;
- Determine threats to shark diversity from increased mortality, habitat destruction or degradation and environmental changes;
- Identify migration routes and barriers to migration;
- Develop genetic studies to reveal the population structure of several species, quantify the degree of relatedness among geographically distinct populations, and determine whether exploited groups need to be managed as single or multiple overlapping stocks;
- Develop a socioeconomic study of the shark fishery focusing on understanding the economic value of sharks to fishermen as well as gather further information on the shark fishing industry in terms of fishing effort, seasonality, scope of gear modifications or introductions to limit by-catch;
- Investigate options for various ecotourism activities and make recommendations;
- Assess the nature and extent of the sports and recreational fishery to determine whether it should be incorporated into the standardized monitoring system.

8.2.4 Education and awareness

To ensure support of management initiatives or research projects by all stakeholders, there is a need to develop and implement a public education and awareness strategy to:

- Educate the public about the myths and realities of shark behavior, conservation and management;

- Emphasize the vulnerability of sharks to fishing pressure and their role in the marine ecosystem;
- Educate stakeholders on the need for shark catch data and species identification as well as the relevant legislation, management measures, reporting requirements and penalties;
- Address by-catch issues and catch and release practices;
- Disseminate identification keys and train stakeholders in their use;
- Train stakeholders in the correct implementation of data gathering protocols.

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.

Table 1.1. Total number of licensed boats (dhows and tarads) registered in each emirate from 1999 to 2009 (MoEW, 2013).

Emirate	Year										
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Abu Dhabi	1,783	856	903	979	1,882	1,100	1,100	2,200	1,100	1,100	2,200
Dubai	994	640	692	734	1,426	712	732	1,444	732	732	1,464
Sharjah	1,836	1,239	930	1,006	1,936	1,162	1,105	2,267	1,105	1,105	2,210
Ajman	358	170	158	172	330	182	187	369	187	187	374
Umm Al Quwain	425	317	343	378	721	391	559	950	559	559	1,118
Ras Al Khaimah	1,380	951	1,019	1,344	2,363	1,279	1,203	2,482	1,203	1,203	2,406
Fujeirah	905	515	544	578	1,122	738	685	1,423	685	685	1,370
TOTAL	7,681	4,688	4,589	5,191	5,052	5,564	5,571	5,571	5,571	5,571	6,054

Table 1.2. Number of fishermen (UAE citizens and expatriates) registered in each emirate from 1999 to 2008 (MoEW, 2013).

Emirate	Year									
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Abu Dhabi	4,847	3,051	3,488	4,827	2,882	1,081	758	4,620	4,620	4,620
Dubai	3,164	2,102	2,379	2,968	2,503	2,515	2,610	3,295	3,295	3,295
Sharjah	4,111	4,113	2,622	3,304	3,074	4,010	4,612	4,199	4,199	4,199
Ajman	521	587	538	1,329	1,489	1,345	1,526	842	842	842
Umm Al Quwain	1,109	1,002	950	1,228	1,355	615	727	2,068	2,068	2,068
Ras Al Khaimah	3,382	2,917	1,544	2,448	2,459	2,768	2,845	4,210	4,210	4,210
Fujeirah	1,624	1,771	806	1,160	986	313	460	1,986	1,986	1,986
TOTAL	18,758	15,543	12,327	17,264	14,748	12,647	13,538	21,220	21,220	21,220

Table 3.1. Study sites in the UAE where interviews were conducted with details on the number of interviews at each site, timings and locations.

Region	Emirate	Site location	Number of interviews	Timings and locations of interviews
WESTERN (Gharbiyah)	ABU DHABI	Free Port	10	4:00 to 8:00 h; Mina Zayed landing site
		Dalma Island	10	12:00 to 19:00 h; Dalma landing site
		Mirfa	2	19:00 to 20:00 h; Fishermen majlis
		Sila	4	16:00 to 19:00 h; Fishermen Cooperative building
CENTRAL (Wustah)	DUBAI	Umm Suqeim	4	16:00 to 18:00 h; Fishermen majlis
		Jumeira	5	16:00 to 18:00 h; Fishermen majlis
		Hamriya Port	8	18:00 to 20:00 h; Fishermen majlis
	SHARJAH	Jubail market	9	17:00 to 20:00 h; Fisheries Cooperative majlis
	AJMAN	Fish market	10	17:00 to 20:00 h; Fisheries Cooperative majlis
	UMM AL QUWAIN	Fish Cooperative	9	18:00 to 21:00 h; Fisheries Cooperative majlis and landing site
NORTHERN (Shamaliyat)	RAS AL KHAIMAH	Fish souk	17	12:00 to 14:00 h; Fisheries Cooperative office
		Maarid souk	5	18:30 to 20:00 h; Fishermen majlis
EASTERN (Sharkiya)	FUJEIRAH	Dibba - Fujeirah	7	17:30 to 19:00 h; Al Aquamiah landing site
		Mina Mirbeh	7	20:30 to 22:30 h; Fishermen majlis
		Mina Al Rogailat	12	9:00 to 11:00 h and 17:00 to 21:00 h; Fishermen majlis
		Khor Fakkan (Sharjah)	5	11:00 to 13:00 h; Fisheries Cooperative building
		Dibba –Al Hosn	2	17:30 to 19:00 h; Al Hosn landing site
TOTAL NUMBER OF INTERVIEWS			**126**	

Table 3.2. Fishermen quotes on the status of the shark fishery in the UAE (quotes selected from representative semi-structured interviews).

Interviewee code	Quote
#3.	Sharks cost like gold… Oman is the one catching the most sharks but even the trade is slowing down because there are no more sharks.
#13.	Sharks used to be closer to shore but now we have to go out far at sea to catch anything.
#26.	Sharks were not valuable before but now it's good to catch them.
#28.	Sharks have become big business. We didn't keep them all in the past because we didn't know their worth.
#31.	We didn't use to fish for sharks in the past cause we didn't know their value.
#45.	There used to be crazy numbers of sharks.
#49.	Most species are now either extinct or disappearing.
#50.	Sawfishes and many species of sharks are either threatened or extinct.
#54.	Sharks are going extinct and so is everything else.
#60.	There has been a 70-80% decline in the number of sharks just in the past 10 years.
#71.	There were fins at the surface every evening before, sharks used to be caught and discarded but now they are targeted.
#79.	Back in the pearling days, sharks were attacking divers but now they are rare…extinct.
#90.	I used to fish for sharks but it's not a business anymore because too few are left.

Table 4.5. Summary of size and maturity data for UAE species compared with data from the scientific literature. **Size** at maturity for males (M) and females (F) from recorded specimens; **Reproductive Mode**: OVO: Ovoviviparous, OPH: Oviphagous, OVI: Oviparous, VIV: Viviparous; **Litter size**; **Gestation time** in months; '-' indicates that data were not available Information adapted from (Compagno *et al.*, 2005; Last & Stevens, 2009; IUCN, 2012; Moore *et al.*, 2012a).

Species name	UAE Size (L_T mm)			Size (L_T mm)		Reproduction			
	M	F	Range	M	F	Max	Mode	Litter	Gestation
Family Hemiscyllidae -- Longtailed carpetsharks									
Chiloscyllium arabicum	619-800	-	619-800	450-620	450-540	700	OVI	4	2-3
Chiloscyllium griseum	754	-	754	450-550	450-550	770	OVI	-	-
Family Ginglymostomatidae -- Nurse sharks									
Nebrius ferrugineus	2191	-	1395-2191	2250-2500	2300-2900	~3200	OVO	1-8	-
Family Stegostomatidae -- Zebra shark									
Stegostoma fasciatum	1835-1993	1915	1494-2110	1470-1830	1690-1710	>2350	OVI	-	-
Family Rhincodontidae -- Whale shark									
Rhincodon typus	-	-	4452	>6000	>8000	>17000	OVO	~300	-
Family Odontaspididae -- Sand tiger sharks									
Carcharias taurus	-	-	2560	1900-1950	2200-2300	>3180	OPH	2	9-12
Family Triakidae -- Houndsharks									
Mustelus mosis	704-913	859-940	569-1073	630-670	8200	1500	VIV	6-10	-
Family Hemigaleidae -- Weasel sharks									
Chaenogaleus macrostoma	723-900	832-841	514-934	680-970		~1000	VIV	4	-
Hemipristis elongata	1311-2052	-	724-2560	1100-1450	1700-2180	~2400	VIV	2-11	7-8
Paragaleus randalli	651-809	785-811	616-848	~600-700	~600-700	>810	VIV	2	-

Table 4.5. *Continued*

Species name	UAE Size (L_T mm)			Size (L_T mm)		Reproduction			
	M	F	Range	M	F	Max	Mode	Litter	Gestation
Family Carcharhinidae -- Requiem sharks									
Carcharhinus amblyrhynchoides	1653-2334	2043-2246	799-2430	1100-1150	1100-1150	~1700	VIV	1-9	9-10
Carcharhinus amblyrhynchos	1627-1805	-	1080-1992	1100-1450	1200-1370	~2550	VIV	1-6	9-14
Carcharhinus amboinensis	2150-2456	2546	642-2586	1950-2100	1980-2230	2800	VIV	3-13	9-12
Carcharhinus brevipinna	1771-2391	2436-2602	556-2670	1300-2030	1500-2000	~3000	VIV	3-20	11-15
Carcharhinus dussumieri	678-921	815-989	362-989	640-740	670-750	~1000	VIV	1-4	-
Carcharhinus falciformis	-	-	757-1081	1860-2250	1930-2460	~3300	VIV	2-16	12
Carcharhinus leiodon	1372	-	531-1372	888-1230				-	-
Carcharhinus leucas	2208-2977	2190	688-2977	1570-2260	1800-2300	~3400	VIV	1-13	10-11
Carcharhinus limbatus	1407-2870	1640-2532	420-2870	1300-1800	1200-1900	~2550	VIV	1-11	10-12
Carcharhinus macloti	746-905	903-951	475-971	690-740	700-890	1100	VIV	1-2	12
Carcharhinus melanopterus	1232-1243	1324-1468	496-1523	900-1100	960-1120	~1800	VIV	2-4	8-9
Carcharhinus plumbeus	1712-1956	1802	1443-2393	1230-1800	1290-1850	~2400	VIV	1-14	8-12
Carcharhinus sorrah	1048-1513	1102-1678	437-1960	900-1060	950-1180	1600	VIV	1-8	10
Galeocerdo cuvier	-	-	2073	2260-3000	2500-3500	~6000	OVO	10-82	12-16
Loxodon macrorhinus	645-901	701-824	469-901	620-820	600-790	990	VIV	2-4	-
Negaprion acutidens	2440	2576-2650	867-2650	2200-2430	~2200	3100	VIV	1-14	10-11
Rhizoprionodon acutus	606-888	618-915	372-981	680-720	700-810	1780	VIV	1-8	~12
Rhizoprionodon oligolinx	609-785	-	552-907	290-380	320-410	700	VIV	3-5	-
Family Sphyrnidae – Hammerheads									
Sphyrna lewini	2543	3027	469-3027	1400-1980	2100-2500	~3700	VIV	12-41	9-12
Sphyrna mokarran	2670-3058	-	543-3820	2340-3090	2100-3360	~6000	VIV	6-42	~11

Table 4.6. Summary of species identification of specimens from Gulf waters based on consensus barcoded sequences from BOLD and GenBank databases. Amplicon size refers to the size of the sequence generated after cleaning and trimming.

Sample number	**Field identification**	**BOLD**		**GenBank**		**Amplicon size (bp)**
		Species identification	Similarity (%)	Most possible organism	Maximum identity (%)	
1	*C. amblyrhynchos*	*C. amblyrhynchos*	100	*C. amblyrhynchos*	99	630
2	*C. amblyrhynchos*	*C. amblyrhynchos*	100	*C. amblyrhynchos*	99	589
3	*C. amblyrhynchos*	*C. amblyrhynchos*	100	*C. amblyrhynchos*	99	598
4	*C. amblyrhynchos*	*C. amblyrhynchos*	99.81	*C. amblyrhynchos*	99	537
5	*C. amblyrhynchos*	*C. amblyrhynchos*	99.26	*C. amblyrhynchos*	99	542
6	*C. melanopterus*	*C. melanopterus*	100	*C. melanopterus*	99	583
7	*C. melanopterus*	*C. melanopterus*	100	*C. melanopterus*	99	592
8	*C. melanopterus*	*C. melanopterus*	100	*C. melanopterus*	99	588
9	*C. melanopterus*	*C. melanopterus*	100	*C. melanopterus*	99	517
10	*C. melanopterus*	*C. melanopterus*	100	*C. melanopterus*	99	599
11	*C. brevipinna*	*C. brevipinna*	100	*C. brevipinna*	99	599
12	*C. brevipinna*	*C. brevipinna*	100	*C. brevipinna*	99	576
13	*C. brevipinna*	*C. brevipinna*	100	*C. brevipinna*	99	591
14	*C. brevipinna*	*C. brevipinna*	100	*C. brevipinna*	99	590
15	*C. brevipinna*	*C. brevipinna*	100	*C. brevipinna*	99	590
16	*C. dussumieri*	*C. dussumieri*	100	*C. dussumieri*	99	563
17	*C. dussumieri*	*C. dussumieri*	100	*C. dussumieri*	99	536
18	*C. dussumieri*	*C. dussumieri*	100	*C. dussumieri*	99	577
19	*C. dussumieri*	*C. dussumieri*	100	*C. dussumieri*	99	570
20	*C. dussumieri*	*C. dussumieri*	100	*C. dussumieri*	99	556

Table 4.6. *Continued*

Sample number	Field identification	BOLD		GenBank		Amplicon size (bp)
		Species identification	Similarity (%)	Most possible organism	Maximum identity (%)	
21	*C. leucas*	*C. leucas*	100	*C. leucas*	100	590
22	*C. leucas*	*C. leucas*	100	*C. leucas*	100	591
24	*C. leucas*	*C. leucas*	100	*C. leucas*	100	591
25	*C. leucas*	*C. leucas*	100	*C. leucas*	100	598
26	*C. amboinensis*	*C. amboinensis*	100	*C. amboinensis*	99	602
27	*C. amboinensis*	*C. amboinensis*	100	*C. amboinensis*	99	590
28	*C. amboinensis*	*C. amboinensis*	100	*C. amboinensis*	99	587
29	*C. amboinensis*	*C. amboinensis*	100	*C. amboinensis*	99	594
30	*C. amboinensis*	*C. amboinensis*	100	*C. amboinensis*	100	597
31	*C. leiodon*	*C. leiodon*	99.84	*C. leiodon*	99	622
32	*C. leiodon*	*C. leiodon*	100	*C. leiodon*	100	541
33	*C. limbatus*	*C. limbatus*	100	*C. limbatus*	100	500
34	*C. limbatus*	*C. limbatus*	100	*C. limbatus*	100	559
35	*C. limbatus*	*C. limbatus*	100	*C. limbatus*	100	570
36	*C. limbatus*	*C. limbatus*	99.81	*C. limbatus*	99	550
37	*C. limbatus*	*C. limbatus*	100	*C. limbatus*	100	509
39	*C. macloti*	*C. macloti*	100	*C. macloti*	99	619
40	*C. macloti*	*C. macloti*	100	*C. macloti*	99	595
41	*C. macloti*	*C. macloti*	100	*C. macloti*	99	585
42	*C. macloti*	*C. macloti*	100	*C. macloti*	99	595
43	*C. plumbeus*	*C. plumbeus*	100	*C. plumbeus*	99	625
44	*C. plumbeus*	*C. plumbeus*	100	*C. plumbeus*	99	622
45	*C. plumbeus*	*C. plumbeus*	100	*C. plumbeus*	99	610
46	*C. plumbeus*	*C. plumbeus*	100	*C. plumbeus*	99	587

Table 4.6. *Continued*

Sample number	Field identification	BOLD		GenBank		Amplicon size (bp)
		Species identification	Similarity (%)	Most possible organism	Maximum identity (%)	
47	*C. plumbeus*	*C. plumbeus*	100	*C. plumbeus*	99	637
48	*C. sorrah*	*C. sorrah*	100	*C. sorrah*	99	570
49	*C. sorrah*	*C. sorrah*	100	*C. sorrah*	100	535
50	*C. sorrah*	*C. sorrah*	100	*C. sorrah*	100	580
51	*C. sorrah*	*C. sorrah*	100	*C. sorrah*	100	579
52	*C. sorrah*	*C. sorrah*	100	*C. sorrah*	100	523
53	*C. amblyrhynchoides*	*C. amblyrhynchoides*	99.83	*C. amblyrhynchoides*	99	579
54	*C. amblyrhynchoides*	*C. amblyrhynchoides*	99.83	*C. amblyrhynchoides*	99	595
55	*C. amblyrhynchoides*	*C. amblyrhynchoides*	99.83	*C. amblyrhynchoides*	99	595
56	*C. amblyrhynchoides*	*C. amblyrhynchoides*	99.83	*C. amblyrhynchoides*	99	588
57	*C. amblyrhynchoides*	*C. amblyrhynchoides*	99.82	*C. amblyrhynchoides*	99	565
58	*L. macrorhinus*	*L. macrorhinus*	99.83	*L. macrorhinus*	99	596
59	*L. macrorhinus*	*L. macrorhinus*	100	*L. macrorhinus*	98	614
60	*L. macrorhinus*	*L. macrorhinus*	100	*L. macrorhinus*	99	601
61	*L. macrorhinus*	*L. macrorhinus*	99.65	*L. macrorhinus*	98	584
62	*L. macrorhinus*	*L. macrorhinus*	100	*L. macrorhinus*	99	595
63	*C. falciformis*	*C. falciformis*	100	*C. falciformis*	99	623
64	*C. falciformis*	*C. falciformis*	100	*C. falciformis*	99	590
65	*C. falciformis*	*C. falciformis*	100	*C. falciformis*	99	578
66	*C. macrostoma*	*C. macrostoma*	100	*P. randalli*	99	585
67	*C. macrostoma*	*C. macrostoma*	100	*P. randalli*	99	613
68	*C. macrostoma*	*C. macrostoma*	100	*P. randalli*	99	585
69	*C. macrostoma*	*C. macrostoma*	99.38	*P. randalli*	99	321
70	*C. macrostoma*	*C. macrostoma*	99.79	*P. randalli*	99	489

Table 4.6. *Continued*

Sample number	Field identification	BOLD		GenBank		Amplicon size (bp)
		Species identification	Similarity (%)	Most possible organism	Maximum identity (%)	
71	*H. elongata*	*H. elongata*	100	*H. elongata*	99	614
72	*H. elongata*	*H. elongata*	100	*H. elongata*	99	627
73	*H. elongata*	*H. elongata*	100	*H. elongata*	99	586
74	*H. elongata*	*H. elongata*	100	*H. elongata*	99	606
75	*H. elongata*	*H. elongata*	100	*H. elongata*	99	632
76	*M. mosis*	*M. mosis*	98.34	*M. mosis*	98	485
77	*M. mosis*	*M. mosis*	100	*M. mosis*	100	592
78	*M. mosis*	*M. mosis*	99.83	*M. mosis*	99	592
79	*M. mosis*	*M. mosis*	100	*M. mosis*	100	583
80	*M. mosis*	*M. mosis*	100	*M. mosis*	99	586
81	*N. acutidens*	*N. acutidens*	100	*N. acutidens*	99	603
85	*N. acutidens*	*N. acutidens*	100	*N. acutidens*	99	622
86	*S. fasciatum*	*S. fasciatum*	100	*S. fasciatum*	100	592
87	*S. fasciatum*	*S. fasciatum*	100	*S. fasciatum*	100	580
88	*S. fasciatum*	*S. fasciatum*	100	*S. fasciatum*	99	630
89	*S. fasciatum*	*S. fasciatum*	100	*S. fasciatum*	99	600
90	*S. fasciatum*	*S. fasciatum*	100	*S. fasciatum*	100	593
91	*P. randalli*	*P. randalli*	100	*P. randalli*	99	612
92	*P. randalli*	*P. randalli*	100	*P. randalli*	99	639
93	*P. randalli*	*P. randalli*	100	*P. randalli*	99	613
94	*P. randalli*	*P. randalli*	100	*P. randalli*	no match	607
95	*P. randalli*	*P. randalli*	100	*P. randalli*	99	597
96	*R. acutus*	*R. acutus*	99.84	*R. acutus*	99	637

Table 4.6. *Continued*

Sample number	Field identification	BOLD		GenBank		Amplicon size (bp)
		Species identification	Similarity (%)	Most possible organism	Maximum identity (%)	
97	*R. acutus*	*R. acutus*	100	*R. acutus*	99	592
98	*R. acutus*	*R. acutus*	99.11	*R. acutus*	98	565
99	*R. acutus*	*R. acutus*	99.83	*R. acutus*	99	608
100	*R. acutus*	*R. acutus*	100	*R. acutus*	99	598
101	*C. arabicum*	*Chiloscyllium* sp.	98.42	*C. hasselti*	93	513
102	*C. arabicum*	*Chiloscyllium* sp.	97.56	*C. hasselti*	92	502
109	*N. ferrugineus*	*N. ferrugineus*	99.62	*N. ferrugineus*	99	532
110	*R. typus*	*R. typus*	100	*R. typus*	100	574
111	*R. oligolinx*	*R. oligolinx*	100	*R. porosus*	95	636
112	*R. oligolinx*	*R. oligolinx*	100	*R. porosus*	95	560
113	*R. oligolinx*	*R. oligolinx*	100	*R. porosus*	95	500
114	*R. oligolinx*	*R. oligolinx*	100	*R. porosus*	95	596
115	*R. oligolinx*	*R. oligolinx*	100	*R. porosus*	95	634
127	*R. oligolinx*	*R. oligolinx*	100	*R. porosus*	95	588
128	*R. oligolinx*	*R. oligolinx*	100	*R. porosus*	95	591
129	*R. oligolinx*	*R. oligolinx*	100	*R. porosus*	95	589
130	*R. oligolinx*	*R. oligolinx*	100	*R. porosus*	95	607
131	*R. oligolinx*	*R. oligolinx*	100	*R. porosus*	95	588
116	*S. mokarran*	*S. mokarran*	99.82	*S. mokarran*	99	562
117	*S. mokarran*	*S. mokarran*	99.65	*S. mokarran*	99	575
118	*S. mokarran*	*S. mokarran*	99.64	*S. mokarran*	99	560
120	*S. mokarran*	*S. mokarran*	100	*S. mokarran*	100	595
124	*S. mokarran*	*S. mokarran*	100	*S. mokarran*	100	603

Table 4.6. *Continued*

Sample number	Field identification	BOLD		GenBank		Amplicon size (bp)
		Species identification	Similarity (%)	Most possible organism	Maximum identity (%)	
121	*S. lewini*	*S. lewini*	100	*S. lewini*	99	595
122	*S. lewini*	*S. lewini*	99.82	*S. lewini*	99	578
123	*S. lewini*	*S. lewini*	100	*S. lewini*	99	591
125	*S. lewini*	*S. lewini*	100	*S. lewini*	99	590
126	*G. cuvier*	*G. cuvier*	100	*G. cuvier*	100	597
133	*C. taurus*	*C. taurus*	99.66	*C. taurus*	99	592

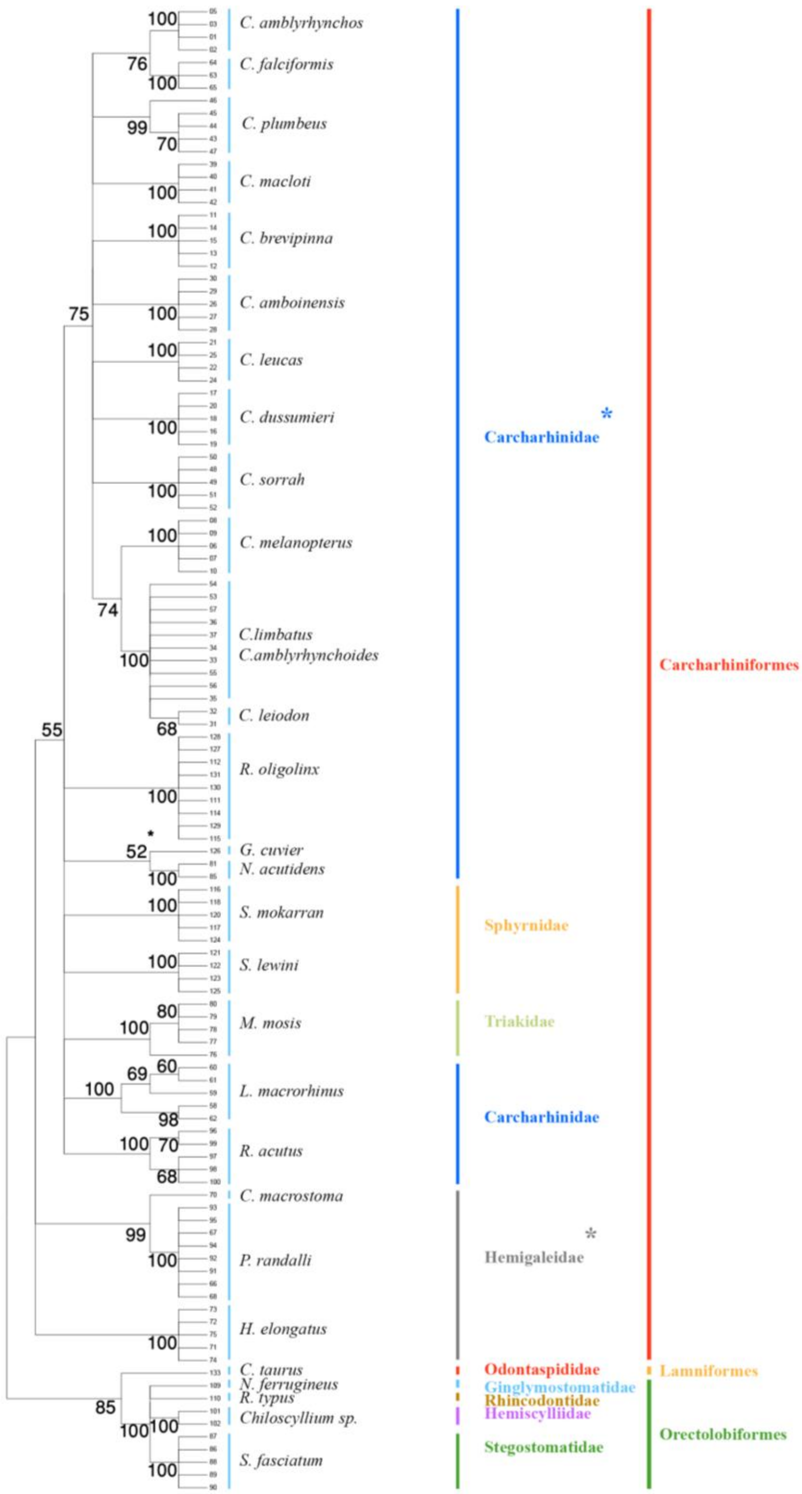

Figure 4.29. NJ tree of COI sequences (417 bp) from shark species found in UAE waters using K2P distances and 1000 bootstraps (values >50 are shown). Clades were color coded by Family and Order of species. * indicates that node did not reflect the majority consensus branching arrangement with MP analysis.

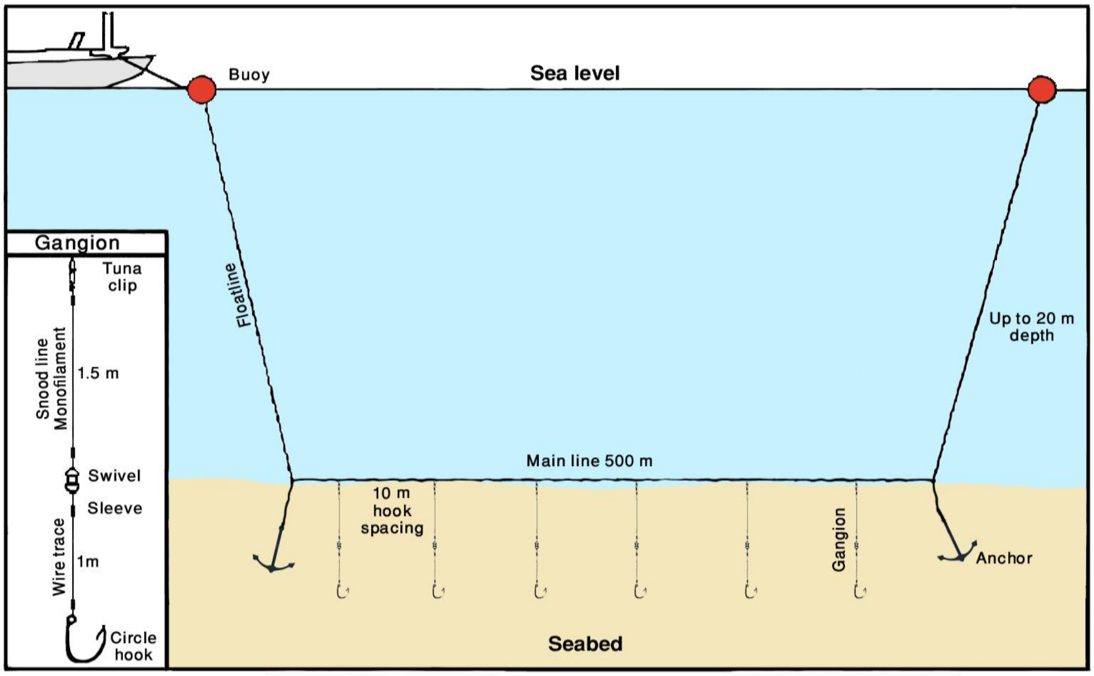

Figure 5.2. Basic longline gear unit used in this study with inset at the left illustrating details of a gangion.

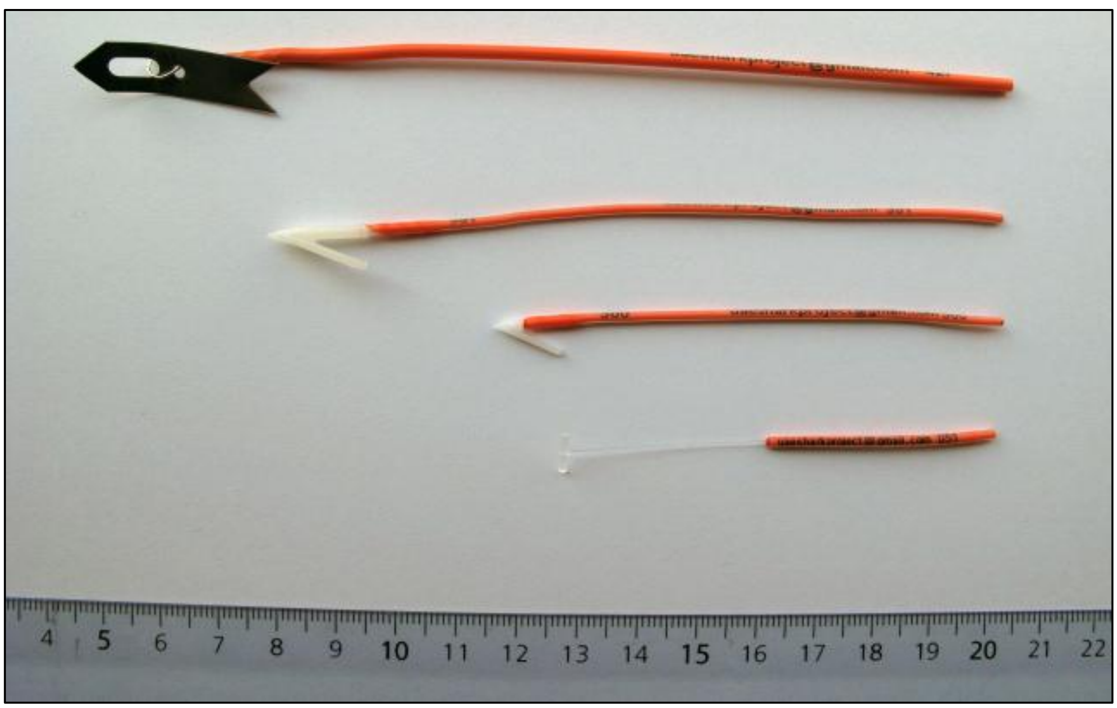

Figure 5.3. From top to bottom, the four tag types used during tagging surveys, stainless steel head dart tag (SSD), plastic tipped dart tags (PDA and PDS), T-Bar anchor tag (TBA).

Table 5.1. Summary of research effort including trip dates, location names and numbers (as referred to in **Figure 5.1.**), hours fished per trip, number of sets, timing of trips (h), depth of set, water temperature T (°C), and number of sharks caught per trip.

Date	Location number and name	Coordinates	Hours fished	# of sets	Time of day	Depth (m)	T (°C)	# of sharks
27.01.11	1. NW World islands	N 25 13 817 -- E 055 05 248	4h30	2	18.00 to 22.30	19.1	21	0
30.04.11	2. E World islands	N 25 15 745 -- E 055 11 478	6h	2	16.00 to 22.00	16.1	26	0
08.05.11	3. Abu Dhabi, Ras Gurab	N 24 60 410 – E 054 47 423	6h	2	11.30 to 17.30	6.0	26	2
27.06.11	4. Abu Dhabi, Ras Gurab	N 24 37 206 – E 054 30 148	6h	2	10.30 to 16.30	5.0	31	0
15.02.12	5.W World islands	N 25 12 156 – E 055 06 939	6h20	2	10.00 to 16.20	15.3	19.0	0
26.05.12	6. NW Sir Bu Nair	N 25 14 987 – E 054 11 496	13h30	3	14.30 to 4.00	16.4	29.1	1
03.07.12	7. W World islands	N 25 12 997 – E 055 07 112	4h	1	11.00 to 15.00	15.7	33.7	1
07.11.12	8. Jasim Wreck – Dubai	N 24 58 780 – E 054 29 739	19h30	4	16.00 to 11.30	22.5	28.6	2
21.11.12	9. W Palm Jebel Ali	N 24 58 958 – E 054 56 533	6h	2	10.30 to 16.30	9.0	28.2	3
08.12.12	10.Abu Dhabi, Ras Gurab	N 24 35 620 – E 054 28 594	5h30	2	11.00 to 15.30	9.6	25.2	0
18.02.13	11. N Palm Jebel Ali	N 25 01 921 – E 054 57 692	5h45	1	11.35 to 17.20	10.5	22.0	0
26.01.13	12. NE World islands	N 25 16 184 – E 055 10 152	6h50	2	14.20 to 21.10	17.5	23.5	2
10.03.13	13. W World islands	N 25 11 773 – E 055 03 628	5h45	2	16.45 to 22.30	12.0	24.0	0
20.03.13	14. NW Palm Jebel Ali	N 25 02 149 – E 054 54 145	5h35	1	11.00 to 16.35	13.4	24.3	0
TOTAL			**101 h**	**28**				**11**

Table 6.3. UAE production and trade in shark products by commodity from 1995 to 2009, including trade flow, in metric tons. * indicates that the figure is an FAO estimate from available sources of information; '0' indicates that the value is more than zero but less than half the unit used; '…' indicates that data were either unavailable; unobtainable or that the data were not separately available but are included in another category; '-' indicates that the magnitude was either known to be nil or zero or was given as 'nil' in the original source. (FAO, 2012)

Commodity	Trade flow	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Shark fins, dried, salted, etc.	Export	0	25*	5*	465*	391*	519*	378*	507*	474*	454*	539*	427*	472*	515*	466*
Shark fins, dried, unsalted	Export	...	...	...	...	...	...	...	...	...	14*	-	-	-	-	-
Shark fins, frozen	Import	...	...	...	...	...	...	...	...	...	...	...	0	-	-	-
Shark fins, salted and in brine (not dried or smoked)	Import	...	...	...	...	...	...	...	...	...	...	...	0	-	-	-
Sharks nei, fresh or chilled	Export	2*	11*	7*	2*	...	...	...	...	...	25*	...	3*	...	...	98
Sharks nei, fresh or chilled	Import	...	...	...	...	...	...	...	5	15	1*	253	-	11	2	28
Sharks nei, fresh or chilled	Reexport	...	...	...	...	...	...	...	2	-	-	5	-	3	80	-
Sharks nei, frozen	Export	...	...	10*	15*	...	...	...	8	0	3*	-	1*	-	-	35
Sharks nei, frozen	Import	181*	...	47*	50*	...	...	...	103	3	...	4	2*	-	-	1
Sharks nei, frozen	Reexport	...	...	...	...	...	...	...	...	2	-	38	-	1	10	-
TOTAL		**183**	**36**	**69**	**532**	**391**	**519**	**378**	**625**	**494**	**497**	**839**	**433**	**487**	**607**	**628**

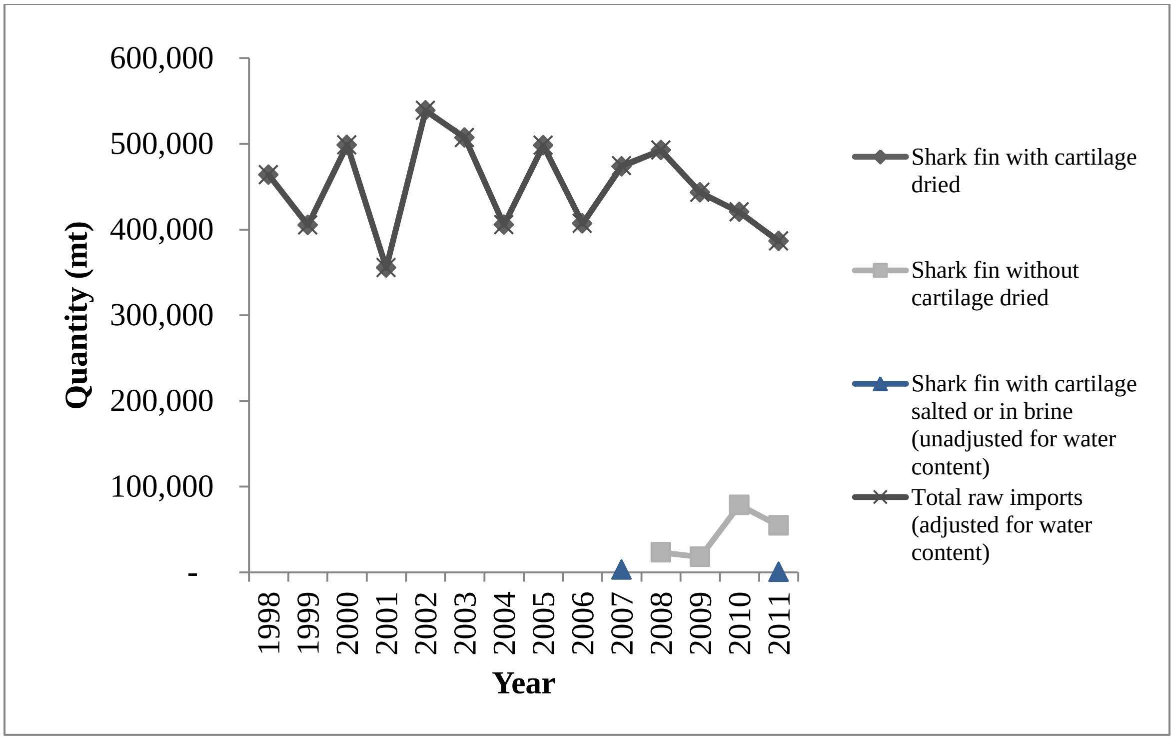

Figure 6.3. Hong Kong imports of shark products from the UAE from 1998 to 2011 based on the country of origin (data from the Hong Kong Census and Statistics Department) (Anon 2012).

Table 6.4. Summary of barcoding results for samples analyzed at KAUST and thru BOLD showing the total number of samples tested for each species (n), number of samples that provided a COI sequence, number of samples that failed, number of samples that yielded low quality sequences, and the number of samples that showed misidentifications in the databases.

Species name	n samples tested	n COI	n failed	n low quality	n mismatched
N. ferrugineus	3	2	0	0	1
S. fasciatum	3	3	0	0	0
A. pelagicus	22	17	5	0	0
A. superciliosus	26	19	4	0	3
I. oxyrinchus	45	38	4	1	3
H. elongata	7	5	2	0	0
C. altimus	17	6	3	0	8
C. amblyrhynchos	4	4	0	0	0
C. amboinensis	39	35	2	2	0
C. brevipinna	38	30	5	1	2
C. falciformis	11	11	0	0	0
C. leiodon	18	4	4	1	9
C. leucas	5	2	2	1	0
C. limbatus	26	6	13	1	6
C. longimanus	3	1	1	1	0
C. macloti	2	1	0	1	0
C. melanopterus	26	18	7	1	0
C. plumbeus	19	16	3	0	0
C. sorrah	50	40	8	1	1
G. cuvier	17	16	0	1	0
N. acutidens	20	16	3	0	1
P. glauca	33	8	21	0	4
R. acutus	3	2	0	1	0
S. lewini	149	143	2	0	4
S. mokarran	19	19	0	0	0
S. zygaena	40	23	1	0	0
Fins	11	7	2	2	0
TOTAL	**655**	**506**	**92**	**15**	**42**

APPENDIX B
PLATES

Plate 1.1. The wooden dhow, *lansh*, operating in UAE waters.

Plate 1.2. The fiberglass vessel, *tarad*, operating in UAE waters.

Plate 3.1. Group interview with Emirati fishermen at Al Aquamiah in Fujeirah.

Plate 3.2. J-hooks used by fishermen to capture sharks on longlines.

Plate 6.1. The Ras Al Khaimah landing site where sharks are auctioned along with other fish species.

Plate 6.2. Small bodied sharks being sold at markets for local consumption.

Plate 6.3. Shark meat cut and dried before being packaged into plastic bags.

Plate 6.4. Sharks unloaded from a dhow at the Abu Dhabi landing site before being loaded onto a truck.

Plate 6.5. Sharks being loaded onto trucks at the Sharjah landing sites and taken to processing facilities.

Plate 6.6. Sharks displayed at the Deira fish market in Dubai prior to auction.

Plate 6.7. Fins originating from Oman without their respective carcasses displayed at the Deira fish market prior to auction.

Plate 6.8. Gunny bags filled with dried fins from small bodied sharks originating from the UAE and Oman displayed for sale at the Deira fish market in Dubai.

Plate 6.9. Dried shark skins transported from Oman for sale in Dubai.

Plate 6.10. Removing fins at the Deira Fish market in Dubai after the end of the auction.

APPENDIX C

QUESTIONNAIRE IN ENGLISH AND ARABIC

OPENING STATEMENT:

My name is Rima Jabado, I am a PhD student at the United Arab Emirates University in Al Ain. The goal of this project is to learn more about the species of sharks found in the Arabian Gulf and their interactions with fisheries. Your participation in this survey is voluntary and confidential. I will record your name only for the purpose of record keeping. I will not share your individual answers with anyone outside of the research group. You do not have to answer any questions that you do not want to.

Date:	**Name of fisherman:**
Location:	**Age/Date of birth:**
Fisherman code:	❑ **Commercial fisherman**

SECTION A – BACKGROUND INFORMATION

1. At what age or in what year did you start fishing in the area? ________________
2. Do you come from a family of fishermen? ❑ **YES** ❑ **NO**
3. Is fishing the main way you earn your living? ❑ **YES** ❑ **NO**

If **NO**, what is/are your other occupations? ________________________________

4. At which times of the year do you usually fish? *If seasonal, indicate season start, end and determine season with most fishing effort*
   ❑ **All year** ❑ **Winter (12-2)** ❑ **Spring (3-5)** ❑ **Summer (6-8)** ❑ **Fall (9-11)**
5. How many days do you go fishing each month?__________________________
6. What is your position on the boat? ❑ **Owner** ❑ **Family member** ❑ **Captain** ❑ **Crew member** ❑ **No fixed position**

SECTION B- BOAT AND GEAR CHARACTERISTICS

7. What type of boat do you own or work on?
   ❑ **Wooden or Fibreglass ('dhow')** ❑ **Fibreglass ('tarad')**
8. What is the length of the boat? ________________ **ft**

9. What type of motors and how many does the boat have?
❑ **Inboard** ❑ **Outboard** **# of motors:____** **HP:____**

10. How many fishers, including yourself, work on the boat? ____________________

11. What is the duration of each trip?
❑ **0-6 hours** ❑ **6-12 hours** ❑ **12-24 hours** ❑ **1-2 days** ❑ **3-5 days**
❑ **>5 days**

12. At which times of the day do you usually fish?
❑ **6 am to 12 pm** ❑ **12 pm to 6 pm** ❑ **6pm to 12 am** ❑ **12 am to 6 am** ❑ **All day**

13. What are your main target fish species?
____

14. Which areas do you usually fish in? *Indicate areas on map* __________________

15. Which areas do you see/catch most sharks in? *Indicate areas on map* __________

16. What is the best time to catch sharks?
❑ **6 am to 12 pm** ❑ **12 pm to 6 pm** ❑ **6pm to 12 am** ❑ **12 am to 6 am** ❑ **Other________________**

17. What type of fishing gears do you use throughout the year? *Use illustrations*
❑ Drift and set gill nets ❑ Longline (many hooks)
❑ Trolling ❑ Handline (1 or few hooks)
❑ Traps (gargour) ❑ OTHER *Describe* ________________

18. In which of these gears do you catch sharks? *List all that apply*
____

19. In which of these gears do you catch small sharks (<1.5 m)?
❑ **Nets** ❑ **Longlines** ❑ **Trolling** ❑ **Other _____**

20. In which of these gears do you catch large sharks (>1.5 m)?
❑ **Nets** ❑ **Longlines** ❑ **Trolling** ❑ **Other _____**

21. In which ONE of these gears do you catch the <u>most</u> sharks? __________________

22. Which species of sharks do you catch in these gears?
____

23. What type of bait do you use to fish? ______________________________________

24. Is there a specific type of bait that attracts sharks most? _____________________

SECTION C- SHARK CATCHES

25. At which times of the year do you catch the most/least sharks?
Most________________ **Least _______________**

26. How many total sharks do you usually catch on a fishing trip in low season and high season? *Circle one*
LOW 0 1-3 4-10 11-20 >20 **HIGH 0 1-3 4-10 11-20 >20**

27. How many species of sharks are found in the Arabian Gulf/Indian Ocean?
______________ ❑ **Don't know**

28. Are sharks usually ❑ **accidentally caught** or ❑ **targeted** or ❑ **both**?
If **targeted**, which are the top shark species that are targeted?
____

29. Have fishermen in your community always fished for sharks?
❑ **YES** ❑ **NO** ❑ **Don't know**

30. Are sharks usually landed full? ❑ **YES** ❑ **NO** ❑ **Don't know**

31. Have you seen a difference in shark catches since you started fishing?
❑ **YES** ❑ **NO** ❑ **Don't know**
If **YES**, what difference and why do you think so?
____

32. Have you seen a difference in shark sizes since you started fishing?
❑ **YES** ❑ **NO** ❑ **Don't know**
If **YES**, what difference and why do you think so?
____

33. Do you think sharks are **more abundant**, **less abundant** or **the same** now compared to **10 years ago? ______ 5 years ago? ______ 2 years ago? ____**
If **LESS OR MORE**, why do you think so? ______________________________

34. Can you pinpoint the start of any changes in numbers to any particular time?
____

35. What do you do with sharks if you catch them?
❑ **Eat** ❑ **Sell** ❑ **Use as bait** ❑ **Discard (dead)**
❑ **Release (alive)** ❑ **Other _________**

36. Where and to whom are sharks usually sold?
____

37. How much can a whole shark be sold for and what does this price depend on?
____

38. How much can the fins be sold for and what does this price depend on?
____

39. What are the most valuable shark species and why?
____

40. Is your boat licensed to fish for sharks? ______________________________

SECTION D- PERCEPTIONS AND PARTICIPATION *Try to get information about the reasoning behind their answers*

41. Do you think we should be concerned about the future of sharks?
❑ **YES** ❑ **NO** ❑ **Don't know**

42. Do you think there should be regulations about the killing of sharks?

❑ **YES** ❑ **NO** ❑ **Don't know**

43. Do you know of any laws protecting sharks in the UAE?

❑ **YES** ❑ **NO** ❑ **Don't know**

If **YES,** which ones and are they enforced?

____

44. Do you think sharks should be protected?

❑ **YES** ❑ **NO** ❑**Don't know**

45. Do you feel that you are consulted or involved in government decisions on fisheries?

❑ **YES** ❑ **NO** ❑ **Don't know**

46. Would you want to be consulted or involved in government initiatives for the protection of sharks? ❑ **YES** ❑ **NO**

مقابلة الصيادين

كلمة الافتتاحية: اسمي ريما جباضو و أنا **طالبة دكتوراة** في جامعة الإمارات العربية المتحدة بالعين.هذا المشروع يهدف لمعرفة المزيد عن أنواع أسماك القرش المتواجدة في مياه الخليج العربي و تفاعلها مع مصايدها. تعد مشاركتك في هذا الاستبيان طوعية وتخضع لسرية تامة. سيتم تسجيل اسمك وبياناتك الشخصية لإستخدامها لهدف التواصل معك لمزيد من التفاصيل. ستتم مناقشة إجاباتك مع فريق البحث العلمي فقط. لك كامل الحرية بالامتناع عن الإجابة على أي سؤال.

التاريخ:	**إسم الصياد:**
الموقع:	**العمر / تاريخ الميلاد:**
رقم الصياد:	❑ **صياد**

القسم الأول: المعلومات الأساسية

1- في أي عمر أو في أي سنة بدأت الصيد في هذه المنطقة؟________________________

2- هل تنحدر من عائلة الصيادين؟ ❑ **نعم** ❑ **لا**

3- هل الصيد هو مصدر رزقك الأساسي؟ ❑ **نعم** ❑ **لا**

إذا كانت الإجابة **لا** ، ما هي الوظيفة / الوظائف التي تعمل بها؟_______________

4- في أي من أوقات السنة تصطاد فيها عادة؟ *اذا كان الصيد موسمي, حدد بداية ونهاية الموسم والموسم الأكثر اصطيادا فيه.*

❑ **طوال العام** ❑ **الشتاء** (12-2) ❑ **الربيع** (3-5) ❑ **الصيف**(6-8)

❑**الخريف** (9-11)

5- كم يومًا تذهبت للصيد خلال الشهر؟__________________________________

6- ما هي وظيفتك على متن المركب؟

❑ **المالك** ❑**عضو من أعضاء العائلة** ❑ **الربان** ❑ **من أفراد الطاقم** ❑ **غير ثابت**

القسم الثاني: خصائص المركب ومعدات الصيد

7- ما نوع المركب الذي تملكه أو تعمل عليه؟ ❑ **خشبي** ❑ **ألياف زجاجية**

8- ما هو طول المركب؟____

9- ما هو نوع وعدد المحركات في المركب؟ ❑ **داخلي** ❑ **خارجي** **عدد المحركات**: _____ **قوة المحرك**:______

10- كم عدد الصيادين الذين يعملون في المركب بما في ذلك انت ؟ ______________________

11- ما هي مدة كل رحلة صيد؟

❑ **0-6 ساعة** ❑ **6-12ساعة** ❑ **12-24 ساعة** ❑**1-2 يوم** ❑ **3-5يوم** ❑**<5 يوم**

12- ما الوقت المعتاد الذي تصطاد فيه؟

❑ 6 ص إلى 12 م ❑ 12 م إلى 6 م ❑ 6 م إلى 12 ص ❑ 12 ص إلى 6 ص ❑ طوال اليوم

13- ما هي الأنواع السمك الرئيسية الذي تستهدف اصطيادها؟ ____________________

14- ماهي المناطق الذي تصطاد منها عادة؟ *أوضح المناطق على الخريطة* ____________________

15- ما هي أنسب الأوقات لاصطياد أسماك القرش؟

❑ 6 ص إلى 12 م ❑ 12 م إلى 6 م ❑ 6 م إلى 12 ص ❑ 12 ص إلى 6 ص

❑ طوال اليوم

16- بأي المناطق التي تشاهد أو تصطاد فيها سمك القرش؟ *أوضح المناطق على الخريطة* __________

17- خلال السنة، ما هي معدات الصيد المستخدمة ؟ *استخدم الرسومات التوضيحية*

❑ هيالة أو ليخ ❑ منشلة

❑ تشخيط أو لفاح ❑ قرقور

❑ حدك أو الخيط (واحد او أكثر من الميادير) ❑ أخرى *اوضح* ____________________

18- بأي وسيلة من هؤلاء تصطاد سمك القرش؟ *عددها* ____________________

19- بأي من الوسائل التالية تصطاد بها أسماك القرش الصغيرة (<1.5م)؟ ❑ **هيالة أو ليخ** ❑ **منشلة** ❑ **تشخيط أو لفاح** ❑ **أخرى** ____________________

20- بأي من الوسائل التالية تصطاد بها أسماك القرش الكبيرة (>1.5م)؟ ❑ **هيالة أو ليخ** ❑ **منشلة** ❑ **تشخيط أو لفاح** ❑ **أخرى** ____________________

21- بأي **وسيلة** من الوسائل التالية تصطاد بها **أكثر** عدد من أسماك القرش ؟ ____________________

22- ما أنواع أسماك القرش الذي تصطادها عند استخدامك لهذه الوسائل؟ ____________________

23- ما نوع الطعم الذي تستخدمه؟ ____________________

24- هل هنالك نوع معين من الطعوم تستخدم لجذب أسماك القرش؟ ____________________

القسم الثالث: صيد سمك القرش

25- بأي من أوقات السنة تصطاد **أكبر** / **أقل** كمية من سمك القرش؟ **أكبر كمية** _____ **أقل كمية** _____

26- كم مجموع عدد أسماك القرش التي تصطادها خلال رحلتك المعتادة في الموسم الذي تقل فيه أسماك القرش وفي الموسم الذي تكثر فيه؟

ضع دائرة واحدة فقط **القليل** **0** **1-3** **4-10** **11-20** **> 20** **الكثير** **0** **1-3** **4-10** **11-20** **> 20**

27- كم نوعًا من أسماك القرش موجود في مياه الخليج العربي؟ ____________________ ❑ **لا أعرف**

28- هل أسماك القرش عادة ❑ **تدخل في معدات الصيد عن طريق الخطأ** أو ❑ **مستهدفة** أو ❑ **الإثنين معا؟**

إذا **مستهدفة**, ما هي الأنواع من أسماك القرش التي تستهدفها خلال الصيد؟ ____________________

29- هل كان الصيادين في مجتعمك يصطادون أسماك القرش دائما ؟ ❑ **نعم** ❑ **لا** ❑ **لا أعرف**

30- هل يتم احضار أسماك القرش بالكامل لليابسة عادة ؟ ❑ **نعم** ❑ **لا** ❑ **لا أعرف**

31- هل لاحظت فرقًا في معدلات صيد أسماك القرش منذ عملك في الصيد؟

❑ **نعم** ❑ **لا** ❑ **لا أعرف**

إذا كانت الإجابة **نعم**، ما هو الفرق و لماذا تعتقد ذلك؟ ______________________________

32- هل لاحظت فرقًا في أحجام أسماك القرش منذ بدأت الصيد؟

❑ **نعم** ❑ **لا** ❑ **لا أعرف**

إذا كانت الإجابة **نعم**، ما هو الفرق و لماذا تعتقد ذلك؟ ______________________________

33- هل تعتقد بأن أعداد اسماك القرش في **تزايد**، أو **تناقص** أو **في نفس المستوى** مقارنة ب:

العشر سنوات الماضية ____ **الخمس سنوات الماضية** _____ **السنتين الماضيتين** _____

وإذا كان **في تزايد أو تناقص**، فما السبب في رأيك؟ ______________________________

34- هل تستطيع التحديد بالضبط متى بدأت أي تغييرات في الأعداد سواء كانت في وقت معين أو بعد حادثة معينة؟ ______________________________

35- ماذا تفعل بأسماك القرش بعد اصطيادها؟

❑ **تأكلها** ❑ **تبيعها** ❑ **تستخدمها كطعم** ❑ **ترميها**

ميتة ❑ **تطلق سراحها** ❑ **أخرى** ____________

36- لمن وأين يتم بيع أسماك القرش؟ ______________________________

37- ما هو سعر سمكة القرش عند عرضها للبيع وعلام يعتمد هذا السعر؟ ____________________

38- ما هو سعر زعانف سمكة القرش وعلام يعتمد هذا السعر؟ ____________________

39- ما هي أنواع سمك القرش الاكثر قيمة ولماذا؟ ____________________

40- هل قاربك مرخص لإصطياد أسماك القرش؟ ____________________

القسم الرابع: التطلعات والمشاركة

41- هل تعتقد بأن علينا أن نهتم ونعتني بأسماك القرش؟

❑ **نعم** ❑ **لا** ❑ **لا أعرف**

42- هل تعتقد بأنه يجب وضع قوانين و تشريعات لحماية أسماك القرش؟

❑ **نعم** ❑ **لا** ❑ **لا أعرف**

43- هل تعلم بوجود أي قوانين تحمي أسماك القرش في دولة الإمارات؟

❑ **نعم** ❑ **لا** ❑ **لا أعرف**

إذا كانت الإجابة **نعم**, ما هي؟ ______________________________

44- هل تعتقد بأنه يجب علينا حماية أسماك القرش؟

❑ **نعم** ❑ **لا** ❑ **لا أعرف**

45- هل تشعر بأنك مستشار أو مشارك في قرارات الحكومة على المصايد؟

❑ **نعم** ❑ **لا** ❑ **لا أعرف**

46- هل تريد أن تكون مستشار أومشارك اذا كانت هناك مبادرات حكومية لحماية أسماك القرش؟

❑ **نعم** ❑ **لا**