IN THE WAKE OF THE DHOW: HISTORICAL CHANGES IN THE MARINE ECOLOGY AND FISHERIES OF THE PERSIAN GULF

by

DALAL AL-ABDULRAZZAK

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ABSTRACT

Marine ecosystems have been altered by human activities over millennia, but ecological and fisheries data used to measure these changes are typically only available over the last few decades. Moreover, recent databases, such as the United Nations Food and Agriculture Organization's (FAO) FishStat, do not reflect the true catch of seafood. The misreporting of catches, coupled with a lack of historical reflection can lead to mismanagement and poor policy decisions that jeopardize food security. While these issues are prevalent worldwide, they are especially problematic in places such as the Persian Gulf, where a rich seafaring history is at odds with recent mega-development projects.

Developing methods to integrate a diversity of data types is essential for better quantifying changes in the distribution and abundance of marine organisms, as well as for clarifying underlying causes of ecological change. Within the field of historical marine ecology, studies have relied on anecdotal evidence, such as written accounts by explorers and interviews of different generations of resource users, to demonstrate the former abundance of certain species and the extent of their ranges. Intercoder reliability tests show that people's perceptions of historical anecdotes are generally consistent and speak to the reliability of using people's perceptions to acquire quantitative data. In the Persian Gulf, anecdotes can be used to examine changes in dugong abundance and distribution and assessing the efficacy of current management targets.

Fishery catch reconstructions for the Persian Gulf from 1950-2010 show that officially reported catches potentially underestimate capture fisheries by a factor of 2, and that countries have primarily reported their artisanal and industrial catches, and substantially underreported their discards, recreational, subsistence, and illegal fishing sectors. In addition, recent advances in remote-sensing technology allow us to view stationary fishing gear such as weirs from

space and mitigate gaps in catch reporting.

This dissertation provides context to marine ecosystem management decisions in the Gulf. Because no empirical studies on the region have incorporated historical data, studies on the present ecosystems are based on distorted historical trends and impair our understanding of the management and policy prescriptions necessary for fisheries sustainability in the region.

PREFACE

Apart from Chapters 1 and 7 all chapters have been prepared as stand-alone manuscripts for submission to a peer-reviewed journal or as a book chapter. They are all currently either published, or at some state between submission and publication. I am the lead author on all papers and assumed primary responsibility for the design, implementation, analysis, and writing of co-authored papers. I am the sole author on Chapters 1 and 7. The contributions of my co-authors to Chapters 2-6 are summarized below.

Chapter 2 is co-authored with Dirk Zeller and Daniel Pauly, both of whom provided insights into the fishery reconstruction method at local, regional and global scales. A version of this chapter has been published as Al-Abdulrazzak, D., Zeller, D., Pauly, D. (2014) Understanding fisheries through historical reconstructions: Applications to fishery management and policy at different governance scales. In: *Marine Historical Ecology in Conservation: Applying the Past to Manage for the Future*. (Eds. J.N. Kittinger, L. McClenachan, K. Gedan, L.K. Blight), University of California Press.

Chapter 3 is co-authored with Dirk Zeller, Dyhia Belhabib, Dawit Tesfamichael, and Daniel Pauly. Dyhia Belhabib and Dawit Tesfamichael provided the reconstructed fishery catch data for Iran and Saudi Arabia respectively. Dirk Zeller and Daniel Pauly provided guidance on all stages of the work.

Chapter 4 is co-authored with Daniel Pauly who suggested a method for accounting for unseen weirs and provided guidance on all stages of the work. A version of this work was published as Al-Abdulrazzak, D., Pauly, D. (2013) Managing fisheries from space: Google Earth improves estimates of distant fish catches. *ICES Journal of Marine Science* **71,** 450-454.

Chapter 5 is co-authored with Robin Naidoo, Maria Lourdes Palomares and Daniel Pauly. Robin Naidoo assisted with the design and execution of Figure 1. Maria Lourdes Palomares provided data from the Falkland Islands and Raja Ampat, Indonesia. Daniel Pauly provided guidance on all stages of the work. This work was approved by the UBC Behavioral Ethics Research Board (BREB number H11-00140) and a version was published as Al-Abdulrazzak, D., Naidoo, R., Palomares, M.L.D., Pauly, D. (2012) Gaining Perspective on What We've Lost: The Reliability of Encoded Anecdotes in Historical Ecology. *Plos One* **7**.

Chapter 6 is co-authored with Daniel Pauly who suggested an approach for estimating ‘pristine’ dugong abundance, and provided guidance on all stages of the work.

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1 INTRODUCTION

Ecological depletion caused by overfishing predates all other human disturbance to coastal ecosystems, including pollution, degradation of water quality, and climate change. Yet, until recently, marine ecologists have tried to explain patterns of distribution and abundance based on short-term experiments and real time observations, without baseline data for the state of ecosystems prior to the industrial revolution and exponential human growth (Jackson, 1997). This short-sightedness has resulted in studying ecological states that were already degraded and concluding that they were healthy, despite overwhelming evidence to the contrary. This is manifest in many examples throughout the world, notably in the collapse of Jamaica's coral reefs, which were thought to be amongst the healthiest and most well studied reefs at the time (Lessios et al., 1984; Hughes, 1994).

The situation is even worse for fisheries science, a discipline that has long suffered from lack of historical reflection. Pauly (1995) coined the term "shifting baseline syndrome" to describe the incremental lowering of standards, with respect to fisheries, so that each new generation redefines what is "natural" according to personal experience and loses sight of how the environment used to be. These shifting ecological baselines have resulted in lowered expectations for natural abundances of marine animals and the ecosystem services they provide (Pauly, 1995b; Jackson et al., 2001). Populations of fishes, large vertebrates, marine mammals, and certain invertebrates thought to persist in "healthy" numbers today may, in fact, be small fractions of their historical abundances (Jackson, 1997; Rogers-Bennett et al., 2002; McClenachan, 2009; Saenz-Arroyo et al., 2005). Historical accounts from the 1700s and early 1800s often mention seas teeming with large fish, yet accounts like these are virtually unheard of today. Lotze and Worm (2009) showed that across 256 case studies that reported absolute abundance estimates of historical and recent population sizes, populations were depleted by 89% on average from their historical baseline. Since 1500, at least 20 marine species have become globally extinct, including the Caribbean monk seal, Steller's sea cow, and the great auk (Dulvy et al. 2009). At local or regional scales, Dulvy and colleagues (2003) reported 133 marine extirpation and extinctions during the 19^{th} and 20^{th} centuries.

These ‘ghosts’ of former marine ecosystems hold the key to understanding ecological change and help demonstrate achievable goals for the restoration and management of coastal ecosystems (Jackson et al. 2001). Historical marine ecology is “the study of past human-environmental interactions in coastal and marine ecosystems and the ecological and social outcomes associated with these interactions” (Kittinger et al. 2014). The field developed out of the growing realization that humans have impacted marine ecosystems over long time scales, but that data used to study marine ecosystems are often over much shorter time scales. In the majority of cases, historical ecology relies on information originally intended for another purpose, and transforms them to meet the standards of modern scientific analysis. Thus researchers looking to answer these ecological questions began to borrow from a variety of fields, including archaeology, geography, history, anthropology, etc., and diverse sources, such as oral histories (Sáenz-Arroyo et al. 2005), restaurant menus (Van Houtan et al. 2013), and photographs (McClenachan 2009), to establish a deeper understanding of how humans have altered ecosystems through time.

Just as the history of societies can inform present day human affairs, the history of human-ocean interactions can help shape our understanding of marine resource use. As historian David McCullough has once written, “[h]istory is a guide to navigation in perilous times. History is who we are and why we are the way we are” (McCullough 1984). Unlike ecologists, who rely on a coding process to strip historical evidence of its richness and variety (Chapter 5), historians must rely on very subjectivity of evidence to understand both the objective past and the subjective interests of those who observed it, as well as their audience, and why the artefact was preserved through the centuries. Historians keep people and culture squarely in their sights, while marine ecologists see humans mainly as the instruments through which ecosystems are altered. Thus, historians will hardly ever be able to provide ecologists with the hard quantitative data that they desire. However, anecdotal evidence taken in quantity, can produce a rough picture of past ecosystems and help to detect changes in the abundance or distribution of marine organisms, declines in the average size or relative abundance of targeted species, and other commonly accepted signals of overexploitation and ecosystem change (Jackson 1997).

Thus, the research questions answered in this dissertation are centered over three fundamental questions: How much has the baseline shifted for fisheries and ecosystems in the Persian Gulf?; What are the trajectories, scale, and tempo of these changes?; How can we use the insights gained from historical marine ecology to ameliorate the degradation of marine resources and biodiversity in the Persian Gulf (Figure 1.1)?

Answering these questions is complicated and requires relinquishing quantitative precision, so often demanded from fishery science, in favor of generality and realism. However, general principles can emerge from studies that describe and predict long-term consequences of overfishing and/or habitat destruction (Jackson et al. 2011). Conventional science's obsession with precision is misguided, focusing on recent fluctuations of few percent, while ignoring extraordinary losses in the past. In other words, we miss the signal by wholly focusing on what is all too commonly statistical noise (Jackson et al. 2011).

For many centuries, dhows littered the coasts of the Persian Gulf. They served as the link between the Persian Gulf pearl diving, clove farming in Zanzibar, the ivory and slave expeditions into the East African interior, and the date groves of East and Southeast Arabia (Villiers, 1940). Indeed, prior to the discovery of oil in the late 1930s, fishing and pearl diving formed the pillars the region's economy (Lorimer, 1908; Lorimer, 1915). Aside from pearling, there were few — if any – employment opportunities for the male populations of most Gulf ports. Most divers and dhow crews were unemployed for the vast majority for the year, making long-distance trading dhows the only employment opportunity (and a seasonable one at that).

While still common today, dhows are often considered relics of the region's economic history. They are often rapidly being replaced by motorized vessels and have come to symbolize a reliance on the sea that has lessened in recent times, perhaps even the marginalization of fisheries as being irrelevant to the region's prosperity and development. It is precisely this lessening reliance on the sea that serves as the main motivation for the research questions asked in this dissertation: What can records from the past tell us about the current and future state of marine ecosystems in the Gulf? What changes occurred before we started looking?

I examine some of the causes of shifting baselines, such as incomplete accounting of all fishery sectors (Chapter 2). Since 1950, fisheries landings data have been compiled by the United Nations Food and Agriculture Organization (FAO) as part of an effort to collect, analyze, and disseminate information related to food, agriculture and nutrition (Ward, 2004). This global capture fishery database provides the only time series of capture fisheries landings and has served as the basis for many global and regional studies that interpret fisheries trends (Pauly and Christensen, 1995; Watson and Pauly, 2001; Tyedmers et al., 2005; Swartz et al., 2010). Despite their wide usage, it is now recognized that these reported data are incomplete and often underestimate or omit the contribution of small-scale sectors such as subsistence and recreational fishing, as well as discards (Watson and Pauly, 2001; Clarke et al., 2006; Zeller et al., 2006; Zeller et al., 2007). In Chapter 2, I present examples of the discrepancy between reported and reconstructed catches and discuss the implications of such misreporting for management and fisheries policy on national, regional, and global scales.

To understand the true magnitude of global fisheries catches, Pauly (1998) outlines the rationale and the methods for reconstructing catches incorporating all available records, including anecdotal information and grey literature. I adapt the 'catch reconstruction' method of Zeller et al. (2007) and apply it to the countries in the Persian Gulf to estimate biomass removals from 1950-2010 (Chapter 3). I demonstrate the need for full accounting of marine fisheries catches, and examine the consequences for the region's fisheries policy and food security.

In the absence of complete accounting for fisheries sectors, innovative techniques are necessary to obtain crucial fishery catch statistics. Recent advances in remote-sensing technology allow us to view fishing practices from space and mitigate gaps in catch reporting. In Chapter 4, I use Google Earth to count intertidal fishing weirs along the coast of the Gulf. Weirs have been an important gear of many historic coastal communities prior to the global spread of industrial fishing in the 1950s. However their true impact has not been considered until recently, due to the marginalization of small-scale fisheries (Pauly 2006). The results, which show regional catches up to 6 times more than what is officially reported, provide the first example of fisheries catch estimates from space and point to the potential for remote-sensing approaches to validate catch statistics and fishing practices in general.

Finally, in order to set appropriate management targets for the restoration and management of coastal ecosystems, retrospective data are necessary to help clarify the underlying causes and rates of ecological change (Jackson et al. 2001). Within the field of historical marine ecology, methods have been developed to join historical narratives with traditional ecological analyses in order to better understand the long-term trajectories and causes of ecosystem change (Baum et al., 2003; Myers and Worm, 2003; Pandolfi et al., 2003; Lotze and Milewski, 2004; Rosenberg et al., 2005; Saenz-Arroyo et al., 2006; Lotze et al., 2006; McClenachan et al., 2006; Ferretti et al., 2008; Jackson, 2008; McClenachan and Cooper, 2008). Yet, do we all agree on how these anecdotes are interpreted? In Chapter 5, I use intercoder reliability tests to examine the way that different people interpret anecdotes extracted from historical narratives and show that people's perceptions of historical anecdotes are generally consistent, thus validating the method.

I then apply the method to establish baselines for dugongs in the Persian Gulf (Chapter 6), which, at present, is home to the second largest dugong population after Australia. I describe the historical ecology of the Persian Gulf dugong within the larger context of Persian Gulf ecosystems. I compile and analyze historic data on dugong encounters to estimate long-term changes in population size and map changes in range distribution through time. I look at the ways that changing social histories have shaped demand for dugongs through time and make recommendations for the management and conservation of this species in light of the new baselines.

In Chapter 7 I conclude by discussing some of the applications and limitations of my research and reflect on the possible root causes for the degradation of the Gulf's marine ecosystems. I then propose possible management actions and future research directions to build upon the work presented here.

This dissertation examines issues of shifting baselines, seafood security, gaps in catch reporting systems, and the ways in which important quantitative data can be estimated in the absence of full information. It explores the ways that historical reconstructions can be used to better understand and manage marine ecosystems in the Gulf. It is my hope that this dissertation at intersection between fisheries statistics, ecology, remote sensing, and history, will provide give context to the rapidly changing coasts and ecosystems of the Persian Gulf.

Figure

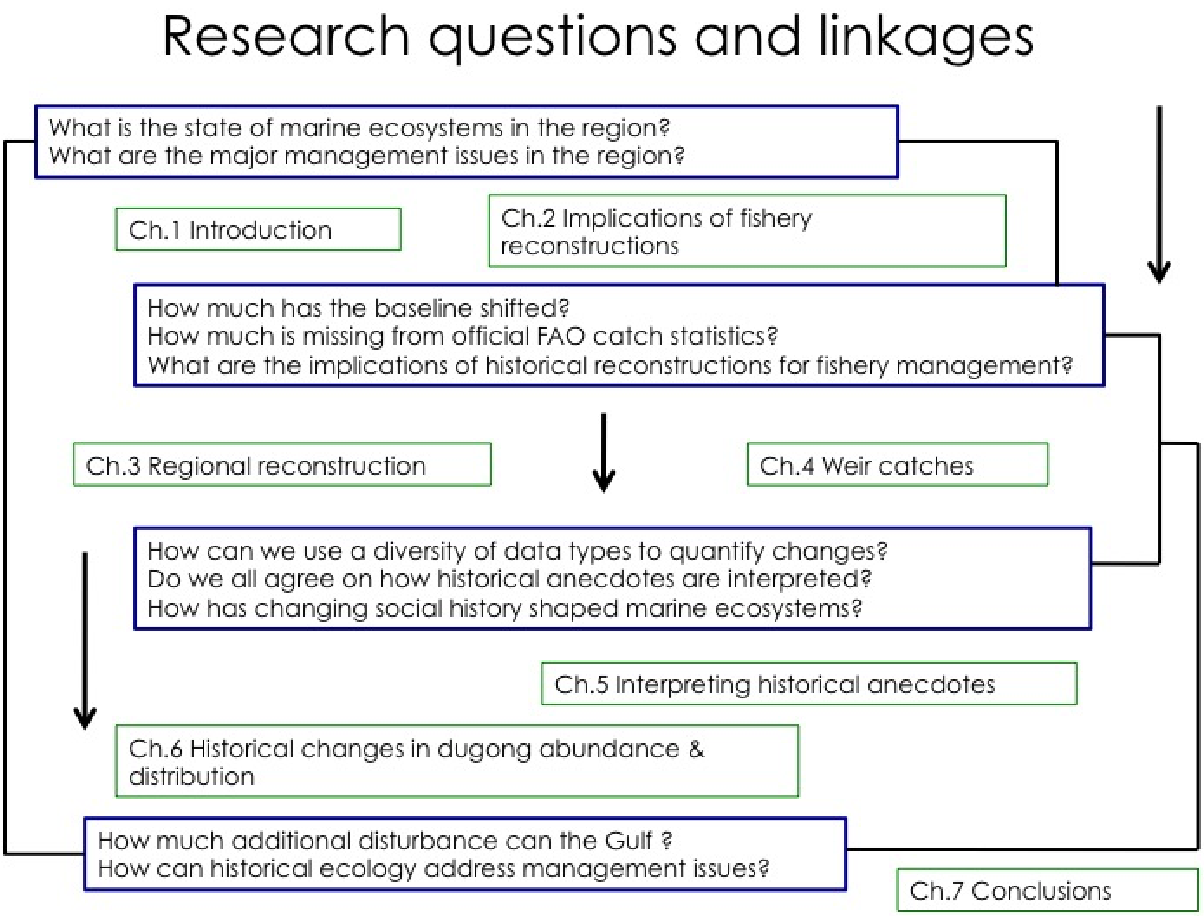

Figure 1.1 Flow chart of main research questions and chapter linkages.

2 UNDERSTANDING FISHERIES THROUGH HISTORICAL RECONSTRUCTIONS: IMPLICATIONS FOR FISHERY MANAGEMENT AND POLICY[1]

[1] A version of this chapter has been published. Al-Abdulrazzak, D., Zeller, D., Pauly, D. (2014) Understanding fisheries through historical reconstructions: Applications to fishery management and policy at different governance scales. In: *Marine Historical Ecology in Conservation: Applying the Past to Manage for the Future*. (Eds. J.N. Kittinger, L. McClenachan, K. Gedan, L.K. Blight), University of California Press.

Introduction

Arguably, the single most important piece of information about a fishery is the total catch, by species, over time (Froese et al., 2012). Catch data increases our knowledge of a fishery by determining two essential things: 1) the scale of the fishery (Zeller et al., 2006, Zeller et al., 2011a); and 2) the status of the stock over time (Froese et al., 2012, Kleisner et al., 2012). Understanding long-term trends (decades to centuries) in catch is critical to managing fisheries sustainably because it allows us to assess the ‘health’ of a fishery within the context of species lifespans, human impacts, environmental disturbances such as El Niño events, as well as long-term changes in oceanographic regimes. Temporal trends also allow us to establish viable restoration targets based on past abundances of species.

Since its creation, the Food and Agriculture Organization of the United Nations (FAO) has been tasked to collect, analyze, and disseminate information related to food, nutrition, and agriculture, including fisheries (Ward, 2004). Since 1950, the FAO has assembled, standardized and distributed annual marine fisheries landings reported by its member countries, broken down by taxa as well as by 19 large statistical areas. This global capture fishery database, known as FishStat (www.fishstat.org), provides the only global time series of national fisheries landings (Garibaldi, 2012), and a detailed analysis of its contents is published every two years (see e.g., FAO 2011).

FishStat has served as a major source of data in many global and regional fisheries studies that analyze and interpret fisheries trends. These global studies include, among others, the first estimation of the primary production required to sustain global fisheries (Pauly and Christensen, 1995), evidence that humans are ‘fishing down’ marine food webs (Pauly et al., 1998), the first global estimation of fuel usage by fishing fleets (Tyedmers et al., 2005), a prediction that fisheries will collapse in 2048 (Worm et al., 2006), and fish biomass trends since 1950 (Tremblay-Boyer et al., 2011, Watson et al., 2012). FishStat data have also formed the core of global catch mapping efforts (Watson et al., 2004), which in turn enabled a greater understanding of the spatial expansion of global fisheries (Swartz et al., 2010a), and conversely, the manner in which they supply fish markets (Swartz et al., 2010b).

Besides scientific studies, FAO data have been used to inform fisheries management policy. For example, organizations such as the World Resources Institute often use FAO catch data to estimate national earnings from fish exports, production trends, and per capita fish consumption rates. Additionally, the ‘Marine Trophic Index’ (which was derived from the ‘fishing down’ concept of Pauly et al., 1998), is partly based on FAO catch data and is one of the indicators used to measure the biodiversity of large fishes by the countries party to the Convention on Biological Diversity (Pauly and Watson, 2005).

Despite their wide usage, numerous studies have called into question how closely FAO data resemble reality (Zeller et al., 2006, Zeller et al., 2007a, Clarke et al., 2006, Watson and Pauly, 2001). Because catch data and other fishery statistics are generally submitted to FAO by national entities, the quality of FAO data is dependent on the accuracy and reliability of statistical data collection within these member countries (Garibaldi, 2012). Thus, perverse incentives (see Watson & Pauly 2001, for the case of China), governmental or institutional change (e.g., see Jacquet et al., 2010; Tanzania), or political interference (e.g., Bhathal and Pauly, 2008; India), can cause such statistical reporting systems to underperform, or decay.

In general, FAO data are recognized as incomplete in many regions; more than half of FAO member countries failed to report their annual fishery statistics over the past decade (Garibaldi 2012). Additionally, FAO does not account for discards in its database, and thus implicitly requires countries to report fisheries ‘landings’ rather than ‘catches’. In contrast, at least one regional fisheries management organization, the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), includes discarded catches obtained via on-board observer programs into their catch database (although they do not label these as discards). Overall, however, the contribution of many sectors, including small-scale fisheries, recreational, and illegal catches are frequently absent or substantially under-reported (e.g., Zeller et al. 2007, 2011a, 2011b; Jacquet et al. 2010; Le Manach et al. 2012).

The chronic misreporting of fisheries data is not trivial; the consequences extend far beyond resource conservation and can lead to inequitable policy decisions that jeopardize food security (Jacquet et al. 2010; Le Manach et al. 2012), underestimate the contribution of small-scale fisheries to rural food security and GDP (Pauly, 2006, Zeller et al., 2006), and incorrectly assume global fish catches are increasing (Watson and Pauly, 2001). This may lead to negative policy outcomes, such as when misreported catches undermine stock assessments and management plans (Zeller et al., 2008), potentially leading to overoptimistic investments or between-country access agreements, which consequently subvert the sustainability of fisheries.

Breaking this cycle requires estimating overall national catches from independent data if possible, or by complementing the data provided by countries to the FAO with estimates for all missing or under-reported components. Pauly (1998) suggested that a complex, multifaceted sector of a given country's or territory's economy cannot operate without casting a 'shadow' onto the other sectors of that economy (ranging from boat building, repairs and supplies to domestic fish consumption). Therefore, if catch data are unavailable, they can be indirectly inferred from other related sectors.

These ideas were operationalized by Zeller et al. (2007), who devised an approach for retroactively estimating or 'reconstructing' the catch of neglected fisheries, and thus to obtain a more accurate picture of historical catch patterns and trends. Often, catch reconstructions rely on information and data sources originally intended for other purposes. Such information can be found in a number of sources, including unpublished studies, grey literature, maritime records, aerial photos, interviews with fishers, or from published studies and surveys whose primary focus is other than catch reporting. These non-traditional sources can be used to derive estimates of catch, catch rates per unit area, per fisher or *per capita* for a given time period. Using a series of such data 'anchor points' (Zeller et al. 2007), total catch time series estimates can then be derived for years with missing data using interpolations.

Fishing predates all other human activities in the ocean (Jackson et al., 2001), and data sets compiled over longer periods (decades to centuries) can be used to detect greater declines in large fishes (McClenachan, 2009). However, the reconstruction method developed by Zeller and colleagues typically starts at 1950 for several reasons, including: (1) this is the year when FAO began to publish its annual 'Yearbook' of global fisheries statistics, (2) in many parts of the world, this time period marks the start of industrialized fishing; and (3) because data availability allows for the development of more robust time catch series. These catch reconstructions are necessary to ascertain fishery trends and develop restoration targets, which are critically important for fishery management.

Marine fisheries catches have been successfully reconstructed in many regions of the world, including for Pacific Island countries and territories (Zeller et al., 2006a, 2007), East Africa and the Western Indian Ocean (Jacquet et al., 2010; Le Manach et al., 2012;), South America (Wielgus et al., 2010), Europe (Zeller et al., 2011b) and the high arctic (Zeller et al., 2011a). A complete coverage of catch reconstructions for all maritime countries of the world will be achieved by the *Sea Around Us* in 2015.

Here we use the basic conceptual framework and approach outlined by these studies to discuss reconstructions and their policy implications at three different scales, including national, regional, and global scales.

National

To illustrate the need and scope for reconstructing catches at the national level, we use the nation of Kuwait as an example (Also see Chapter 3). Kuwait, like many countries, possesses a diversity of coastal fishery types, and faces challenges in data collection, accuracy, and lack of understanding of historical trends in fisheries. Despite their predominately small-scale nature, Kuwait’s fisheries remain the second most important natural resource after oil (Carpenter et al., 1997). For centuries prior to the discovery of oil in 1938, pearl diving dominated the country’s economy. Indeed, at the height of pearling, 80% of the world’s natural pearls came from the Persian Gulf. However, the production of Japanese cultured pearls in the 1920s, the global recession in the 1930s, World War II, and the production of crude oil in the late 1940s dealt consecutive blows to the Gulf’s pearl industry, leading to its rapid demise.

In general, Kuwait’s fisheries are poorly managed and officially reported catch is haphazard at best. Substantial sectors are missing from reported data including recreational catches, discards by the shrimp fishery, and illegal catches. Using catch reconstruction methods (see Chapter 3), we can see that the reported catches for Kuwait’s artisanal and industrial fisheries potentially underestimate total catches by a factor of 7 over the 1950-2010 time period (Figure 2.1; Appendix A.3). Such substantial differences between reported landings and reconstructed total catches illustrate the magnitude of the data reporting problems faced by countries with small-scale, data-poor fisheries (e.g., Zeller et al 2007, 2011a, 2011b). It also points at a fundamental problem of fisheries catch data being viewed purely from a commercial, market perspective, which accounts only for what is landed and utilized for commercial sale or export (Zeller and Pauly, 2004, Pauly and Zeller, 2003). In contrast, given the global move towards viewing and managing fisheries on an ecosystem scale (Pikitch et al., 2004), fisheries data collection, and hence catch accounting, needs to account for total catches. This requires comprehensive accounting for the entire catch of fish and invertebrates, including the recording (or estimation) and reporting of discarded catch, and the estimation and reporting of catches from unregulated sectors such as subsistence, cultural, and recreational fisheries. Given the high costs of monitoring such sectors using traditional catch monitoring approaches, alternative methods such as utilizing national surveys and census opportunities have been suggested for the more widely dispersed and hard to monitor small-scale and recreational fisheries sectors (Zeller et al., 2007). Al-Abdulrazzak & Pauly (2014) (Also see Chapter 4) use Google Earth to ‘groundtruth’ weir fish catches, speaking to the potential of satellite technologies for monitoring fisheries remotely, particularly in areas that were once considered too dangerous or expensive for fisheries surveillance and enforcement.

The reconstructed time series also illustrates the magnitude and importance of discards (Figure 2.2). In terms of tonnage, discards amounted to almost 10 times the total amount of landed finfish in Kuwait. Although local fisheries are currently not essential to Kuwait's food security (because much of the country's food resources are imported), recent climate change studies predict that the Persian Gulf may lose over 50% of its fisheries in the coming decades (Huelsenbeck, 2012), prompting a greater demand for imports in the near future. To adequately prepare for climate change impacts, as well as for sound fisheries management, managers should consider policies that reduce discarding practices. Such approaches may also help bolster local food security policy as fisheries resources shift under global climate change. In general, a more complete estimate of total fisheries extractions is fundamental to effectively managing fisheries resources in order to mediate potential threats to food security and to assess ecological resilience. The future success of many countries relies, in part, on their ability to keep pace with an increasingly global economy while maintaining a healthy supply of resources for domestic purposes.

Regional

The importance of historical reconstructions for food security policy can also be examined from a regional scale. Historical catches have been reconstructed for all small island states or territories of the Caribbean (e.g., see Frotté et al., 2009, Harper et al., 2009), thus enabling some generalizations. The first is that, in the Caribbean, catches are systematically underreported, from 32-35% in Guadeloupe and Martinique to 430% in Jamaica, with a median of 250% for all islands in this region. Such underreporting—which includes only a small amount of the discarded fish that is reported to FAO—implies that the fisheries of the Caribbean region are systematically underreported in terms of their contribution to food security and GDP, just as in other areas of the world (Zeller et al., 2007b).

As is the case for the Caribbean, catches by Pacific island countries have also been systematically under-reported (see e.g., Zeller and Harper, 2009, Harper and Zeller, 2011). Most Pacific small-island countries have shifted their focus to lucrative pelagic tuna fisheries. These fisheries are conducted almost exclusively through foreign fishing interests, either via fishing access agreements, through so-called joint venture or charter operations, or even reflagging of foreign vessels to permit easier and cheaper access to Pacific island countries' waters. Fishing access fees often provide a major share of a country's foreign exchange earnings in this region (Gillett et al., 2001, Gillett, 2011, Gillett, 2009), but such approaches also discount future production from domestic fisheries, which may provide for the current food security in a region with few other domestic protein sources (SPC, 2008).

Fishery reconstructions can also benefit public policy by providing improved catch statistics and a better accounting of the role of fisheries in national, regional, and global economies. For example, reconstructed catches for Mozambique and Tanzania (Jacquet and Zeller, 2007a, Jacquet and Zeller, 2007b, Jacquet et al., 2010) contributed directly to changes in how these two countries estimate and report their data. Mozambique, which was shown to have 6 times higher catches than the reported data suggested at the time (mid 2000s), has subsequently been able to improve its catch sampling program, which is reflected in substantially improved catch data in recent years. Such increased accuracy of reported catch data can assist during foreign fishing access negotiations, which often focus on a perceived 'surplus production'. Fisheries reconstructions can reveal the true catch landed by domestic fisheries, thus preventing excessive allocation to foreign fishing and reducing the likelihood of "selling the same fish twice" to both domestic and foreign fishers operating in the same waters (see also Le Manach et al., 2012a, Le Manach et al., 2012b).

Another example comes from Tanzania, where catch statistics from a major region of the country (the island group of Zanzibar), despite being collected by the Zanzibar fisheries agency, were missing entirely from the data reported by the government of

Tanzania to FAO (Jacquet and Zeller, 2007b). These catch statistics were retroactively included as of 2000 (Jacquet et al., 2010). This reporting oversight was likely brought to light through catch reconstructions, which were shared with local authorities, thus influencing the subsequent data correction. In the Pacific Islands, local catch data are critical for understanding food security, and household income and expenditure surveys are undertaken periodically to assess fisheries performance and importance to local economies.

Global

Reconstructed time series can also be used to influence policy in the international arena. For example, in recent years the representatives of Caribbean countries sided with Japan in voting for whaling in successive meetings meeting of the International Whaling Commission, citing the need to maintain a “balance in the ecosystem” (Swartz and Pauly, 2008). Robust catch time series data, which include all withdrawals from fisheries ecosystems, can provide an important first step in provisioning data for ecosystem-based fisheries management, and one that is required for any kind of ‘balance’ to be assessed. This is especially important as it can be shown that fisheries, through their catches, have strong impacts on the structure and functioning of Caribbean marine ecosystems, while marine mammals in general, and whales in particular, have only negligible effects on these ecosystems, even when abundant (Gerber et al., 2009).

One major insight emerging from catch reconstructions is the global footprint of fisheries, and the full extent of living marine resource extraction. Reconstructions are illustrating the trajectories of fisheries, which can contrast with official reported statistics and challenge existing assumptions about global trends. For example, contrary to the FAO’s (2011) description of global fisheries being ‘stable’, reconstructed catches, when pooled for the whole world, show a rapidly declining trend. This suggests that increased catches from newly exploited areas are no longer replacing those from depleted stocks, as was the case for the last few decades when geographically expanding fisheries masked the overfishing of traditional stocks (Swartz et al., 2010a). These insights, which have critical consequences for the way global fisheries are managed, are not possible without a historical perspective.

Conclusion

In conclusion, when fisheries managers rely solely on conventional quantitative data (i.e., data collected from mainly commercial fisheries using logbook or landings site/port or market sampling) catch data often suffers from massive underreporting. Such approaches can result in incorrect assumptions that small-scale fishery catches are small or negligible, resulting in inappropriate management, often with unintended outcomes and consequences both for fisheries resources and coastal communities. In many areas of science, researchers are paying more attention to methods that make use of imperfect records of the past. Researchers are accessing and using a wide range of ‘nontraditional’ sources such as historical anecdotes, which can be “as factual as a temperature record” (Pauly, 1995). As we show in the context of fisheries reconstructions, marine historical ecology approaches can counter the underestimation of traditionally neglected sectors, and the shifting baselines syndrome, which can result in mismanagement of fisheries resources.

Despite data uncertainties and the need to appropriately qualify data assumptions, catch reconstruction approaches are preferable to the alternative, which assumes low levels of catch, or even worse, leaving whole sectors out of reported data, which may be erroneously interpreted as ‘zero’ catch in the policy and management arena (Zeller et al., 2006). Such ‘zero’ interpretations of missing data components will certainly be more misleading than reconstructed estimates (despite uncertainties), especially if reconstructions remain conservative. Some managers and practitioners may be understandably uneasy with the imprecisions of such approaches due to uncertainty of the data and information sources underlying catch reconstructions, rather than on the trends and improved accuracy (i.e., accounting for sectors ignored in reported data).

However, as the economist John Maynard Keynes is attributed as saying, “It is better to be vaguely right than precisely wrong.”

With increased availability of historical fisheries catch reconstructions, fisheries managers and policymakers will be able to focus on trends in the available data rather than focusing on the uncertainty surrounding these data (Rosenberg et al., 2005). We hope an increased recognition of the validity and value of such approaches will help inform much-needed shifts in fisheries data collection and accounting towards considering and embedding fisheries in long-term reconstructions of marine ecosystems. As we show above, the incorporation of missing fisheries sectors often results in distinctly different baselines of past catches and these can have strong policy and management implications.

Even among fisheries scientists, there remain debates about the global status of fisheries, and even the value and need for basic fisheries data such as catch (Pauly et al., 2013). Many believe that rigorous quantification of the uncertainties surrounding stock assessments and the subsequent delivery of results to managers in the form of risk assessments sufficiently addresses the overfishing crisis (Pauly and Zeller, 2003). Yet, the major challenges in fisheries are ones that are based in the realm of public policy. Issues of equitable resource allocation require public involvement, participatory democratic planning, and provisioning of decision-making with the most accurate and reliable data. As we show here, fisheries reconstructions can provide a critical long-term view on fisheries performance, sectoral contributions, and risks associated with various management strategies (e.g., not managing discards appropriately).

Fisheries reconstructions and other data from marine historical ecology can be critical in informing the public and the public policy decision-makers who represent them, of the true status and trend of fisheries and their associated effects on ocean health (Pauly and Zeller, 2003). Findings from marine historical ecology will continue to be challenged, but continuous efforts on behalf of the scientific and practitioner community to effectively communicate this emerging area not only to scientific colleagues, but also to the policy makers and their constituents, the general public are making headway. Historical reconstruction approaches have much potential to remove ‘lack of data’ from the list of excuses used to maintain the *status quo*, and increase public transparency and involvement in fishery policy by the true owners of the marine resources, the present and future global citizens.

Figures

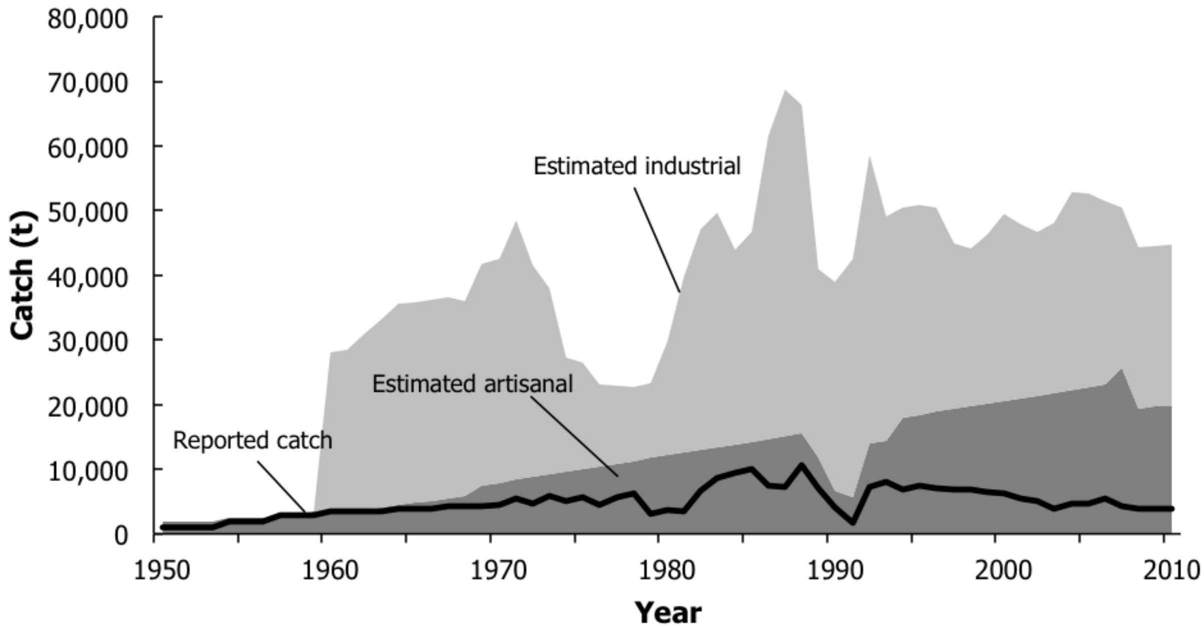

Figure 2.1 Reconstructed estimates of small-scale and industrial catches in Kuwait compared to officially reported catch.

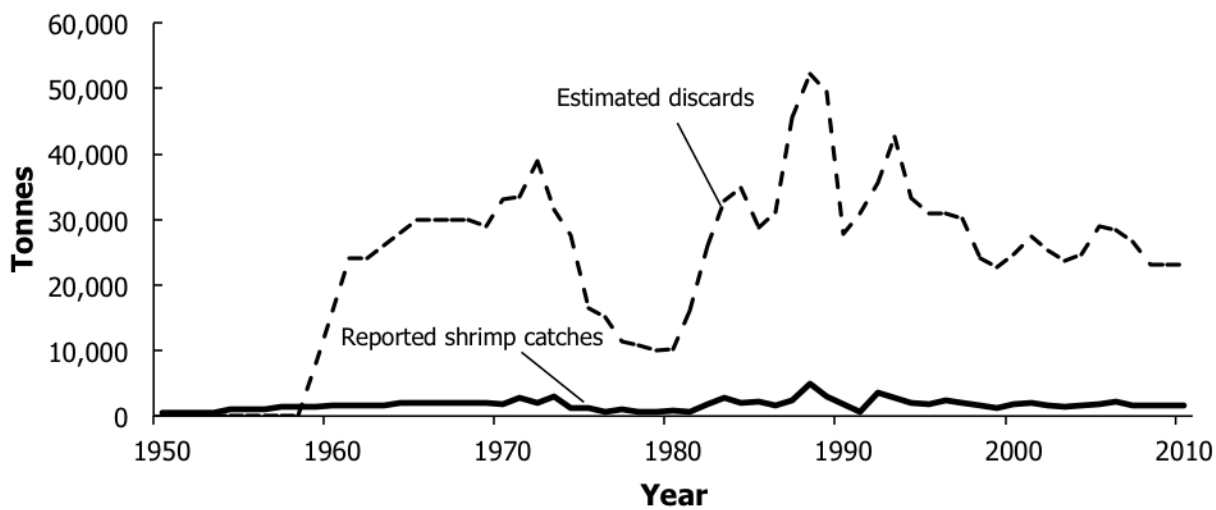

Figure 2.2 Estimated discards from Kuwait's industrial shrimp fishery.

3 A BRIEF (AND RECENT) HISTORY OF MARINE FISHERIES CATCHES IN THE PERSIAN GULF[2]

[2] A version of this chapter is in review as a journal article. Al-Abdulrazzak, D., Zeller, D., Belhabib, D., Tesfamichael, D., Pauly, D. A brief (and recent) history of the Persian Gulf's marine fishery catches.

Introduction

The Persian Gulf* is a semi-enclosed body of water, situated within a subtropical, hyper-arid region of the Middle East. It is bounded by the Shatt al-Arab river delta in the north and by the Strait of Hormuz in the south (Figure 3.1). It is bordered by Bahrain, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates (UAE), all of whom are 1978 signatories of the Regional Organization for the Protection of the Marine Environment (ROPME).

Because of its relative shallowness and good water quality, the Gulf supports highly productive coastal habitats, including intertidal mudflats, seagrass, algal beds, mangroves, and coral reefs (Price, 1993; Sheppard et al., 2010; Sale et al., 2011). These habitats support important commercial fisheries as well as endangered species such as the green turtle (*Chelonia mydas*) and the dugong (*Dugong dugon*). Though the Gulf supports a variety of productive habitats, and contains a number of endemic species, it is less biologically diverse than the adjacent Indian Ocean (Khan and Munawar, 2002).

For hundreds of years prior the discovery of oil, the region was sparsely populated by nomadic and semi-nomadic people, who depended on fishing, pearling, and maritime trade through dhows (Streeter, 1886; Lorimer, 1915; Villiers, 1940). Indeed, archaeological records indicate that fisheries have been a significant economic activity for the people of the region since the 6th millennium BC (Beech, 2002). However, the discovery of oil in the late 1930s and the subsequent industrial boom in the 1970s brought enormous wealth to the region, and with it intense economic activity with far reaching environmental, social, and cultural implications for the Gulf's ecosystems (Khan and Munawar, 2002). Presently, fisheries are the second most important natural resource after oil and gas, and the most important renewable resource (Carpenter, 1997; Sale et al., 2011; Grandcourt, 2012). Besides their contribution to the region's

* Although the name of this body of water remains contentious, the term recognized by UNCLOS is used here.

food security, fisheries also provide a source of income, cultural heritage, and recreational opportunities to the Gulf's coastal population.

Present-day fisheries are multi-species and multi-gear, and mostly artisanal in nature, with the exception of trawlers that target shrimp a few months out of the year. Little information is available on the region's fisheries, particularly on a regional level. Traditional wooden dhows and fiberglass boats are currently the most common vessels, while hook-and-line, gillnets, hemispherical wire traps (*gargoor*), and weirs (*hadrah*) are the most common gears. In general, fisheries predominantly target demersal species in the south and west, while shrimp and pelagic fish species are targeted in the north (Sale et al., 2011; Grandcourt, 2012). According to the United Nations Food and Agriculture Organization (FAO), the fishery potential in the Gulf is estimated to be 8 times greater than that of the Gulf of Oman (Kardovani, 1995; Sale et al., 2011).

Existing fisheries regulations aim to control effort, however many species in the Gulf are presently overfished and fishing effort exceeds that needed to extract Maximum Sustainable Yield (MSY) for most demersal species (Samuel, 1988; El Sayed, 1996; Grandcourt et al., 2003; Dadzie et al., 2005; Grandcourt et al., 2010; Grandcourt, 2012). In addition, stock assessments are rare and most catch data are recorded to family level only, making it impossible to use single-species approaches for assessments, for example catch-at-age models (Sale et al., 2011).

Since its establishment in 2001 the aim of the Regional Commission for Fisheries (RECOFI), has been to "promote the development, conservation, rational management and best utilization of living marine resources, as well as the sustainable development of aquaculture." In 2012 RECOFI agreed on minimum data reporting that includes catch and effort data separated by gear. However, these data are not readily disseminated and certain sectors such as catches by weirs are missing (Al-Abdulrazzak and Pauly, 2014). In addition, the 2012 decision is based on each member country setting their own standards, which can result in no reporting at all, as was the case in 2013 when 4 countries failed to report their catches (Al-Abdulrazzak and Pauly 2014).

The Gulf is changing rapidly due to numerous industrial, residential, and tourism development activities (Sheppard et al., 2010). Meaningful ecological baselines are rare due to extensive ongoing projects such as the artificial Palm Jumeirah Island in Dubai or the extensive land reclamation near Manama, Bahrain, many of which remain confidential for alleged commercial or security reasons (Sheppard et al., 2010). This is one of the main reasons why Gulf marine ecosystems are so poorly understood and why regional coordination efforts are rarely effective (Sheppard et al., 2010). In addition, the Gulf's population has grown dramatically since the discovery of oil, subsequently driving up fisheries exploitation in order to meet demand. The increased demand coincided with the mechanization of fishing fleets, enhancing fishing capacity and exerting further pressure on the region's marine resources.

Since its creation in 1945, it has been the FAO's mandate to collect, analyze and distribute information related to nutrition, food, and agriculture, including fisheries, to assess global trends in hunger and malnutrition. The FAO's global capture fishery database, or FishStat (www.fishstat.org), is the only global sources of time series of national fisheries landings (Garibaldi 2012), and has provided essential data for a number of global fisheries studies (Pauly and Christensen, 1995; Pauly et al., 1998; Tyedmers et al., 2005; Worm et al., 2006; Swartz et al., 2010; Tremblay-Boyer et al., 2011; Watson et al., 2012). However, despite their wide usage, studies have called into question the reliability of FAO data (Watson and Pauly, 2001; Clarke et al., 2006; Zeller et al., 2006; Al-Abdulrazzak and Pauly, 2013b). Because member countries voluntarily report their catches and other fishery statistics, the quality of the FAO database is only as good as each country's capacity and political willingness for statistical collection and estimation (Watson and Pauly, 2001; Bhathal and Pauly, 2008; Jacquet et al., 2010). It is generally recognized that the contribution of many sectors, especially those from small-scale fisheries, are frequently absent or substantially under-reported (Zeller et al., 2006; Zeller et al., 2007; Le Manach et al., 2012; Al-Abdulrazzak and Pauly, 2013b).

Despite the historical importance of fisheries in the Gulf, the region's fisheries remain understudied and catch data remain inaccurate (Al-Abdulrazzak and Pauly, 2013a; Al-Abdulrazzak and Pauly, 2013b). Here, an established catch reconstruction approach was used to estimate total marine fisheries catches for all countries in the Gulf from 1950-2010 to evaluate the overall magnitude of misreporting and establish more accurate historical baselines.

Methods

Official data, as reported by Bahrain, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the UAE were extracted from the FAO's FishStat database and served as the baseline for the analysis. Data from national agencies were also compiled and compared to FAO data, but no differences were found. Because Saudi Arabia and the UAE also have coasts on the Red Sea and the Gulf of Oman respectively, the reported national data for each coast were disaggregated and the catch reconstructed separately.

The conceptual framework of the catch reconstruction method as outlined by previous studies (Pitcher 2001; Pitcher et al. 2002; Zeller et al., 2006; Zeller et al., 2007; Jacquet et al., 2010; Le Manach et al., 2012) was followed. Utilizing all available quantitative and qualitative data from both peer-reviewed and grey literature, and local expert interviews, 'anchor points', hard data such as fisher population data, national human census data, and estimates of catch per fisher, were identified to estimate total marine catches in the Gulf from 1950-2010. To account for uncertainty, we use the scoring method presented by Zeller et al. (2014) for evaluating the quality of time series of reconstructed catches and the associated uncertainty, which is based on criteria developed by the IPCC criteria (Mastrandrea et al. 2010; Table 3.1). The scoring was done for periods of 20 and 21 years (i.e., 1950-1969; 1970-1989 and 1990-2010).

Here, methods and results are described regionally, and the major sectors absent from reported data (i.e., IUU): discards, subsistence, recreational, and other unreported and/or illegal catches are examined. Details of the total catch reconstruction, including minor components, are fully described in the technical report underlying this study (Appendix A; Al-Abdulrazzak and Pauly, 2013a).

Discards

Discards are considered to be to be an integral part of 'catches' given global considerations of ecosystem-based fisheries management (Pikitch et al., 2004), but officially reported data historically focus on 'landings', and hence by definition ignore discarded catch. Discards which are mostly associated with the region's shrimp trawl fisheries, but also result from finfish bottom trawl fisheries, are unaccounted for in officially reported statistics.

In Kuwait, the shrimp fishery has a shrimp-to-fish bycatch ratio of 1:15.32 (Ye *et al.* 2000). Of this bycatch, 98% is discarded at sea and the remaining 2% is landed, yet not reported (FAO 2006). Thus, both landed and discarded catches are unaccounted for. Species composition ratios were applied from the Ye *et al.* (2000) study. Marine catfish (Ariidae) and elasmobranchs (sharks and rays), which are not consumed in Kuwait for religious reasons, comprise the bulk of the discarded bycatch. Bycatch was estimated as a multiple of both the reported legal shrimp catch and the unreported illegal catch, and then smoothed by applying a 3-year moving average.

Because of Iraq's close proximity to Kuwait (and the lack of Iraq-specific data) we apply a bycatch ratio (1:15) to reported, estimated and illegal Iraqi shrimp catches, of which 98% of the fish is discarded and only 2% is retained (as miscellaneous marine fishes), derived from the nearby Kuwait shrimp fishery (Ye *et al.* 2000). We also applied the same species composition from Kuwait to the discards.

Bahrain has a similar shrimp-to-fish bycatch ratio of 1:15, as reported by Abdulqader (2002). Abdulqader (2002) and Kelleher *et al.* (2005) estimate that Bahrain's discard rate was 24% in the 2000s. It was assumed that more discarding occurred at the start of the fishery, thus a conservative discard rate of 80% was applied from 1950-1979, followed by 50% from 1980-1999, and 24% from 2000-2010. A 3-year moving average was applied for smoothing and species composition ratios were applied from the Abdulqader (2002) study.

For Iran, it was assumed the majority of discarding is associated with large trawlers. A discard ratio of 1:4.17 was applied to landed shrimp and demersal species by large trawlers as per Alverson *et al.* (1996). Discarding by the artisanal fleet was not estimated; thus, our estimate of discarding is likely a conservative under-estimate.

In Qatar, Ibrahim (1989) estimates that 496-635 t were discarded by Qatar's bottom trawl fishery for 1986-1987. The study also presents the percent contribution of the bottom trawl fishery to the total finfish landings (excluding sharks) and the average percent contribution (32%) was used to determine the amount of finfish reported landings from 1970 (start of the fishery) to 1993 (when it was closed) that came from the bottom trawl fishery. A discard rate of 50% (Ibrahim *et al.* 1989) was applied to the bottom trawl fishery (i.e., 50% of the total catch was discarded). The same study also provided a discard rate of 4% (of the total catch) for the rest of the artisanal fishery, and this rate was applied to all other artisanal finfish catches (reported, unreported, and discarded). Discarded species composition originates from the same Ibrahim *et al.* (1989) study.

In UAE, telosts *Lethrinus borbonicus*, *Lethrinus microdon*, *Pomacanthus maculosus*, and *Scolopsis taeniata* are caught as incidental and generally discarded bycatch by *gargoors* targeting emperors, groupers, jacks, and sweetlips (Morgan 2004; Grandcourt *et al.* 2010). Weizhong *et al.* (2012) estimate *gargoor* discard rates to be 2.56%, and this figure was used to extrapolate total discards for the fishery. The species composition was applied in equal ratios among the above species.

In Saudi Arabia, discards from the industrial trawl fishery were estimated by applying a discard ratio of 1:5.8, derived from the discard ratio for the Red Sea (Tesfamichael and

Rossing 2012). Species composition was also estimated from the same study based on the Red Sea.

Subsistence

Despite the high GDP in Bahrain, Kuwait, Qatar, and the UAE, subsistence fishing occurs by the fishing industry's foreign laborers. To estimate this sector, national statistics were used to determine the number of foreign fishers in each country, and it was conservatively assumed that fishers take home an average of 5 kg of fish per week, starting with the oil boom in 1960 until 2010. Because these take-home catches are made up of less desirable species (which lack a targeted fishery), the discarded species composition data was applied.

Subsistence fishing in Iran and Iraq was approximated using estimates of the coastal population, and combining these with a conservative consumption rate time series based on the assumption that 500g of fish is consumed per meal and extrapolating to 20.5 $kg \cdot person^{-1} \cdot year^{-1}$ consumed for Iran and 26 $kg \cdot person^{-1} \cdot year^{-1}$ for Iraq (Al-Abdulrazzak and Pauly, 2013a).

Saudi Arabia's subsistence catch was estimated based on interviews with local fishers on their individual consumption habits and tradition of gifting fish to family members (Tesfamichael et al., 2014). This catch can be substantial, up to 50% of the catch and does not appear in any fishery data recording system. Similar to the Red Sea, subsistence catch was assumed to be 30% of artisanal catch until 1963, the start of motorization of the fishery. For more recent years, 20% was allocated to 1964 and 10% to 2010, and the percentage was linearly interpolated between 1965-2009. Before these percentages were applied, some taxa which are not customarily given freely, were eliminated. These included taxa usually intended for export market, i.e., sharks fished for their fins and many invertebrates such as shrimp, crab and lobster. Traditionally, most of these taxa were not consumed locally and their consumption was introduced by foreign (mainly European) visitors to the region. However, nowadays, these non-traditional species are consumed by people in the affluent larger urban centers and are not usually given freely to family and friends.

Recreational

Recreational fisheries are a small but growing sector in the region, particularly given the region's 'youth bulge' and growing wealth and leisure time. To estimate these catches in Kuwait, Bahrain, Qatar, and the UAE, methods were developed based on a recreational participation rate of 0.12% estimated by Cisneros-Montemayor and Sumaila (2010). It was assumed that recreational fishing began in 1960, and thus this participation rate was applied to total population from 1960-2010 to obtain a time series of recreational fishers. It was further assumed that no recreational fishing occurred during and immediately after war periods (Iran-Iraq, Persian Gulf War, etc.). A conservative catch rate of 1 $kg \cdot trip^{-1}$, along with 104 fishing trips per recreational fisher per year (based on the annual number of weekend days) was used to estimate recreational catches.

Saudi recreational catches were estimated based on methods derived for the Red Sea (see Tesfamichael and Rossing, 2012 for further details). Although recreational fishing occurs in Saudi Arabia's Gulf waters, the only data available were for 1996, when it was reported that there were 2,528 boats involved in the recreational fishery in the Gulf, while in the Red Sea there were 2,446 (Sakurai 1998). Thus, the recreational fishery and its composition for the Gulf were calculated using the ratio of boats for 1996 and the reconstructed recreational fishery of the Red Sea (Tesfamichael and Rossing 2012).

Due to the number of wars in Iraq's history and due to its short coastline and minor coastal population, it was assumed that negligible recreational fishing occurs in Iraq and therefore it was unaccounted for.

Species compositions were estimated using all available information for each country (Uwate et al., 1994; Rao and Behbahani, 1999; Bishop, 2002; De Young, 2006; Tesfamichael and Pauly, 2013).

Other unreported catches

In addition to the sectors described above, certain minor components such as catches from weirs (Al-Abdulrazzak and Pauly, 2013b), illegal catches (De Young, 2006; Al-Sabbagh and Dashti, 2009; Richer, 2009; Lessware and Mahdi, 2010; Barakat, 2012), and shark catches (Moore et al., 2012; Moore, 2012) are unaccounted for. Similar to the previously described methods, grey and peer-reviewed literature were used to find 'anchor' points and to extrapolate a catch time series based on these known points (See Table 3.2 for example of anchor points used to estimate illegal driftnet catches in UAE; specific details of all other sectors are available in Al-Abdulrazzak and Pauly 2013a).

Results

Catch data for the Gulf as reported by the FAO suggest a steady increase in reported landings from 24,136 t in 1950 to 274,134 t in 2010 (Figure 3.2). In contrast, the reconstructed total marine fisheries catches suggest a gradual increase from 196,237 t in 1950 to a peak of 621,270 t in 1997, followed by a sharp decline to 381,678 t in 2004, followed by a relative stability in total catches (Figure 3.2).

Artisanal catches contributed 75% of total catches, followed by industrial (4%), subsistence (2%), and recreational (0.4%) (Figure 3.2). The increased capacity of shrimp trawlers in the 1960s corresponds with an increase in bycatch (landed), and hence discards (not landed), which average 18% of total catches. Declines were seen in all sectors after 1997. Trends in catch series often reflect political events that impacted the fishery sector in a country; in this case, the 'dip' in catches between 1980 and 1988 is probably due to the Iran-Iraq war (see declining Iranian catches, Figure 3.3).

Iran accounts for the largest catches, with 56%, followed by the UAE (12%), and Kuwait, Saudi Arabia, and Bahrain (all 9%) (Figure 3.3). Qatar and Iraq's catch contributions are comparatively minor, with 2% and 3% respectively. All countries, with the exception of the UAE, under-report their catches. Until 2004, a market survey program (which includes imported seafood) was used in the UAE to estimate catches, inevitably yielding inflated figures for truly domestic catches (see Al-Abdulrazzak, 2013 for further details of the readjustment).

There are 264 taxa that make up the total reconstructed catch in the region as compared to 182 taxa reported by FAO. The dominant invertebrate groups are shrimps and prawns (7%), and crabs and lobsters (6%). The major fish groups consist of Clupeiformes (10%), sharks and rays (8%), ponyfishes (6%), and catfishes (6%) (Figure 3.4).

Discussion

The overall reported catches for the Gulf's fisheries potentially underestimate total catches by a factor of 2 over the 1950-2010 time period (Figure 3.5). Such large differences between reported landings and reconstructed total catches illustrate the magnitude of the data reporting problems faced by Gulf countries, and, by inference, other countries. It also points at a fundamental problem of fisheries catch data being viewed purely from a commercial or market perspective, which accounts only for what is landed and utilized for commercial sale or export (Pauly and Zeller, 2003; Zeller and Pauly, 2004).

Small-scale fisheries have often been underrepresented in officially reported catch statistics for political and socio-economic reasons, as well as their physical remoteness from urban centers (Pauly, 1997; Zeller et al., 2011). Although data reported by FAO are not readily distinguishable by sector (e.g., commercial vs. subsistence), the results suggest that industrial catches make up 4% of total catch compared to all other sectors. The dichotomy between the actual contribution of industrial fisheries and the government attention they receive is directly reflected in the data collection emphasis, which is problematic and misrepresents regional and global trends.

This catch reconstruction justifies concerns over the status of fisheries in the Gulf (De Young, 2006; Sheppard et al., 2010; Sale et al., 2011; Grandcourt, 2012). Sharp declines in all sectors, coupled with other indicators of overexploitation such as the reduced mean size of landed fish and decreased catch per effort, suggest that fisheries are suffering from overcapacity (Dadzie et al., 2005; Al-Sabbagh and Dashti, 2009). Although catches from 2004 to 2010 appear to be leveling off after declines since 1998, it is more likely that further declines are masked by previously discarded groups such as swimming crabs and jellyfish being retained.

The reconstructed time series also illustrates the magnitude and hence the importance of accounting for discards (Figure 3.2). In terms of tonnage, discards amounted to 18% of the total landed catch, or 2 times greater than the global average of 8% (Kelleher, 2005). This is particularly problematic in a region that is dependent on fish for its food security. In some countries, such as Bahrain and Kuwait, good estimates of discards are available. Yet in most other cases, particularly in developing countries, there is a general lack of quantitative information on discards or discard rates (Kelleher, 2005). This is partly because several different fishing gears may be used, different species may be targeted on a single fishing trip or vessel, and because fisheries change over time.

Fisheries management in the Gulf is rudimentary at best, with no regional management plan for any stock or well-developed institutional arrangements, despite many stocks being shared between countries (De Young, 2006; Grandcourt, 2012). Basic stock assessment data, rates of effort, and fishery market potentials are also lacking, further constraining management. The few management tools in place focus on input controls (i.e., gear restrictions) rather than the badly needed output (i.e., size limits, quotas), or are often designed as a basis for administrative procedures, rather than a strategic policy framework for the long-term sustainability of a sector (De Young, 2006; Grandcourt, 2012). In addition, enforcement of management regulations is weak and cheap migrant labor and low operating costs act as indirect subsidies, maintaining the profitability of fisheries despite declining stocks (Grandcourt, 2012). Combined, unregulated fishing practices and population pressure suggest that 'Malthusian overfishing' occurs in the region, a situation where declining yield coupled with socio-economic conditions drive fishers to overexploit and destroy their resources (Pauly, 2006).

In order to accommodate expanding industries and rapid population growth in the region, major coastal development projects are underway, resulting in land reclamation and dredging, with little to no studies on their short- and long-term ecological impacts on marine life, and hence fisheries resources (Sheppard et al., 2010). These development projects are certain to impact fisheries, yet are not addressed, since no formal management plan exists for any fishery and baseline data is lacking.

If the overall status of the Gulf's fisheries—and marine ecosystems more generally—are to improve, there needs to be a significant shift towards a precautionary approach to the management of the region's marine resources. New management plans should be data-driven and regional in scale. In addition, efforts should be made garnering public interest and participation in relevant decision-making processes, beginning with making environmental data publically available.

Given the global trend towards managing fisheries on an ecosystem scale (Pikitch et al., 2004), fisheries data collection, and hence catch accounting needs to include all catches. This requires comprehensive accounting for all fishery extractions, including the reporting (or estimation) of discarded catch, and catches from unregulated sectors such as recreational and subsistence fisheries. Given the high costs of monitoring such sectors using traditional approaches, alternative methods such as utilizing national surveys, census opportunities, and the use of satellite imagery have been suggested for more widely dispersed and hard to monitor fishery sectors (Zeller et al., 2007; Al-Abdulrazzak and Pauly, 2013b).

Despite data uncertainties and the need to appropriately qualify data assumptions, this catch reconstruction provides the best estimate of total marine catches in the Gulf over the last 60 years, and is preferable to the alternative of assuming low levels of catch, or worse, ‘zero’ catch for sectors with missing data. Fisheries managers and policymakers in the Gulf should focus on the available trends rather than the uncertainty surrounding these data (Rosenberg et al., 2005). The reliance on incomplete and/or misreported catch data compromises countries’ food security and marine ecosystems more generally.

Tables

Table 3.1 Score for evaluating the quality of time series of reconstructed catches, based on Figure 1 of Mastrandrea et al. (2010). The uncertainty ranges, here updated from Zeller et al. (2014), are adapted from Ainsworth and Pitcher (2005) and Tesfamichael and Pitcher (2007).

Score	Uncertainty		Corresponding IPCC Criteria
	-%	+%	
4 Very high	10	20	High agreement and robust evidence
3 High	20	30	High agreement and medium evidence or medium agreement and robust evidence
2 Low	30	50	High agreement and limited evidence or medium agreement and medium evidence or low agreement and robust evidence
1 Very low	50	90	Low agreement and low evidence

Table 3.2 Parameters used for estimating illegal driftnet catches in the UAE.

Year	Number of participating vessels	Annual illegal catch per vessel (t)	Annual catch (t)
1989	564	20	11,280
1990	564	20	11,280
1991	564	20	11,280
1992	564	20	11,280
1993	564	20	11,280
1994	564	20	11,280
1995	564	20	11,280
1996	564	20	11,280
1997	564	20	11,178
1998	770	18	13,762
1999	619	23	14,106
2000	469	27	12,648
2001	459	29	13,500
2002	519	23	11,701
2003	505	23	11,411
2004	556	19	10,793
2005	557	19	10,401
2006	557	18	9,892
2007	557	17	9,388
2008	557	16	8,880
2009	605	15	9,294
2010	605	16	9,538

Figures

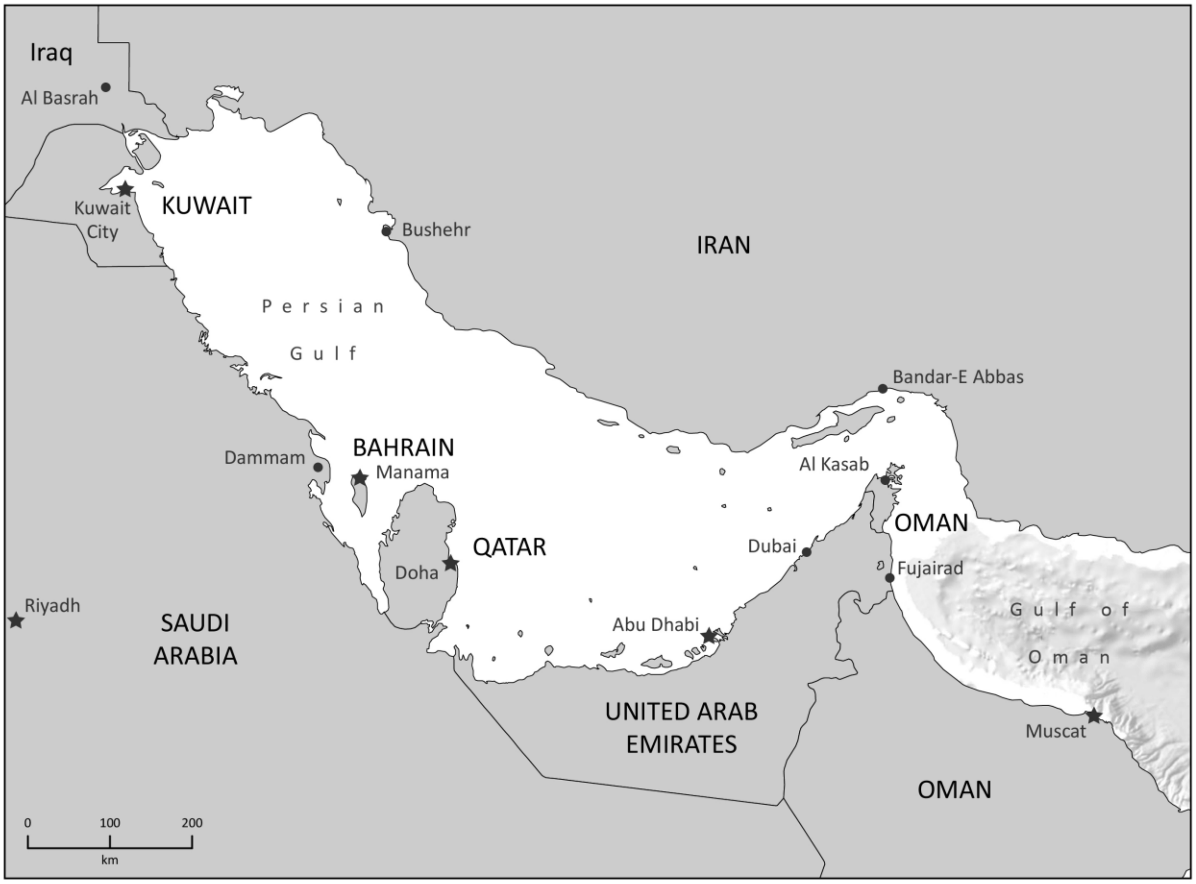

Figure 3.1 Map of the Persian Gulf.

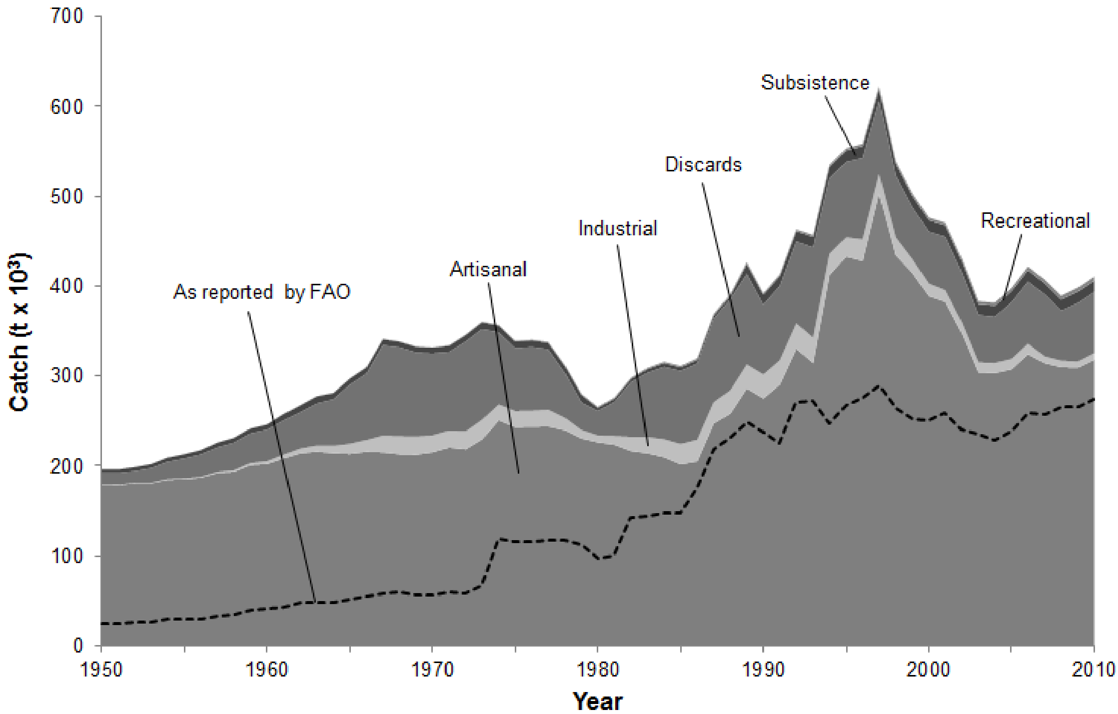

Figure 3.2 Total reconstructed catch for the Persian Gulf by sector, as compared to catch reported by FAO.

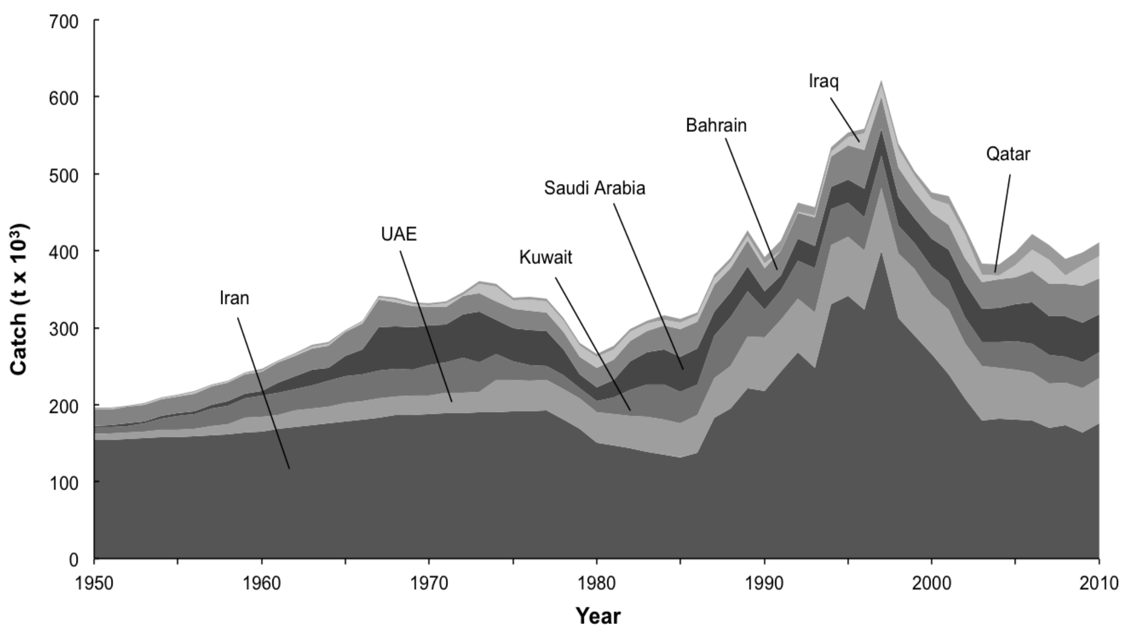

Figure 3.3 Total reconstructed catch for the Persian Gulf by country.

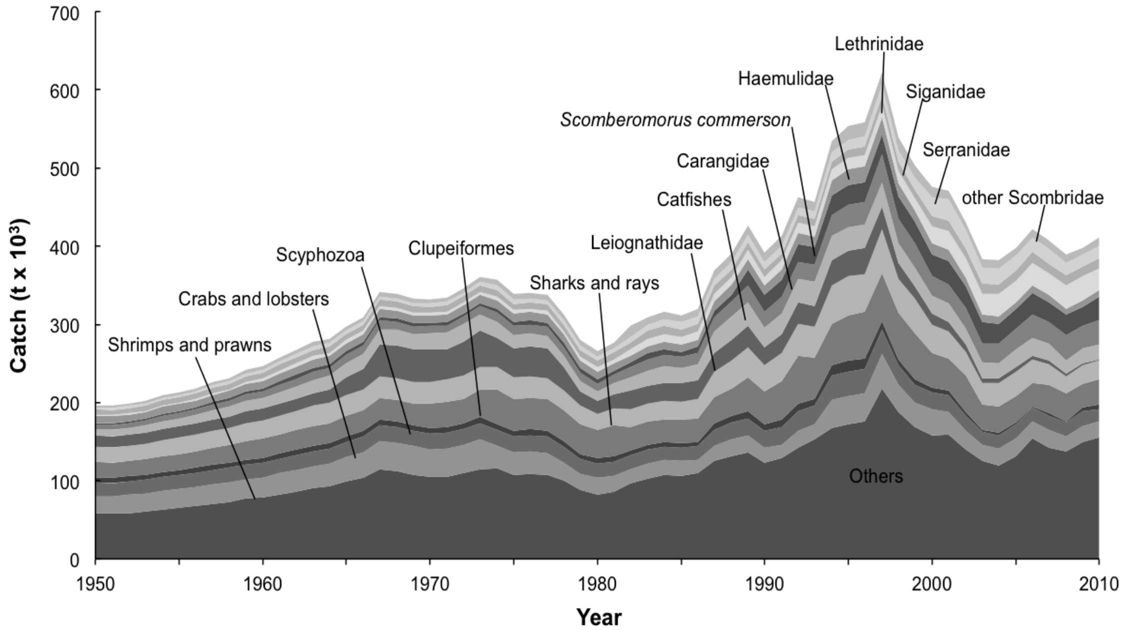

Figure 3.4 Total reconstructed catch for the Persian Gulf by major taxonomic groups. The category 'others' consists of 131 additional taxa with smaller individual contributions.

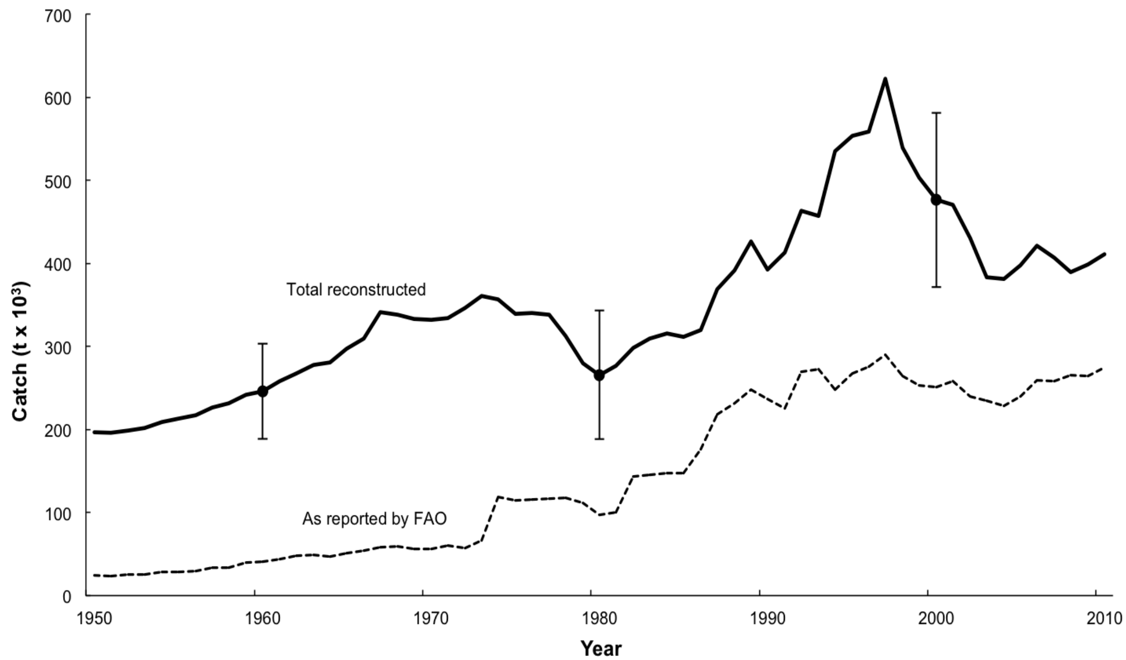

Figure 3.5 Reconstructed total catch for all 7 countries in the Persian Gulf as compared to data reported by FAO. The uncertainty associated with the reconstruction are shown for 1960 (representing 1950-1969), 1980 (representing 1970-1989), and 2000 (representing 1990-2010), based on the scoring method in Zeller et al. (2014).

4 MANAGING FISHERIES FROM SPACE: GOOGLE EARTH IMPROVES ESTIMATES OF DISTANT FISH CATCHES[3]

[3] A version of this chapter has been published. Al-Abdulrazzak, D., Pauly, D. (2013) Managing fisheries from space: Google Earth improves estimates of distant fish catches. *ICES Journal of Marine Science* **71,** 450-454 (See also Appendix B).

Introduction

Fishery catch statistics are often unreliable (Watson and Pauly, 2001; Clarke et al., 2006; Zeller et al., 2006; Zeller et al., 2007). Statistics submitted annually by member countries to the United Nations Food and Agriculture Organization (FAO) frequently neglect or under-report the contribution of small-scale fisheries, as well as illegal catches and discards (Zeller et al., 2007). In the wake of global overfishing, negligent reporting can lead to poor policy decisions that jeopardize food security (Jacquet et al., 2010; Le Manach et al., 2012), impair resource conservation, and generate incorrect assumptions that global catch trends are plateauing (Pauly and Froese, 2012) or even increasing (Watson and Pauly, 2001). In the absence of robust catch data, catches can be 'reconstructed' from the bottom up using diverse data types such as interviews with fishermen, per-capita consumption rates, maritime records, and other historical data (Zeller et al., 2007; McClenachan and Kittinger, 2012). The results of these studies have shown that fishing has extracted far more marine resources than previously estimated and provided critical insights for fisheries management.

Freely-available global satellite imagery via Google Earth has been a valuable multi-disciplinary tool for examining a number of questions including ecological theory (Hughes et al., 2011; Madin et al., 2011), ground-truthing aquaculture production (Trujillo et al., 2012), estimating forestry biomass (Ploton et al., 2012), and assessing looting in archeological sites (Pringle, 2010). Areas that were once considered too remote or expensive – or even prohibited – to access are now ripe for scientific investigation. Satellite imagery via Google Earth allows fishing gears deployed at the surface, like weirs to be seen in coastal regions (Figure 4.1).

Fishing weirs have been used throughout the world as far back as 3,000 years (Moss et al., 1990; Connaway, 2007) and were a fundamental gear of many coastal societies prior to the global spread of industrial fishing, starting in the 1950s. Although weir technologies differ across geographies, their basic purpose is to capture fish by limiting their movement without greatly impeding water flow. In the case of intertidal weirs, fish swimming parallel to shore at high tide encounter the 'wing' and invariably try to escape by swimming into deeper water, eventually entering the smaller enclosure, where they are captured by the receding tides (Beech and Al Shaiba, 2004; Al-Baz et al., 2007). Weirs are still used today throughout Southeast Asia, Africa, the Middle-East (Tharwat, 2003), and parts of North America (Gabriel et al., 2005). However, their contribution to catches may be assessed erroneously for reasons related to their mode of operation (as a passive gear, they are lumped with the often neglected small-scale fisheries), ownership (e.g., tribal), and traditional forms of governance.

In the Persian Gulf, weirs (Arabic: *hadrah*; Farsi: *moshta*) are constructed in intertidal and shallow subtidal zones and catch a wide variety of marine species (Ross et al., 1881; Erdman, 1950; Bowen Jr., 1951; Serjeant, 1968; Carpenter, 1997; Tharwat, 2003; Jawad, 2006; Al-Baz et al., 2007). Traditionally they were built using woven date palm, but today are made using bamboo and galvanized mesh wire. Although the Persian Gulf's semi-diurnal tides allow weirs to be checked twice a day, in practice they are checked once (Al-Baz et al., 2007). Here, Google Earth's potential for quantifying fish catches in the Persian Gulf is explored. The Gulf is an ideal location to groundtruth weir catches due to the high fraction of coastal imagery available via Google Earth, the large concentration of weirs along the coast, the historical significance of weirs in the region, and because the Gulf's marine ecosystems remain understudied.

Methods

Google Earth imagery was available for The Persian Gulf for the years 2005-2010. Catches for 2005 were estimated because this year had the greatest coverage of the coast at low tide, allowing most weirs to be visible. The coast of all Gulf countries (inward of the Strait of Hormuz) were surveyed three times and each weir was marked with the Google marker tool (Figure 4.2). For each weir, the three trap components (wing, yard, and pocket) were measured using the Google ruler tool calibrated to tennis courts (Trujillo et al., 2012).

Because weir visibility is correlated with the physical conditions in which the image was taken (e.g., cloud cover, glare) and because certain areas appear under poor resolution, a visual survey is likely to underestimate the true number of weirs. Thus, a visibility scheme was designed with 5 categories (0-20%, 21-40%, 41-60%, 61-80%, 81-100%) based on the proportion of each weir that was visible, and each weir was assigned to one of the categories. Similar to a population depletion model, the percentage visible of each weir was plotted against the cumulative number of weirs, the visibility was set to zero, and the total (seen & unseen) weirs were solved for.

While the above method estimates weirs under sufficient conditions (i.e., adequate resolution), necessary conditions (i.e., the availability of imagery with a suitable resolution) must also be established. Missing imagery was accounted for by using the Google 'Grid' view and for each country, counting the number of coastal grid squares (with sides of 5km or less) with and without imagery to determine the percentages of available and missing imagery. The total number of weirs corrected for poor resolution was then raised by the percentages of missing imagery.

The mean catch rates used to calculate total catch were 62.2 $kg \cdot day^{-1}$ (n=3; s.d. = 32.4 kg) for Kuwait (A. Al-Baz, Kuwait Institute for Scientific Research, pers. comm.) and 42.6 $kg \cdot day^{-1}$ for Bahrain (A.H. AlRadhi, Directorate of Fisheries Resources, pers. comm.). Estimates for fishing season lengths and species composition ratios were also obtained from the same sources, as well as for the UAE (S.A. Hartmann, Environmental Agency- Abu Dhabi, pers comm.), while regional averages were applied for countries without these data (Iran, Saudi Arabia, and Qatar). To estimate total annual catch, the number of estimated weirs was combined with daily catch rates and fishing season lengths (and the confidence intervals associated with all these parameters) in a Monte Carlo procedure (Uhler, 1980) for each country and for the entire region.

Results

A total of 1,656 weirs were counted in the coastal waters of the Persian Gulf. The correction for low visibility yielded an increase of 6.2 % in the estimated number of weirs (Figure 4.3), while the correction for imagery availability lead to an increase of 8.0%. Jointly, these two factors raised the number of weirs estimated to be in the Persian Gulf in 2005 to 1900 +/- 79, with an estimated catch of 31,433 tonnes (+/- 9,827) (Table 4.1). Compared to regional catches reported by FAO in the same year, these estimated weir catches represent additional catches of 6-8%.

The majority of the weirs were found in Bahrain (50%), followed by Iran (37%) and Kuwait (5%). Bahrain also leads in estimated catch (54%), along with Iran (39%) (Table 4.1). Estimated catches for Iran, Qatar, and UAE represent an additional 4%, 2%, and 0.01% respectively as compared to total catches reported to FAO. In Saudi Arabia, estimated weir catches represent only 0.07% of total catches. However, because Saudi Arabia does not separate its catches amongst the two coastlines (Red Sea and Persian Gulf), the proportion of additional catch in the Gulf is likely to be greater. This is also the case for Iran, which does not separate their catches between the Persian Gulf and the Arabian Sea. Estimated versus reported catches in Kuwait were within 300-845 t. Estimated catches for Bahrain were 142% greater than total catches reported to FAO across all sectors. The largest weirs were found in in the UAE (321 m), followed by Iran (222 m) and Qatar (179 m) (Table 4.2).

Species composition varies among Gulf countries. Kuwait’s catch is dominated by mackerels (Scombridae; 30%), breams (Sparidae; 19%) and morrajas (Gerreidae; 15%), while Bahrain’s catch is dominated by rabbitfish (Siganidae; 26%), swimming crabs (Portunidae; 26%), and sardines (Clupeidae; 15%). Over 96% of UAE’s catch is reported as snappers (Lutjanidae). The regional average species composition is dominated by Siganidae (22%), Portunidae (22%) and Clupeidae (13%).

Discussion

The regional estimate of 1,900 weirs contributing to a catch of 31,433 t·year^{-1} is up to 6 times greater than the officially reported catch of 5,260 tonnes. At the national level, FAO catch data are available for weirs in Bahrain, UAE and Kuwait; this study's estimates are 9 and 2 times higher than reported for Bahrain and UAE, respectively, but rather close (within 300 tonnes) for Kuwait. No data on catch or number of weirs were reported for Iran, Saudi Arabia, and Qatar. While this is not surprising in the case of Saudi Arabia and Qatar, which were estimated to have weir catches of less than 500 tonnes year^{-1}, it is problematic in the case of Iran, which was estimated to catch over 12,000 tonnes year^{-1} for their 728 weirs. Very little information is available on the Iranian weir fishery despite it being the largest in the region and one of the largest in the world. Although no weirs were detected in our survey of Iraq, this is probably a result of poor satellite imagery (beyond our ability to correct), as literature sources indicate their presence (e.g., Serjeant, 1968; Jawad, 2006).

Overall, these results document the unreliability of catch data from the Persian Gulf, a small part of a global misreporting problem. Because catch data are submitted to the FAO by member countries (Garibaldi, 2012), the quality of FAO data are dependent on the accuracy of statistical data collection within these countries. Therefore, political interference (Bhathal and Pauly, 2008), perverse incentives (Watson and Pauly, 2001; Sumaila, 2013), and legacy issues (Jacquet et al., 2010) can all impair the reliability of catch data.

Although regulations governing fishing effort (e.g., fishing licenses, spatial restrictions) in the Persian Gulf have been implemented since the 1960s, most stocks are either fully or over-exploited (Grandcourt, 2012). This is partly because fisheries management (if any) is based on unreliable fishery data and limited stock assessments, and also because weak or ill-enforced regulations are commonplace. Fishery agencies in the area tend to be development focused, rather than implementing long-term sustainability plans (Grandcourt, 2012).

In addition, these results speak to the potential for satellite imagery and remote sensing to expose illegal fishing practices. In the same way that industrial fisheries rely on technology to target catches (i.e., Fishfinders, GPS Chartplotters etc.), technological advances in satellite imagery can be used to monitor fisheries remotely, particularly in areas that were once considered too remote or expensive to enforce. In the case of Qatar, 17 operating weirs (14 visible directly and 3 added to compensate for poor resolution and imagery availability) were found, despite their ban in 1994 (M.S. Al-Muhindi, Ministry of Fisheries, pers. comm.). Beyond other large semi-permanent structures such as fish ponds in Hawaii and Japan, *vywers* in South Africa, or *sakkar* in the U.A.E., satellite imagery can be used to expose other illegal marine practices such as verifying the magnitude of oil spills (Amos, 2010), assessing the use of illegal fishing gears, and monitoring activities in Marine Protected Areas (MPAs), among others. This is particularly useful for improving data collection in countries with known data inaccuracies, or in developing countries where resources allocated towards conservation and/or management are scarce.

This study also provide further rationale for reporting catch by gear types. Fishing gear types are rarely included in compendia of fisheries statistics (Watson et al., 2006) and yet their associated impacts on marine ecosystems are highly variable and far-reaching. Because weir catches in the Persian Gulf consist mostly of juvenile commercially important species (Tharwat, 2003; Al-Baz et al., 2007), growth overfishing can occur even when certain spatial restrictions (e.g., spatial closures) are put into place. These finer scale interactions between marine habitats and fishing gear cannot be discerned by reporting tonnage alone, but this study demonstrate that Google Earth can be used to improve the quality of catch reporting and therefore overcome some of these limitations.

Despite the uncertainties, in particular the unavailability of mean daily catches for all countries, this study provides the best possible estimates for weir catches in the Persian Gulf at present (see Appendix B). Zero catch estimates in the case of Iran, Saudi

Arabia, and Qatar, and vastly under-reported catches in the case of Bahrain are more incorrect than conservative estimates. Should improved daily mean catch rates emerge, they can be incorporated into these methods to refine the estimates.

Our findings demonstrate both underreporting in the case of the Persian Gulf countries and that the use of freely available satellite imagery can improve catch statistics, therefore providing a more accurate view of fishery resource use. By coupling compelling images with robust data we are able to more accurately assess human impacts in marine ecosystems, thereby supporting sustainable management of marine resources. Because satellites have near global coverage and can repeatedly capture images over the same area, they provide a cost effective way to monitor vast areas of the ocean over time.

Tables

Table 4.1 Number of observed and inferred weirs in the Persian Gulf and their estimated annual catch (+/- 1 st. dev.) Fishing days were obtained from unpublished national reports (see methods for details). Annual reported catches come from Morgan (2006).

Country	Weirs counted	Corrected for poor visibility	Corrected for imagery availability	Fishing days	Estimated annual catch (t)	Annual reported catch (t)
Kuwait	93	95 ± 1	106 ± 1	274 ± 10	1,855 ± 550	2,700
Saudi Arabia	54	58 ± 3	58 ± 3	[263 ± 46]	382 ± 897	0
Qatar	14	16 ± 1	17 ± 1	[263 ± 46]	286 ± 100	0
UAE	78	80 ± 1	95 ± 1	213 ± 10	1,292 ± 381	600
Iran	618	654 ± 25	726 ± 28	[263 ± 46]	12,240 ± 4,223	0
Bahrain	799	880 ± 57	880 ± 57	304 ± 10	17,125 ± 5,147	1,960
Total	1,656	1,759 ± 73	1,900 ± 79	[263 ± 46]	31,433 ± 9,827	5,260

Table 4.2 Average size (+/- 1 st. dev.) of weir components across Persian Gulf countries.

	Wing (m)	Yard (m)	Pocket (m)	Total (m)
Kuwait	79 ± 37.6	63 ± 15.6	10 ± 2.23	147 ± 46.8
Saudi Arabia	95 ± 45.5	80 ± 32.7	7 ± 7.22	145 ± 75.7
Qatar	140 ± 92.5	32 ± 19.1	12 ± 2.34	179 ± 87.7
UAE	129 ± 67.1	71 ± 28.3	38 ± 7.67	321 ± 178
Iran	115 ± 59.4	94 ± 31.9	10 ± 3.47	222 ± 123
Bahrain	103 ± 65.8	52 ± 44.1	10 ± 3.40	162 ± 92.3

Figures

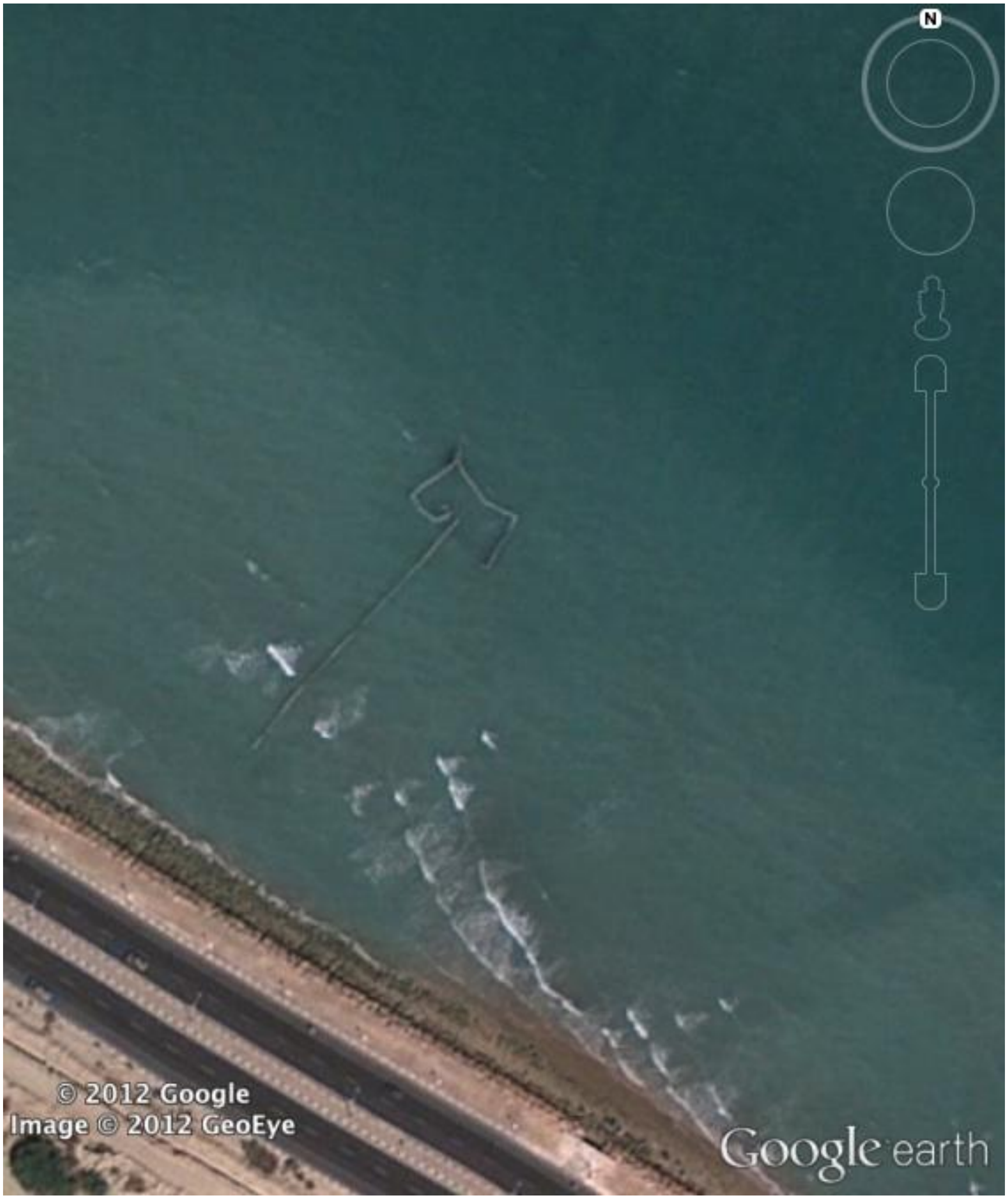

Figure 4.1 Example image from Google Earth showing a weir off the coast of Iran.

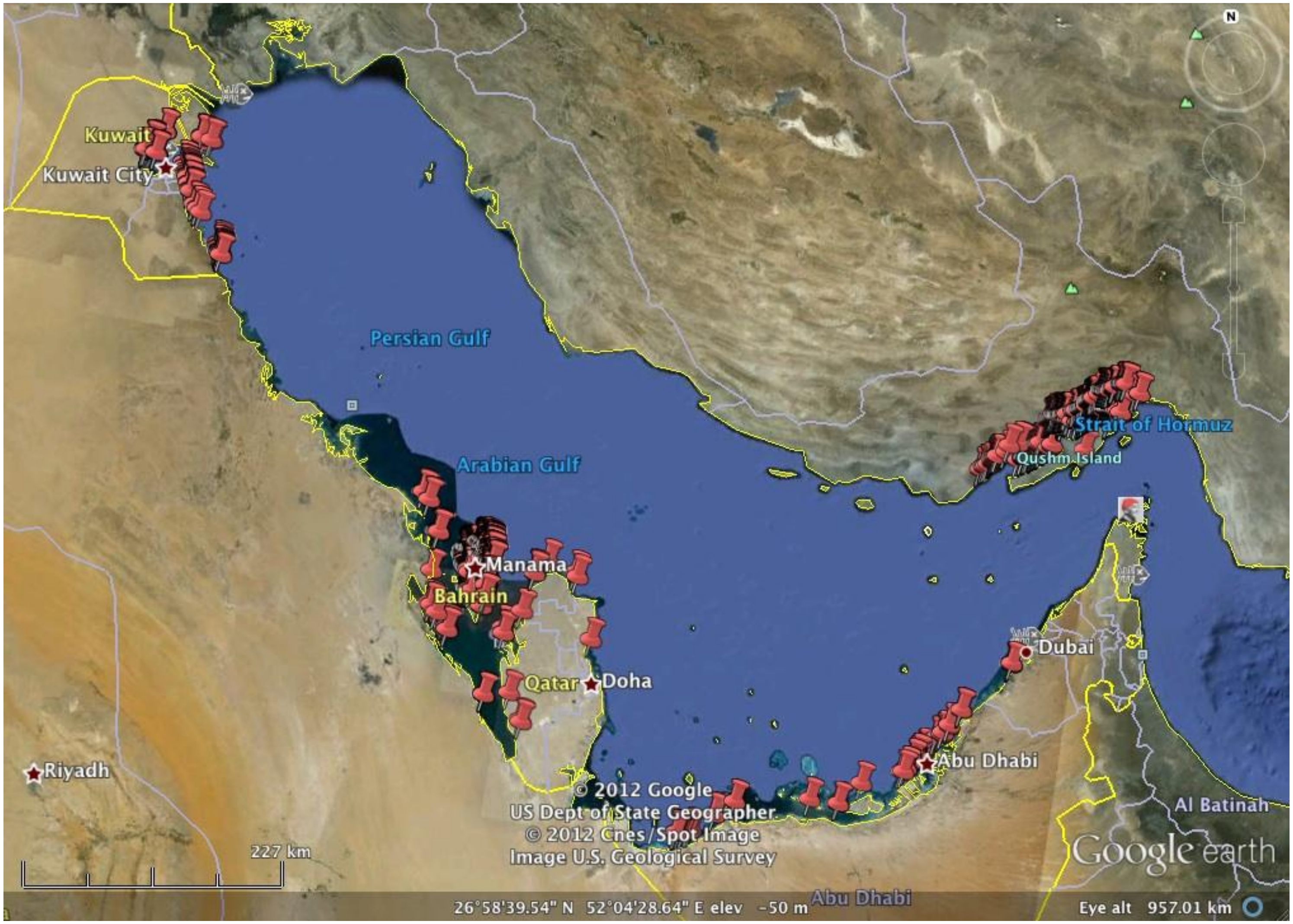

Figure 4.2 Surveyed coast of the Persian Gulf with assigned 'pins' for each visible weir. Weirs were found in all countries but Iraq.

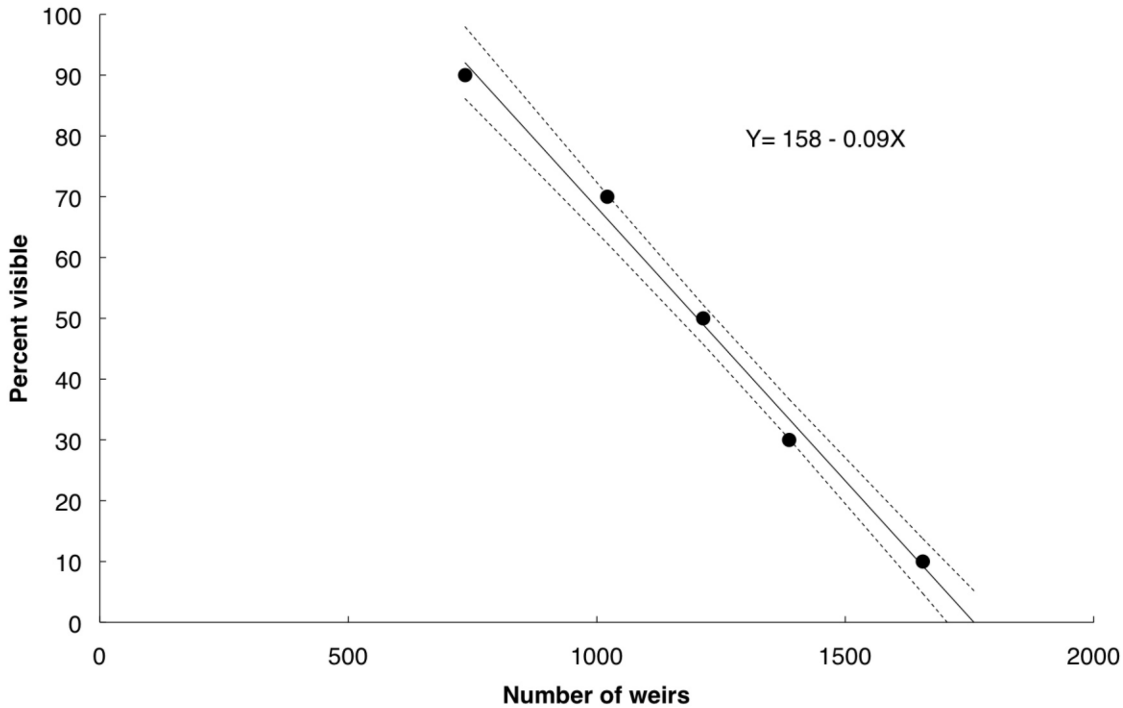

Figure 4.3 Plot showing estimated number of weirs (X) at 'zero' visibility (Y=0).

5 GAINING PERSPECTIVE ON WHAT WE'VE LOST: THE RELIABILITY OF ENCODED ANECDOTES IN HISTORICAL ECOLOGY[4]

[4] A version of this chapter has been published. Al-Abdulrazzak, D., Naidoo, R., Palomares, M.L.D., Pauly, D. (2012) Gaining Perspective on What We've Lost: The Reliability of Encoded Anecdotes in Historical Ecology. *Plos One* **7**.

Introduction

Marine ecology is a relatively young science, with few descriptive studies extending back for more than a century. Thus until recently, marine ecologists have tried to explain patterns of distribution and abundance based on short-term experiments and ‘real time’ observations (Jackson, 1997). This shortsightedness has resulted in studying ecological states that were already degraded, yet believing they were ‘pristine’. This is manifest in many examples throughout the world, but most notably the collapse of Jamaica’s coral reefs, which were thought to be amongst the healthiest and most well-studied reefs at the time (Lessios et al., 1984).

The situation is even worse for fisheries science, a discipline that has long suffered from a lack of historical reflection. In 1995 Daniel Pauly coined the term “shifting baseline syndrome” to describe the incremental lowering of standards, with respect to fisheries, so that each new generation redefines what is ‘natural’ according to personal experience and loses sight of how the environment used to be (Pauly, 1995a). These shifting ecological baselines have resulted in lowered expectations for the natural abundances of marine animals and the ecosystem services they provide (Dayton et al., 1998; Jackson et al., 2001; Sáenz-Arroyo et al., 2006; McClenachan and Cooper, 2008). Populations of fishes, large vertebrates, marine mammals, and certain invertebrates thought to persist in “healthy” numbers today may, in fact, be small fractions of their historical abundance. Historical accounts from the 1700s and early 1800s mention seas teeming with large fish, yet accounts like these are virtually unheard of today.

Pauly’s (1995) call for the incorporation of earlier anecdotal knowledge into traditional ecological studies prompted a body of literature based on the premise that historical anecdotes, rooted in human experience, can provide powerful insights into long-term changes in marine ecosystems. These studies in historical marine ecology have uncovered surprising findings about the structure and function of past ecosystems, and have affected our understanding of species declines, trends in global fisheries, and overall ecological integrity (Jackson et al., 2001; Pandolfi et al., 2003; Lotze and Milewski, 2004; Rosenberg et al., 2005; Sáenz-Arroyo et al., 2006). Results of these analyses have shown that human impacts in coastal ecosystems have been far more substantial than previously thought, and have deepened our understanding of the connection between social history and marine ecosystems.

While historical perspectives are increasingly necessary to understand marine ecosystem structure and function, the majority of species-associated historical data prior to the second half of the 20th century remains anecdotal, (Saenz-Arroyo et al., 2005; Palomares et al., 2006; Fortibuoni et al., 2010) raising questions about the validity of findings. Deriving quantitative insights from qualitative historical narratives often requires a form of content analysis. One such method is coding, or the categorization of large amounts of narratives to identify common patterns or themes. This method is most often used in social sciences, where qualitative surveys or interviews are coded to draw patterns in subjective experiences (Ryan and Bernard, 2003). Although the majority of coding studies have relied on *ad hoc* categories based on the judgment and objectives of the researcher, studies with meaningful categories from which to code accounts can assimilate seemingly disparate events or objects to identify new patterns (Whyte, 1977).

Within historical ecology the majority of coding studies have reconstructed ecological trajectories of species over time by applying consistent criteria to code anecdotes (Pandolfi et al., 2003; Lotze et al., 2006; Palomares et al., 2006; Palomares, 2007; Fortibuoni et al., 2010). Yet, because these reconstructions were based on a single person's perception of a set of historical anecdotes or many people coding different anecdotes, the external validity of these results cannot be evaluated.

To overcome criticism that the interpretation of qualitative anecdotal data in historical ecology is overly subjective, people's perceptions of species' abundances from historical anecdotes were tested. Intercoder reliability testing, a standard measure of consistency, was used to determine the degree to which independent coders agree on the ranking of historical anecdotes using the same coding scheme. Similar to the subjectivity encountered in fish age interpretation by otolith readers (Eklund et al., 2000; Marriott et al., 2010), repeated readings of historical anecdotes by different people can verify that the original vision of authors remains implicit, and therefore whether the conclusions drawn are valid.

Methods

Ethics statement

This study was approval by the Behavioral Research ethics Board of the University of British Columbia. Written consent was obtained by completion of the questionnaire. The University of British Columbia Behavioural Research Ethics Board (BREB) procedures and Guidance Notes comply with the second edition of the Tri-Council Policy Statement (TCPS) on 'Ethical Conduct for Research Involving Humans' (TCPS2). The UBC BREB operates under the authority of UBC Policy 89 on Research and Other Studies Involving Human Subjects.

Survey

Fifty anecdotal accounts (defined here as informal—often brief—earlier accounts of species' abundances) of marine organisms were extracted from historical texts on the Persian Gulf, the Falkland Islands, and Raja Ampat (Papua, Indonesia), ranging in date from 1330 to 1940 (Table 5.1; Appendix C). Because an anecdote's date may be inferred from certain features, such as the dates and names of people and places, we remove any identifying information. Passages where the style of language was immediately indicative of the era were also excluded, as to ensure that coders were not positively biased towards passages that were perceived as older (i.e., interpreting greater abundance from older anecdotes, and less from newer anecdotes).

A multi-level species abundance classification scheme was created (Table 5.2) based on systems used in other studies (Pandolfi et al., 2003; Palomares et al., 2006). For each of the 50 anecdotal accounts, participants were asked to select one of five ‘species abundance descriptors,’ based on their perceived abundance of the species described in the passage. Although species’ abundances are typically relative to their trophic level (i.e., predators are often less abundant than prey), the criteria describe relative depletion of species, rather than absolute values in species abundance. This distinction was made because it is possible to have a small population of highly productive small prey animals supporting a relatively high biomass of larger predators (Friedlander et al., 2010).

The survey was outsourced to 50 people using Amazon Mechanical Turk (www.mturk.com), a crowd-sourcing Internet marketplace that coordinates the supply and demand of tasks requiring human intelligence. Studies have shown that micro-task markets are useful for studies that require access to a large user pool for subjective information gathering (Kittur et al., 2008). Since the so-called ‘Turks’ are drawn from a wide range of users (virtually anyone connected to the internet), they represent a diverse range of perspectives and therefore complimented the goals of our study.

Since there is no incorrect way to answer our survey, an attempt was made to reduce the likelihood of Turks ‘gaming’ the system (i.e., providing nonsense answers in order to decrease their time spent on the task and thus increase their rate of pay) by planting a ‘trick’ question within the survey to determine the authenticity of responses. Those surveys where Turks did not answer the trick question correctly were removed. The time taken to complete each survey was also reviewed and surveys that were submitted in 10 minutes or less were removed, as it was considered unlikely that respondents could reliably answer in this time.

Furthermore, because there are 39 agreement indices and no consensus on the best index to determine intercoder reliability, the 3 most common reliability tests for categorical rankings were used to determine the proportion of variance in rankings due to between-subject variability in the true scores: 1) Intraclass Correlation Coefficient (ICC), describes how strongly units in the same group resemble each other, while 2)

Fleiss Kappa and 3) Finn-Coefficient which describe the reliability of agreement between a fixed number of coders assigning categorical rankings (Hughes and Garrett, 1990; Lombard et al., 2002). Coefficient values range from 0 to 1, with 1 representing perfect agreement. Although there is no minimum acceptable level of reliability for all indices, coefficients of .80 or higher are acceptable in most cases, and lower levels are acceptable for more conservative indices such as the Fleiss Kappa (Lombard et al., 2002).

Results

Of the 50 surveys solicited, 4 coders failed to answer the ‘trick’ question correctly, and 6 coders submitted the survey in less than 10 minutes, resulting in a total of 40 surveys that were suitable for analysis.

The results of all responses across questions were graphed using a modified dot plot to show the level of agreement among the respondents across all questions (Figure 5.1). For each question, dot size is proportional to response frequency: the larger the dot, the more frequently a species abundance descriptor was selected by respondents and therefore the greater the level of agreement. Questions with lower levels of agreement are indicated by an even distribution of smaller dots across species abundance indicators. Questions were ordered in decreasing order of response frequency of the "Abundant" descriptor, with ties broken by decreasing order of the "Common" descriptor, and further ties broken by subsequent descriptors. “Common” and “Abundant” were the most commonly selected species descriptors (41% and 32% of total responses, respectively), while the average (weighted by response frequency) number of descriptors selected per question was 1.45 (minimum = 1, maximum = 2.35).

The results of both the ICC test and Finn-Coefficient indicate strong intercoder reliability (ICC = 0.743; Finn-Coefficient = 0.834; Table 5.3), while the Fleiss Kappa indicates moderate reliability (Kappa = 0.407; Table 5.3). Although the Fleiss Kappa value is lower than the other two indices, it does not necessarily point to low levels of agreement, because unlike the other two indices the Fleiss Kappa considers the prevalence of rankings, indicating an uneven distribution of categorical rankings (Feinstein and Cicchetti, 1990). When taken in context of the high levels of agreement by the other two indices, and the fact that 73% of total responses were “Common” and “Abundant,” the low levels of Kappa are most likely an artifact of rarely chosen rankings.

Discussion

Intercoder reliability, or the extent to which independent coders evaluate a characteristic of a subject (anecdotes in this case) and reach the same conclusion, is a critical component of content analysis (Lombard et al., 2002; Neuendorf, 2002). Reliable coding demonstrates replicability, a fundamental component of scientific research. Here, text coding, a method commonly used in historical marine ecology, is shown to achieve high levels of intercoder reliability, challenging the notion that anecdotal evidence is irrelevant (Shermer, 1997; Shermer, 2003). In this way, intercoder reliability can be used as a proxy for the validity of conclusions drawn from anecdotal data.

Humans, possessing both consciousness and culture, are predisposed to see or miss things, count or ignore them (Vickers and McClenachan, 2011). While the precision and clarity of individual historical accounts may vary, using many anecdotes that exhibit similar ecological trends greatly increases confidence in the results (Jackson et al., 2001; Kittur et al., 2008). Anecdotal evidence, taken in quantity, can overcome the particular biases of individual sources, to produce a rough picture of how ecosystems used to look (Jackson et al., 2001).

Despite the importance of historical baselines in setting recovery and conservation goals, historical data in the form of anecdotes or narratives are not commonly incorporated into existing management contexts (McClenachan et al., 2012). Integrating qualitative information into established quantitative frameworks or standardized assessment protocols is challenging at best. In the absence of quantitative data, coding anecdotal accounts can help overcome the psychological barrier that leads one to believe that no data exist. For example, coding historical accounts may be useful in establishing historical baselines for endangered species such as sawfishes (Pristidae) in the Persian Gulf. Eyewitness accounts by pearl divers in the 18th century suggest sawfishes were once abundant, yet accounts of sawfishes today are extremely rare. Despite the apparent decline in sawfish populations, management plans are stalled by the lack of quantitative data. Establishing intercoder reliability can add legitimacy to studies based on historical anecdotes, facilitating their integration into conservation and management frameworks.

Future coding studies in historical ecology should perform intercoder reliability tests to verify if the particular scale chosen is appropriate; low levels of agreement among coders may suggest weaknesses in research methods, including the possibility of poor category definitions and coder training. High intercoder agreement, on the other hand, strengthens conclusions drawn from anecdotal evidence. In this way, the calibration of people's perceptions of qualitative narratives adds value to anecdotal evidence allowing for the integration of varying data types.

The establishment of high levels of reliability among coders also has the practical benefit of allowing researchers to distribute the coding work among many different coders, thus improving efficiency (Neuendorf, 2002). Here, the utility of outsourcing coding tasks using Amazon Turk was demonstrated. Despite their lack of training (and perhaps interest) in the subject, Turks were able to achieve acceptable levels of intercoder reliability. It is predicated that with some preliminary training, outsourced coding studies can achieve even higher reliability values. Furthermore, it is thought that historical ecology researchers (i.e., experts) are likely to generate a more cohesive result due to their disciplinary training devoted to the critical examination of historical sources. Since Turks are composed of a wide range of users, they likely use different sets of criteria in subjective decision-making than expert populations (Kittur et al., 2008).

While the calibration of perspectives is useful, it is important to note that coding allows only for broad inferences in past species abundances. Stripping qualitative narratives of their richness and variety, and transforming them into categorical units, sacrifices historical and/or ecological precision, impeding our ability to make prescriptive statements about the state of past or future ecosystems. Only by incorporating a variety of sources and analytical techniques with expert knowledge can we begin to have a more nuanced perspective to make broad estimates on the general pace and direction of changes in species biodiversity and biomass.

A historical perspective is needed to envision what oceans might have looked like in the past and what they can produce in the future. In the face of limited knowledge, anecdotes serve as useful starting points for ecological studies. If limits are placed on the conclusions drawn, anecdotes can provide rich insights into structure and function of past ecosystems (Paxton, 2009). This contribution suggests that people’s perceptions of species’ abundances from historical narratives are generally consistent and that intercoder reliability can complement future studies in historical ecology by calibrating perceptions of anecdotes.

Tables

Table 5.1 Examples of historical anecdotes used in the coding survey. Identifying features are replaced by“-------”.

Reference	Passage
Battutah (2002)	“Most of the fish in it are the species called sardin, which are extremely fat there. It is a strange fact that their beasts have their sole fodder these sardines, and likewise their flocks, and I have never seen this any other place."
Pernety (1771)	“We did not catch any beautiful shell-fish here; the only one deserving notice was a helmet shell, which was at least eight inches in diameter.”
Streeter (1886)	“Among the dangers of the pearler in the ------- the dreaded saw fish may be mentioned as the chief enemy. This shark like creature is furnished with a formidable weapon in the shape of a flat projecting snout reaching a length of perhaps six feet and armed along its edges with strong toothlike spines. In the presence of such a terrific weapon the diver is almost powerless and instances are recorded in which the poor fellows have been completely cut in two.”
Villiers (1940)	"Fine edible fish seemed extraordinarily numerous off that coast, and all day long the fishermen were landing their heavy catches through the surf”

Table 5.2 Coding criteria of perceived species' abundances following the ranking system applied in Palomares *et al*. (2007, 2006) and Pandolfi *et al.* (2003).

Species Abundance Descriptor	Criteria for Classification
Abundant	Account lacks any evidence of human use or reduced species abundance
Common	Account describes some human use, but no evidence of reduced species abundance
Present	Account describes some human use and evidence of reduced species abundance
Rare	Account describes extreme human use and severely reduced species abundance
Absent	Species no longer in existence

Table 5.3 Statistical summary for three commonly used intercoder reliability tests.

Test	Value	P-Value	Confidence interval
Intraclass correlation Coefficient (ICC)	0.743	p<0.001	0.665 - 0.819
Fleiss' Kappa	0.407	p<0.001	N/A
Finn Coefficient	0.835	p<0.001	N/A

Figures

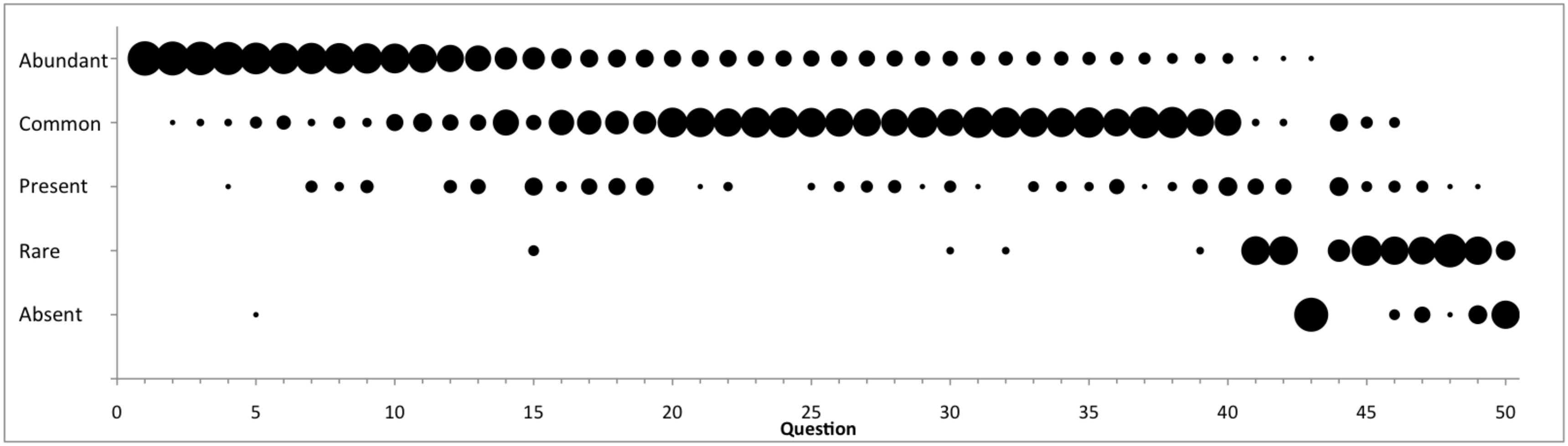

Figure 5.1 Summary of responses across all 50 questions. Questions are ordered on the x-axis by decreasing frequency of the most abundant descriptor ranking (i.e. "Abundant" to "Absent"). Circle size is proportional to frequency of response.

6 RECONSTRUCTING HISTORICAL BASELINES FOR THE PERSIAN GULF DUGONG (*Dugong dugon*)[5]

[5] A version of this chapter is being prepared for submission to a journal.

Introduction

Historical data are necessary to help clarify the underlying causes and rates of ecological change in order to set appropriate management targets for the restoration and management of coastal ecosystems (Jackson *et al.* 2001). Retrospective estimates of historic abundances and distributions of marine organisms are crucial to understanding the profound and long-lasting effects of human activity to the structure of coastal ecosystems (Baum *et al.* 2003; Myers and Worm 2003; Pandolfi *et al.* 2003; Lotze and Milewski 2004; McClenachan *et al.* 2006; Jackson 2008). This is especially important for vulnerable species, such as the dugong (*Dugong dugon*).

The dugong is one of the four living species of the order Sirenia and the only surviving member of the once-diverse Dugongidae family. Dugongs are found in the waters of at least 48 countries. Although dugongs are classified as vulnerable to extinction by the IUCN (Marsh 2002), little information is known of their true distribution and abundance. The dugong is thought to be declining or extinct in at least a third of its range and of unknown status in about half its range (Marsh 2008). According to the IUCN, global dugong populations have declined by 30% in the last 6 decades (Marsh 2008).

The Persian Gulf[*] is home to about 7,300 dugong, the second largest dugong population in the world after Australia, and the most important dugong habitat in the western half of the dugong's range (Preen 1989; Marsh 2002). Though numerous studies have described the abundance, distribution, and ecological role of dugongs in Australia (Anderson and Birtles 1978; Marsh *et al.* 1982; Marsh *et al.* 2005), far less is known about the dugong population in the Persian Gulf (Preen 2004).

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[*] Although the name of this body of water remains contentious, the term recognized by UNCLOS is used here.

History of dugong exploitation in the Gulf

Dugongs are known by several local names including *baqarah al bahr* (Arabic: cow of the sea), *arus al bahr* (Arabic: bride of the sea) and *cow diryali* (Farsi: marine cow). The earliest evidence for their exploitation in the Persian Gulf has been found in middens dating back to 3500-3200 BC (Mery *et al.* 2009; Beech 2010). Also, archaeological excavations have revealed carefully selected dugong remains arranged in ritualistic displays, suggesting the long-term presence and cultural importance of the species to the region (Mery *et al.* 2009; Beech 2010). Interestingly, analogs to the ritualistic mound have been found in other places in the world (albeit at much later date) such as on the coasts of the Torres Strait in Australia (Mery *et al.* 2009).

Indeed, dugongs provided a rich source of meat, oil, fat and hide to the prehistoric and historic coastal communities of the Gulf (Beech 2010). A single individual weighed between 200-300 kg and provided 24-56 liters of oil, which would have been used for cooking, fuel for lamps, medicine, and as a sealant for wooden boats (Agius 2009; Beech 2010). Dugong meat was used for personal consumption, or dried into strips and traded with neighboring villages. The bone marrow was also consumed, but the tailstock was the preferred section. The hide was used to make sandals and the tusks were used in the sword handles of Emirs and Sheikhs. Traditionally, dugongs were hunted by herding individuals into shallow water and clubbing them to death (Preen 1989). Prior to the discovery of oil in the Gulf, tribes of traditional dugong hunters in Bahrain may have killed up to hundreds of dugongs each year (Marsh *et al.* 2002).

While the significance of dugongs to local culture and diet has lessened in recent decades, they are still occasionally captured intentionally or as bycatch. Interviews conducted by the Emirates Natural History Group in 1976 estimated between 50 to 70 dugongs were sold every year. By the mid-1980s between 70 to 100 dugongs were captured every year and sold at the Abu Dhabi Fish market (Preen 1989).

At present, dugongs in the Gulf are only offered protection in UAE waters

(Federal Law No. 23 and Article 28/2000 Amiri Decree). It is worth noting that dugongs are considered *halal* or permissible to eat by Islam. In contrast, the meat of terrestrial animals cannot be eaten unless they have been killed in according to *halal* requirements.

Despite their cultural significance to the region, very little is known about dugongs' true status in the Gulf. Only a handful of scientific articles describing dugongs in the Gulf exist (Preen 1989; Baldwin and Cockcroft 1997) and the most recent ecological study was published more than a decade ago (Preen 2004). Here, an estimate of the historical population size and distribution for the Persian Gulf dugong is provided which may assist in setting conservation targets and may be incorporated into management plans.

Methods

Historical and present-day observations of dugongs in the Persian Gulf were compiled from published and written sources including the British National Archives in London, New York Public Library, and the University of British Columbia. The majority of archival records on the Persian Gulf are held outside the region (much of it in London) due to historic circumstances, and also for preservation purposes. Accounts in Arabic, Farsi and English were compiled (See Appendix C).

In total, 155 records were found and categorized according to usefulness and type. The records were then ranked against a species abundance classification scheme based on previously established methods (See Chapter 5; Pandolfi *et al.* 2003; Palomares *et al.* 2006; Al-Abdulrazzak *et al.* 2012) to infer long-term changes in relative species abundance. The ranking system is based on five categories (1= Absent, 2= Rare, 3= Present, 4= Common, 5= Abundant) and the average rank for each decade was graphed.

Of these 155 records, 80 were location-specific and were mapped in a geographic information systems database in 2 categories, sightings dated before 1950 and after 1950, to examine changes in species range and distribution (Figure 6.1).

Data compiled from the historical records represent a small fraction of the total number of actual dugong encounters in the Gulf. Because relying solely on the historical evidence would likely result in an underestimation of the distribution and abundance of dugongs, we developed methods for estimating a range of dugong abundances using habitat density data. Dugongs are almost entirely dependent on seagrass for food and are therefore closely associated with seagrass beds (Marsh and Saalfeld 1986; Preen 1989). Between 6,790-7,320 km^2 of seagrass have been mapped in the Gulf (Erftemeijer and Shuail 2012), but that estimate excludes Iran. Therefore, to account for total seagrass areas in the Gulf (including Iran), mapped seagrass areas were correlated with areas that are 10 m or less in depth (the most common depth range for seagrass in the Gulf; Erftemeijer and Shuail 2012) for each country (Table 6.1). To determine the total extent of areas of 10 m or less depth, half-degree grid cells were overlaid along the coast of the Gulf (with the exception of the Iraqi coast which, because of the Shatt Al Arab, has a low salinity and no seagrass; Erftemeijer and Shuail 2012), and for each cell, the areas of 10 m or less depth were calculated and grouped by country (Figure 6.2). The mean of the countries' ratios (0.141) and the mean ratio (0.195) were both calculated, but the latter was used to estimate total seagrass areas in Iran, because it not biased by the ratios from small countries (Table 6.1). The resulting estimated seagrass of 2,149 km^2 for Iran was added to the estimate of Erftemeijer and Shuail (2012) of 6,790-7,320 km^2

Next, thirty-six estimates of dugong densities on seagrass beds were compiled from peer-reviewed literature (Table 6.2); the average ratio (after omitting 4 outliers from Shark Bay Australia[6]) was applied to the estimated total extent of seagrass in the Persian Gulf.

[6] The outliers were identified from the shape of the distribution of density values, which is quasi-(log)normal once the lowest 4 densities are removed (see Figure 6.7).

To estimate potential range contraction, the areas of 10 m or less depth in each grid cell with anecdotal sightings prior to 1950 were counted and compared to sightings contained in cells after 1950. A structured overview of the methods is presented in Figure 6.3.

Results

Accounts of dugongs were found in all countries in the Persian Gulf except for Iraq and Oman (which have limited coastline in the Gulf; Figure 6.1). The majority of sightings were found in the UAE (30%) and Bahrain (27%), followed by Saudi Arabia (11%), Iran (5%), Qatar (4%) and Kuwait (2%). Mapping historical dugong sightings indicates that the population may have experienced a range contraction of up to 26%, as records were found in Kuwait and Iran, which were previously thought not to have dugongs (Figure 6.4).

A cumulative curve of dugong sightings indicates a sharp increase in dugong interest in the 1980s, coinciding with the 1983 Nowruz oil spill (Figure 6.5). Not surprising, the types of records containing information on dugongs changed over time; travel narratives dominated from 1800-1930s, while scientific studies began in the early 1900s. Interest from news media began in in the mid-1900s, long after the start of dugong exploitation. Perceived abundance of dugongs has generally declined in the Gulf from ‘Abundant’ and ‘Common’ through the 1850s, to ‘Rare’ starting about 1950 (Figure 6.6).

Correlating mapped seagrass areas and depth range in Gulf countries yielded an estimated total seagrass area of 12,231 km^2 (Table 6.1). When applied to the mean dugong on seagrass density ratio (0.878 individuals·km^{-2}; Figure 6.7), we estimate a ‘current’ population of 10,739 ± 2,785 individuals.

Discussion

The first field survey for dugongs in the Gulf was conducted in 1986, long after populations were exploited. Aerial surveys conducted by Preen (1989) indicated that they were restricted to the southern and southwestern coastline between Ras Tannurah in Saudi Arabia and Abu Dhabi in the United Arab Emirates. Within this area the population was estimated to be 7,307 ± 1,302 individuals. Our methods yield estimates of 10,739 ± 2,785 individuals, suggesting that despite dugong populations in the Gulf being the second largest in the world, their average density is much lower than at other sites in the Indo-Pacific. This may indicate that their populations in the Gulf are more impacted than previously considered.

Thus, to explore the effect of higher densities that are likely to have occurred in the Gulf in the past, before dugongs were heavily targeted for exploitation, a conservative density value of 1.47 individuals·$km^{-2}$of seagrass was selected as 'past value', corresponding to one standard deviation above the mean of the distribution in Figure 6.7. In this case, the estimates indicate a potential 'pristine' population of about 18,000 ± 4,600 dugongs. This 'pristine abundance' is more than twice the current population, and may explain people's perception of declining dugong abundance (Figure 6.6). Obviously, selecting a higher pristine density value, for example two standard deviations above the mean, would generate a much more dramatic decline to present abundance. The method used here is fraught with uncertainties; however, it offers a starting point for scenarios for understanding historical trajectories as well as comparing the health of the Gulf's dugong population to other populations in the Indo-Pacific, where density surveys are available.

Contrary to previous studies (Preen 1989; Preen 2004), historical records (as well as modern sightings in the case of Iran; Keijl and van der Have 2002; Braulik *et al.* 2010) suggest that dugongs had a larger range than previously thought. Their present range appears to be about 74% of the historical range.

Thus, setting conservation targets on partial information may result in lowered expectations for the ecological role of dugongs. For example, although the IUCN lists populations in Iran to be 'vagrant', the findings from this study suggest a past resident population, which has management implications that were previously not considered. In addition, based on the 1986 survey (Preen, 1989), the sustainable annual take is 60-120 dugongs (2-4%). However, this estimate is based on a population that is thought to be relatively stable, without consideration of its historic 'pristine' population, and therefore, the take limits may be set too high.

Dugongs face a number of threats in the Gulf due to rapid coastal development including dredging, trawling, and land reclamation, all of which damage their crucial seagrass habitats. Several large dredging and reclamation sites occur within critical dugong habitats in the Gulf, such as the seagrass beds of the Gulf of Salwa, between Saudi Arabia and Qatar (Marsh *et al.* 2002). Dredging may increase salinity by impeding water flow (Marsh *et al.* 2002), and thus further threatening seagrass beds.

Dugongs are also captured as incidental bycatch in gillnet and driftnet fisheries. Interviews with fishers in the UAE suggest that dugongs are most often caught in 14-18 cm gillnets targeting kingfish (*Scomberomorus* spp.) and sharks (Baldwin and Cockcroft 1997). About 15 new dugong carcasses are seen along the coastline of the UAE every year and are thought to be discarded bycatch (Marsh *et al.* 2002). In some cases some dugong meat is missing from the carcasses, indicating that some fishers will take a portion of meat for their own consumption. Currently, no bycatch mitigation efforts are enforced.

Oil spills are unfortunately common in the Gulf and two of the largest spills ever recorded occurred during the Iran-Iraq War in 1983 and the Gulf war in 1991, and resulted in large dugong mortalities. The Strait of Hormuz is considered the world's most important 'oil chokepoint' with an oil flow of 17 million barrels per day in 2013, about 30% of all seaborne-traded oil[7]. The present-day distribution of dugongs in the Gulf corresponds with habitats most at risk from oil pollution, due to the location of oil

[7] http://www.eia.gov/countries/regions-topics.cfm?fips=wotc&trk=p3

loading terminals in the immediate vicinity (Marsh *et al.* 2002). Moreover, it is thought that the counter-clockwise current in the Gulf will force oil-polluted water from the northwestern Gulf, where the majority of oil extraction occurs, to the center of dugong habitats in the southwest (Marsh *et al.* 2002).

There have been few examples of effective management practices to reduce human impacts on dugongs. Although management plans exist for about 25% of dugongs' range, the majority occurs in Australia and not much is known about their efficacy. A new tri-party agreement signed in 2014 between ExxonMobil Research Qatar, Qatar University, and Texas A&M University may be a good first step into setting appropriate management targets in place. In addition, the creation of MPAs in the Gulf, starting with Saudi Arabia in 2003, is promising. However, despite the difficult political climate, countries must work in coordination to protect transboundary species such as the dugong.

Historical accounts such as those by British explorers or archeological records hold clues to the past population abundance and distribution of marine mammals. As we gain a better understanding of the historical trajectories for dugongs in the Gulf, the need for improved management becomes clearer, which will hopefully garner public support for greater conservation initiatives in the region.

Tables

Table 6.1 Surface area of 0-10 m depth range and of mapped seagrass areas in Gulf countries, as used to convert depth range to suitable dugong habitat. The mean ratio (0.195) was used to estimate 2,149 km^2 of seagrass in Iran.

Country	**Area of 0-10m depth**	**Mapped seagrass (km^2)**	**Ratios**
Bahrain	4,051	750	0.185
Kuwait	2,749	53	0.019
Qatar	7,365	30	0.004
Saudi Arabia	9,141	565	0.062
UAE	12,970	5,663	0.437
Mean of ratios	-	-	0.141
Sums (mean ratio)	36,276	7,061	**(0.195)**
Iran [inferred seagrass]	10,746	[2,149]	-

Table 6.2 Estimates of dugong density on seagrass beds in the Indo-Pacific. Four outlying estimates (in brackets) were omitted from the analysis (see footnote 6 on p. 71).

Location	Site Remarks	Reference	Density (individuals/km^2)
Shark Bay, Australia	Site 1	Heithaus *et al.* (2007)	(0.01)
Shark Bay, Australia	Site 4	Heithaus *et al.* (2007)	(0.015)
Shark Bay, Australia	Site 2	Heithaus *et al.* (2007)	(0.02)
Shark Bay, Australia	Site 2	Heithaus *et al.* (2007)	(0.021)
Shark Bay, Australia	Site 3	Heithaus *et al.* (2007)	0.03
Shark Bay, Australia	Site 3	Heithaus *et al.* (2007)	0.035
Shark Bay, Australia	Site 1	Heithaus *et al.* (2007)	0.07
Shark Bay, Australia	Site 4	Heithaus *et al.* (2007)	0.07
Andaman coast, Thailand	03/31/2001	Hines *et al.* (2005)	0.1
Andaman coast, Thailand	04/02/2001	Hines *et al.* (2005)	0.1
Andaman coast, Thailand	03/08/2000	Hines *et al.* (2005)	0.1
Andaman coast, Thailand	03/09/2000	Hines *et al.* (2005)	0.1
Andaman coast, Thailand	04/01/2001	Hines *et al.* (2005)	0.2
Andaman coast, Thailand	04/12/2001	Hines *et al.* (2005)	0.2
Andaman coast, Thailand	03/13/2000	Hines *et al.* (2005)	0.2
Andaman coast, Thailand	03/10/2000	Hines *et al.* (2005)	0.4
Andaman coast, Thailand	03/17/2000	Hines *et al.* (2005)	0.4
Great Barrier Reef, Australia	Site 1	Marsh and Saalfeld (1986)	0.5
Andaman coast, Thailand	04/11/2001	Hines *et al.* (2005)	0.5
Andaman coast, Thailand	03/07/2000	Hines *et al.* (2005)	0.6
Andaman coast, Thailand	03/08/2000	Hines *et al.* (2005)	0.6
Andaman coast, Thailand	03/20/2000	Hines *et al.* (2005)	0.6
Andaman coast, Thailand	04/05/2001	Hines *et al.* (2005)	0.6
Andaman coast, Thailand	04/10/2001	Hines *et al.* (2005)	0.6
Andaman coast, Thailand	03/18/2000	Hines *et al.* (2005)	0.7
Andaman coast, Thailand	04/08/2001	Hines *et al.* (2005)	0.8
Andaman coast, Thailand	03/06/2000	Hines *et al.* (2005)	1
Andaman coast, Thailand	03/19/2001	Hines *et al.* (2005)	1
Great Barrier Reef Australia	Site 2	Marsh and Saalfeld (1986)	1.1
Exmouth Gulf, Australia	NA	Preen *et al.* (1997)	1.114
Ningaloo, Australia	NA	Preen *et al.* (1997)	1.142
Andaman coast, Thailand	04/06/2001	Hines *et al.* (2005)	1.2
Hervey Bay, Australia	NA	Preen and Marsh (1995)	1.25
Andaman coast, Thailand	04/07/2001	Hines *et al.* (2005)	1.3
Shark Bay, Australia	NA	Preen *et al.* (1997)	5.1
Moreton Bay, Australia	NA	Lanyon (2003)	7.25

Figures

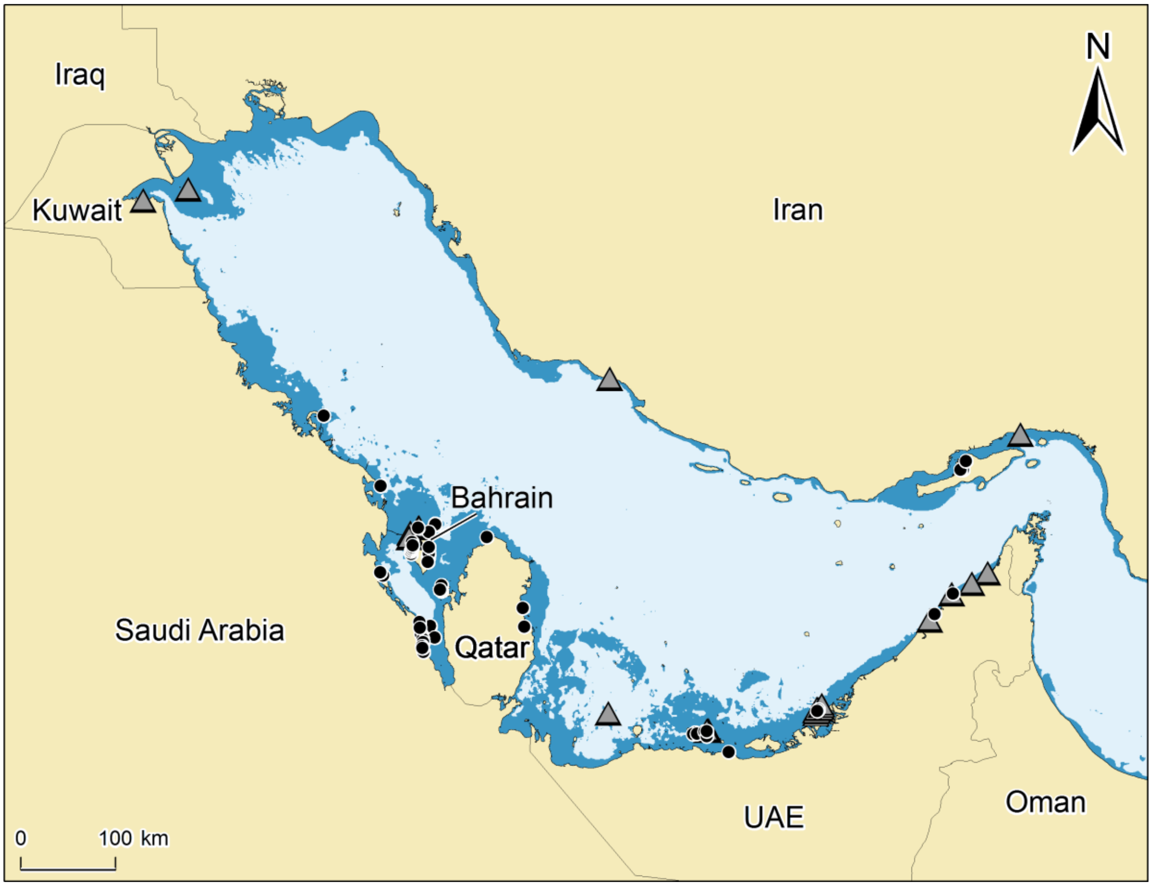

Figure 6.1 Map of dugong sightings in the Persian Gulf. Grey triangles represent sightings prior to 1950. Black circles are sightings after 1950. Dark blue represents a depth of 10 m or shallower.

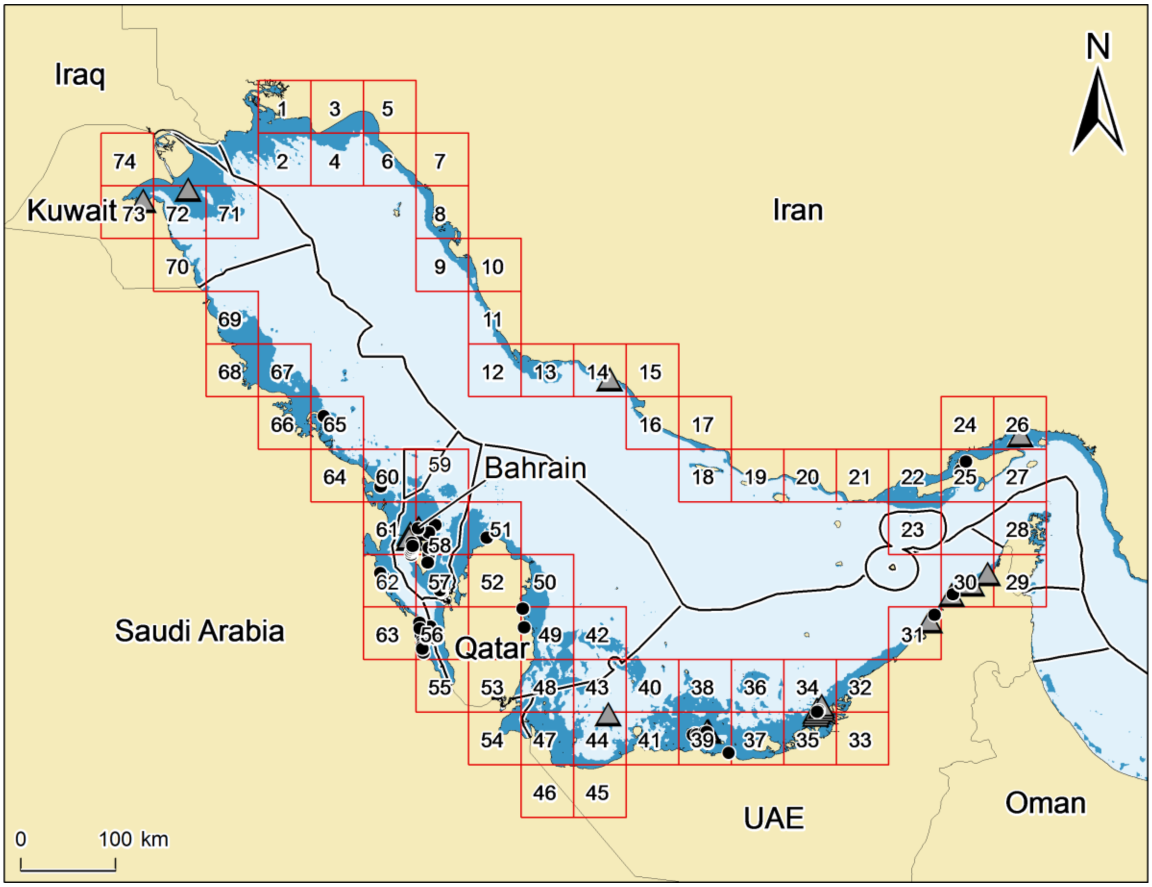

Figure 6.2 Map of dugong sightings in the Persian Gulf with half-degree cells overlaid (#1-74). Grey triangles represent sightings prior to 1950. Black circles are sightings after 1950. Dark blue represents a depth of 10 m or shallower.

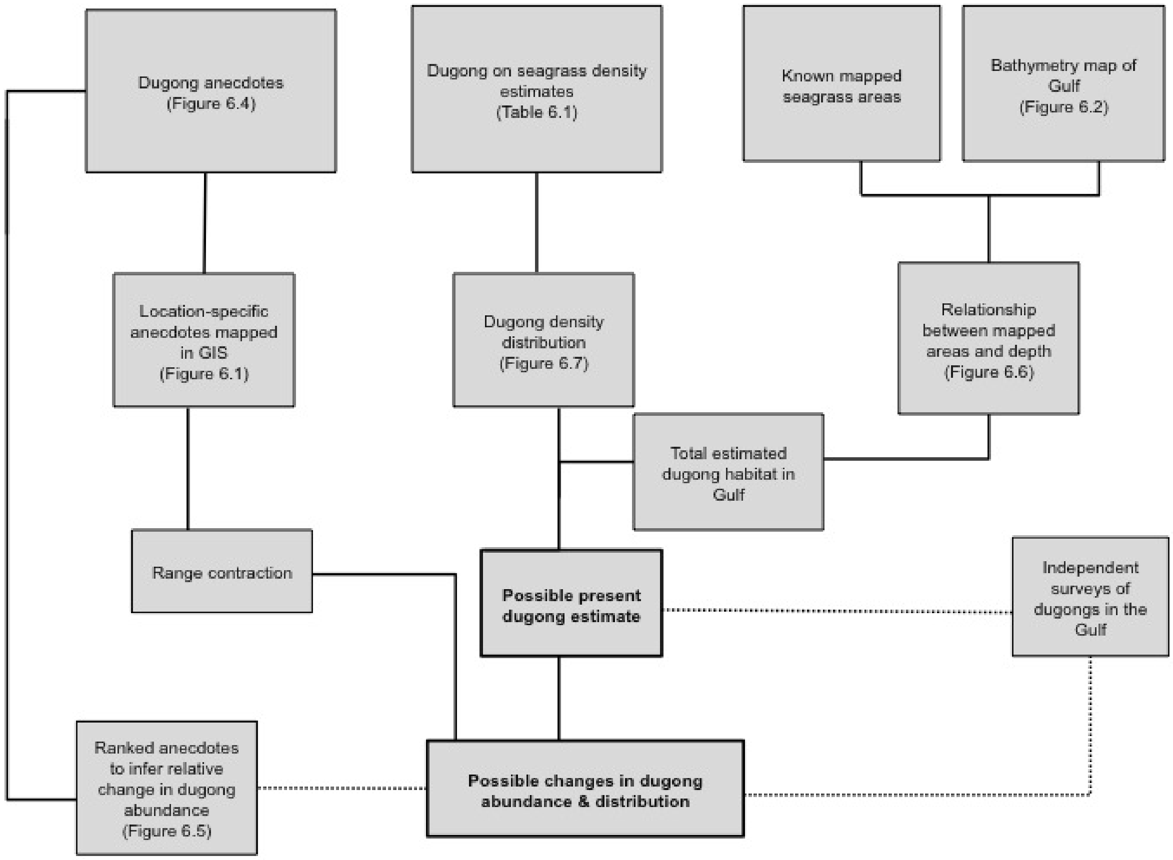

Figure 6.3 Flow chart of methodology. Solid lines represent direct inputs, while dashed lines represent comparisons between similar values. Dugong anecdotes were used to examine range contraction and to infer relative change in abundance. Estimates of dugong density on seagrass from Indo-Pacific surveys were applied to estimates of the total extent of seagrass in the Gulf. Results from the anecdotal analysis and density distribution were compared to independent surveys of dugongs in the Gulf.

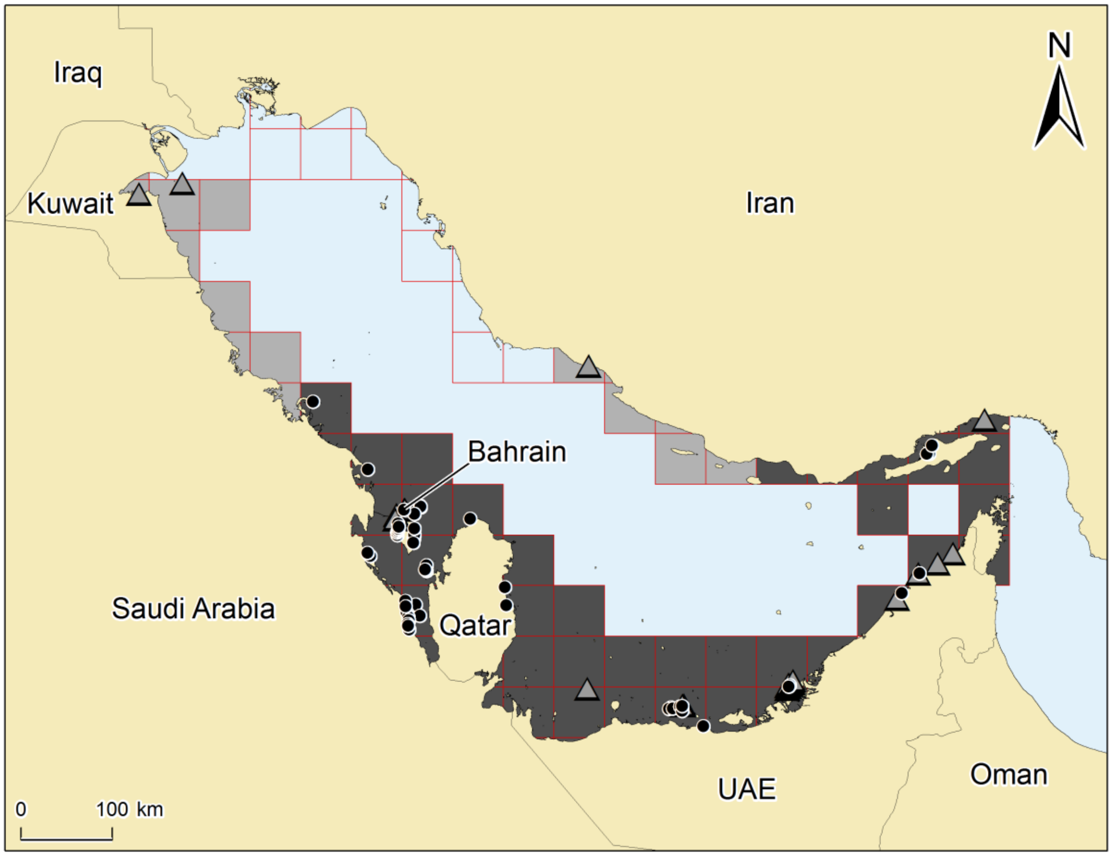

Figure 6.4 Map of potential dugong range contraction in the Persian Gulf. Dark grey is the present dugong range; light grey represents inferred past range.

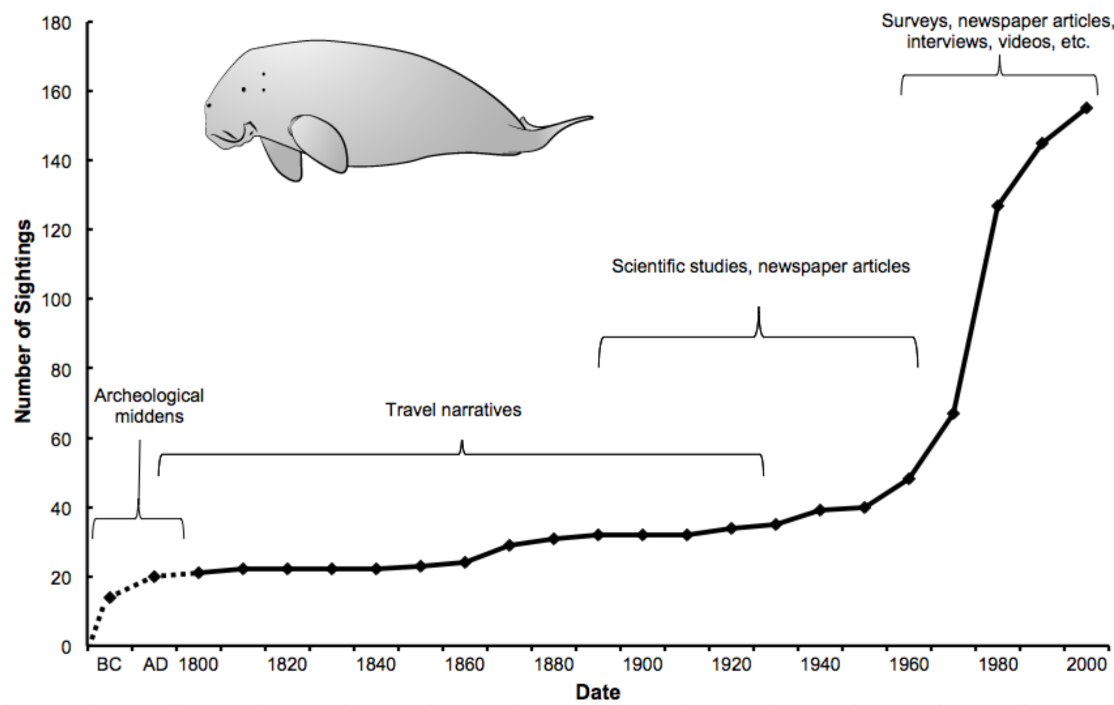

Figure 6.5 Dugong discovery curve for the Persian Gulf. Interest in dugongs peaked in the 1980s due to the Nowruz oil spill in Iran, which was thought to have eradicated the local population.

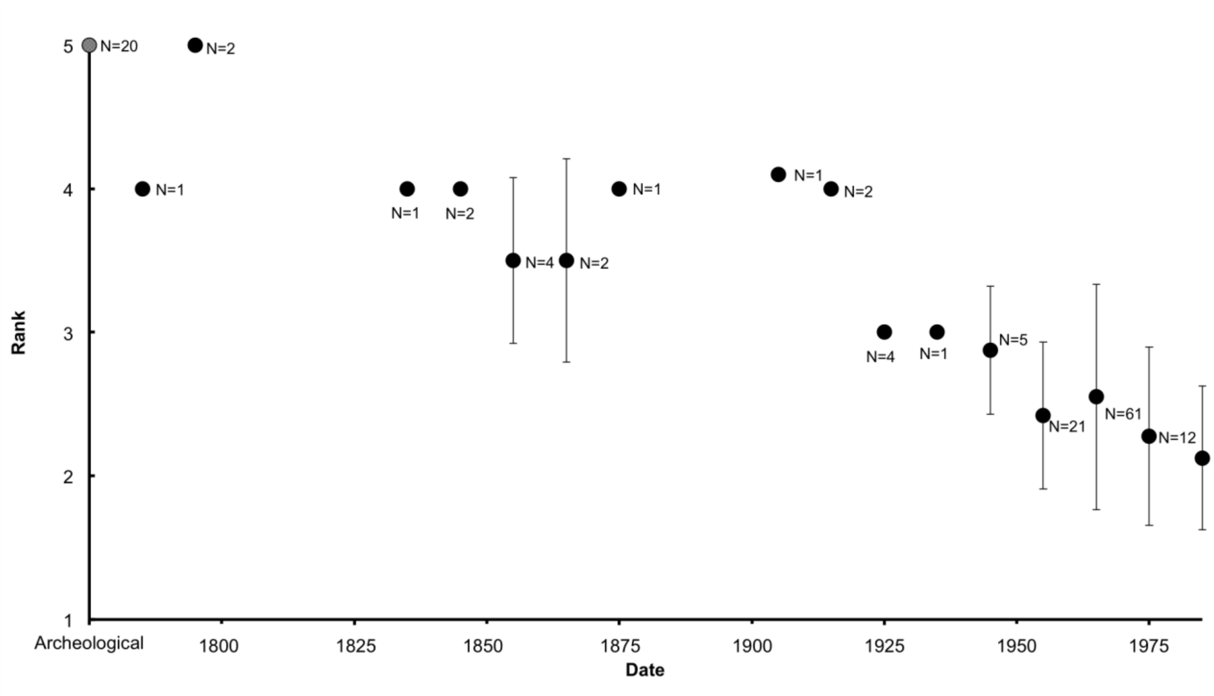

Figure 6.6 Changes in the perceived abundance of dugongs in the Persian Gulf through time (1= Absent, 2= Rare, 3= Present, 4= Common, 5= Abundant).

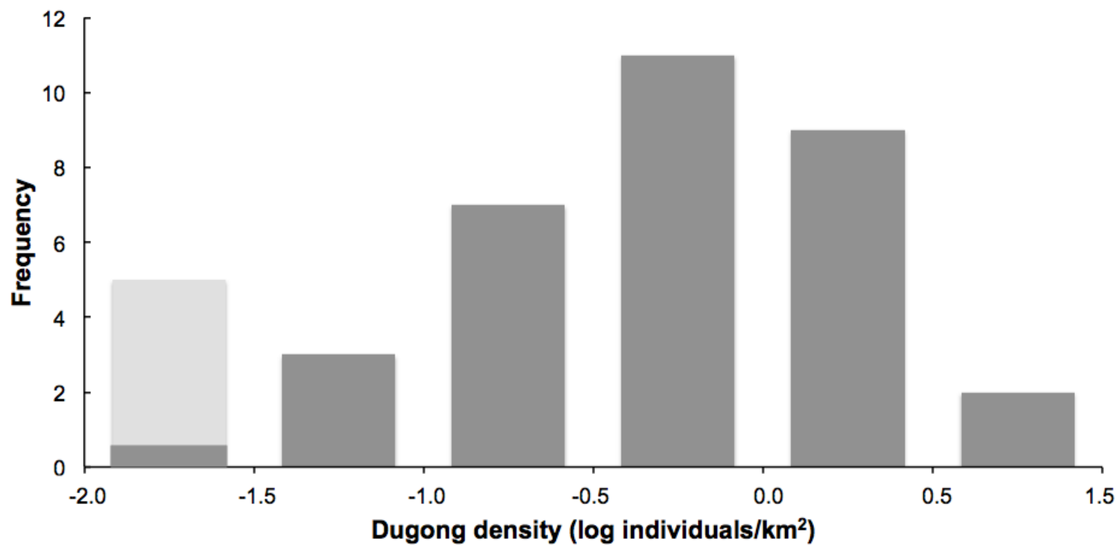

Figure 6.7 Frequency of published dugong density estimates in the Indo-Pacific Data from Table 6.2. Estimates from Shark Bay presumed to be outliers (given the overall shape of the distribution) are shown in light grey.

7 FROM DHOWS TO TRAWLERS: THE FUTURE OF FISHERIES IN THE GULF

Since the oil boom of the 1970s, Gulf countries have undergone dramatic economic transformations. Populations have more than tripled over the past four decades, and many of the small fishing and trading villages that historically peppered the Gulf's coastline have grown into metropolises. Today a number of Gulf countries now rank among the richest countries in the world and the annual growth rate (2.1%) is nearly double the global average (Van Lavieren et al., 2011). The population of the Gulf has more than tripled in size over the past four decades and as a result more than 85% of the population lives within 100 km of the coast in five of the eight Gulf countries (Bahrain, Kuwait, Oman, Qatar and the UAE).

However, after oil, fish is the second most important natural resource in the Persian Gulf. Indeed, marine ecosystems have played an important role in the cultural and economic history of the Gulf. Prior to the discovery of oil in the 1930s, the region's economy was built on pearls. Lorimer (1908) wrote that "[p]earl fishing is the premier industry of the Persian Gulf; it is, besides being the occupation most peculiar to that region, the principal or only source of wealth among the residents of the Arabian side. Were the supply of pearls to fail, the trade of Kuwait would be severely crippled, while that of Bahrain might—it is estimated— be reduced to about one-fifth of its present dimensions and the ports of Trucial Oman, which have no other resources, would practically cease to exist." Shortly after this statement was made, Japanese cultured pearl farming precipitated the collapse of pearl industry and hence the regional economy.

One wonders whether the collapse of the pearl industry foreshadows the collapse of the region's fisheries. In fact, history is filled with examples of sequential overfishing (Pauly et al., 1998; Jackson et al., 2001). When one species has been depleted, fisheries target the next, and so on. Globally, total marine fisheries catches quadrupled from less than 20 million t in the 1950s to over 80 million t by the late 1980s. At present, however, global catches are stagnant (or perhaps even in decline), suggesting that global fisheries catches are not sustainable (Watson and Pauly, 2001; Worm et al., 2006). Moreover, a closer examination of global landing statistics over the past 60 years reveals that the observed growth from landings is primarily from the geographic expansion of fishing fleets (Swartz et al., 2010). In the case of the Gulf, although catches from 2004 to 2010 appear to be leveling off, it is much more likely that declines are masked by the retention of species that were previously discarded, such as blue swimming crabs and jellyfish.

Three out of the top 10 countries most at risk for food insecurity are in the Gulf, with predications of up to 50% loss in catches (Huelsenbeck, 2012). Moreover, no regional management plan exists despite many stocks being shared by multiple countries. Basic stock assessment data and rates of efforts are also lacking, further hindering management. Overfishing in the absence of accurate baselines imperils the region's fisheries, food security, and marine ecosystems more generally.

In Chapter 2, I describe examples of the discrepancy between reported and reconstructed catches and discuss the implications of such misreporting for management and fisheries policy on national, regional, and global scales. I then look at the ways that fisheries catch and indeed past species abundances distribution can be retrospectively estimated using historical records and grey literature to establish proxies (Chapters 3 & 6). Capture fisheries in the Gulf may be underestimated by a factor of 2 from 1950-2010, and countries have substantially underreported their discards, recreational subsistence, and illegal fishing sectors (Chapter 3). In Chapter 4, I demonstrate how innovative techniques, such as Google Earth Imagery, can be used to supplement or validate officially reported catch statistics from large stationary fishing gears such as weirs

In Chapter 5 I show that intercoder reliability can be high among coders in historical marine ecology, challenging the notion that anecdotal evidence is irrelevant or overly subjective. While the precision and clarity of individual historical accounts may vary, anecdotal evidence in large quantity can overcome the particular biases of individual sources to produce a rough picture of how ecosystems used to be.

The incorporation of anecdotes into scientific studies allows us to understand the true magnitude and impact of anthropogenic impacts on marine ecosystems. In the case of the dugong, what was considered a stable population may represent only a fraction of its past potential abundance and distribution range (Chapter 6). I show that while dugongs were once thought to only occur in the southwestern areas of the Gulf, historical data suggest that their range was much larger, and included countries such as Iran and Kuwait. In the absence of historical baselines restoration targets for historically exploited species such as the dugongs can be set far too low and management decisions are made without the proper ecological context.

Perhaps the most insidious result of the “shifting baseline syndrome” is a growing sentiment among fisheries managers to accept the status quo. It is my hope that the findings in this dissertation will serve as a starting point for the better management of marine resources in the region. Discrepancies in reported versus estimated catch data should be seen as warning that better management and enforcement actions are needed, and soon. In addition, measures should be taken by national governments to reduce bycatch and illegal fishing, as well as issuing limited licenses to boat owners and recreational fishers. If the overall status of marine ecosystems in the Gulf are to improve, new baselines, such as the ones provided here, need to be taken into account when national and regional plans are developed (Chapter 3-4,6). New technologies, such as remote sensing, have the potential to help regulate fisheries practices in large areas of the ocean at little to no cost (Chapter 4). Coastal developments should have impact assessments, and MPAs should be created, especially in sensitive areas such a dugong habitat and coastal fish nurseries.

Moreover, this thesis provides the basis for dealing with important ethical questions pertaining to what society wants for the future of marine ecosystems. For example, how can long-term baselines best be used to plan for and recover depleted and endangered marine species? What kind of ecosystems do we want to have? How much of a marine resource should there be, and how should the rights to its exploitation be allocated? Can fisheries be productive enough to support growing populations and also be environmentally sustainable? What do we stand to gain by recovering coastal ecosystems? How does a historical understanding of past ecosystems shape a collective vision for future sustainable ecosystems? Finally: how reversible are our actions?

Though they often require relinquishing precision usually demanded from traditional fisheries research, historical reconstructions, when corroborated with other evidence, can provide ‘signals’ on the general pace and direction of marine ecosystems. Achieving 100% accuracy in describing past ecosystems is not possible; however roughly understanding where species occurred in the past and in what numbers, is much more favorable than the ‘collective amnesia’ that serves as alternative. Moreover, reconstructions should not be viewed as substitute for stock assessments and scientific surveys, but as a complementary tool, when data from traditional analyses are unavailable. Despite the lack of precision and the need to caveat assumptions, countries must have the political will to make precautionary management decisions in the face of data uncertainties (Chapter 2).

Admittedly, one of the main limitations of this work, is that true interdisciplinarity is very difficult to achieve. In the same way that this dissertation can be viewed as overly subjective by ecologists, historians may feel that the thesis is too quantitative to fit in their field. Integrative interdisciplinary research has eluded many researchers, whose efforts often result in work that is better described as ‘additive multidisciplinary research’ (Roy et al. 2013). For example, Chapter 6 would have benefited from a deeper understanding of the changing culture and customs surrounding dugong hunting in the past. What was the role of changing social history in shaping demand for dugong meat? Why were dugong artifacts preserved? For practical purposes, however, limitations had to be placed on the work; future iterations could add much more richness to our understanding of dugong exploitation in the Gulf.

Another potential limitation is that despite the importance and the relatively good documentation of the pearl trade in the Gulf, the ecological impact of the historic pearl diving industry was not explicitly considered. Historical information on the pearl trade was gathered and used in Chapter 5; however the topic was not explored in a dedicated chapter. This is due two reasons: the first is that Gulf pearls have been subject to numerous studies (i.e, Almatar et al. 1993); the second is that the topic was dropped in favor for other topics that were not originally proposed, such as the use of Google Earth in estimating fish catches in Chapter 3. Future research could examine whether changes in range contraction of pearl beds can be detected through historical maps, or whether pearl diving had previously unconsidered impacts on other habitats and species.

Other future applications of this research could explore how traditional stock assessments can be integrated into interdisciplinary approaches such as the ones presented here, in order to better understand the long-term trajectories and causes of ecosystem change. In addition, Ecopath models could help synthesize the information gained in the dissertation and provide a platform from which potential management strategies could be evaluated. Various policy approaches will require predictions about the impact of non-traditional policy choices, and as such, ecosystem modeling can inform these predictions (Christensen and Walters 2005).

Moreover, there is immense value in exploring the potential of Google Earth imagery for monitoring other stationary fish traps globally. Historic aerial imagery can be overlaid with present day satellite imagery to explore changes in stationary fish traps and/or coastal development and its effects on the integrity of marine ecosystems. Finally, the digitalization of millions of books by Google Books (Michel et al., 2011), may allow for changes in marine ecosystems to be detected and studied through ‘culturomics’, the emerging field of studying human behavior and cultural trends (which also reflect environmental changes) through the quantitative analysis of digitized texts.

Despite intense and long-term anthropogenic pressure, most marine species still persist and 10-50% of depleted populations and ecosystems show some recovery, although rarely to their former abundances (Lotze et al. 2011). Civil society needs to set goals and priorities that reflect the realities of our lost and dying marine resources, as well as the main drivers and timescales needed to achieve meaningful recovery. Deciding on such options will take immense economic, political, and social will. However, in most cases, further research is not necessary to set the initial 'sustainability' plans.

Policies often reflect public values. The lack of environmental regulations and the rapid and widespread degradation of marine ecosystems in the region convey the lack of an 'ocean ethic'. As Aldo Leopold (1949) once wrote "[w*]e abuse land because we regard it as a commodity belonging to us. When we see land as a community to which we belong, we may begin to use it with love and respect."* At the root of the problem, is that the Gulf's industrial and economic boom has outpaced a sense of stewardship. There is no public perception of the magnitude of our loss. Direct experience with nature, especially during childhood, is the most important source of environmental sensitivity and therefore environmental conservation (Tanner, 1980; Dunn et al., 2006). Paradoxically, future incentives for conservation will depend on people's interactions with ecosystems that are already degraded, such as those of the Persian Gulf. Perhaps this is the most important role of historical marine ecology: to create mythologies surrounding fish and marine species that will inspire an ethical shift to conserve marine species rather than commodify them.

REFERENCES

Abdulqader, E.A.A. (2002) The finfish bycatch of the Bahrain shrimp trawl fisheries. *Arab Gulf Journal of Scientific Research* **20,** 165-174.

Agius D.A. (2009) Seafaring in the Arabian Gulf and Oman: People of the Dhow. Routledge, New York.

Ainsworth, C.H., Pitcher, T.J. (2005) Estimating illegal, unreported and unregulated catch in British Columbia's marine fisheries. *Fisheries Research* **75,** 40-55.

Al-Abdulrazzak D, Naidoo R, Palomares MLD and Pauly D (2012) Gaining Perspective on What We've Lost: The Reliability of Encoded Anecdotes in Historical Ecology. Plos One **7**, DOI: 10.1371.

Al-Abdulrazzak, D. (2013) Estimating total fish extractions in the United Arab Emirates: 1950-2010. In: *From dhows to trawlers: A recent history of fisheries in the Gulf countries, 1950 to 2010* (Eds. D. Al-Abdulrazzak and D. Pauly). Fisheries Centre Research Reports **21**, Vancouver, 59 pp.

Al-Abdulrazzak, D., Pauly, D. (Eds.) (2013a) From dhows to trawlers: A recent history of fisheries in the Gulf countries, 1950 to 2010. Fisheries Centre Research Reports **21**, Vancouver, 59 pp.

Al-Abdulrazzak, D., Pauly, D. (2013b) Managing fisheries from space: Google Earth improves estimates of distant fish catches. *ICES Journal of Marine Science* **71,** 450-454.

Al-Abdulrazzak, D., Pauly, D. (2014) Ground-truthing the ground-truth: reply to Garibaldi et al.'s comment on "Managing fisheries from space: Google Earth improves estimates of distant fish catches". *ICES Journal of Marine Science* **71**, 1927-1931.

Al-Abdulrazzak, D., Zeller, D., Pauly, D. (2014) Understanding fisheries through historical reconstructions: Applications to fishery management and policy at different governance scales. In: *Marine Historical Ecology in Conservation: Applying the Past to Manage for the Future*. (Eds. J.N. Kittinger, L. McClenachan, K. Gedan, L.K. Blight), University of California Press.

Al-Baz, A.F., Chen, W., Bishop, J.M., Al-Husaini, M., Al-Ayoub, S.A. (2007) On fishing selectivity of hadrah (fixed stake trap) in the coastal waters of Kuwait. *Fisheries Research* **84,** 202-209.

Almatar, S.M., Carpenter, K.E., Jackson, R., Alhazeem, S.H., Alsaffar, A.H., Ghaffar, A.R.A., Carpenter, C. (1993) Observations on the pearl oyster fishery of Kuwait *Journal of Shellfish Research* **12,** 35-40.

Al-Sabbagh, T., Dashti, J. (2009) Post-invasion status of Kuwait’s fin-fish and shrimp fisheries (1991-1992). *World Journal of Fish and Marine Sciences* **1,** 94-96.

Alverson, D.L., Hughes, S.E. (1996) Bycatch: From emotion to effective natural resource management. *Reviews in Fish Biology and Fisheries* **6,** 443-462.

Amos, J. (2010) BP / Gulf Oil Spill - How big is it? In: *Skytruth.* 2013.

Anderson P.K. and Birtles A. (1978) Behavior and ecology of dugong, Dugong-dugon (Sirenia)- Observations in Shoalwater and Cleveland bays, Queensland. *Australian Wildlife Research* **5**, 1-23.

Baldwin R., Cockcroft V.G. (1997) Are dugongs, Dugong dugon, in the Arabian Gulf safe? *Aquatic Mammals* **23**, 73-74.

Barakat, N. (2012) Greedy fishermen use illegal nets. In: *Gulf News,* March 25 2012. Dubai.

Battutah, I. (2002) *The Travels of Ibn Battutah.* Picador, London.

Baum, J.K., Myers, R.A., Kehler, D.G., Worm, B., Harley, S.J., Doherty, P.A. (2003) Collapse and conservation of shark populations in the Northwest Atlantic. *Science* **299,** 389-392.

Beech, M. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2**, 3-18.

Beech, M. (2002) Fishing in the Ubaid: A review of fish-bone assemblages from early prehistoric coastal settlements in the Arabian Gulf. *Journal of Oman Studies* **12**, 25-40.

Beech, M., Al Shaiba, N. (2004) Intertidal Archaeology on Marawah Island: New Evidence for Ancient Boat Mooring Sites. *Tribulus* **14**, 8-16.

Bhathal, B., Pauly, D. (2008) 'Fishing down marine food webs' and spatial expansion of coastal fisheries in India, 1950-2000. *Fisheries Research* **91,** 26-34.

Bishop, J.M. (2002) Fishing and mariculture. In: *The Gulf Ecosystem: Health and Sustainability*. (Eds. N.Y. Khan, M. Munawar, A. Price), Backhuys, Leiden, pp. 253-277.

Bowen Jr., R.L. (1951) Marine Industries of Eastern Arabia. *Geographical Review* **41,** 384-400.

Braulik, G.T., Ranjbar, S., Owfi, F., Aminrad, T., Dakhteh, S.M.H., Kamrani, E., Mohsenizadeh, F. (2010) Marine mammal records from Iran. *Journal of Cetacean Research and Management* **11**, 49-63.

Carpenter, K.E. (1997) *Living marine resources of Kuwait, eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates,* Food and Agriculture Organization of the United Nations, Rome, 293 pp.

Carter, R., Killick, R. (2010) *Al-Khor Island: Investigating Coastal Exploitation in Bronze Age Qatar*, Moonrise Press, Ludlow, 80 pp.

Chang, A., Parrales, M., Jimenez, J., Sobieszczyk, M., Hammer, S., Copenhaver, D., Kulkarni, R. (2009) Combining Google Earth and GIS mapping technologies in a dengue surveillance system for developing countries. *International Journal of Health Geographics* **8,** 49.

Cheung, W.W.L., Pauly, D., Sarmiento, J.L. (2013) How to make progress in projecting climate change impacts. *ICES Journal of Marine Science: Journal du Conseil* **70,** 1069-1074.

Christensen, V., Walters, C.J. (2004) Ecopath with Ecosim: methods, capabilities and limitations. *Ecological Modelling* **172,** 109-139.

Cisneros-Montemayor, A., Sumaila, R. (2010) A global estimate of benefits from ecosystem-based marine recreational: potential impacts and implications for management. *Journal of Bioeconomics* **12,** 245-268.

Clarke, S.C., McAllister, M.K., Milner-Gulland, E.J., Kirkwood, G.P., Michielsens, C.G.J., Agnew, D.J., Pikitch, E.K., Nakano, H., Shivji, M.S. (2006) Global estimates of shark catches using trade records from commercial markets. *Ecology Letters* **9,** 1115-1126.

Connaway, J.M. (2007) *Fishweirs: a world perspective with emphasis on the fishweirs of Mississippi,* Mississippi Dept. of Archives and History, Jackson, 584 pp.

Dadzie, S., Manyala, J.O., Abou-Seedo, F. (2005) Aspects of the population dynamics of *Liza klunzingeri* in the Kuwait Bay. *Cybium* **29,** 13-20.

Dawkins, M. (1971) Perceptual changes in chicks: Another look at the search image concept *Animal Behaviour* **19,** 566-574.

Dayton, P.K., Tegner, M.J., Edwards, P.B., Riser, K.L. (1998) Sliding baselines, ghosts, and reduced expectations in kelp forest communities. *Ecological Applications* **8,** 309-322.

De Young, C. (2006) Review of the State of World Marine Capture Fisheries Management: Indian Ocean. Food and Agriculture Organization of the United Nations, Rome, 458 pp.

Dulvy, N.K., Sadovy, Y., Reynolds, J.D. (2003) Extinction vulnerability in marine populations. *Fish and Fisheries* **4,** 25-64.

Dulvy, N.K., Pinnegar, J.K., Reynolds, J.D. (2009) Holocene extinctions in the sea. In: *Holocene Extinctions*. (Ed. S.T. Turvey), Oxford University Press, Oxford, 129-150.

Dunn, R.R., Gavin, M.C., Sanchez, M.C., Solomon, J.N. (2006) The pigeon paradox: Dependence of global conservation on urban nature. *Conservation Biology* **20,** 1814-1816.

Eklund, J., Parmanne, R., Aneer, G. (2000) Between-reader variation in herring otolith ages and effects on estimated population parameters. *Fisheries Research* **46,** 147-154.

El Sayed, A.F.M. (1996) Effects of overfishing and abandoning bottom trawling on Qatar's fisheries. *Qatar University Science Journal* **16,** 173-178.

Erdman, D.S. (1950) Fishing in Arabia. *The Scientific Monthly* **70,** 58-65.

Erftemeijer, P.L.A., Shuail, D.A. (2012) Seagrass habitats in the Arabian Gulf: distribution, tolerance thresholds and threats. *Aquatic Ecosystem Health & Management* **15**, 73-83.

FAO (2013) Report of the sixth meeting of the RECOFI working group on fisheries management. Doha, The State of Qatar, 5-8 November 2012.

Feinstein, A.R., Cicchetti, D.V. (1990) High agreement but low Kappa: I. the problems of two paradoxes. *Journal of Clinical Epidemiology* **43,** 543-549.

Ferretti, F., Myers, R.A., Serena, F., Lotze, H.K. (2008) Loss of large predatory sharks from the Mediterranean Sea. *Conservation Biology* **22,** 952-964.

Fortibuoni, T., Libralato, S., Raicevich, S., Giovanardi, O., Solidoro, C. (2010) Coding Early Naturalists' Accounts into Long-Term Fish Community Changes in the Adriatic Sea (1800-2000). *Plos One* **5**, DOI: 10.1371.

Friedlander, A.M., Sandin, S.A., DeMartini, E.E., Sala, E. (2010) Spatial patterns of the structure of reef fish assemblages at a pristine atoll in the central Pacific. *Marine Ecology Progress Series* **410,** 219-231.

Froese, R., Zeller, D., Kleisner, K., Pauly, D. (2012) What catch data can tell us about the status of global fisheries. *Marine Biology* **159,** 1283-1292.

Frotté, L., Harper, S., Veitch, L., Booth, S., Zeller, D. (2009) Reconstruction of marine fisheries catches for Guadeloupe from 1950-2007. Fisheries Centre Research Reports 13-19.

Gabriel, O., Lange, K., Dahm, E., Wendt, T. (2005) *Fish Catching Methods of the World,* John Wiley & Sons, Oxford, 536 pp.

Garibaldi, L. (2012) The FAO global capture production database: A six-decade effort to catch the trend. *Marine Policy* **36,** 760-768.

Garibaldi, L., Gee, J., Tsuji, S., Mannini, P., Currie, D. (2014) Comment on: "Managing fisheries from space: Google Earth improves estimates of distant fish catchs" by Al-Abdulrazzak and Pauly. *ICES Journal of Marine Science* **71,** 1921-1926.

Gerber, L., Morissette, L., Kaschner, K., Pauly, D. (2009) Should wahles be culled to increase fishery yields? *Science* **323,** 880-881.

Gillett, R. (2009) Fisheries in the Economies of Pacific Island Countries and Territories. Pacific Studies Series, Asian Development Bank, Forum Fisheries Agency, Secretariat of the Pacific Community, and Australian Agency for International Development, 520 pp.

Gillett, R. (2011) Catch attribution in the Western and Central Pacific Fisheries Commission. Western and Central Pacific Fisheries Commission, Pohnpei, 55 pp.

Gillett, R., McCoy, M., Rodwell, L., Tamate, J. (2001) Tuna: A Key Economic Resource in the Pacific Islands - A Report Prepared for the Asian Development Bank and the Forum Fisheries Agency. Pacific Studies Series, 95 pp.

Grandcourt, E. (2012) Reef fish and fisheries in the Gulf. In: *Coral Reefs of the Gulf: Adaptation to climactic extremes*. (Eds. B. Riegl, S. Purkis), Springer Science+Business Media, pp. 127-161.

Grandcourt, E., Al Abdessalaam, T.Z., Francis, F., Al Shamsi, A. (2010) Age-based life history parameters and status assessments of by-catch species (Lethrinus borbonicus, *Lethrinus microdon, Pomacanthus maculosus* and *Scolopsis taeniatus*) in the southern Arabian Gulf. *Journal of Applied Ichthyology* **26,** 381-389.

Grandcourt, E., Francis, F., Al Shamsi, A., Al Ali, K., Al Ali, S. (2003) Stock assessment and biology of key species in the demersal fisheries of the Emirate of Abu Dhabi. Marine Environmental Research Centre and Wildlife Development Agency.

Harper, S., Bothwell, J., Bale, S., Booth, S., Zeller, D. (2009) Cayman Island fisheries catches: 1950-2007. Fisheries Centre Research Reports, University of British Columbia, Vancouver, 3-11.

Harper, S., Zeller, D. (2011) Fisheries catch reconstructions: Islands, Part II. Fisheries Centre Research Reports 19(4). University of British Columbia, Vancouver, 143, pp.

Heithaus, M.R., Wirsing, A.J., Frid, A., Dill, L.M. (2007) Behavioral indicators in marine conservation: Lessons from a pristine seagrass ecosystem. *Israel Journal of Ecology & Evolution* **53**, 355-370.

Hines, E.M., Adulyanukosol, K., Duffus, D.A. (2005) Dugong (*Dugong dugon*) abundance along the Andaman Coast of Thailand. *Marine Mammal Science* **21**, 536-549.

Huelsenbeck, M. (2012) Ocean-Based Food Security Threatened in a High CO_2 World: A Ranking of Nations' Vulnerability to Climate Change and Ocean Acidification, Oceana, 16 pp.

Hughes, B.J., Martin, G.R., Reynolds, S.J. (2011) The use of Google Earth (TM) satellite imagery to detect the nests of masked boobies Sula dactylatra. *Wildlife Biology* **17,** 210-216.
Hughes, M.A., Garrett, D.E. (1990) Intercoder Reliability Estimation Approaches in Marketing: A Generalizability Theory Framework for Quantitative Data. *Journal of Marketing Research* **27,** 185-195.
Hughes, T.P. (1994) Catastrophes, phase shifts, and large-scale degradation of a Caribbean coral reef. *Science* **265,** 1547-1551.
Ibrahim, M.A., El-Bary, K.A., Al-Khayat, J.A. (1989) By-catch of commercial bottom trawl fishery from Qatar waters, Arabian Gulf. *Qatar University Science Journal* **9,** 309-319.
Jackson, J.B.C. (1997) Reefs since Columbus. *Coral Reefs* **16,** S23-S32.
Jackson, J.B.C. (2008) Ecological extinction and evolution in the brave new ocean. *Proceedings of the National Academy of Sciences of the United States of America* **105,** 11458-11465.
Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R. (2001) Historical overfishing and the recent collapse of coastal ecosystems. *Science* **293,** 629-638.
Jackson, J.B.C., Alexander, K.E. (2011) Introduction: The importance of shifting baselines. In: *Shifting Baselines: The Past and the Future of Ocean Fisheries*. (Eds. J.B.C. Jackson, K.E. Alexander, E. Sala), Island Press, Washington D.C., 312 pp.
Jacquet, J.L., Fox, H., Motta, H., Ngusaru, A., Zeller, D. (2010) Few data but many fish: Marine small-scale fisheries catches for Mozambique and Tanzania. *African Journal of Marine Science* **32,** 197-206.
Jacquet, J.L., Zeller, D. (2007a) National conflict and fisheries: reconstructing marine fisheries catches for Mozambique. In: *Reconstruction of marine fisheries catches for key countries and regions (1950-2005)*. (Eds. D. Zeller, D. Pauly), Fisheries Centre Research Reports 15(2). University of British Columbia Fisheries Centre, Vancouver, pp. 35-47.
Jacquet, J.L., Zeller, D. (2007b) Putting the 'United' in the United Republic of Tanzania: Reconstructing marine fisheries catches. In: *Reconstruction of marine fisheries catches for key countries and regions (1950-2005)*. (Eds. D. Zeller, D. Pauly), Fisheries Centre Research Reports 15(2). University of British Columbia Fisheries Centre, Vancouver, pp. 49-60.
Jawad, L.A. (2006) Fishing gear and methods of the lower Mesopotamian Plain with reference to fishing management. *Marina Mesopotamica* **1,** 1-37.
Kardovani, P. (1995) *Iranian marine ecosystem (The Persian Gulf and the Caspian Sea).* Ghomes, Tehran.
Keijl, G.O., van der Have, T.M. (2002) Observations on marine mammals in southern Iran, January 2000. *Zoology in the Middle East* **26**, 37-40.
Kelleher, K. (2005) Discards in the World's Marine Fisheries: An Update*. FAO Technical Paper No.470.* Food and Agriculture Organization of the United Nations, Rome, 131 pp.

Khan, N.Y., Munawar, M. (2002) Physical and human geography. In: *The Gulf Ecosystem, Heath and Sustainability*. (Eds. N.Y. Khan, M. Munawar, A.R. Price), Backhuys, pp. 3-21.

Kittinger, J.N., Blight, L.K., McClenachan, L. (2014) Managing human legacies in a changing sea. In: *Marine Historical Ecology in Conservation*. (Eds. J.N. Kittinger, L.K. Blight, L. McClenachan), University of California Press.

Kittur, A., Chi, E.H., Suh, B. (2008) Crowdsourcing user studies with Mechanical Turk. In: *Proceeding of the twenty-sixth annual SIGCHI conference on Human factors in computing systems*. ACM, Florence, Italy, pp. 453-456.

Kleisner, K., Zeller, D., Froese, R., Pauly, D. (2012) Using global catch data for inferences on the world's marine fisheries. *Fish and Fisheries* **14**, 293-311.

Lanyon, J.M. (2003) Distribution and abundance of dugongs in Moreton Bay, Queensland, Australia. *Wildlife Research* **30**, 397-409.

Le Manach, F., Andriamahefazafy, M., Harper, S., Harris, A., Hosch, G., Lange, G.-M., Zeller, D., Sumaila, U.R. (2012a) Who gets what? Developing a more equitable framework for EU fishing agreements. *Marine Policy*, **38**, 257-266.

Le Manach, F., Gough, C., Harris, A., Humber, F., Harper, S., Zeller, D. (2012b) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? *Marine Policy* **36,** 218-225.

Leopold, A. (1949) *A Sand County Almanac, and Sketches Here and There,* Oxford University Press, 320 pp.

Lessios, H.A., Robertson, D.R., Cubit, J.D. (1984) Spread of diadema mass mortality through the Caribbean. *Science* **226,** 335-337.

Lessware, J., Mahdi, M. (2010) Troubled waters between Bahrain and Qatar bring suspension of bridge project. In: *The National*. Manama, Bahrain.

Lombard, M., Snyder-Duch, J., Bracken, C.C. (2002) Content analysis in mass communication: Assessment and reporting of intercoder reliability. *Human Communication Research* **28,** 587-604.

Lorimer, J.G. (1908) *Gazetteer of the Persian Gulf, Oman, and Central Arabia. Volume 2: Geographical and Statistical,* Supt. Government Printing, Calcutta.

Lorimer, J.G. (1915) The pearl and mother-of-pearl fisheries of the Persian Gulf. In: *Gazetter of the Persian Gulf, Oman and Central Arabia.* Vol. Historical, Part II. pp. 2220-2293.

Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, R.G., Kay, M.C., Kidwell, S.M., Kirby, M.X., Peterson, C.H., Jackson, J.B.C. (2006) Depletion, degradation, and recovery potential of estuaries and coastal seas. *Science* **312,** 1806-1809.

Lotze, H.K., Milewski, I. (2004) Two centuries of multiple human impacts and successive changes in a North Atlantic food web. *Ecological Applications* **14,** 1428-1447.

Lotze, H.K., Worm, B. (2009) Historical baselines for large marine animals. *Trends in Ecology & Evolution* **24,** 254-262.

Lotze, H.K., Coll, M., Magera, A.M., Ward-Paige, C., Airoldi, L. (2011) Recovery of marine animal populations and ecosystems. *Trends in Ecology & Evolution* **26,** 595-605.

MacIvor, I. (1881) Notes on sea-fishing in the Persian Gulf. Report on the Administration of the Persian Gulf Political Residency and Muscat Political Agency for the Year. Foreign Department Press.

Madin, E.M.P., Madin, J.S., Booth, D.J. (2011) Landscape of fear visible from space. *Scientific Reports* **1**.

Marriott, R.J., Mapstone, B.D., Ballagh, A.C., Currey, L.M., Penny, A., Williams, A.J., Jackson, G., Lou, D., Mapleston, A.J., Jarvis, N.D.C., Keay, I.S., Newman, S.J. (2010) Accepting final counts from repeat readings of otoliths: should a common criterion apply to the age estimation of fish? *Marine and Freshwater Research* **61,** 1171-1184.

Marsh, H. (2002) Dugong dugon. IUCN Red List of Threatened Species Version 2010.4. Available at: http://www.iucnredlist.org [Accessed: March 21 2014].

Marsh, H., Saalfeld, W.K. (1986) Aerial census of dugongs in the northern sections of the Great Barrier Reef Marine Park. Report to the Great Barrier Reef Marine Park Authority. 1-21 p.

Marsh, H., Channells, P.W., Heinsohn, G.E., Morrissey, J. (1982) Analysis of stomach contents of dugongs from Queensland. *Australian Wildlife Research* **9**, 55-67.

Marsh, H., De'Ath, G., Gribble, N., Lane, B. (2005) Historical marine population estimates: Triggers or targets for conservation? The dugong case study. *Ecological Applications* **15**, 481-492.

Marsh, H., Penrose, H., Eros, C., Hugues, J. (2002) Dugong status report and action plans for countries and territories Early Warning and Assessment Report Series UNEP/DEWA/RS.02-1. United Nations Environment Programme, Nairobi, 162 pp.

Mastrandrea, M.D., Field, C.B., Stocker, T.F., Edenhofer, O., Ebi, K.L., Frame, D.J., Held, H., Kriegler, E., Mach, K.J., Matschoss, P.R. (2010) Guidance note for lead authors of the IPCC fifth assessment report on consistent treatment of uncertainties. Intergovernmental Panel on Climate Change (IPCC). Available at www.ipcc.ch/pdf/supporting-material/uncertainty-guidance-note.pdf

McClenachan, L. (2009) Documenting Loss of Large Trophy Fish from the Florida Keys with Historical Photographs. *Conservation Biology* **23,** 636-643.

McClenachan, L., Cooper, A.B. (2008) Extinction rate, historical population structure and ecological role of the Caribbean monk seal. *Proceedings of the Royal Society B-Biological Sciences* **275,** 1351-1358.

McClenachan, L., Ferretti, F., Baum, J.K. (2012) From archives to conservation: why historical data are needed to set baselines for marine animals and ecosystems. *Conservation Letters* **5,** 349-359.

McClenachan, L., Jackson, J.B.C., Newman, M.J.H. (2006) Conservation implications of historic sea turtle nesting beach loss. *Frontiers in Ecology and the Environment* **4,** 290-296.

McClenachan, L., Kittinger, J.N. (2013) Multicentury trends and the sustainability of coral reef fisheries in Hawai"i and Florida. *Fish and Fisheries* **14,** 239-255.

McCullough, D. (1984) Commencement address at Wesleyan University, June 3.

Mery, S., Charpentier, V., Auxiette, G., Pelle, E. (2009) A dugong bone mound: the Neolithic ritual site on Akab in Umm al-Quwain, United Arab Emirates. *Antiquity* **83**: 696-708.

Michel, J.-B., Shen, Y.K., Aiden, A.P., Veres, A., Gray, M.K., Team, T.G.B., Pickett, J.P., Hoiberg, D., Clancy, D., Norvig, P., Orwant, J., Pinker, S., Nowak, M.A., Aiden, E.L. (2011) Quantitative Analysis of Culture Using Millions of Digitized Books. *Science* **331,** 176-182
Moore, A.B.M., McCarthy, I.D., Carvalho, G.R., Peirce, R. (2012) Species, sex, size and male maturity composition of previously unreported elasmobranch landings in Kuwait, Qatar and Abu Dhabi Emirate. *Journal of Fish Biology* **80,** 1619-1642.
Moore, A.M. (2012) Elasmobranchs of the Persian (Arabian) Gulf: ecology, human aspects and research priorities for their improved management. *Reviews in Fish Biology and Fisheries* **22,** 35-61.
Moss, M.L., Erlandson, J.M., Stuckenrath, R. (1990) Wood Stake Weirs and Salmon Fishing on the Northwest Coast: Evidence from Southeast Alaska. *Canadian Journal of Archaeology* **14,** 143-158.
Myers, R.A., Worm, B. (2003) Rapid worldwide depletion of predatory fish communities. *Nature* **423,** 280-283.
Neuendorf, K.A. (2002) *The content analysis guidebook,* Sage Publications, London, 320 pp.
Palomares, M.L.D., Johanna J Heymans, and Daniel Pauly (2007) Historical ecology of the Raja Ampat Archipelago, Papua Province, Indonesia. *History and philosophy of the life sciences* **29,** 33-56.
Palomares, M.L.D., Mohammed, E., Pauly, D. (2006) Maria Lourdes D. Palomares, Elizabeth Mohammed, and Daniel Pauly on European expeditions as a source of historic abundance data on marine organisms: A case study of the Falkland Islands. *Environmental History* **11,** 835-847.
Pandolfi, J.M., Bradbury, R.H., Sala, E., Hughes, T.P., Bjorndal, K.A., Cooke, R.G., McArdle, D., McClenachan, L., Newman, M.J.H., Paredes, G., Warner, R.R., Jackson, J.B.C. (2003) Global trajectories of the long-term decline of coral reef ecosystems. *Science* **301,** 955-958.
Pauly, D. (1995) Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology & Evolution* **10,** 430-430.
Pauly, D. (1997) Small-scale fisheries in the tropics: marginality, marginalization, and some implications for fisheries management. In: *Global trends: fisheries management*. (Eds. E.K. Pikitch, D. Huppert, M. Sissenwine), American Fisheries Society Symposium, Bethesda, Maryland, pp. 40-49.
Pauly, D. (1998) Rationale for recontructing catch time series. *EC Fisheries Cooperation Bulletin* **11,** 4-7.
Pauly, D. (2006) Major trends in small-scale marine fisheries, with emphasis on developing countries, and some implications for the social sciences. *Maritime Studies (MAST)* **4,** 7-22.
Pauly, D., Christensen, V., Dalsgaard, J., Froese, R., Torres, F. (1998) Fishing down marine food webs. *Science* **279,** 860-863.
Pauly, D., Froese, R. (2012) Comments on FAO's State of Fisheries and Aquaculture, or 'SOFIA 2010'. *Marine Policy* **36,** 746-752.
Pauly, D., (2013) Comment: Does catch reflect abundance? Yes, it is a crucial signal. *Nature* **494,** 303-306.

Pauly, D., Watson, R. (2005) Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity. *Philosophical Transactions of the Royal Society B-Biological Sciences* **360,** 415-423.

Pauly, D., Zeller, D. (2003) The global fisheries crisis as a rationale for improving the FAO's database of fisheries statistics. In: *From Mexico to Brazil: Central Atlantic fisheries catch trends and ecosystem models*. *Fisheries Centre Research Report* (Eds. D. Zeller, S. Booth, E. Mohammed, D. Pauly), University of British Columbia, Vancouver, Canada.

Paxton, C.G.M. (2009) The plural of 'anecdote' can be 'data': statistical analysis of viewing distances in reports of unidentified large marine animals 1758–2000. *Journal of Zoology* **279,** 381-387.

Pernety, A.J. (1771) *The history of a voyage to the Malouine, or Falkland, islands, made in 1763 and 1764, under the command of m. de Bougainville ... and of two voyages to the Streights of Magellan, with an account of the Patagonians. Translated.* London, printed for T. Jefferys.

Pikitch, E.K., Santora, C., Babcock, E.A*., et al.* (2004) Ecosystem-Based Fishery Management. *Science* **305,** 346-347.

Pitcher, T.J. (2001) Fisheries Managed to Rebuild Ecosystems? Reconstructing the Past to Salvage the Future. *Ecological Applications* **11,** 601-617.

Pitcher, T.J., Watson, R., Forrest, R., Valtýsson, H.ó., Guénette, S. (2002) Estimating illegal and unreported catches from marine ecosystems: a basis for change. *Fish and Fisheries* **3,** 317-339.

Ploton, P., Pelissier, R., Proisy, C., Flavenot, T., Barbier, N., Rai, S.N., Couteron, P. (2012) Assessing aboveground tropical forest biomass using Google Earth canopy images. *Ecological Applications* **22,** 993-1003.

Popper, K. (2005) *The Logic of Scientific Discovery.* Taylor & Francis, New York, 544 pp.

Preen A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, Meterological and Environmental Protection Administration, Jeddah, Saudi Arabia. 200 pp.

Preen A. (2004) Distribution, abundance and conservation status of dugongs and dolphins in the southern and western Arabian Gulf. *Biological Conservation* **118**, 205-218.

Preen A. and Marsh H. (1995) Response of dugongs to large-scale loss of seagrass from Hervey Bay, Queensland, Australia. *Wildlife Research* **22**, 507-519.

Preen A.R., Marsh H., Lawler I.R., Prince R.I.T. and Shepherd R. (1997) Distribution and abundance of dugongs, turtles, dolphins and other Megafauna in Shark Bay, Ningaloo Reef and Exmouth Gulf, western Australia. *Wildlife Research* **24**, 185-208.

Price, A.R.G. (1993) The Gulf: Human impacts and management initiatives. *Marine Pollution Bulletin* **27,** 17-27.

Price, A.R.G. (1993) The Gulf: Human impacts and management initiatives. *Marine Pollution Bulletin* **27,** 17-27.

Pringle, H. (2010) Google Earth Shows Clandestine Worlds. *Science* **329,** 1008-1009.

Rao, D.V., Behbahani, M. (1999) Current and planned development of marine based recreation. *Development study for the optimal utilization of the marine*

environment no. KSIR5511. Kuwait Institute for Scientific Research, Safat, Kuwait, 123 pp.
Richer, R. (2009) Conservation in Qatar: Impacts of Increasing Industrialization. Occasional Paper. Centre for International and Regional Studies, Georgetown University of Foreign Service in Qatar., 23 pp.
Rogers-Bennett, L., Haaker, P.L., Huff, T.O., Dayton, P.K. (2002) Estimating baseline abundances of abalone in California for restoration. *California Cooperative Oceanic Fisheries Investigations Reports* **43,** 97-111.
Rosenberg, A.A., Bolster, W.J., Alexander, K.E., Leavenworth, W.B., Cooper, A.B., McKenzie, M.G. (2005) The history of ocean resources: modeling cod biomass using historical records. *Frontiers in Ecology and the Environment* **3,** 84-90.
Ross, E.C., Residency, P.G.P., Agency, M.P. (1881) *Report on the Administration of the Persian Gulf Political Residency and Muscat Political Agency for the Year,* Foreign Department Press.
Roy, E.D., Morzillo, A.T., Seijo, F.*, et al.* (2013) The elusive pursuit of interdisciplinarity at the human-environment interface. *BioScience* **63,** 745-753.
Ryan, G.W., Bernard, H.R. (2003) Techniques to Identify Themes. *Field Methods* **15,** 85-109.
Sáenz-Arroyo, A., Roberts, C.M., Torre, J., Carino-Olvera, M. (2005) Using fishers' anecdotes, naturalists' observations and grey literature to reassess marine species at risk: the case of the Gulf grouper in the Gulf of California, Mexico. *Fish and Fisheries* **6,** 121-133.
Sáenz-Arroyo, A., Roberts, C.M., Torre, J., Cariño-Olvera, M., Hawkins, J.P. (2006) The value of evidence about past abundance: marine fauna of the Gulf of California through the eyes of 16th to 19th century travellers. *Fish and Fisheries* **7,** 128-146.
Sakurai, T. (1998) Fisheries of Saudi Arabia. Ministry of Agriculture and Water, Department of Marine Fisheries and Japan International Cooperation Agency.
Sale, P.F., Feary, D.A., Burt, J.A., Bauman, A.G., Cavalcante, G.H., Drouillard, K.G., Kjerfve, B., Marquis, E., Trick, C.G., Usseglio, P., Van Lavieren, H. (2011) The Growing Need for Sustainable Ecological Management of Marine Communities of the Persian Gulf. *Ambio* **40,** 4-17.
Samuel, M. (1988) Catch rates and sustinable yeild of Kuwait's trawl fishery. *Indian Journal of Fisheries* **45,** 229-238.
Serjeant, R.B. (1968) Fisher-Folk and Fish-Traps in al-Bahrain. *Bulletin of the School of Oriental and African Studies* **31,** 486-514.
Serjeant, R.B. (1978) Historical sketch of the Gulf in the Islamic Era, from the seventh to the eighteenth century A.D. In: *Qatar Archaeological Report-- Excavations 1973*. (Ed. B. De Cardi), Oxford University Press, Oxford.
Sheppard, C., Al-Husiani, M., Al-Jamali, F.*, et al.* (2010) The Gulf: A young sea in decline. *Marine Pollution Bulletin* **60,** 13-38.
Shermer, M. (1997) *Why people believe weird things*. W. H. Freeman, New York.
Shermer, M. (2003) Show me the body. In: *Scientific American.* Vol. 288.
SPC (2008) Fish and Food Security. Policy Brief no.1.
Streeter, E. (1886) *Pearls and pearling life.* G. Bell & Sons, London, pp. 366.

Sumaila, U.R. (2013) How to make progress in disciplining overfishing subsidies. *ICES Journal of Marine Science: Journal du Conseil* **70,** 251-258.
Swartz, W., Pauly, D. (2008) Who's Eating all the Fish? The Food Security Rational for Culling Cetaceans. A Report to Humane Society International, Washington D.C., 322 pp.
Swartz, W., Sala, E., Tracey, S., Watson, R., Pauly, D. (2010) The Spatial Expansion and Ecological Footprint of Fisheries (1950 to Present). *Plos One* **5**. DOI: 10.371.
Swartz, W., Sumaila, U.R., Watson, R., Pauly, D. (2010b) Sourcing seafood for the three major markets: The EU, Japan and the USA. *Marine Policy* **34,** 1366-1373.
Tanner, T. (1980) Significant life experiences- A new research area in environmental education *Journal of Environmental Education* **11,** 20-24.
Tesfamichael, D., Pauly, D. (2013) Catch reconstruction of the fisheries of Saudi Arabia in The Gulf, 1950-2010. In: *From dhows to trawlers: A recent history of fisheries in the Gulf countries, 1950 to 2010* (Eds. D. Al-Abdulrazzak and D. Pauly). Fisheries Centre Research Reports, **21**, Vancouver, pp.41-59.
Tesfamichael, D., Pitcher, T.J. (2007) Estimating the unreported catch of Eritrean Red Sea fisheries. *African Journal of Marine Science* **29,** 55-63.
Tesfamichael, D., Pitcher, T.J., Pauly, D. (2014) Assessing changes in fisheries using fishers' knowledge to generate long time series of catch rates: a case study from the Red Sea. *Ecology and Society* **19,** 18.
Tesfamichael, D., Rossing, P. (2012) Red Sea fishery catches of Saudi Arabia: National wealth and transformation. In: *Catch reconstruction for the Red Sea Large Marine Ecosystem by countries (1950-2010)* (Eds. D. Tesfamichael and D. Pauly). Fisheries Centre Research Reports **20**, Vancouver, p.153-178.
Tharwat, A.A. (2003) Evaluation of the traditional fishing gear (haddrah) along the coastline of Arabian Gulf in Saudi Arabia. *Journal of Agricultural Science Mansoura University* **28,** 1-19.
Tinbergen, L. (1960) The natural control of insects in pine-woods. I. Factors influencing the intensity of predation by songbirds. *Archives Neerlandaises de Zoologie* **13,** 265-343.
Tremblay-Boyer, L., Gascuel, D., Watson, R., Christensen, V., Pauly, D. (2011) Modelling the effects of fishing on the biomass of the world's oceans from 1950 to 2006. *Marine Ecology-Progress Series* **442,** 169-U188.
Trujillo, P., Piroddi, C., Jacquet, J. (2012) Fish Farms at Sea: The Ground Truth from Google Earth. *Plos One* **7**. DOI: 10.1371.
Tyedmers, P.H., Watson, R., Pauly, D. (2005) Fueling global fishing fleets. *Ambio* **34,** 635-638.
Uhler, R.S. (1980) Least Squares Regression Estimates of the Schaefer Production Model: Some Monte Carlo Simulation Results. *Canadian Journal of Fisheries and Aquatic Sciences* **37,** 1284-1294.
Uwate, K.R., Al-Rumaihi, E., Mansoor, J. (1994) A survey of marina based recreational boating and fishing in Bahrain. Directorate of Fisheries, Ministry of Commerical and Agriculture, Manama, Bahrain.
Van Houtan, K., Pauly, D. (2007) Snapshot: Ghosts of Destruction. *Nature* **447,** 123.
Van Houtan, K.S., McClenachan, L., Kittinger, J.N. (2013) Seafood menus reflect long-term ocean changes. *Frontiers in Ecology and the Environment* **11,** 289-290.

Van Lavieren, H., Burt, J., Feary, D., *et al.* (2011) Managing the growting impacts of development on fragile coastal and marine ecosystems: lessons from The Gulf. United Nations University, Tokyo, 100 pp.
Vickers, D., McClenachan, L. (2011) The Past and History. *In: Shifting Baselines: The Past and Future of Ocean Fisheries (eds.* J.B.C. Jackson, K.E. Alexander, and Enric Sala). Island Press, Washington D.C., pp. 312.
Villiers, A. (1940) *Sons of Sinbad: An Account of Sailing with the Arabs in their Dhows, in the Red Sea, round the Coasts of Arabia, and to Zanzibar and Tanganyika; Pearling in the Persian Gulf; and the Life of the Shipmasters and the Mariners of Kuwait,* Vol., Charles Scribner's Sons, NewYork.
Ward, M. (2004) *Quantifying the world: UN ideas and statistics,* Vol., Indiana University Press, Bloomington.
Watson, R., Kitchingman, A., Gelchu, A., Pauly, D. (2004) Mapping global fisheries: sharpening our focus. *Fish and Fisheries* **5,** 168-177.
Watson, R., Pauly, D. (2001) Systematic distortions in world fisheries catch trends. *Nature* **414,** 534-536.
Watson, R., Revenga, C., Kura, Y. (2006) Fishing gear associated with global marine catches - I. Database development. *Fisheries Research* **79,** 97-102.
Watson, R.A., Cheung, W.W.L., Anticamara, J.A., Sumaila, R.U., Zeller, D., Pauly, D. (2012) Global marine yield halved as fishing intensity redoubles. *Fish and Fisheries* **14,** 493-503.
Whyte, A.V.T. (1977) Guidelines for field studies in environmental perception. International Council of Scientific Unions.
Wielgus, J., Zeller, D., Caicedo-Herrera, D., Sumaila, R. (2010) Estimation of fisheries removals and primary economic impact of the small-scale and industrial marine fisheries in Colombia. *Marine Policy* **34,** 506-513.
Worm, B., Barbier, E.B., Beaumont, N., Duffy, J.E., Folke, C., Halpern, B.S., Jackson, J.B.C., Lotze, H.K., Micheli, F., Palumbi, S.R., Sala, E., Selkoe, K.A., Stachowicz, J.J., Watson, R. (2006) Impacts of biodiversity loss on ocean ecosystem services. *Science* **314,** 787-790.
Ye, Y.M., Alsaffar, A.H., Mohammed, H.M.A. (2000) Bycatch and discards of the Kuwait shrimp fishery. *Fisheries Research* **45,** 9-19.
Zeller, D., Booth, S., Craig, P., Pauly, D. (2006) Reconstruction of coral reef fisheries catches in American Samoa, 1950-2002. *Coral Reefs* **25,** 144-152.
Zeller, D., Booth, S., Davis, G., Pauly, D. (2007) Re-estimation of small-scale fishery catches for US flag-associated island areas in the western Pacific: the last 50 years. *Fishery Bulletin* **105,** 266-277.
Zeller, D., Booth, S., Pakhomov, E., Swartz, W., Pauly, D. (2011) Arctic fisheries catches in Russia, USA, and Canada: baselines for neglected ecosystems. *Polar Biology* **34,** 955-973.
Zeller, D., Booth, S., Pauly, D. (2007b) Fisheries Contribution to the Gross Domestic Product: Underestimating Small-scale Fisheries in the Pacific. *Marine Resource Economics* **21**, 355-374.
Zeller, D., Darcy, M., Booth, S., Lowe, M.K., Martell, S. (2008) What about recreational catch?: Potential impact on stock assessment for Hawaii's bottomfish fisheries. *Fisheries Research* **91,** 88-97.

Zeller, D., Harper, S. (2009) Fisheries catch reconstructions: Islands, Part I. Fisheries Centre Research Reports **17**. Fisheries Centre, University of British Columbia, Vancouver, 104 pp.

Zeller, D., Harper, S., Zylich, K., Pauly, D. (2014) Synthesis of underreported small-scale fisheries catch in Pacific island waters. *Coral Reefs* **34,** 25-39.

Zeller, D., Pauly, D. (2004) The future of fisheries: from 'exclusive' resource policy to 'inclusive' public policy. *Marine Ecology-Progress Series* **274,** 295-303.

Zeller, D., Rossing, P., Harper, S., Persson, L., Booth, S., Pauly, D. (2011b) The Baltic Sea: Estimates of total fisheries removals 1950-2007. *Fisheries Research* **108,** 356-363.

APPENDICES

Appendix A. Details for reconstructing the fishery catches of the Persian Gulf.

The appendix presents the published reports for the 5 countries for which I was first author. The work served as the basis for the regional reconstruction in Chapter 3 of this thesis. Details for Iran and Saudi Arabia (which has other first authors) can be found in:

Al-Abdulrazzak, D., Pauly, D. (2013) From dhows to trawlers: A recent history of fisheries in the Gulf countries, 1950 to 2010. Fisheries Centre Research Reports, 21(2), 9-16, 41-48 p.

Missing sectors from Bahrain's reported fisheries catches: 1950-2010[1]

Dalal Al-Abdulrazzak

Sea Around Us Project, Fisheries Centre, University of British Columbia,
2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada
d.alabdulrazzak@fisheries.ubc.ca

Abstract

This study applies previously established catch reconstruction approaches to re-estimate total marine catches for Bahrain from 1950 to 2010. Utilizing all available quantitative and qualitative data from both peer-reviewed and grey literature, combined with conservative assumptions and interpolations, the catches for all Bahraini marine fisheries are estimated. When accounting for catches from discards, illegal fishing, recreational catches, and other missing small-scale sectors, these estimates suggest that data supplied to the FAO by Bahrain potentially underestimate catches by a factor of 5 since 1950. Incomplete and under-reported data can lead to mismanaged fish stocks which is particularly problematic in the case of Bahrain, which is small, and thus shares many stocks with other Gulf countries.

Introduction

Bahrain is the smallest of the Persian Gulf states and the only island country in the region (Figure 1). Archipelagic in nature, Bahrain consists of about 40 low lying islands, with the 55 km long and 18 km wide Bahrain Island being the largest; consequently, Bahrain has a rich maritime history that includes fishing (CBD 2012) and pearling, as evidenced by its 'Pearling Trail', a UNESCO Word Heritage Site. Due to the wide range of seasonal variation in hydrological parameters in the Persian Gulf (Longhurst 2007), as well as the small area of Bahrain's Exclusive Economic Zone (EEZ), a significant number of fish species utilize Bahrain's waters on a seasonal basis. Consequently, Bahrain shares many of its fish fauna with other Gulf countries (Randall *et al.* 1978; Carpenter *et al.* 1997; also see FishBase [www.fishbase.org]).

Despite the historical presence of large-scale shrimp fishing, fisheries were of minor economic importance (prior to the discovery of oil in the 1960s) and now are valued mostly for their cultural contribution. Possibly because of the minuscule contribution of fisheries to the economy (0.4% of GDP), their management receives little attention, and regulations are not strongly enforced, and thus largely ineffective.

The main fishing gears used are shrimp trawls, gillnets, large wire traps (Arabic: *gargoor*) and hook-and-line. All commercial fishing is conducted as single-day trips. In the inshore areas, tidal weirs (Arabic: *hadrah*) are also used. Most of the catch is consumed locally, although some shrimp and crab are exported to neighbouring countries such as Saudi Arabia. A small number of seafood processing companies purchase surplus shrimp not destined for export. Bahrain's landings do not meet the fish demand of its over 1.3 million inhabitants, and therefore must be supplemented by imports.

Habitat destruction from coastal development, compounded with ill-enforced fisheries regulations, has led to a number of challenges for fisheries. Land reclamation is particularly problematic because fishermen are forced to fish further out and into Qatar's EEZ, leading to illegal catches and violent standoffs (Mahdi 2010). Other challenges include the deployment of banned gears such as driftnets

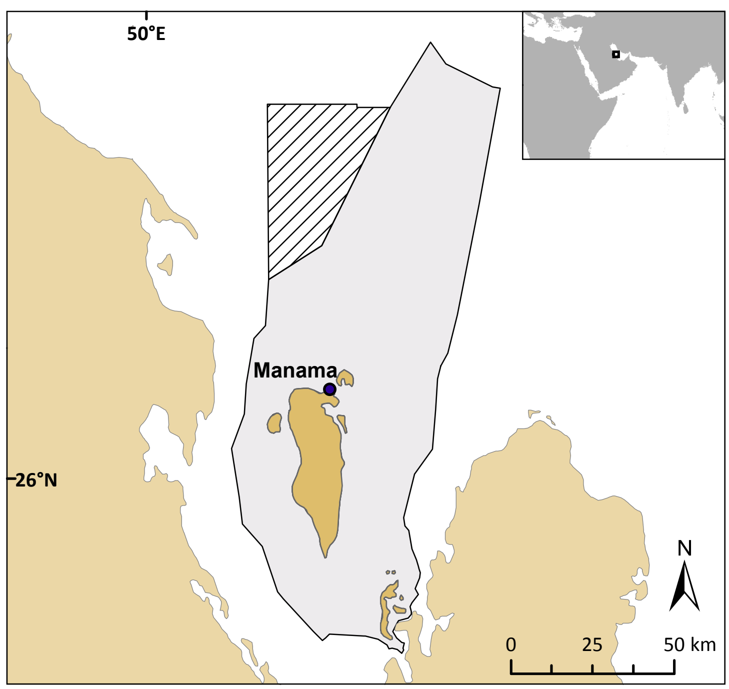

Figure 1. Map of Bahrain; showing the extent of its EEZ in grey; including the joint-regulation zone with Saudi Arabia (stripped area).

[1] Cite as: Al-Abdulrazzak D (2013) Missing sectors from Bahrain's reported fisheries catches: 1950-2010. pp. 1-6. *In*: Al-Abdulrazzak D and Pauly D (eds.) From dhows to trawlers: a recent history of fisheries in the Gulf countries, 1950 to 2010. Fisheries Centre Research Reports 21(2). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

and the operation of unauthorized foreign vessels in Bahrain's EEZ. Bahrain also has a rapidly growing recreational fisheries sector (Uwate *et al.* 1994), which may be taking large quantities of commercially important species, but is unregulated and therefore unreported.

Species composition of landings has changed over time, masking the decline of traditionally exploited species such as orange-spotted grouper (*Epinephelus coioides*) and penaeid shrimps, which have been offset by increased catches of blue swimming crab (*Portunus pelagicus*), a species that was previously discarded, but is now being retained to meet demand from a growing immigrant community. Catches of more desirable species and shrimp have declined dramatically.

Methods

This contribution follows the conceptual framework of the catch reconstruction as outlined by previous studies (Zeller *et al.* 2006; Zeller *et al.* 2007; Jacquet *et al.* 2010; Le Manach *et al.* 2012).

Using Google Earth, Al-Abdulrazzak and Pauly (2013), estimate 880 ± 57 *hadrah* were operating in Bahrain in 2005, generating an annual catch of 17,125 ± 5,147 t. These estimates are 8.7 times larger than what is reported to FAO for Bahrain in 2005. Since the number of *hadrah* is not known to have substantially fluctuated in the last five decades, the total reported catch from 2005 (1,960 t) was subtracted from all years, and the estimated catch (17,125 t) was added instead. From 1950-1964, reported landings were less than 1,960 t and therefore applying this method resulted in slightly lower overall catches (i.e., less than 17,125 t). Although it is known that *hadrah* catches have not fluctuated much in the last five decades, less information is known regarding the 1950s. Therefore, we kept the methodology the same for the entire time period, as it is not unreasonable to assume that catches may have been slightly lower in those early years. Species composition was estimated from data supplied by the Ministry of Fisheries in Bahrain (A.H. Al-Radhi, pers. comm., Directorate of Fisheries Resources).

To estimate discards by the shrimp trawlers, the shrimp to fish ratio of 1:15 reported by Abdulqader (2002) was applied to obtain the total by-catch. Abdulqader (2002) and Kelleher *et al.* (2005) estimate that Bahrain's discard rate was 24% in the 2000s. It was assumed that more discarding occurred at the start of the fishery, thus a conservative discard rate of 80% was applied from 1950-1979, followed by 50% from 1980-1999, and 24% from 2000-2010. A 3-year moving average was applied for smoothing and species composition ratios were applied from the Abdulqader (2002) study.

A number of sources reporting on the border disputes between Qatar and Bahrain highlight illegal fishing by Bahraini fishermen in Qatar's EEZ (e.g., Lessware and Mahdi 2010; Mahdi 2010; Khatri 2012). Here it is assumed that illegal fishing took place since the start of the border dispute in 1980, and that illegal fishing amounts to only 2% of commercial catch in the period from 1980 to 2010. Species composition were applied based on landed catch ratios.

Driftnets were banned in 1998 after complaints from trap fishermen that trawlers were operating in shallow water and cutting their floats (De Young 2006). Despite the ban, illegal driftnets for narrow-barred Spanish mackerel continue to be used (Uwate and Shams 1996, 1997; Abdulqader 2010) and pose a significant problem. It is conservatively assumed that since the 1998 ban, illegal catches by driftnets constitute 1% of total reported catch.

Uwate *et al.* (1994) conducted a survey of recreational fishermen and estimated that recreational catch amounts to 4% of commercial catch. It was assumed that this percentage was the same since the start of reporting and therefore was applied from 1950-2010. Because no data were available on species composition, species composition ratios from Kuwait were applied to the reconstructed recreational catch.

As in other Gulf countries, fishers are migrant labourers from Southeast Asia and Bahrain who make very little incomes, and therefore have a high incentive to fish for subsistence. From 1960-2010 foreign fishers made up 0.0046% of the population. It was assumed that fishers take 5 kg·week^{-1} for subsistence purposes, extrapolated from the start of the oil boom in 1960 until 2010. Because these take home catches are composed of less desirable species, subsistence catches were assigned species composition based on discarded species.

Results and discussion

For the period of FAO reporting, 1950-2010, estimated fisheries catches were almost 5 times what is reported by the FAO on behalf of Bahrain. Reconstructed catches for Bahrain totalled 1,877,300 t over the 1950-2010 period compared to 379,238 t reported by FAO.

Catch data as reported by FAO on behalf of Bahrain suggest a steady increase in catches from 800 t in 1950 to a peak of 16,359 t in 2009, before a slight decrease in 2010. In contrast, reconstructed time series data suggest a fluctuating increase in catches throughout, with a sharp peak of 50,600 t in 1996. Catches declined until 2001 and then increased up to 2010.

The catch of recreational fisheries is likely underestimated, for two reasons. First, the study of Uwate *et al.* (1994), which formed the basis of the estimates presented here, is likely outdated at present. Bahrain's population has strongly increased in recent years leading us to predict that participation has also greatly increased. Second, the study, which was conducted by people working for Bahrain's Fisheries Directorate, was only carried out in selected ports, not all ports that service recreational fisheries. Other sources (e.g., Uwate and Shams 1996; De Young 2006) highlight the significance of recreational catches in Bahrain, but without providing tonnage. However, the study estimates catches to be only 4% of all commercial catches. Ultimately, this value was chosen in order to remain conservative.

Discards, as reconstructed here, were substantial, and on average accounted for 28% of total estimated catches each year (Figure 2a; Appendix Table A1). Bahrain's by-catch to trawled shrimp ratio of 15:1 is nearly 3 times the global average and highlights the need for concern regarding the ecological and economic impacts of this wasteful practice (Alverson and Hughes 1996; Kelleher *et al.* 2005).

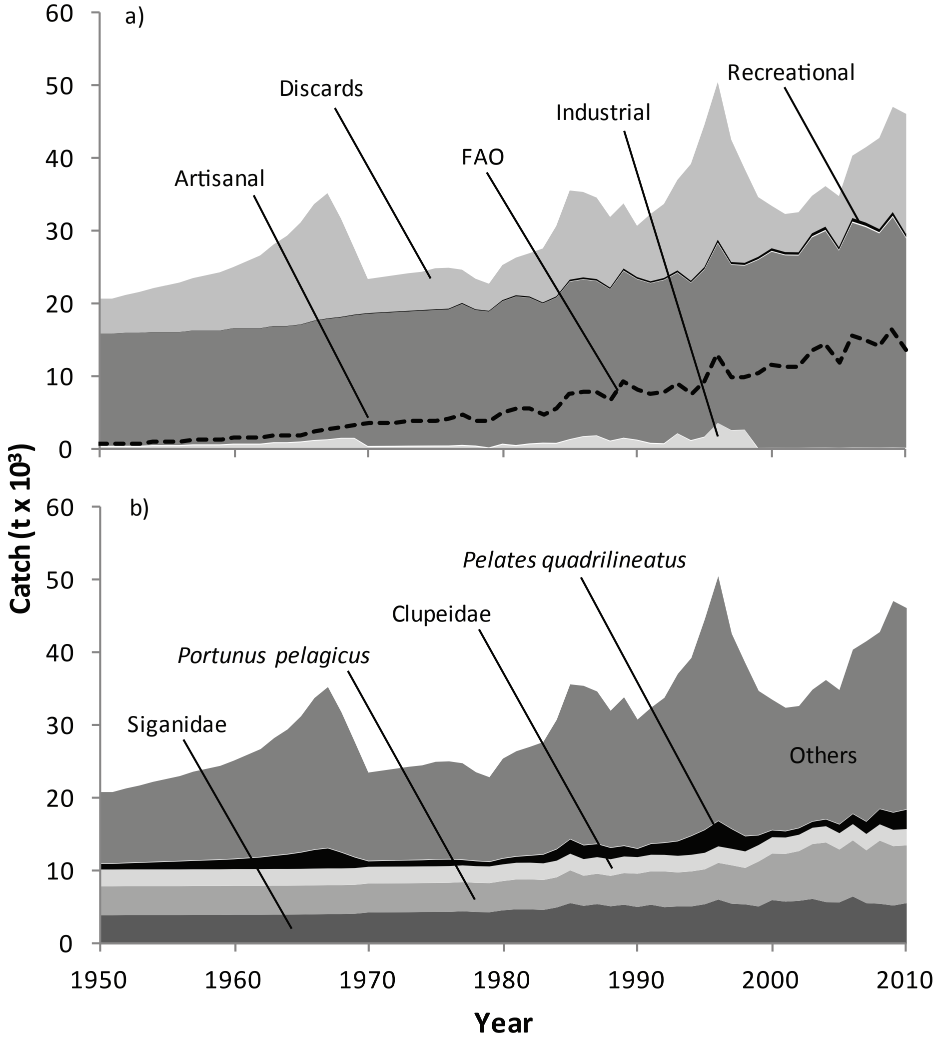

Figure 2. Total reconstructed catch for Bahrain by a) sector (with comparison to FAO data), and b) major taxa, 1950-2010. Note that subsitence catches were included on the sector graph (a) but are not visible (too small).

The four main taxa caught by Bahrain are Siganidae (15.7%), *Portunus pelagicus* (15.5%), Clupeidae (7.4%), and *Pelates quadrilineatus* (4.7%) (Figure 2b; Appendix Table A2). Juveniles of commercially important species make up the majority of by-catch and *hadrah* catches, which may lead to growth overfishing.

This reconstruction supports growing concern over the status of Bahrain's fisheries. Although catches appear to be increasing, it is more likely that the declines are masked by previously discarded species being retained. Masked declines, coupled with shared stocks, unsustainable fishing practices through illegal driftnets and high discard rates all point to stocks that are overfished. In addition, Bahrain's population has essentially doubled in the last decade, from 638,000 in 2000 to 1.3 million in 2010, placing enormous pressure on the country's natural resources.

In addition, this reconstruction indicates poor data coverage for Bahrain's officially reported catch series. The reconstruction undertaken here accounts for missing sectors, including discards, illegal and recreational catches, and offers a more complete accounting for *hadrah* catches. Thus, the reconstructed time series better reflects the catches extracted from Bahrain's marine ecosystems. Although there is some uncertainty surrounding the estimates, assumptions in this report are conservative throughout and illustrate more likely historical trends and patterns.

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References

Abdulqader EAA (2002) The finfish bycatch of the Bahrain shrimp trawl fisheries. Arab Gulf Journal of Scientific Research 20(3): 165-174.

Abdulqader EAA (2010) Turtle captures in shrimp trawl nets in Bahrain. Aquatic Ecosystem Health & Management 13(3): 307-318.

Al-Abdulrazzak D and Pauly D (2013) Managing fisheries from space: Google Earth improves estimates of distant fish catches. ICES Journal of Marine Science, doi.10.1093/icesjms/fst178.

Alverson DL and Hughes SE (1996) Bycatch: from emotion to effective natural resource management. Reviews in Fish Biology and Fisheries 6(4): 443-462.

Carpenter KE, Krupp F, Jones DA and Zajonz U (1997) Living marine resources of Kuwait, eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates. Food and Agriculture Organization of the United Nations (FAO), European Commission (EC), Rome. viii+293 p.

De Young C, editor (2006) Review of the state of world marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper No. 488. Food and Agriculture Organization of the United Nations (FAO). 458 p.

Jacquet J, Fox H, Motta H, Ngusaru A and Zeller D (2010) Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania. African Journal of Marine Science 32(2): 197-206.

Kelleher K (2005) Discards in the world's marine fisheries: an update. FAO Fisheries Technical Paper 470. Food and Agriculture Organization of the United Nations (FAO). xix+131 p.

Khatri S (2012) Families worry as Indian fishermen held in Qatar arraigned on criminal charges. Doha News, edition of October 12, 2012.

Le Manach F, Gough C, Harris A, Humber F, Harper S and Zeller D (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy 36(1): 218-225.

Lessware J and Mahdi M (2010) Trouble waters between Bahrain and Qatar bring suspension of bridge project. The National, edition of June 17, 2010.

Longhurst AR (2007) Ecological geography of the sea, 2nd edition. Academic Press, San Diego.

Mahdi M (2010) Bahraini fishermen blame development for forcing them into gunsights of Qatar. The National, edition of May 13, 2010. Available at: http://www.thenational.ae/news/world/middle-east/bahraini-fishermen-blame-development-for-forcing-them-into-gunsights-of-qatar [Accessed: February 5, 2013].

Randall JE, Allen GR and Smith-Vaniz WF (1978) Regional fishery survey and development project. Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates. Illustrated Identification Guide to Commercial Fisheries. Food and Agriculture Organization of the United Nations (FAO), United Nations Development Programme (UNDP), Rome. v+221 p.

Uwate KR, Al-Rumaihi E and Mansoor J (1994) A survey of marine based recreational boating and fishing in Bahrain. Directiorate of Fisheries, Ministry of Commercia and Agriculture, Manama, Bahrain.

Uwate KR and Shams AJ (1996) Video technology applied to the management of Bahrain's marine resources. Naga, The ICLARM Quarterly 19(2): 9-11.

Uwate KR and Shams AJ (1997) Bahrain fish stock enhancement: lessons learned and prospects for the future. SPC Live Reef Fish Information Bulletin 3: 9-12.

Zeller D, Booth S, Craig P and Pauly D (2006) Reconstruction of coral reef fisheries catches in American Samoa, 1950-2002. Coral Reefs 25(1): 144-152.

Zeller D, Booth S, Davis G and Pauly D (2007) Re-estimation of small-scale fishery catches for US flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266-277.

Reconstructing Iraq's fisheries: 1950-2010[1]

Dalal Al-Abdulrazzak and Daniel Pauly

Sea Around Us Project, Fisheries Centre, University of British Columbia,
2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada
d.alabdulrazzak@fisheries.ubc.ca; d.pauly@fisheries.ubc.ca

Abstract

Iraq's fraction of the Persian Gulf waters, surrounding the mouth of the Shatt al-Arab, is tiny, and so are its marine fisheries, which, moreover, have been impacted by a succession of wars over the past few decades. Its fisheries remain underdeveloped and understudied, and hence little documented. Here, Iraqi marine fisheries catches are reconstructed from 1950 to 2010, based on admittedly fragmentary evidence. Overall, the catches reconstructed here are 1.8 times those reported to FAO on behalf of Iraq, and are dominated by unreported catches of hilsa shad (*Tenualosa ilisha*). This study illustrates the need to establish management infrastructure for fisheries monitoring and regulation enforcement, especially in light of the many stocks that are shared with other Persian Gulf countries.

Introduction

Iraq has the smallest fishing grounds of the Persian Gulf countries, essentially near the mouth of the Shatt al-Arab River, which is formed by the confluence of the Euphrates and Tigris river about 200 km upstream. Thus Iraq's marine fisheries are of minor importance compared to its freshwater fisheries. The marine fisheries are all artisanal in nature, with gillnetting for hilsa shad (*Tenualosa ilisha*), pomfret (*Pampus* spp.), and mullet (*Liza* spp.) being dominant fishing activities, complemented by some traditional dhows operating small trawl nets. Fish supply is relatively low throughout the region and does not meet local demand (Jawad 2006). There are apparently no marine recreational fisheries.

Iraq has one of the richest water resources in the Middle East due to the presence of the Tigris and Euphrates rivers, the smaller Shatt al-Arab and Shatt al-Basrah rivers, and the Mesopotamian marshes. The marshlands serve as nursery grounds for a number of migratory fish such as the hilsa shad, and also provide important nutrients to the fisheries of the northern Gulf through the Shatt al-Arab River (Jawad 2006).

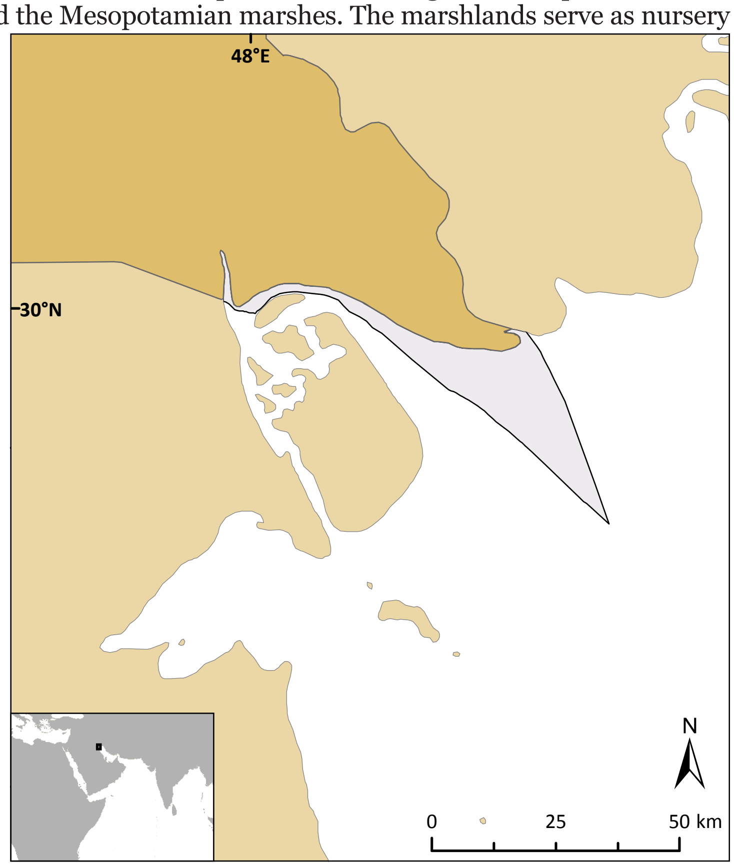

Figure 1. Map of Iraq, showing the extent of its small EEZ (in grey).

Between the 1950s and 1990s, large areas of the Mesopotamian marshes were drained, at different times and for different reasons (Al-Yamani *et al.* 2007). Although the initial draining of the central marshes was intended for land reclamation for agricultural purposes, it later became a political attempt to force Marsh Arabs (Ma'dan people) out of the area through water diversion tactics. The marshes, which have been reduced in extent by over 90%, have long been considered as a refuge for people persecuted by Saddam Hussein's government. Not surprisingly, thousands of fish and waterfowl died as the waters receded (North 1994). In addition, damming naturally flowing rivers reduces freshwater discharge into the sea, leading to reduced nutrient concentration in coastal waters, which consequently diminishes plankton productivity, and in turn, fish landings (Al-Yamani *et al.* 2007). It is speculated that the damming could also increase the salinity of the northwestern Gulf, raising concerns about jellyfish outbreaks and changes in plankton (and hence fish) community density and distribution (Al-Yamani *et al.* 2007).

A number of major wars have greatly shaped the country's fisheries. The Iran-Iraq war, which lasted from 1980-1988, presumably led to decreased

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marine fisheries catch, though the lack of detailed records precludes firm inferences (Ali 2001). In addition, the first Gulf War in 1991 led to UN imposed sanctions which implied that areas in the Northern Persian Gulf traditionally exploited by Iraqi fishers could no longer be accessed. Thus, patrols by non-Iraqi forces meant that the Shatt al-Arab waterway and areas around Bubiyan Island and Warba Island (Kuwait) were closed to all forms of fishing. This, combined with other factors (general insecurity and perhaps oil pollution, see below), meant that Iraq's reported catches dropped to near zero in 1991 and 1992.

Several studies were carried out on the impact of the 1991 Gulf War oil spill on fisheries stocks (e.g., Linden *et al.* 2004; Al-Sabbagh and Dashti 2009). Impacts of oil spills tend to be highly variable, affecting food webs, life history cycles, and entire marine ecosystems (Al-Sabbagh and Dashti 2009). In this case, it has been suggested that declines in fish stocks were a result of planktonic larval or egg mortality, not adult mortality because many of the fish species live in depths below the oil slick, and because the warm waters sped up the breakdown of oil (Linden *et al.* 2004).

As the northern Gulf became safer to navigate in 1994-1995, fisheries catches started to recover. However, the funds allocated towards fisheries management and monitoring suffered as a result of the UN sanctions, leading fisheries to be essentially unregulated. The damming of the upper Tigris and Euphrates rivers and the draining of the marshes in the Shatt al-Arab delta also negatively affected marine resources, particularly in the case of the hilsa shad, *Tenuolosa ilisha* (Al-Dubakel 2011).

Following the combats that led to the change of government in 2003, Iraqi fishers began to expand their fishing southward, returning to Bubiyan and Warba Islands, as well as fishing illegally in other parts of Kuwait's Exclusive Economic Zone (EEZ).

While the ichthyofauna of Iraq has been reasonably well documented (www.fishbase.org), there are currently no management plans in place for any of Iraq's fisheries. Detailed catch statistics have not been collected since the early 1990s and no stock assessments have been performed. Thus, the numbers presented here will remain tentative until this situation is addressed.

Corrupt governance and lack of infrastructure have complicated data gathering on Iraqi fisheries. For example, under the former Ba'athist government, the State Organization of Fisheries controlled the administration of freshwater and marine fisheries, including the administration of fishing licenses. As such, they discriminated against non-Ba'ath people, especially Marsh Arabs (Jawad 2006), refusing to issue licenses. In addition, Uday Hussein, the eldest son of Saddam Hussein controlled the most productive areas of the marshlands and demanded payments from fishers in exchange for access (Jawad 2006). Later, the State Organization of Fisheries was dissolved and replaced by a marine fisheries cooperative that only served the Basrah province.

Methods

Iraq reports to FAO only a miscellaneous category called 'marine fishes nei' up until 2003. From 2004 on, catches are also reported for 'hilsa shad, 'mullets' (Family Mugilidae) and '*Penaeus* shrimps'. To improve the taxonomic resolution, taxonomic information from the 2004-2010 time period, as well as information on the species caught in the waters of neighbouring Kuwait, was used to disaggregate the data from 1950-2003. The 'marine fishes nei' category was initially assigned to 76% Mugilidae, 2% Penaeidae, 22% miscellaneous marine fish, which was adapted from relative proportions in the reported data. The miscellaneous marine fish portion was then broken down further; ten percent remained miscellanous marine fish, while the other 90% was assigned to the four most common families found in Kuwait waters (croakers, 40%; groupers, 35%; grunts, 15%; and snappers 10%) (see Kuwait; Al-Abdulrazzak, this volume). These methods were also utilized (with slight adjustments) for the 2004-2010 time period as there was still large amounts of 'marine fishes nei' reported. Note that 'hilsa shad' was not part of the disaggregation breakdown as there was additional information utilized to reconstruct these catches.

Al-Dubakel (2011) reports shad catches from 1990-2007, as well as average percentages of shad catches compared to total catch from 1965-1975 (56.9%), 1990-1992 (38.9%), and 2003-2007 (5.1%). Because Al-Dubakel's total catch estimates are much higher than FAO's over the same time period, and because they were not reported as part of the freshwater catches, we assumed that the shad is not already reported in the miscellaneous marine fishes category and therefore adopted Al-Dubakel's (2011) estimates as unreported 'hilsa shad' catch.

Iraq's coastline is very short (Figure 1) and only 0.001% of the population of Iraq lives within 10 km of the coast. We assume a conservative subsistence catch rate of 500 g/person/week (i.e., the equivalent of two servings per week) and apply this to the derived coastal population from 1950-2010. We used the 2004-2010 FAO data (excluding shrimp) as a guideline to derive a subsistence breakdown (approximately 44% *Tenualosa ilisha*, 32% miscenalleous marine fish, and 24% Mugilidae).

A number of accounts exist of significant illegal fishing by Iraqi trawlers and gillnetters in Kuwait's and Iran's EEZs (e.g., De Young 2006; Al-Saadoun 2012; Saleh 2012). We estimated illegal fishing in Kuwait's EEZ to be 10% of reported catches for the years 2003-2010, and disaggregated it into shrimp (Penaeidae, 5%), pomfret (*Pampus* *argenteus*, 2%), shad (*Tenualosa ilisha*, 2%), and mullet (Mugilidae, 1%). For illegal fishing in Iran, we estimate catches to be 3% of reported and apply the same species composition ratios used for catches in Kuwait.

Finally, we apply a bycatch ratio (15:1) to reported, estimated and illegal Iraqi shrimp catches, of which 98% of the fish is discarded and only 2% is retained (as miscellaneous marine fishes), derived from the nearby Kuwait shrimp fishery (Ye *et al.* 2000). We also applied the same species composition from Kuwait to the discards.

Results and discussion

Data supplied to FAO offer poor taxonomic resolution and omit illegal catches and shrimp discards. After incorporating these components in our reconstruction, our catch estimates over the 1950-2010 time period are 1.8 times what is reported to FAO (Figure 2a; Appendix Table A1). We predict that our reconstructed catches are likely to be an underestimate, as without more information on fishing practices in Iraq, our assumptions were conservative.

Since shrimp stocks are shared with Iran and Kuwait, the unregulated and illegal trawling may impact landings in these countries. Iraqi vessels are landing significant quantities of shrimp, particularly species that have not been previously landed in Iraq in these large quantities (Al-Dubakel 2011). Catches from Iran and Kuwait waters (2003-2010) were estimated to be 3% and 10%, respectively, of the total reonstructed catch from 1950-2010.

Discards are likely present from more than just the shrimp fishery, but scant information exists, and is therefore difficult to quantify. In Iraq, the majority of fishermen are Shiite Muslims who therefore do not consume fish without scales visible to the naked eye. Therefore, bycatch species such as *Muraenesox cinereus, Arius thalassinus,* and *Trichiurus lepturus* are discarded back to sea (Jawad 2006). Discards made up 26% of the total estimated catch.

The main species of Iraq's marine fisheries were Mugilidae (39%), *Tenualosa ilisha* (17%), *Arius thalassinus* (8%), Sciaenidae (5%), and *Epinephelus* spp. (5%) (Figure 2b; Appendix Table A2).

Jawad (2006) suggests that regulating access may be more effective than implementing catch or effort controls. Due to the remoteness of certain areas in the marshlands, and because most fishers make their own gear, size and gear control are difficult to implement. Concerns have also been raised concerning oil pollution and runoff from industrial and household wastes (Al-Dubakel 2011). Oil spills are commonly seen along the Shatt Al-Arab, particularly from the *Abu Flous* port (Al-Dubakel 2011).

A number of major challenges hinder Iraq's ability to manage its fisheries. First, infrastructure for fisheries management and monitoring needs to be rebuilt. Enforcement of existing and new fisheries legislature cannot be implemented otherwise. Second, marine habitat degradation, particularly the draining of the marshes, must be addressed. Finally, and perhaps most importantly, Iraq should be incorporated into regional fisheries management plans since many stocks are shared with other Gulf countries.

The management of Iraq's marine fisheries has deteriorated

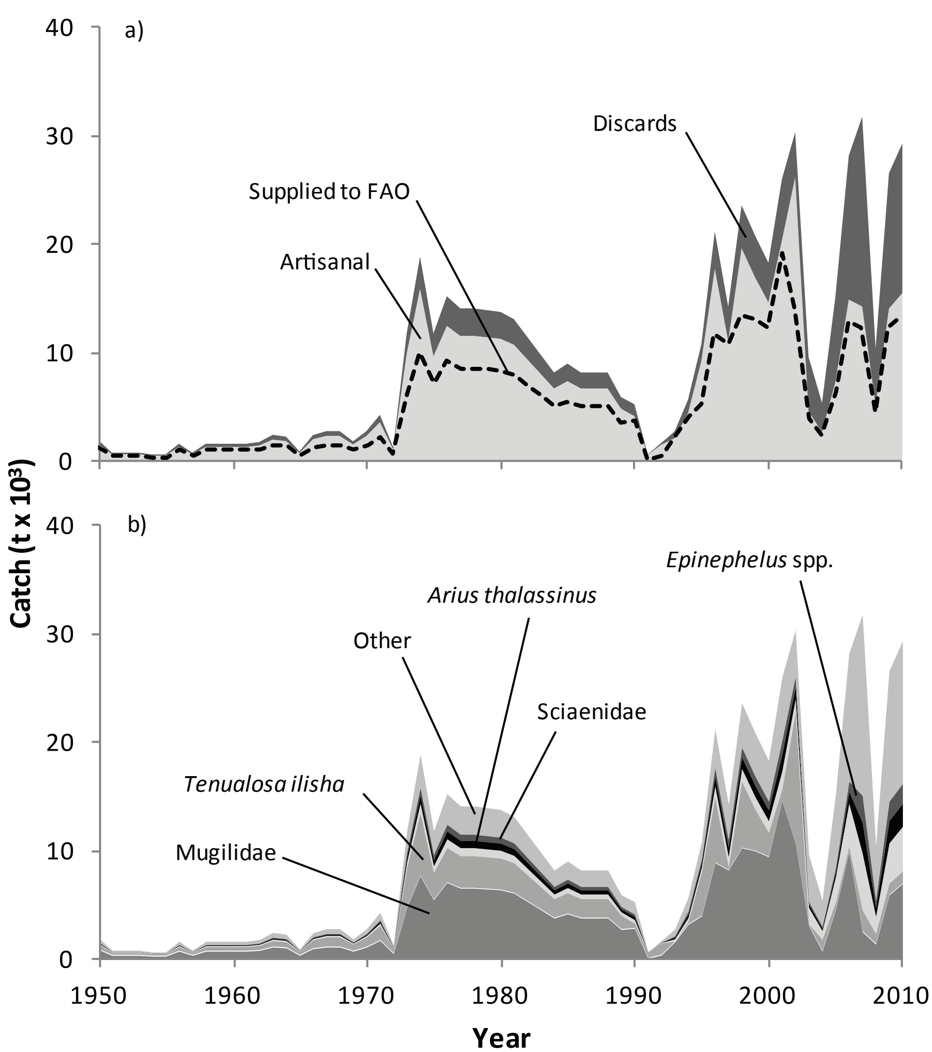

Figure 2. Total reconstructed catch for Iraq, 1950-2010, by a) sector (with comparison to FAO), and b) major taxa. Note that subsistence catches were included in the sector graph (a) but are not visible (too small).

significantly since 2003, while increased fishing effort (and a corresponding increase in landings) has occurred during the same time. This does not bode well for the long-term sustainability of the country's fisheries. It is clear that unregulated fishing of shared fish and shrimp stocks of the northern Gulf must be brought under control.

Acknowledgements

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References

Al-Dubakel AY (2011) Commercial fishing and marketing of hilsa shad *Tenualosa ilisha* (Hamilton-Buchanon, 1822) in Basrah-Southern Iraq. Emirates Journal of Food and Agriculture 23(2): 178-186.

Al-Saadoun H (2012) Iraqi fishing boat stopped. Kuwait Times, edition of March 24. Available at: http://news.kuwaittimes.net/2012/03/24/iraqi-fishing-boat-stopped.

Al-Sabbagh T and Dashti J (2009) Post-invasion status of Kuwait's fin-fish and shrimp fisheries (1991-1992). World Journal of Fish and Marine Sciences 1(2): 94-96.

Al-Yamani FY, Bishop JM, Al-Rifaie K and Ismail W (2007) The effects of the river diversion, Mesopotamian marsh drainage and restoration, and river damming on the marine environment of the northwestern Arabian Gulf. Aquatic Ecosystem Health & Management 10(3): 277-289.

Ali TS (2001) Effects of shrimp trawlers on the fisheries status and environment of the northwest Arabian Gulf. Acta Ichthyologica et Piscatoria 31(2): 77-86.

De Young C, editor (2006) Review of the state of world marine capture fisheries management: Indian Ocean. FAO fisheries Tehnical Paper 488. Food and Agriculture Organization of the United Nations (FAO), Rome. viii+458 p.

Jawad LA (2006) Fishing gear and methods of the lower Mesopotamian Plain with reference to fishing management. Marina Mesopotamica 1(1): 1-37.

Linden O, Jernelov A and Egerup J (2004) The environmental impacts of the Gulf War 1991. Interim Reports, International Institute for Applied Systems Analysis (IIASA). xi+82 p. Available at: http://webarchive.iiasa.ac.at/Admin/PUB/Documents/IR-04-019.pdf [Accessed: November 15, 2012].

North A (1994) Saddam drains life from Arab marshes: Scientists fear Iraq's historic wetlands face destruction in 10 to 20 years, says Andrew North. The Independent, edition of May 17.

Saleh A (2012) Iraq claims five more fishermen captured in Kuwait. Kuwait Times, edition of April 27. Available at: http://news.kuwaittimes.net/2012/03/24/iraqi-fishing-boat-stopped.

Ye YM, Alsaffar AH and Mohammed HMA (2000) Bycatch and discards of the Kuwait shrimp fishery. Fisheries Research 45(1): 9-19.

Reconstructing Kuwait's marine fishery catches: 1950-2010[1]

Dalal Al-Abdulrazzak

Sea Around Us Project, Fisheries Centre, University of British Columbia,
2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada
d.alabdulrazzak@fisheries.ubc.ca

Abstract

Kuwait's fisheries have grown substantially over the past 60 years. Here, Kuwait's fisheries are reconstructed to include discards, recreational, and illegal catches. The resulting estimates of just under 2 million t are 6.4 times the 312,250 t reported to FAO, and discards, which constitute the largest missing sector, are 10 times greater than the total landed finfish in the country. This study illustrates the magnitude of the data reporting problems faced by Kuwait and provides further evidence for the need for more and better-enforced fisheries regulations in the region.

Introduction

Kuwait is located in the northeast of the Arabian Peninsula, on the shore of the Persian Gulf (Figure 1). It lies between latitudes 28° and 31° N, and longitudes 46° and 49° E, and borders Saudi Arabia to the south and Iraq to the north. Kuwait is one of the world's smallest countries in terms of land mass and is characterized by flat, sandy desert. It has nine islands, eight of which remain uninhabited. The capital, Kuwait City is located on Kuwait Bay, a natural deep-water harbor.

Kuwait was a British colony from 1899-1961 and is now a constitutional emirate with the oldest directly elected parliament among the Arab Persian Gulf countries. Kuwaiti nationals are a minority of the population, making up just 1 million out of the 3.5 million people. The country's economy is almost solely based on crude oil, which makes up nearly half of GDP and 95% of export revenues (World Factbook, 2011)

Interestingly, despite their predominately small-scale nature, Kuwait's fisheries remain the second most important natural resource after oil (Carpenter 1997). In general, fisheries management in Kuwait is not well developed, although weakly enforced legislation has been in place for the industrial shrimp fishery since the early 1980s. Because fisheries are of minor economic importance (at least when compared to oil), and therefore are of low political significance. The fisheries consist of two main sectors: a limited industrial (large-scale) shrimp fishery and substantial artisanal (small-scale) finfish and shrimp fisheries.

Methods

Fisheries catches as presented by the FAO on behalf of Kuwait occur in FAO statistical area 51. Total fish catches were estimated by following the conceptual framework outlined in Zeller (2006; 2007). Data were gathered from published and grey literature, and subsequently combined with clearly defined assumptions and interpolations.

Industrial sector

The industrial, or large-scale sector, consists exclusively of a shrimp trawl fishery. This sector started in the early 1960s and expanded rapidly, and by 2006, it grew to 35 trawlers. The main shrimp species targeted are the green tiger prawn (*Penaeus semisulcatus*), jinga shrimp (*Metapenaeus affinis*) and the kidi shrimp (*Parapenaeopsis stylifera*), with seasonal reported landings ranging from 1,000 to 5,200 t (Ye *et al.* 1999a). The official shrimp fishing

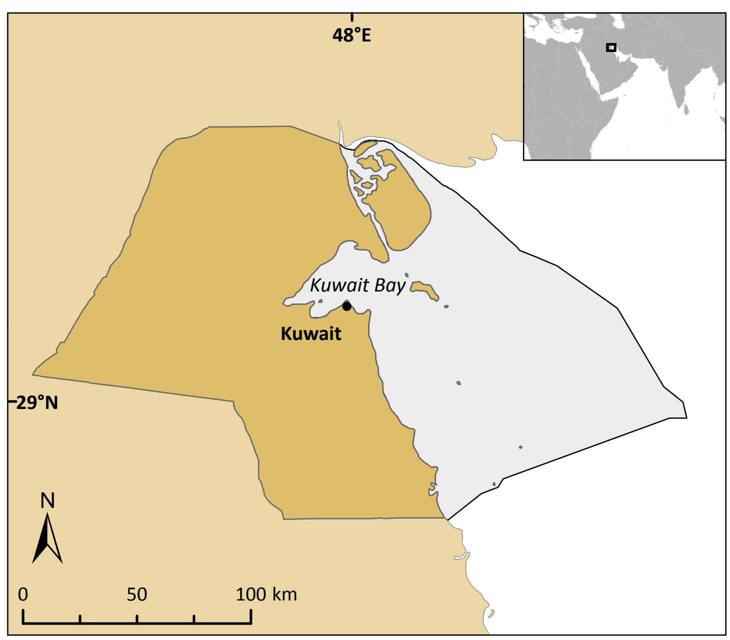

Figure 1. Map of Kuwait, showing the extent of its EEZ (grey area).

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season runs from September 1 of any given year to early/late spring of the next depending on catch rates. Trawling occurs in the coastal waters from 5 to 35 m depth, although Kuwait Bay and a three-mile coastal zone have been closed to trawling since 1983 (Ye *et al.* 1999b). Official reported shrimp landings were assigned to both the industrial and artisanal sectors. It has been reported that 45% of total shrimp landings are caught by artisanal vessels. As the industrial shrimp fishery did not begin until 1960, the proportion of shrimp catches caught be industrial vessels was interpolated from zero percent in 1959 to 55% in 1965. From 1965-2010, the proportion of 55% was kept constant.

Considerable illegal shrimp fishing occurs during the 3-6 month closed season (Mohammed *et al.* 1998; Siddiqui and Al-Mubarak 1998; Al-Sabbagh and Dashti 2009), suggesting poor to non-existent monitoring and enforcement of management rules. Here, it was conservatively estimated that out-of-season shrimp catches comprise 10% of total reported shrimp catch, starting from the earliest incident (1990) of illegal catches mentioned in the literature (Al-Sabbagh and Dashti 2009) to 2010. A set tonnage of 500 t was reported as being caught illegally in 1992. These illegal shrimp catches were also assigned to both the artisanal and industrial sectors using the same proportions as were used for the reported catches.

Bycatch (i.e., species that are unintentionally retained by fishing gear) is a major component of shrimp fisheries globally, raising concerns of ecological and economic impacts (Alverson and Hughes 1996; Kelleher *et al.* 2005). The average ratio of bycatch to shrimp is 5:1 in temperate and subtropical waters, and 10:1 in tropical waters (Slavin 1982). The subtropical Kuwaiti shrimp trawl fishery, however, has a fish-to-shrimp bycatch ratio of 15.32:1 (Ye *et al.* 2000). Of this bycatch, 98% is discarded at sea and the remaining 2% is landed, yet not reported (FAO 2006). Thus, both landed and discarded catches are unaccounted for. Species composition ratios were applied from the Ye *et al.* (2000) study. Marine catfish (Ariidae) and elasmobranchs (sharks and rays), which are not consumed in Kuwait for religious reasons, comprise the bulk of the discarded bycatch.

Bycatch was estimated as a multiple of both the reported legal shrimp catch and the unreported illegal catch, and then smoothed by applying a 3-year moving average. The estimated bycatch was subsequently disaggregated into unreported discards (98%) and unreported landed bycatch (2%). On average, the discards from the Kuwaiti shrimp fishery were 10 times higher than the tonnage of finfish reported to be landed in Kuwait annually.

Artisanal sector

The artisanal sector essentially comprises three components: a shrimp fishery, a boat-based finfish fishery and a traditional fixed intertidal stake net fishery. The artisanal shrimp fleet catches 45% of total shrimp landings using both traditional dhows and small outboard motor fibreglass vessels (FAO 2006). Since the industrial shrimp fishery did not begin until 1960, shrimp catches from 1950-1959 were labelled as 100% artisanal. Then, as described above, the artisanal proportion of the shrimp fishery was interpolated from 100% in 1959 to 45% in 1965, and kept constant to 2010. Improvements in the equipment of these fleets have resulted in dhows being able to access the same fishing grounds as the fibreglass vessels. Ye *et al.* (1999a) found nearly identical rates of bycatch and discard between artisanal and industrial shrimp fleets, and therefore the same 15.32:1 ratio was applied to the artisanal shrimp catches (including the illegal catches calculated above) to estimate unreported discards and unreported landed bycatch.

Kuwait's boat-based finfish fishery consists of two vessel types: wooden dhows and speedboats. These vessels are licensed for a single gear type, which can be hemispherical wire traps (*gargoor*), or drift or fixed gillnets of various mesh sizes. The dhow fleet consists of 120 boats, of which 94 use *gargoor* traps and 26 use gillnets (FAO 2006). The speedboat fleet consists of 748 vessels, 28 of which are licensed for *gargoor*, and 720 for gillnets (FAO 2006). The boat-based finfish fishery has seen significant declines in catches in recent years, with a record low of 2,500 tonnes in 2001. This has been attributed to overcapacity, although no efforts have been put into place to reduce capacity and effort (FAO 2006). The reported FAO data (minus the shrimp catch) were taken to be representative of the baseline catch for the boat-based artisanal fishery plus the traditional fixed intertidal stake net fishery.

Significant numbers of sharks are landed in Kuwait, yet are not listed in FAO catch data (Moore *et al.* 2012). The majority of these are caught as bycatch by small speedboats operating gillnets to target teleosts, or less commonly, dhows operating *gargoor* traps. Despite sharks being impermissible to eat by Shiite Muslims, a growing expatriate community has lead to sharks being landed whole and consumed within the country (Moore *et al.* 2012). A handful of countries in the Gulf do report their shark landings, and FAO data from Bahrain (based on its proximity and similar fishery profile) were used to estimate the potential contribution of sharks in Kuwait's catches. Bahrain reported shark catches (Carcharhinidae) for 2004-2010, and these catches were divided by the total reported finfish catch to obtain an average shark to finfish ratio of 5%. This ratio was applied to Kuwait's reported finfish time series.

Recreational sector

An active recreational fishery targets demersal species from small speedboats, but no data are available on the number of participants or species landings (FAO 2006). Cisneros-Montemayor and Sumaila (2010) estimate that recreational fisheries involve 0.12% of Kuwait's population. Thus, this ratio was applied to the total population from 1950-2010 to get a time series of number of recreational fishers. As a conservative estimate, it was assumed that recreational fishers catch 1 kg of fish per trip and that they only fish on the weekends. Therefore, the number of fishers was multiplied by the number of fishing days (104 days) and by a catch of 1 kg to obtain a rough time series of recreational catches. The estimated catches for the years during and immediately after the first Gulf War (1990-1992) were eliminated, as it was assumed that no recreational fishing occurred. Rao and Behbahani (1999) estimate that the majority of species caught by recreational fishermen are *Epinephelus chlorostigma*, *Sparidentex hasta*, *Otolithes ruber*, and *Acanthopagrus latus*; thus the recreational catch was evenly distributed among those 4 species.

Subsistence Sector

Although vessel owners are Kuwaiti nationals, fishers are foreign workers from Southeast Asia and Iran, who have modest incomes, and therefore have a high incentive to fish for subsistence. From 1960-2010, foreign fishers made up 0.0015% of the population and it was assumed that each fisher takes 5 kg per week for subsistence purposes from the start of the oil boom in 1960 until 2010. It was further assumed that no subsistence fishing occurred during and immediately after the Gulf War, from 1990-1992. Finally, because these take home catches are composed of less desirable species, the catch composition of the discarded species were applied to the subsistence catches.

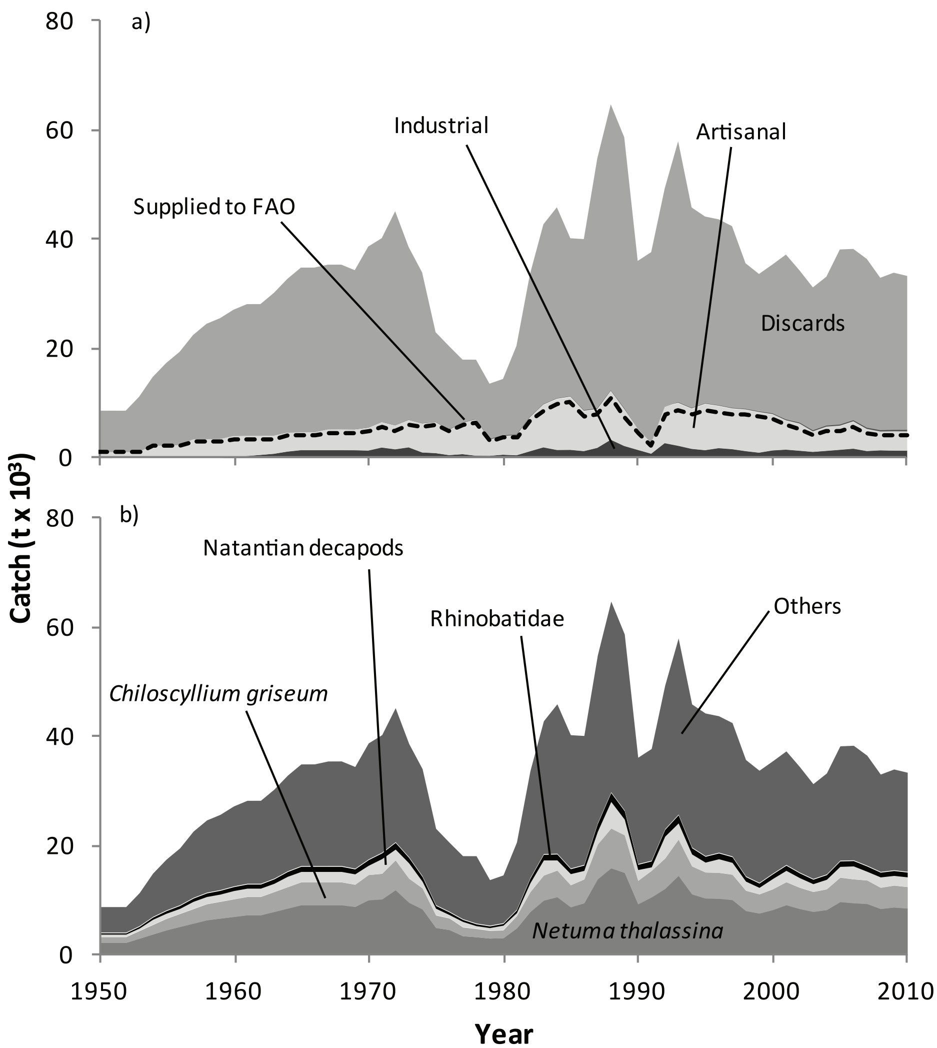

Figure 2. Total reconstructed catch for Kuwait by a) sector (with comparison to FAO data), and b) major taxa, 1950-2010.

Results and discussion

Catch data for Kuwait as reported by the FAO suggest a gradual increase in reported landings from 1,000 t in 1950 to a peak of 10,788 t in 1988, before declining to an average of around 4,700 t per year in the 2000s (Figure 2a; Appendix Table A1). In contrast, the reconstructed total marine fisheries catches suggest a rapid increase in catches at the start of the industrialized shrimp fishery in 1960, peaking at 45,000 t in 1972, with a second peak of 64,600 t occurring in 1988 (Figure 2a). A final peak is present in 1993 (57,800 t) before declining to a final tonnage of 33,200 t in 2010 (Figure 2a). Trends in catch series often reflect political events that impacted the fishery sector in a country; in this case, the decline in catches from 1972 to 1979 is most likely a result of the Iran-Iraq war. Similarly, the decline in catches in 1990 is reflective of the first Gulf War and the occupation of Kuwait by Iraqi forces.

Total reconstructed catch for Kuwait fisheries was estimated to be 1,997,000 t which is 6.4 times the amount reported by the FAO (312,250 t) on behalf of Kuwait (Figure 2a). Kuwait's fisheries were estimated to be 42.8% industrial, 56.8% artisanal, 0.01% subsistence and 0.45% recreational. Although it appears that non-commerical sectors are fairly insignificant, these estimates were made with limited information and therefore were made to be conservative. This is an area that requires further study.

The main taxa caught in Kuwait are *Netuma thalassina* (25%), *Chiloscyllium griseum* (11%), natantian decapods (5%) and Rhinobatidae (3%) (Figure 2b; Appendix Table A2). The three non-shrimp categories mostly consist of dicards. If we look only at retained catch the top taxa include natantian decapods (29%), *Pampus* spp. (7%), Serranidae (6%), Sciaenidae (6%), Mugilidae (5%) and *Tenualosa ilisha* (5%).

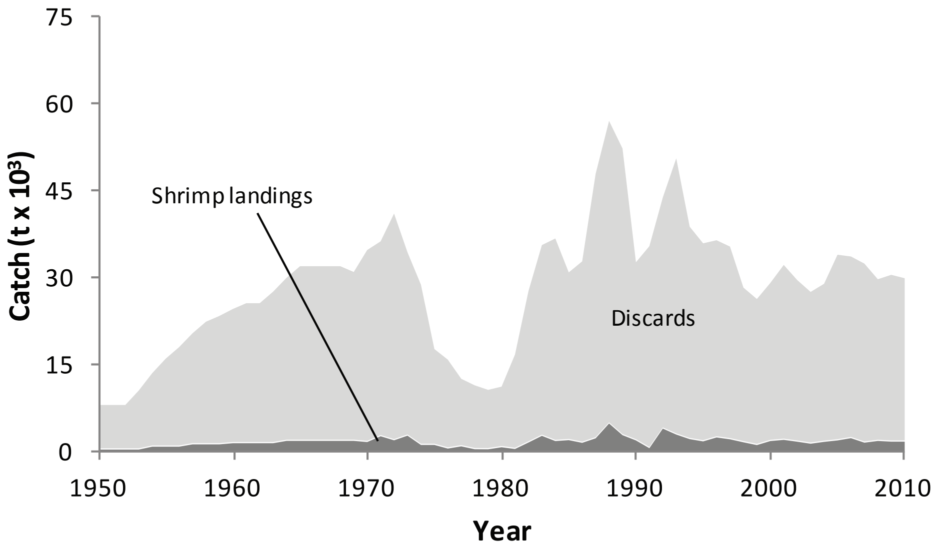

Figure 3. Estimated discards from Kuwait's shrimp fishery in comparison to shrimp landings (includes data from legal and illegal shrimp fishery).

As seen from the values above, the estimated time series also illustrates the magnitude and importance of discards (Figure 3). In terms of tonnage, discards amounted to almost 10 times the amount of reported, landed finfish. The non-reporting of discards is particularly problematic. In some countries, such as Kuwait, good estimates of discards are available. Yet in most other cases, particularly in developing countries, there is a general lack of quantitative information on discards or discard rates (Kelleher *et al.* 2005). This is partly because several different fishing gears may be used, different species may be targeted on a single fishing trip or vessel, and because fisheries change over time (Kelleher *et al.* 2005). Therefore, attributing a single discard rate to a particular fishery may lead to large errors. Globally, discards are reported to be to 8% of reported landings (Kelleher *et al.* 2005).

The catch reconstruction supports concerns over the status of fisheries in Kuwait. Sharp declines in all sectors, coupled with other indicators of overexploitation such as the reduced mean size of landed fish (Dadzie *et al.* 2005; Al-Sabbagh and Dashti 2009) and a decline of catch per effort suggest that the fisheries are suffering from overcapacity. Additionally, population pressure also occurs, as a 'youth bulge,' a common demographic characteristic in the Middle East, is certain to cause further strain on resources. Combined, unregulated fishing practices and population pressure suggest that 'Malthusian overfishing' occurs in Kuwait, a situation where declining yield coupled with socio-economic conditions drive fishers to over-exploit and destroy their resource base (Pauly 2006).

The overall reported catches for Kuwait's artisanal and industrial fisheries potentially underestimate total catches by a factor of 6.4 over the 1950-2010 time period. Such substantial differences between reported landings and reconstructed total catches illustrate the magnitude of the data reporting problems faced by Kuwait, and, by inference, other countries (e.g., Zeller *et al.* 2007; Zeller *et al.* 2011a; Zeller *et al.* 2011b). It also points at a fundamental problem of fisheries catch data being viewed purely from a commercial, market perspective, which accounts only for what is landed and utilized for commercial sale or export (Pauly and Zeller 2003; Zeller and Pauly 2004). In contrast, given the global move towards viewing and managing fisheries on an ecosystem scale (Pikitch *et al.* 2004), fisheries data collection, and hence catch accounting, needs to account for total catches, notably to be able to maintain important ecosystem processes (Pauly 1985a, b; Pauly and Matthew 1986; Pauly and Palomares 1987). This requires comprehensive accounting for all extractions of fish and invertebrates during fishing operations, including the recording (or estimation) and reporting of discarded catch, and the estimation and reporting of catches from unregulated sectors such as the recreational fishery and the traditional stake net fishery. Given the high costs of monitoring such sectors using traditional catch monitoring approaches, alternative methods such as utilizing national surveys and census opportunities have been suggested (Zeller *et al.* 2007) for the more widely dispersed and hard to monitor small-scale and recreational fisheries sectors.

Acknowledgements

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References

Al-Sabbagh T and Dashti J (2009) Post-invasion status of Kuwait's fin-fish and shrimp fisheries (1991-1992). World Journal of Fish and Marine Sciences 1(2): 94-96.

Alverson DL and Hughes SE (1996) Bycatch: from emotion to effective natural resource management. Reviews in Fish Biology and Fisheries 6(4): 443-462.

Carpenter KE (1997) Living marine resources of Kuwait, eastern Saudi Arabia, Bahrain, Qatar, and the United Arab Emirates. Food and Agriculture Organization of the United Nations (FAO), European Commission (EC), Rome. viii+293 p.

Dadzie S, Manyala JO and Abou-Seedo F (2005) Aspects of the population dynamics of *Liza klunzingeri* in the Kuwait Bay. Cybium 29(1): 13-20.

Kelleher K (2005) Discards in the world's marine fisheries: an update. FAO Fisheries Technical Paper No. 470. Food and Agriculture Organization of the United Nations (FAO), Rome. xix + 131 p.

Mohammed HMA, Bishop JM and Ye YM (1998) Kuwait's post Gulf-War shrimp fishery and stock status from 1991/92 through 1995/96. Reviews in Fisheries Science 6(3): 253-280.

Moore ABM, McCarthy ID, Carvalho GR and Peirce R (2012) Species, sex, size and male maturity composition of previously unreported elasmobranch landings in Kuwait, Qatar and Abu Dhabi Emirate. Journal of Fish Biology 80(5): 1619-1642.

Pauly D (1985a) Consultant's report: Ecological Modelling and the Integration of Fishery Research by KISR/MFD. Report to the Kuwait Institute for Scientific Research/Mariculture and Fisheries Department. ICLARM, 11 p. + Appendices.

Pauly D (1985b) A methodology for studying the recruitment into Kuwait's shrimp stocks, pp. 32-44. In: Mathews CP (ed.) Proceedings of the 1984 Shrimp and Fin Fisheries Management Workshop. Kuwait Institute of Scientific Research, Kuwait.

Pauly D (2006) Major trends in small-scale marine fisheries, with emphasis on developing countries, and some implications for the social sciences. Maritime Studies (MAST) 4(2): 7-22.

Pauly D and Mathews CP (1986) Kuwait's finfish catch three times more than its trawlers. Naga, the ICLARM Quarterly 9(1): 11-12.

Pauly D and Palomares ML (1987) Shrimp consumption by fish in Kuwait water: a methodology, preliminary results and their implications for management and research. Kuwait Bulletin of Marine Science (9): 101-125.

Pauly D and Zeller D (2003) The global fisheries crisis as a rationale for improving the FAO's database of fisheries statistics. In Zeller D, Booth S, Mohammed E and Pauly D (eds.), From Mexico to Brazil: Central Atlantic fisheries catch trends and ecosystem models. University of British Columbia, Vancouver, Canada.

Pikitch EK, Santora C, Babcock EA, Bakun A, Bonfil R, Conover DO, Dayton P, Doukakis P, Fluharty D, Heneman B, Houde ED, Link J, Livingston PA, Mangel M, McAllister MK, Pope J and Sainsbury KJ (2004) Ecosystem-based fishery management. Science 305(5682): 346-347.

Siddiqui MS and Al-Mubarak KA (1998) The post-Gulf-War shrimp fishery management in the territorial waters of Kuwait. Environment International 24(1-2): 105-108.

Slavin JW (1982) Utilization of shrimp bycatch. pp. 21-28 *In* Fish bycatch - bonus from the sea. Report of a technical consulation on shrimp bycatch utilization held in Georgetown, Guyana, 27-30 October 1981. IDRC and FAO, Ottawa, Ontario.

Ye YM, Mohammed HMA and Bishop JM (1999a) Shrimp resources and fisheries in Kuwait waters. Technical Report KISR 5473, Kuwait Institute for Scientific Research, Kuwait. 39 p.

Ye YM, Mohammed HMA and Bishop JM (1999b) Depth, temperature and salinity preferences of newly recruited penaeid shrimps in Kuwait waters. Fisheries Oceanography 8(2): 128-138.

Ye YM, Alsaffar AH and Mohammed HMA (2000) Bycatch and discards of the Kuwait shrimp fishery. Fisheries Research 45(1): 9-19.

Zeller D, Booth S, Craig P and Pauly D (2006) Reconstruction of coral reef fisheries catches in American Samoa, 1950-2002. Coral Reefs 25(1): 144-152.

Zeller D, Booth S, Davis G and Pauly D (2007) Re-estimation of small-scale fishery catches for US flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266-277.

Zeller D, Booth S, Pakhomov E, Swartz W and Pauly D (2011a) Arctic fisheries catches in Russia, USA, and Canada: baselines for neglected ecosystems. Polar Biology 34(7): 955-973.

Zeller D and Pauly D (2004) The future of fisheries: from 'exclusive' resource policy to 'inclusive' public policy. Marine Ecology-Progress Series 274: 295-303.

Zeller D, Rossing P, Harper S, Persson L, Booth S and Pauly D (2011b) The Baltic Sea: estimates of total fisheries removals 1950-2007. Fisheries Research 108(2-3): 356-363.

Total fishery extractions for Qatar: 1950-2010[1]

Dalal Al-Abdulrazzak

Sea Around Us Project, Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada
d.alabdulrazzak@fisheries.ubc.ca

Abstract

Qatar is an Arab state that occupies a small peninsula on the northeasterly coast of the much larger Arabian Peninsula. It shares its southern border with Saudi Arabia and is surrounded by the Persian Gulf on the other sides. Qatar's fish catches have increased sharply over the past decade due to increased fishing effort, in response to the increasing demand emanating from a rapidly growing population. Following the reconstruction approach, all available peer-reviewed and grey literature was searched for qualitative and/or quantitative data on catches that are missing from the statistics reported to FAO. Overall, data reported to the FAO from 1950-2010 underestimate catches by 38%. In the period between 1970 and 1993, discards from Qatar's bottom trawl fishery were equivalent to 30% of the reported catch. This study illustrates the urgent need to establish management infrastructure for fisheries monitoring and regulation enforcement, especially given Qatar's rate of population increase.

Introduction

Qatar is a small Arab country located on a peninsula on the western shores of the Persian Gulf, and borders Saudi Arabia in the South. The island country of Bahrain lies to the northwest of Qatar (Figure 1), whose maritime boundaries with Bahrain have only been settled as of 2001. Qatar's small size and proximity to other Arab states means that it shares marine resources with Saudi Arabia, Bahrain, and the United Arab Emirates, which further emphasizes the need for regional fisheries management cooperation.

Qatar has been ruled as an absolute monarchy of the Al-Thani family since 1825, but also was a British protectorate until it gained independence in 1971. Up until the 1940s, it was one of the poorest Gulf States, with an economy based solely on pearl diving. However, rapid industrialization following the development of the oil and gas industries has vastly increased the country's economy, and today it has the second highest GDP per capita in the world.

Qatar's waters are characterized by extreme meteorological and hydrological conditions, with water temperatures reaching over 33°C during the summer, leading to high evaporation and salinity levels. Its fisheries are almost entirely confined to the eastern side of the peninsula, which has a maximum depth of 50 m (Al-Ansi and Priede 1996). Over 150 fish species belonging to 50 families have been recorded in Qatari waters, and of these, the majority belong to the families Lethrinidae (17.2%), Serranidae (16%), Carangidae (12.6%), 'Pomadasydae'[2] (9.1%) and Scombridae (8%) (El Sayed 1992; Al-Ansi *et al.* 2002). During 1995-1996, a 'red tide' occurred which was probably the reason why 30-40 tonnes of dead fish subsequently washed up on shore (Al-Ansi *et al.* 2002).

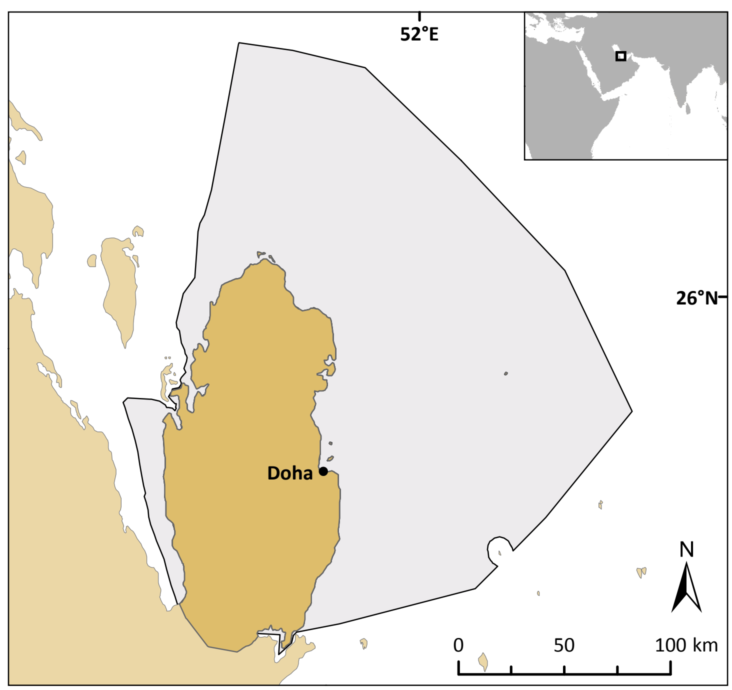

Figure 1. Map of Qatar, showing the extent of its EEZ (in grey).

Qatari fisheries are artisanal in nature and are composed of 2 distinct vessel types: traditional *dhows* and small outboard-powered fibreglass vessels both with an operational range of 60-100 km (Al-Ansi and Priede 1996). Both vessel types target pelagic and demersal species, with fish traps (*gargoor*) being the most common fishing gear, followed by

[1] Cite as: Al-Abdulrazzak D (2013) Total fishery extractions for Qatar: 1950-2010. pp. 31-37. *In*: Al-Abdulrazzak D and Pauly D (eds.) From dhows to trawlers: a recent history of fisheries in the Gulf countries, 1950 to 2010. Fisheries Centre Research Reports 21(2). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

[2] Now part of the family Haemulidae (see www.fishbase.org)

gillnets, hand and troll lines. Seasonal trolling and hand-lining for Spanish mackerel (*Scomberomorus* spp.) also takes place. The commercial shrimp fishery was closed in 1993 and periodic re-assessments of the country's shrimp stocks have not warranted its re-opening. Since the closure of the Qatari National Fishing Company (QNFC), which operated 3 bottom trawlers, a sharp increase in the number of artisanal boats occurred, in order to compensate for the decreased CPUE (El Sayed 1996).

As in neighbouring countries, the ownership of vessels is restricted to citizens, while actual fishing operations employ expatriate labour from India, Bangladesh, and Iran. Due to increased standards of living as a result of the oil boom, few Qatari's are drawn to fishing. Yet, per capita fish consumption in the country is 16.5 kg·year^{-1}, more than twice the average in the Arab world for 1995.

Fisheries management in Qatar is rudimentary at best, although in theory, vessel fishing licenses are required. No fisheries management plans exist and as a result, policy directions for fisheries management are unclear and subject to frequent change. Basic stock assessment data, rates of effort, and fishery market potentials are also lacking (El Sayed 1992). In 1998, the Fisheries Department of the Ministry of Municipal Affairs and Agriculture ceased issuing new fishing licenses, capping the fleet at 515 vessels (Morgan 2004). No restrictions were places on gear or vessel size, and as a result, new higher-capacity vessels were introduced to replace the smaller vessels in the fleet, hence the increased fishing effort in recent years. Because robust stock assessments are lacking, it is uncertain to what extent the increased fishing effort can be sustained.

Illegal fishing is a major problem for Qatar, given the small scale and economic importance of the industry. Illegal fishing (such as by driftnets) is common because enforcement agencies are unable to ensure compliance with regulations (Morgan 2004; Richer 2009). In addition, a growing and uncontrolled recreational fishing sector, estimated to deploy over 1,000 crafts, catches significant quantities of fish (Morgan 2004).

Methods

This contribution follows the conceptual framework of the catch reconstruction method as outlined by previous studies (Zeller *et al.* 2006; Zeller *et al.* 2007; Jacquet *et al.* 2010; Le Manach *et al.* 2012).

A preliminary step in this reconstruction was to attempt to improve the taxonomic resolution of the reported data. Prior to 1982, the data presented by the FAO on behalf of Qatar consist solely of "marine fishes nei" and "green tiger prawn". In 1982, 20 new taxa entered the data and the proportion (and tonnage) of "marine fishes nei" greatly decreased. Therefore, it was assumed that species which appeared in 1982 were being caught previously, and thus could be used to disaggregate the miscellaneous category. For the period 1950-1981, the species proportions from the 1982 data (excluding the green tiger prawn) were applied to the "marine fishes nei" catch to disaggregate it into more informative taxonomic groups. The disaggregated data were then used as the baseline for the reconstruction.

Al-Abdulrazzak and Pauly (2013) estimate that in 2005, 17 *hadrah* (tidal weirs) contribute to an annual catch of 286 ± 100 t annually, despite their being banned since 1994 (M.S. Al-Muhindi, Ministry of Fisheries, pers. comm.). It was assumed that *hadrah* were more abundant prior to the ban in 1994, and therefore that 286 t were caught annually from 1994-2010, and twice that amount (572 t) prior to the ban. The species composition of *hadrah* in Al-Abdulrazzak and Pauly (2013) was also used here.

To estimate recreational catch, the same method as was used in the Kuwait reconstruction, was applied, where a 0.12% participation rate was applied to total population from 1960-2010 to obtain a time series of recreational fishers, and a conservative estimate of 1 kg of fish per trip, along with 104 fishing days per year (See Kuwait, Al-Abdulrazzak, this volume). Similarly, Kuwait's reconstructed recreational catch species composition ratios were applied.

Although Qatar's bottom trawl fishery is considered "semi-industrial" by FAO (Morgan 2004), for the purposes of this report it was considered to be industrial. Ibrahim (1989) estimates that 496-635 t were discarded by Qatar's bottom trawl fishery for 1986-1987. The study also presents the percent contribution of the bottom trawl fishery to the total finfish landings (excluding sharks) and the average percent contribution (32%) was used to determine the amount of finfish reported landings from 1970 (start of the fishery) to 1993 (when it was closed) that came from the bottom trawl fishery. A discard rate of 50% (Ibrahim *et al.* 1989) was applied to the bottom trawl fishery (i.e., 50% of the total catch was discarded). The same study also provided a discard rate of 4% (of the total catch) for the rest of the artisanal fishery, and this rate was applied to all other artisanal finfish catches (reported, unreported, and discarded). Discarded species composition originates from the same Ibrahim *et al.* (1989) study.

Qatar reports requiem shark landings for 1982 and 1983 (1 and 5 t respectively), but not for other years. However, studies exist which show that sharks are frequently caught in both targeted and bycatch fisheries (Al-Ansi and Priede 1996; Moore 2012), and a graph in Sivasubramaniam and Ibrahim (1983) documents monthly shark landings in 1982 at Al Khor, eastern Qatar. Annual shark landing data of 133 t were extracted from Sivasubramaniam and Ibrahim (1983), and a per capita rate for 1983 estimated (0.00048 t). Neighbouring UAE and Saudi Arabia report steadily increasing shark landings to FAO, but both are also known to be shark fin re-exporting countries and therefore it is difficult to interpret these trends (Moore 2012). As a conservative estimate, it was assumed the per capita shark rate was constant from 1950-1994, but then declined to 90% from 1995-1999, 80% from 2000-2005, 70% from 2006-2007, and 60% from 2008-2010. A 3-year moving average was used for smoothing.

Driftnets were banned in 1989, but continue to be used routinely with 2-3 violations occurring per day (Richer 2009). A rough estimation of illegal driftnet catch is presented here which was inspired by the work of Sumaila *et al.* (2006). First, because of the large numbers of violations occurring, it is assumed that 10% of 515 registered vessels take part in illegal driftnetting. Next, the ratio of registered vessels to total reported catch is estimated, to obtain the annual total catch per vessel from 1989-2010. For illegal fishing to be worthwhile, the expected penalty must be at least equal to the expected gain; it is here conservatively assumed that vessels deploying driftnets are catching 20% more than they would legally (i.e., deploying *gargoor* traps from their boats instead of illegal driftnets). Finally, the annual total catch per vessel fishing illegally was multiplied by the estimated number of participating vessels (56) to estimate illegal driftnet catches for from 1989-2010.

Like other countries in the Gulf, commercial fishing is undertaken by foreign labourers who have a high incentive to subsistence fish. In order to estimate this sector, it was assumed that fishers (0.0066% of the population) take home an average of 5 kg per week, and extrapolate from the start of the oil boom in 1960 to 2010. Because these catches are composed of less desirable species subsistence catches were assigned based on the family level of discarded species.

Results and discussion

For the period of FAO reporting, 1950-2010, reported catches for Qatar are annually, on average, under-reported by 62% (Figure 2a; Appendix Table A1). Total catches reported to the FAO over the same period were 258,253 t, while the methods used here estimate an additional 98,900 t were extracted but unreported.

Catch data as reported by the FAO on behalf of Qatar show a steady increase of catches, more than doubling in the last few decades (Al Jedah *et al.* 1999; Feidi 2005), with a sharp increase from 2001 until 2010. This is unsurprising given that Qatar's population grew from 770,000 in 2001 to 1.4 million in 2009 (Sale *et al.* 2011), generating an increase in demand and a corresponding increase in effort, with new, higher-capacity vessels replacing the older smaller vessels in the fleet (Morgan 2004).

The five main taxa caught by Qatar are Lethrinidae (18%), Serranidae (9%), *Scomberomorus commerson* (8%), Carangidae (6%), and Siganidae (5%) (Figure 2b; Appendix Table A2).

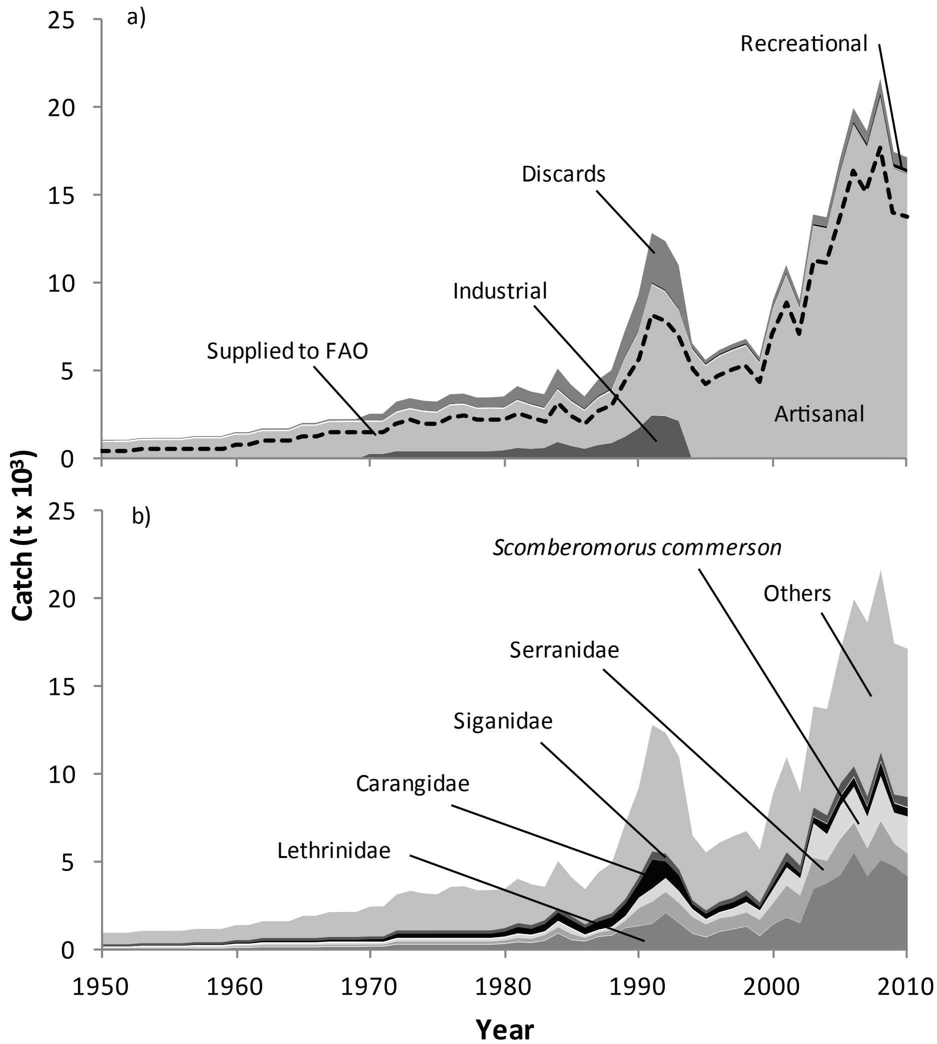

Figure 2. Total reconstructed catch for Qatar by a) sector (with comparison to FAO data), and b) major taxa, 1950-2010. Note that the subsistence sector is not visible on the sector graph (a) and recreational catches are only slightly visible at the end of the time period (black fill).

In particular, the reconstruction highlights the extent of illegal fishing in Qatar. The small scale and minor economic value of Qatar's fisheries means that directing resources at fisheries enforcement is not economically justifiable (Morgan 2004). Although Qatar has banned the use of *hadrah* since 1994, the contribution of Al-Abdulrazzak and Pauly's (2013) suggests that from 286 to 572 t (or 429 t on average) of fish are caught annually by *hadrah* since 1994. In addition, it was estimated that on average, 1,082 t were caught annually by illegal driftnetting from 1989 to 2010. These estimates of illegal catches presented here are very tentative, and are likely to be replaced by higher figures when the assumptions used here are replaced by field estimates.

The reconstruction also highlights the magnitude of discarding in the region. For the years when the QNFC was operational (1970-1993), discards from the bottom-trawl fishery constituted 30% of reported catch; of this, 38% consisted of fish of length above 15 cm, i.e., suitable for human consumption (Ibrahim *et al*. 1989). An additional 18% was greater than 20 cm and of commercial value in Qatar (Ibrahim *et al*. 1989). If retained, these fish could have increased QNFC's annual income by more than 15-30% (Ibrahim *et al*. 1989).

Given the country's rapidly growing population, the corresponding increase in recreational fishing is unsurprising. However, Morgan (2004) predicts that the catch of the recreational sector (which is unmonitored) could one day exceed that of the commercial sector. Thus, management issues for this growing sector must be addressed. Unlike neighbouring countries, Qatar currently meets most of the fish demands of its 1.8 million residents, only importing 1,679 t in 2001 (Morgan 2004). However, Qatar's reliance on imports is likely to increase in light of its growing population.

In order to accommodate expanding industries and rapid population growth, major coastal development projects are underway resulting in land reclamation and dredging, with little to no studies on their short- and long-term ecological impacts on marine life (Sheppard *et al*. 2010). These development projects are certain to impact fisheries yet are not addressed, since no formal management plan exists for any fishery. In addition, although fishery input controls are used (gear restrictions, limiting number of vessels, etc.), they are ineffective because compliance is limited. Given these rapid developments, the lack of stock assessments and fishery management plans is cause to worry about the future prospects of Qatar's fish stocks.

The reconstruction approach undertaken here accounts for missing sectors, including discards, shark catches, illegal and recreational catches. Thus, the reconstructed time series may better reflect the catches extracted from Qatar's marine ecosystems from 1950-2010 than the official statistics. Although the reconstructed time series are entirely dependent on the assumptions made by this study, they are preferable to the alternative of assuming 'zero' catch for sectors with missing data components. Thus, despite considerable data uncertainties and lack of precision, conservative catch reconstruction approaches are far less misleading (particularly in with respect for fisheries policy formulation) than assuming no data means 'zero' catch.

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References

Al-Abdulrazzak D and Pauly D (2013) Managing fisheries from space: Google Earth improves estimates of distant fish catches. ICES Journal of Marine Science, doi.10.1093/icesjms/fst178.

Al-Ansi M and Priede IG (1996) Expansion of fisheries in Qatar (1980-1992): growth of an artisanal fleet and closure of a trawling company. Fisheries Research 26(1-2): 101-111.

Al-Ansi MA, Abdel-Moati MAR and Al-Ansari IS (2002) Causes of fish mortality along the Qatari waters (Arabian Gulf). International Journal of Environmental Studies 59(1): 59-71.

Al Jedah JH, Ali MZ and Robinson RK (1999) The nutritional importance to local communities of fish caught off the coast of Qatar. Nutrition & Food Science 6: 288-294.

El Sayed AFM (1992) The status of Qatar's fisheries during 1980-1990. Qatar University Science Journal 12: 233-238.

El Sayed AFM (1996) Effects of overfishing and abandoning bottom trawling on Qatar's fisheries. Qatar University Science Journal 16(1): 173-178.

Feidi IH (2005) Fisheries development in the Arab world. Middle Eastern Natural Environments 103: 388-406.

Ibrahim MA (1989) Studies on bottom trawling and demersal fishes of Qatar waters, Arabian Gulf. Qatar University Science Journal 9: 291-308.

Ibrahim MA, El-Bary KA and Al-Khayat JA (1989) By-catch of commercial bottom trawl fishery from Qatar waters, Arabian Gulf. Qatar University Science Journal 9: 309-319.

Jacquet J, Fox H, Motta H, Ngusaru A and Zeller D (2010) Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania. African Journal of Marine Science 32(2): 197-206.

Le Manach F, Gough C, Harris A, Humber F, Harper S and Zeller D (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy 36(1): 218-225.

Moore ABM (2012) Elasmobranchs of the Persian (Arabian) Gulf: ecology, human aspects and research priorities for their improved management. Reviews in Fish Biology and Fisheries 22(1): 35-61.

Morgan G (2004) Country review: Qatar. pp. 297-301 *In* De Young C (ed.), Review of the state of world marine capture fisheries management: Indian Ocean. FAO Fisheries Technical Paper 488. Food and Agriculture Organization of the United Nations (FAO), Rome.

Richer R (2009) Conservation in Qatar: impacts of increasing industrialization. Centre for International and Regional Studies Georgetown University. 23 p.

Sale PF, Feary DA, Burt JA, Bauman AG, Cavalcante GH, Drouillard KG, Kjerfve B, Marquis E, Trick CG, Usseglio P and Van Lavieren H (2011) The growing need for sustainable ecological management of marine communities of the Persian Gulf. Ambio 40(1): 4-17.

Sheppard C, Al-Husiani M, Al-Jamali F, Al-Yamani F, Baldwin R, Bishop J, Benzoni F, Dutrieux E, Dulvy NK, Durvasula SRV, Jones DA, Loughland R, Medio D, Nithyanandan M, Pilling GM, Polikarpov I, Price ARG, Purkis S, Riegl B, Saburova M, Samimi-Namin K, Taylor O, Wilson S and Zainal K (2010) The Gulf: a young sea in decline. Marine Pollution Bulletin 60(1): 13-38.

Sivasubramaniam K and Ibrahim MA (1983) Pelagic fish resources and their fishery around Qatar. Qatar Science Bulletin 3: 297-327.

Sumaila UR, Alder J and Keither H (2006) Global scope and economics of illegal fishing. Marine Policy 30: 696-703.

Zeller D, Booth S, Craig P and Pauly D (2006) Reconstruction of coral reef fisheries catches in American Samoa, 1950-2002. Coral Reefs 25(1): 144-152.

Zeller D, Booth S, Davis G and Pauly D (2007) Re-estimation of small-scale fishery catches for US flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266-277.

Estimating total fish extractions in the United Arab Emirates: 1950-2010[1]

Dalal Al-Abdulrazzak

Sea Around Us Project, Fisheries Centre, University of British Columbia,
2202 Main Mall, Vancouver, BC, V6T 1Z4, Canada
d.alabdulrazzak@fisheries.ubc.ca

Abstract

The United Arab Emirates (UAE) is an Arab country located along the southwestern coast of the Persian Gulf, and with a small coastline along the Gulf of Oman. Its fisheries are all small-scale in nature, with catches increasing steadily until 1999, after which they started to decline. Due to reliance on a market-sampling program for their estimation, which does not differentiate between locally caught and imported catch, the UAE is thought to systematically over-report its catches. Following the reconstruction approach, the UAE's domestic catches in the Persian Gulf were re-estimated using all available peer-reviewed and grey literature sources for quantitative and/or qualitative information on sectors missing from or misreported to statistics presented by the FAO on behalf of the UAE. Overall, the figures reported to the FAO from 1950-2010 over-estimate actual domestic catches by an average of 51% annually (47% overall) when compared to reconstructed totals, despite the reconstruction accounting for subsistence and recreational catches that are entirely missed by market-sampling. On the resource side, introduced fisheries management measures are encouraging, but not sufficient given the scale of the country's overfishing problem.

Introduction

The United Arab Emirates (UAE) has coasts on both the southern Persian Gulf and the northern Gulf of Oman (Figure 1). The country is a federation of 7 Emirates with shared administrative and political power between the federal government and the various Emirates. One of the Emirates (Fujairah) has its coastline only in the Gulf of Oman, where substantial catches may be taken (Pearson *et al.* 1998), but which are not considered here. Another Emirate (Sarjah) has a coastline both in the Persian Gulf and along the Gulf of Oman, but the latter is very small and is also not considered here. In 1962, Abu Dhabi became the first of the emirates to export oil, transforming the country's economy and infrastructure. Today, its oil reserves are ranked the 6th largest in the world (OPEC 2012).

Prior to the discovery of oil in the 1950s, pearl diving was the basis of the country's economy. The First World War, the economic depression in the late 1920s, and the development of cultured pearls in Japan led to the sector's demise.

The fisheries of UAE are all small-scale in nature, with the vast majority taking place in the Emirate of Abu Dhabi, which is reported to comprise over 60% of the country's marine area (Morgan 2004). Fishers employ two distinct fishing vessel types: fibreglass *tarads* and traditional wooden *dhows*. The *tarads* are typically 6-8m in length and equipped with 1-2 outboard engines, allowing a crew of 1-4 people to fish for 6-8 hours at a time (Grandcourt *et al.* 2002). *Dhows,* on the other hand, range from 12-22 m and are equipped with inboard diesel engines and insulated cool boxes, allowing the crew of 4-6 people to fish for 3-5 days at a time. Like other Gulf countries, vessels are owned by UAE nationals, while the majority of workers on the vessels are migrant labourers from India, Bangladesh and Iran.

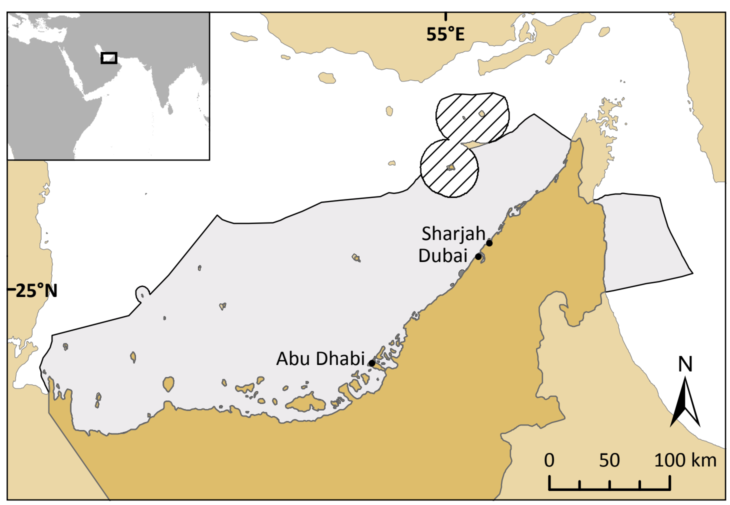

Figure 1. Map of the United Arab Emirates (UAE), showing the extent of its EEZ in grey (including the area contested with Iran; stripped area). The three capital cities of the major Emirates of Abu Dhabi, Dubai and Sharjah are also shown.

The UAE's fisheries are multi-gear and multi-species, with over 100 species occurring in the catch (Grandcourt *et al.* 2010). The majority of fish species caught belong to the families Serranidae, Lethrinidae, Lujanidae, Haemulidae, Sparidae, Carangidae and

[1] Cite as: Al-Abdulrazzak D (2013) Estimating total fish extractions in the United Arab Emirates: 1950-2010. pp. 53-59. *In*: Al-Abdulrazzak D and Pauly D (eds.) From dhows to trawlers: a recent history of fisheries in the Gulf countries, 1950 to 2010. Fisheries Centre Research Reports 21(2). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

Mugilidae. The main fishing gear is a dome-shaped wire trap called a *gargoor*, but hand-lines, intertidal weirs (*hadrah*), trolling, gillnets, and encircling nets are also used (Grandcourt *et al.* 2002). Though fisheries are of minor importance to the UAE's economy, they are valued for the recreational opportunities they provide, for their contributions to food security, and as a part of the country's cultural heritage.

Fish are landed at one of over 30 designated landing sites along the Gulf coast, principally in Abu Dhabi, Dubai, and Sharjah. Most landing sites also have facilities for storing, auctioning, wholesale and retailing the catch. Some of the larger sites also have processing facilities for wholesale and retail markets. Imported fish (from Oman) is sold in the markets alongside locally caught fish, which does not allow for differentiation of domestic form imported seafood through market-only surveys .

Until 2004, a market survey program (which includes imports) was used to estimate catches, inevitably yielding inflated figures for truly domestic catches. Surveys performed by the Environmental Research and Wildlife Development Agency (ERDWA) compared reported and estimated catches for 2000, and found that, while estimated domestic landings were 20,000 tonnes, reported landings (as estimated from the market survey) were 110,000 tonnes (Grandcourt *et al.* 2003).

Morgan (2004) reports that both commercial and non-commercial fish stocks have declined significantly over the past 25 years (some by as much as 90%) as a result of overfishing and extensive coastal development. As a result, the number of registered fishing vessels has decreased, from 7,700 in 1998 to 5,191 in 2002 (Morgan 2004). A law requiring a UAE national to be physically present on the vessels during fishing operations has also contributed to the reduction in registered vessels (Morgan 2004).

Illegal fishing is common and likely encouraged by low enforcement of management rules. In particular, the use of driftnets for pelagic fishes such as Spanish mackerel (Morgan 2004; Barakat 2012), as well as shark fishing during the closed season (Moore 2012; Simpson 2012) are widespread.

The UAE was revealed to be the fifth largest exporter of shark fins to the Hong Kong market (Fowler *et al.* 2005; Moore 2012), despite a shark-finning ban. However, it is thought that the majority of these fins are re-exported from shark catches made in Oman (Moore *et al.* 2012). Catch statistics reported by the FAO on behalf of the UAE show steadily increasing shark catches from 1989-2008, followed by a drastic decline in 2009 (presumably due to the finning ban). This, however, is likely to be an underestimate because enforcement is weak, and sharks that are finned at sea and/or fished during the January-April closed season remain unreported.

Methods

This contribution follows catch reconstruction methods as previously outlined by other studies (e.g., Zeller *et al.* 2006; Zeller *et al.* 2007; Le Manach *et al.* 2012).

Although issues with over-reporting are acknowledged by the FAO (Morgan 2004), no efforts appear to have been made by the relevant reporting agency in the UAE to improve data reporting. Morgan (2004) estimates that catches for 2000 were over-reported by 90,000 t, while Luca Garibalidi (FAO, pers. comm.) thinks that this over-reporting figure is "too high". Therefore, in the absence of better data, reported catches were adjusted using the median of 20,000 t (Morgan's estimate of domestic catches) and 110,000 t (FAO data) as an anchor point for domestic reported catches, and all reported catches were decreased by 40%. These adjusted catches were used as the new baseline of reported landings for the analysis.

Using Google Earth, Al-Abdulrazzak & Pauly (2013) estimate 95 ± 1 *hadrah* were operating in the UAE in 2005, generating an annual catch of 1,292 ± 381 t. The UAE reports half that amount (i.e., 600 t) for the same year. Since the number of *hadrah* is not known to have substantially fluctuated in the last five decades, the reported *hadrah* catch for 2005 (600 t) was adjusted to the estimated catch (1,292 $t \cdot year^{-1}$) for all years. Species composition was estimated from data supplied by the Abu Dhabi Environmental Agency (S. Hartmann, pers. comm.).

To estimate illegal driftnet catches, an approach developed for Qatar was followed (see Qatar, Al-Abdulrazzak, this volume). To estimate annual total catch per vessel, the number of registered fishing vessels from 1998 (start of records) to 2010 was obtained from the UAE's Ministry of Environment and Water database. For the years without these records, the average number of registered vessels was used. It was assumed that 10% take part in illegal drift-netting (Table 1). As in the case of Qatar, it was estimated that vessels deploying driftnets were catching 20% more than they would legally (i.e., when deploying *gargoor* traps from their boats instead of illegal driftnets). The annual total catch per illegal fishing vessel (Table 1) was multiplied by the estimated number of participating vessels, to create a time series of illegal catch from 1989 (the start of the driftnet ban) to 2010.

The UAE has a growing recreational fishery, and although (free) recreational fishing licenses are required in Dubai and Abu Dhabi, no data on the number of participants or quantity of catches exist (Morgan 2004). Therefore, to estimate this sector, methods originally developed for Kuwait were used: it was assumed that recreational fishing began in 1960, a 0.12% participation rate was applied to the total population from 1960-2010 to obtain a time series of recreational fishers, and a conservative catch rate estimate of 1 $kg \cdot trip^{-1}$, along with 104 fishing trips per person per year was used to calculate total recreational catch (see Kuwait, Al-Abdulrazzak, this volume). UAE's recreational fishers target Spanish mackerel, tuna, sailfish and demersal species (Bishop 2002; Morgan 2004) and this species composition was applied in equal ratios to disaggregate the recreational catch.

The telosts *Lethrinus borbonicus*, *Lethrinus microdon*, *Pomacanthus maculosus*, and *Scolopsis taeniata* are caught as incidental and generally discarded bycatch by *gargoors* targeting emperors, groupers, jacks, and sweetlips (Morgan 2004; Grandcourt *et al.* 2010). Weizhong *et al.* (2012) estimate *gargoor* discard rates to be 2.56%, and this figure was used to extrapolate total discards for the fishery. The species composition was applied in equal ratios among the above species.

Table 1. Parameters used for estimating illegal driftnet fishery.

Year	Number of participating vessels	Annual illegal catch per vessel (t)	Annual catch (t)
1989	564	20	11,280
1990	564	20	11,280
1991	564	20	11,280
1992	564	20	11,280
1993	564	20	11,280
1994	564	20	11,280
1995	564	20	11,280
1996	564	20	11,280
1997	564	20	11,178
1998	770	18	13,762
1999	619	23	14,106
2000	469	27	12,648
2001	459	29	13,500
2002	519	23	11,701
2003	505	23	11,411
2004	556	19	10,793
2005	557	19	10,401
2006	557	18	9,892
2007	557	17	9,388
2008	557	16	8,880
2009	605	15	9,294
2010	605	16	9,538

Despite the UAE's high GDP, subsistence fishing occurs by the industry's foreign labourers. Foreign fishers make up 0.0046% of the country's total population, and it was assumed that fishers take home an average of 5 kg of fish per week, starting with the oil boom in 1960 until 2010. Because these take home catches are made up of less desirable species (which lack a targeted fishery), the ratios from species discarded from the *gargoor* fishery was applied.

Results and discussion

Fisheries landings as reported by FAO show steady increases from 12,000 t·year^{-1} in 1950 to 43,001 t·year^{-1} in 1973, followed by a dramatic increase to 67,800 t·year^{-1} in 1974. Catches continue to increase steadily until their peak of 117,607 t·year^{-1} in 1999, before declining to 79,610 t·year^{-1} by 2010 (Figure 2a; Appendix Table A1). However, adjusted reported landings (i.e., domestic) increased from 7,200 t·year^{-1} in 1950 to a peak of 70,600 t·year^{-1} in 1999 before declining to 47,800 t·year^{-1} by 2010 (Figure 2a).

Total reconstructed catches are annually, on average, 34% less than landings reported by FAO on behalf of the UAE (32% overall), but are 11% higher (annual average) than the adjusted reported domestic landings (14% overall; Figure 2a). Reconstructed total catches increase gradually from 7,920 t·year^{-1} in 1950 to a peak of 86,200 t·year^{-1} in 1999, followed by a decline to 55,400 t·year^{-1} in 2008. Catches in 2010 have increased again to 59,500 t·year^{-1}.

For the 1950-2010 time period, artisanal catches accounted for 99.5% of the total reconstructed catch, while the subsistence and recreational sectors contributed 0.05% and 0.45%, respectively (Figure 2a). Estimated discards were low and accounted for 0.6% of the total catch.

The main taxa caught in the UAE are *Scomberomorus commerson* (15%) and Lethrinidae (11%), followed by *Sardinella* spp. (8%), *Stolephorus* spp. (7%), Serranidae (7%), and Carangidae (7%; Figure 2b; Appendix Table A2).

Overfishing is of particular concern for the *Scomberomorus commerson* fishery, as recruitment failure has been associated with increased fishing pressure (Grandcourt *et al.* 2005). In the neighbouring Gulf of Oman, there has been a 10-fold decrease in the yields of this species in recent years (Grandcourt *et al.* 2005).

Despite declining landings, fisheries management in the UAE remains rudimentary. At the national level, the Ministry of Agriculture and Fisheries (MAF) regulates fisheries management, but some legislative authority for policy development exists on a regional scale within component Emirates. Fisheries Regulation Committees (which comprise the MAF), fisher cooperatives, municipalities, and the Coast Guard exist in each Emirate, and address regional fisheries policy and enforcement. However, due to a lack of consensus on overarching national fisheries planning goals, differing and inconsistent decisions (or no decisions at all) are often the outcome. The coordination of the various federal and regional managing bodies into a single comprehensive and consistent national fisheries policy may prove to be the greatest challenge (Morgan 2004).

The UAE has only recently introduced fisheries management legislation and therefore, there remain significant gaps, both legislatively and managerially. Like Qatar (Qatar, Al-Abdulrazzak, this volume), UAE management practices rely on input rather than output controls. Marine protected areas, closed seasons for some migratory pelagic fish, and escape gaps in *gargoor* are the most important fisheries management measures. Until recently, the only restrictions on commercial fishing were bans on trawling and driftnets. However, in 2003, Abu Dhabi began to set limits on the number of *gargoor* fish traps. No gear restrictions have been applied in other Emirates to date. Enforcement is also problematic as it is limited by the fisheries-specific training of the Coast Guard staff, the lack of strategic protocol, and the traditional right of appeal for misdemeanours to ministers and sheikhs. As a result, many fisheries prosecutions are never pursued and regulations are often ignored.

Stakeholder participation in fisheries policy development takes place in the form of traditional discussions, often directly with senior government figures. While these often result in compromised solutions, stakeholder participation is limited to UAE nationals only, who are the vessel owners, but are not necessarily actively engaged in fishing activities (Morgan 2004).

Compounding the fisheries crisis is the rapid development and urbanization of coastal areas in the UAE, which is expected to have pervasive and lasting effects on Gulf ecosystems. For example, in 2002, Dubai commenced construction on a series of large scale artificial island-lagoon complexes along the entire coast of the Emirate (Sale *et al.* 2011). Because of the construction's proximity to coral reefs, the sedimentation buried coral reefs (Sheppard *et al.* 2010; Sale *et al.* 2011), thus affecting fish habitat.

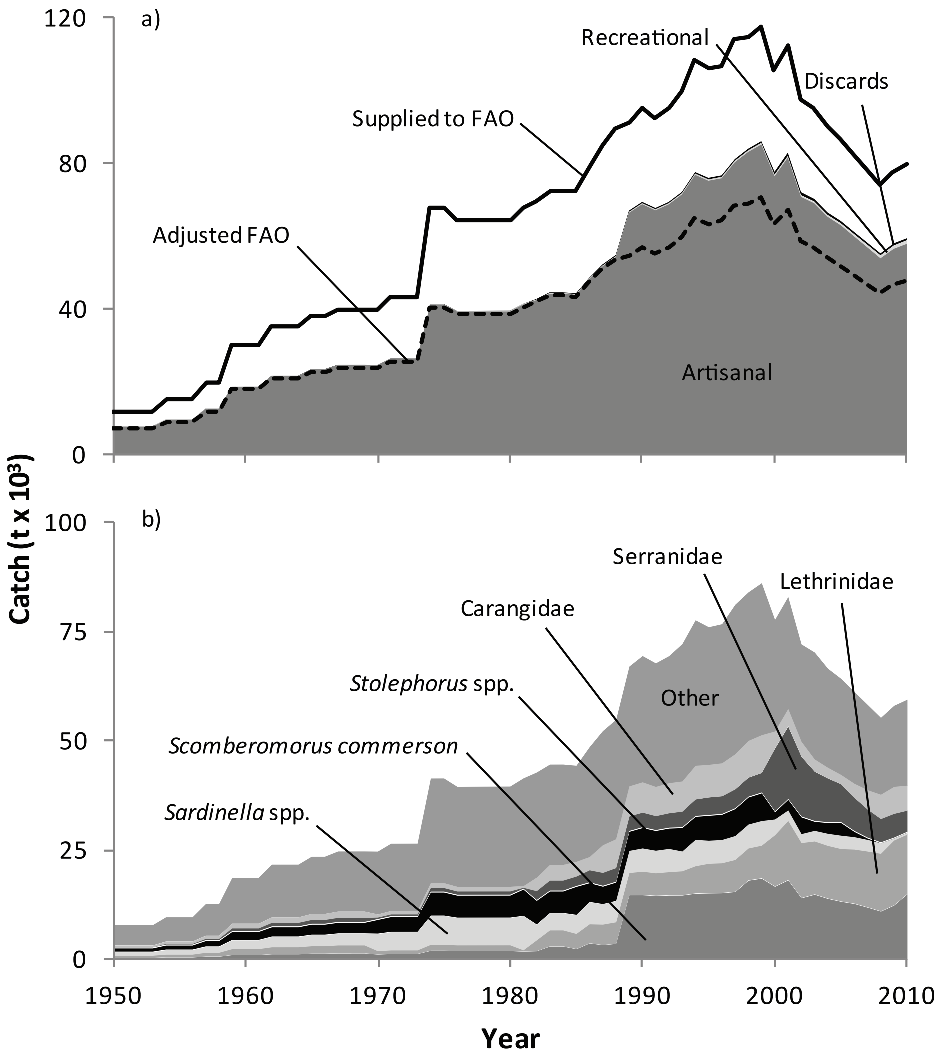

Figure 2. Total reconstructed catch for the United Arab Emirates by a) sector (with the solid line representing the landings data transmitted to FAO and the dashed line the 'adjusted FAO data'); and b) major taxa, 1950-2010. Note that subsistence catches were included in the sector graph (a) but are not visible (too small). Recreational catches are the light coloured area and discards the darker line on top.

The re-estimated catches account for missing sectors including recreational and subsistence catches, as well as discards, illegal catches, and over-reporting errors. Thus, the reconstructed time series may better reflect the catches extracted from the Persian Gulf by the UAE's fisheries from 1950-2010 than the officially reported statistics. While the reconstructed catches are entirely dependent on the assumptions made by this study and despite the considerable data uncertainties associated with the estimates, they seem preferable to the alternative of assuming 'zero' catch for sectors lacking quantitative data.

Finally, it may be noted that it would be appropriate, in subsequent analyses, to reconstruct the UAE's catches along the Gulf of Oman coast, and in the process, to revisit the assumption that these catches did not enter the fisheries statistics considered here.

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References

Al-Abdulrazzak D and Pauly D (2013) Managing fisheries from space: Google Earth improves estimates of distant fish catches. ICES Journal of Marine Science, doi.10.1093/icesjms/fst178.

Barakat N (2012) Greedy fishermen use illegal nets. Gulf News, edition of March 25 2012. Available at: http://gulfnews.com/news/gulf/uae/environment/greedy-fishermen-use-illegal-nets-1.999210 [Accessed: January 17, 2013].

Fowler SL, Cavanagh RD, Camhi M, Burgess GH, Cailliet GM, Fordham SV, Simpfendorfer CA and Musick JA (2005) Sharks, rays and chimaeras: the status of the chondrichthyan fishes. International Union for the Conservation of Nature (IUCN), Gland, Switzerland and Cambridge, UK. x + 461 p.

Grandcourt E, Al Abdessalaam TZ, Francis F and Al Shamsi A (2010) Age-based life history parameters and status assessments of by-catch species (*Lethrinus borbonicus*, *Lethrinus microdon*, *Pomacanthus maculosus* and *Scolopsis taeniatus*) in the southern Arabian Gulf. Journal of Applied Ichthyology 26(3): 381-389.

Grandcourt E, Francis F, Al-Shamsi A, Al- Ali K and Al-Ali S (2002) Annual fisheries statistics for Abu Dhabi Emirate 2001. Marine Environmental Research Center, Abu Dhabi., UAE. 94 p.

Grandcourt E, Francis F, Al Shamsi A, Al Ali K and Al Ali S (2003) Stock assessment and biology of key species in the demersal fisheries of the Emirate of Abu Dhabi. Environmental Research and Wildlife Development Agency.

Grandcourt EM, Abdessalaam TZA, Francis F and Shamsi ATA (2005) Preliminary assessment of the biology and fishery for the narrow-barred Spanish mackerel, *Scomberomorus commerson* (Lacépède, 1800), in the southern Arabian Gulf. Fisheries Research 76(2): 277-290.

Le Manach F, Gough C, Harris A, Humber F, Harper S and Zeller D (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy 36(1): 218-225.

Moore ABM (2012) Elasmobranchs of the Persian (Arabian) Gulf: ecology, human aspects and research priorities for their improved management. Reviews in Fish Biology and Fisheries 22(1): 35-61.

Moore ABM, McCarthy ID, Carvalho GR and Peirce R (2012) Species, sex, size and male maturity composition of previously unreported elasmobranch landings in Kuwait, Qatar and Abu Dhabi Emirate. Journal of Fish Biology 80(5): 1619-1642.

Morgan G (2004) Country review: United Arab Emirates. pp. 327-335. *In*: De Young C (ed.), Review of the state of world marine capture fisheries managment: Indian Ocean. FAO Fisheries Technical Paper 488. Food and Agriculture Organization of the United Nations (FAO), Rome.

Pearson WH, Al-Ghais SM, Neff JM, Brandt J, Wellman K and Green T (1998) Assessment of damages to commercial fisheries and marine environment of Fujairah, United Arab Emirates, resulting from the Seki oil spill of March 1994: a case study. Yale School of Forestry and Environmental Studies Bulletin 103: 407-428.

Sale PF, Feary DA, Burt JA, Bauman AG, Cavalcante GH, Drouillard KG, Kjerfve B, Marquis E, Trick CG, Usseglio P and Van Lavieren H (2011) The growing need for sustainable ecological management of marine communities of the Persian Gulf. AMBIO 40(1): 4-17.

Sheppard C, Al-Husiani M, Al-Jamali F, Al-Yamani F, Baldwin R, Bishop J, Benzoni F, Dutrieux E, Dulvy NK, Durvasula SRV, Jones DA, Loughland R, Medio D, Nithyanandan M, Pilling GM, Polikarpov I, Price ARG, Purkis S, Riegl B, Saburova M, Samimi-Namin K, Taylor O, Wilson S and Zainal K (2010) The Gulf: a young sea in decline. Marine Pollution Bulletin 60(1): 13-38.

Simpson C (2012) Fishermen defy UAE ban on shark hunting. The National edition of October 11 2012. Available at: http://www.thenational.ae/news/uae-news/environment/fishermen-defy-uae-ban-on-shark-hunting [Accessed: January 17, 2013].

Weizhong C, Al-Baz A, Bishop J and Al-Husaini M (2012) Field experiments to improve the efficacy of gargoor (fish trap) fishery in Kuwait's waters. Chinese Journal of Oceanology and Limnology 30(3): 535-546.

Zeller D, Booth S, Craig P and Pauly D (2006) Reconstruction of coral reef fisheries catches in American Samoa, 1950-2002. Coral Reefs 25(1): 144-152.

Zeller D, Booth S, Davis G and Pauly D (2007) Re-estimation of small-scale fishery catches for US flag-associated island areas in the western Pacific: the last 50 years. Fishery Bulletin 105(2): 266-277.

Appendix B. Groundtruthing the ground truth.

The appendix provides supporting evidence for Chapter 4 of this thesis, and was published following comments on the original paper. A version of this Appendix has been published:

Al-Abdulrazzak and D. Pauly, D. (2014) Ground-truthing the ground-truth: reply to Garibaldi et al.'s comment on "Managing fisheries from space: Google Earth improves estimates of distant fish catches". *ICES Journal of Marine Science* **71,** 1927-1931.

Introduction

A major reason why, throughout the world, the food provisioning role and ecosystem impacts of small-scale fisheries are thought to be negligible is that catch data for these fisheries are hard to come by, especially data produced in the context of rigorous sampling designs as traditionally required by fisheries scientists (Pauly, 1995b). However, not accounting for the catch of small-scale fisheries will generally be far more misleading than using conservative estimates derived from anecdotal estimates (Zeller et al., 2006). Thus, a call for incorporating non-traditional sources of data into fisheries science (Pauly, 1995b) has resulted in a number of studies that have attempted to estimate missing or under-represented fisheries sectors using a diversity of methods including household surveys, interviews with fishermen, historical records and, more recently, Google Earth (Saenz-Arroyo et al., 2005; Zeller et al., 2007; Jacquet et al., 2010; Le Manach et al., 2012; Al-Abdulrazzak and Pauly, 2013b; McClenachan and Kittinger, 2013; Al-Abdulrazzak et al., 2014).

Weirs have been a common feature on the coast of the Persian Gulf for decades (Figure B.1), and even centuries (MacIvor, 1881), but their actual impact was not considered until recently. To assess the impact of weirs, it was necessary to accept the possibility that many relatively simple fishing gears can have, in aggregate, effects similar to that of industrial fishing gear. Indeed, weirs, given their relatively low construction cost, will tend to proliferate where the physical and social conditions are appropriate. However, the latter conditions may not favor catch monitoring and, hence, their role may be unappreciated, and even their existence denied, e.g., because, in some countries, the complex rules regulating their beneficial ownership may not fit into the top-down administrative structure of fisheries management. Multiple examples of this can be found in the Asia-Pacific region, where many countries, for a long time, pursued centralizing policies that they inherited from earlier colonial masters. These policies often suppressed traditional community-based management and resulted in a reduction on the contribution of local fish catches to livelihoods and diets of people in rural areas (Ruddle, 1993). In situations such as this, Google Earth-based studies can be invaluable, as they can generate compelling existential and quantitative data on fisheries. Garibaldi et al. (2014a), while endorsing the use of such studies in principle, criticize the assumptions, methodology, statistics, results and conclusions of Al-Abdulrazzak & Pauly (2013), primarily on the basis of what they contend is a ground-truthing exercise which, however, only revealed (i) a lack of local knowledge, and (ii) insufficient reflection on the concept and nature of 'ground-truthing'.

The key issue with the concept of 'ground truthing' is that is contains the word 'truth', which is always a problem in Science, given that in practice, we only deal with evidence that either supports or contradicts hypotheses (Popper, 2005). Ground truthing satellite imagery is therefore not a matter a concocting a story about what may be happening on the ground, as the second author painfully discovered when the Chinese 'trawlers' he thought he had ground 'truthed' in a much reproduced photograph (Van Houtan and Pauly, 2007) turned out to show anchored vessels operating like weirs against tidal currents. Rather, ground truthing, as is all of evidence-based science, is a matter of formulating and testing hypotheses, i.e., processes for which both local expertise and restraint in the face of uncertainty are needed. As shown below, lack of local knowledge, in this case, completely invalidated the ground truthing intended by Garibaldi et al. (2014).

Rebuttal to the criticisms levied by Garibaldi et al.

The objections of Garibaldi et al. were addressed in what was considered a logical progression, although this is not the sequence in which they were presented in their comment.

1) Garibaldi et al. criticize the use of only three estimates for the daily catch of weirs, obtained from a thorough literature review and interactions with local experts in each Gulf country. These three catch rates were the only estimates available. This data scarcity – which admittedly is real – was accommodated as best possibly, by accepting large confidence intervals, i.e., using the Monte-Carlo method to explicitly account for uncertainty. This seems more constructive than entirely ignoring a fishing gear because of data scarcity. It is telling that, despite their own local contacts, and access to Governments and national databases in the Gulf region, Garibaldi et al. (2014) did not present any alternate estimates.

2) Garibaldi et al. (2014) write that “daily catch of weirs can differ substantially according to season, area, shape of gear, fish migration, ocean currents, weather conditions, etc.” While this seems reasonable, it should be pointed out that these alleged relationships are hypotheses, and that hypotheses are tested with data – which they do not present. Accounting for the relationship between weir catch rates and any of the factors listed by Garibaldi et al. (2014) (which can be straightforwardly incorporated into the Monte Carlo approach that was used) could have improved the results. In fact, the sizes of the 3 different components of each weir that was encountered were recorded (Al-Abdulrazzak & Pauly 2013; see Table 2) and, thus, if/when data on catch per weir of different sizes become available, they will be considered, along with the effect of tides and seasons.

3) Garibaldi et al. (2014) consider that “when only a portion of a weir is visible it is in fact due to the weir being only partially present through either disrepair or abandonment.” This statement is refuted by Figure B.2, which shows that the physical conditions encountered when an image is taken has a strong influence on the visibility of weirs. It

was assumed that weirs that fall into such a state of disrepair that they are not fishing (or ghost fishing, which would be equivalent here), would not be standing and therefore not visible from Google Earth. Thus, not accounting for suboptimal visibility obscuring some weirs would have rightly been considered a source of downward bias. However, this correction for underestimation only added 6% to the total weirs that were actually counted.

4) Both Figures 2A & 2B of Garibaldi et al. (2014), which are supposed to support their assertion (addressed in 3 above) that derelict weirs may have been included in the estimate, do not, in fact, illustrate a derelict weir. Rather, Garibaldi et al. (2014) have mistaken a *maskar*, an entirely different gear, for a weir (Arabic: *hadrah*). *Maskars* are low stone barriers used in Qatar (and to a lesser extent the United Arab Emirates) that run parallel to shore allowing fish to swim over the top at high tide and require active fishing at low tide (Serjeant, 1978; Carter and Killick, 2010). *Hadrahs*, on the other hand, are made from bamboo poles and chicken wire (or historically, woven date palm fronds) and run perpendicular to shore (Figure B.3). The obvious differences in appearance, orientation, and materials between *hadrahs* and *maskars* make it possible to differentiate between them solely from the satellite images. Because of these differences, and others (e.g., effort, catch composition, fishing season), *maskars* were not included in the study. However, this identifies another stationary gear whose impact could be monitored using Google Earth.

5) Garibaldi et al. (2014) suggest that the methods “introduced positive biases” by needlessly inflating the number of estimated weirs when accounting for the low resolution of some of the satellite images that were used. Figure B.4, which depicts Failaka Island, off Kuwait, for which only a partial area of sufficient resolution was available at the time of the study, illustrates how certain areas of the coast which are likely to have weirs present may not have sufficient imagery resolution to detect them. At the time that the survey was conducted, only the north part of Failaka Island had sufficient resolution, which enabled the detection of 4 weirs in this area. However, imagery for 2012 (which only became available after the survey was completed)

indicates that indeed 8 additional weirs were present in the southern part of the island. Low resolution was accounted for by counting the number of coastal grid squares in each country with and without available imagery, and raising the total number of weirs by the percentage of missing imagery. This method adds only an additional 8% to the total weirs counted in the Gulf. Obviously, this correction would not have been necessary if there was access to images with better resolution. However, since such was not available at the time, a reasonable correction was applied to the poor resolution images.

6) Serendipitously, the GPS coordinates that Garibaldi et al. (2014) provided to illustrate a 'weir fragment' in Kuwait corresponds to the coastal area directly in front of the first author's home (Figure B.5a). Having lived in this house for over two decades, she can state with certainty that the dark line in question was never a weir, but a remnant from a boat anchoring system that her father installed in the 1980s. That system was destroyed in the 1990-1991 Gulf War. However, the two one ton weights and the lead line remain, creating a dark line in the satellite image that was mistaken by Garibaldi et al. (2014) for a derelict weir (Figure B.5b).

7) Beyond the coincidence described in 6), there are easily observable features in Google Earth that make it possible to determine that the object in the images is not a derelict weir. (i) The Google Earth time slider tool makes it possible to scan images of the same area taken in years prior to and after 2005. Doing so demonstrates that the dark line was never part of the 'wing' section of a weir. (ii) The location of the sandbar in the middle of the 'weir' would not allow fish to swim into the pocket during the receding tide, since weirs require gradually sloping sea floors. (iii) Examining nearby (<1 km) weirs reveals that all 8 weirs in the area were well-maintained from 2004-2013, indicating that the region is a productive fishing area and making it unlikely that one single weir in the same area would have been left derelict.

All of the preceding dealt with technical matters. The following points deal with data and transparency issues.

8) Garibaldi et al. (2014) state that Al-Abdulrazzak and Pauly 2013 erroneously assert that 'the FAO database' does not separate Saudi Arabia's catch data from the Gulf and the Red Sea, and they point to the Gulf Regional Commission for Fisheries (RECOFI) database having such disaggregated data. Databases surely exist in which this differentiation is made. The FAO Fishstat database, which is the one referred to here, does not.

9) Garibaldi et al. (2014) refer to an "unpublished document for domestic inter-organizational purposes" as something that should have been consulted. They also state that the RECOFI was ignored. However, this organization does not widely disseminate the data it holds, and its decision on minimum data reporting standards a) does not include catches by weirs (FAO, 2013); b) is based on each member country setting their own standards which can result in no reporting at all, as was the case in 2013 when 4 countries failed to report. It remains to be seen whether tangible improvements will result from the RECOFI process.

10) Garibaldi et al. (2014) state, "it is very probable that catches from weirs are included in the catch statistics reported to FAO." This lack of confidence in the details of the FAO database by the very people who are in charge of it illustrates the lack of transparency and the need to improve the quality of the database through objective third-party estimates. Interestingly, the preliminary estimates presented by Garibaldi et al. (2014) of weirs contributing at most 10% of total catches in Kuwait, Bahrain, and Iran, is consistent with Al-Abdulrazzak and Pauly's (2014) regional estimate of 6-8% .

Proposed best practice for use of Google Earth satellite images

Google Earth is emerging as a powerful and cost-effective tool for scientists in a wide variety of disciplines including archeology, ecological theory, and public health (Chang et al., 2009; Pringle, 2010; Madin et al., 2011; Ploton et al., 2012). Although Google Earth cannot be used everywhere – image resolution varies spatially and temporally—

the potential to rapidly survey inaccessible or cost-prohibitive areas is tremendous. Here, 'best practices' that should be considered when using Google Earth satellite images are proposed:

a) Develop a search image. Although predators may at first overlook potential prey, with experience, they 'learn' to detect cryptic prey (Tinbergen, 1960; Dawkins, 1971). The same concept applies to Google Earth, where with time, users can detect what they are looking for more quickly—and more accurately. For this reason, the coast of entire Gulf was scanned 3 times to ensure a complete count of weirs and to minimize the possibility that other structures were mistakenly included.

b) When in doubt, err on the side of caution. If a structure is difficult to verify do not include it in the survey. For example, in the case of weirs, at least 2 out of the 3 components (wing, yard, pocket) should be visible.

c) Ground truth in the light of local knowledge. As explained above, ground truthing exercises are only useful when they include an understanding of the local landscape and customs.

d) Consider the dates of image availability. Different areas of the world have different years of image availability. Consider whether the dates are appropriate for the study and whether scanning several years can aid in verifying an object.

e) Accommodate for lack of images. Two conservative and straightforward ways of accounting for common problems were demonstrated: image availability and poor resolution (Al-Abdulrazzak & Pauly, 2014). These methods can easily be modified to other studies that rely on object counts.

Conclusion

When a new approach is presented that leads to a scientific advance, it is very easy to point out its weaknesses and propose how it could be improved. Stating that reality is far more complicated than the new approach allows for, and using that argument to dismiss the results, does not move the science forward (Cheung et al., 2013). Rather, critiques of this nature in effect discourage innovation and the exploration of new tools. A more constructive approach would be to propose how a new method could be improved and demonstrate that with studies that build upon the original work.

References

Al-Abdulrazzak, D., Pauly, D. (2013) Managing fisheries from space: Google Earth improves estimates of distant fish catches. *ICES Journal of Marine Science* **71,** 450-454.

Al-Abdulrazzak, D., Zeller, D., Pauly, D. (2014) Understanding fisheries through historical reconstructions: Applications to fishery management and policy at different governance scales. In: *Marine Historical Ecology in Conservation: Applying the Past to Manage for the Future*. (Eds. J.N. Kittinger, L. McClenachan, K. Gedan, L.K. Blight), University of California Press.

Carter, R., Killick, R. (2010) *Al-Khor Island: Investigating Coastal Exploitation in Bronze Age Qatar,* Vol., Moonrise Press, Ludlow.

Chang, A., Parrales, M., Jimenez, J.*, et al.* (2009) Combining Google Earth and GIS mapping technologies in a dengue surveillance system for developing countries. *International Journal of Health Geographics* **8,** 49.

Cheung, W.W.L., Pauly, D., Sarmiento, J.L. (2013) How to make progress in projecting climate change impacts. *ICES Journal of Marine Science: Journal du Conseil* **70,** 1069-1074.

Dawkins, M. (1971) Perceptual changes in chicks: Another look at the search image concept *Animal Behaviour* **19,** 566-574.

FAO (2013) Report of the sixth meeting of the RECOFI working group on fisheries management. Doha, The State of Qatar, 5-8 November 2012.

Garibaldi, L., Gee, J., Sachiko, T., Mannini, P., Currie, D. (2014) Comment on: "Managing fisheries from space: Google Earth improves estimates of distant fish catchs" by Al-Abdulrazzak and Pauly. *ICES Journal of Marine Science* **71,** 1921-1926.

Jacquet, J., Fox, H., Motta, H., Ngusaru, A., Zeller, D. (2010) Few data but many fish: marine small-scale fisheries catches for Mozambique and Tanzania. *African Journal of Marine Science* **32,** 197-206.

Le Manach, F., Gough, C., Harris, A., Humber, F., Harper, S., Zeller, D. (2012) Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? *Marine Policy* **36,** 218-225.

MacIvor, I. (1881) Notes on sea-fishing in the Persian Gulf. Report on the Administration of the Persian Gulf Political Residency and Muscat Political Agency for the Year.

Madin, E.M.P., Madin, J.S., Booth, D.J. (2011) Landscape of fear visible from space. *Scientific Reports* **1**.

McClenachan, L., Kittinger, J.N. (2013) Multicentury trends and the sustainability of coral reef fisheries in Hawai"i and Florida. *Fish and Fisheries* **14,** 239-255.

Pauly, D. (1995) Anecdotes and the shifting baseline syndrome of fisheries. *Trends in Ecology & Evolution* **10,** 430-430.
Ploton, P., Pelissier, R., Proisy, C.*, et al.* (2012) Assessing aboveground tropical forest biomass using Google Earth canopy images. *Ecological Applications* **22,** 993-1003.
Popper, K. (2005) *The Logic of Scientific Discovery,* Vol., Taylor & Francis, New York.
Pringle, H. (2010) Google Earth Shows Clandestine Worlds. *Science* **329,** 1008-1009.
Saenz-Arroyo, A., Roberts, C.M., Torre, J., Carino-Olvera, M. (2005) Using fishers' anecdotes, naturalists' observations and grey literature to reassess marine species at risk: the case of the Gulf grouper in the Gulf of California, Mexico. *Fish and Fisheries* **6,** 121-133.
Serjeant, R.B. (1978) Historical sketch of the Gulf in the Islamic Era, from the seventh to the eighteenth century A.D. In: *Qatar Archaeological Report-- Excavations 1973*. (Ed. B. De Cardi), Oxford University Press, Oxford.
Tinbergen, L. (1960) The natural control of insects in pine-woods. I. Factors influencing the intensity of predation by songbirds. *Archives Neerlandaises de Zoologie* **13,** 265-343.
Van Houtan, K., Pauly, D. (2007) Snapshot: Ghosts of Destruction. *Nature* **447,** 123.
Zeller, D., Booth, S., Craig, P., Pauly, D. (2006) Reconstruction of coral reef fisheries catches in American Samoa, 1950-2002. *Coral Reefs* **25,** 144-152.
Zeller, D., Booth, S., Davis, G., Pauly, D. (2007) Re-estimation of small-scale fishery catches for US flag-associated island areas in the western Pacific: the last 50 years. *Fishery Bulletin* **105,** 266-277.

Figures

Figure B.1 Three Blackburn B-101 Beverley heavy transporters flying over weirs off the coast of Bahrain. A reference to the (British) Royal Air Force squadron 84 suggests this photo was taken c. 1964.

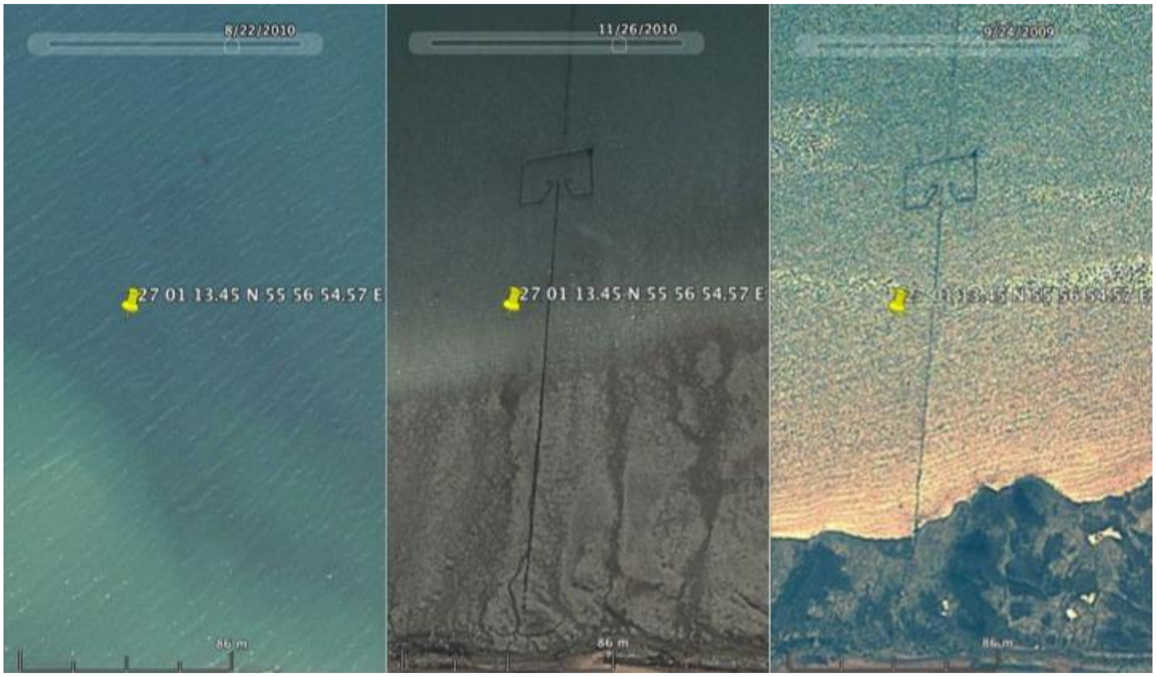

Figure B.2 A single weir off the coast of Iran under three different conditions to illustrate the effect of physical conditions on visibility. Pin represents GPS coordinates.

Figure B.3 Ground photograph of weir to contrast the image provided by Garibaldi et al. (2014) purported to be a weir (*hadrah*), but which was actually a *maskar*.

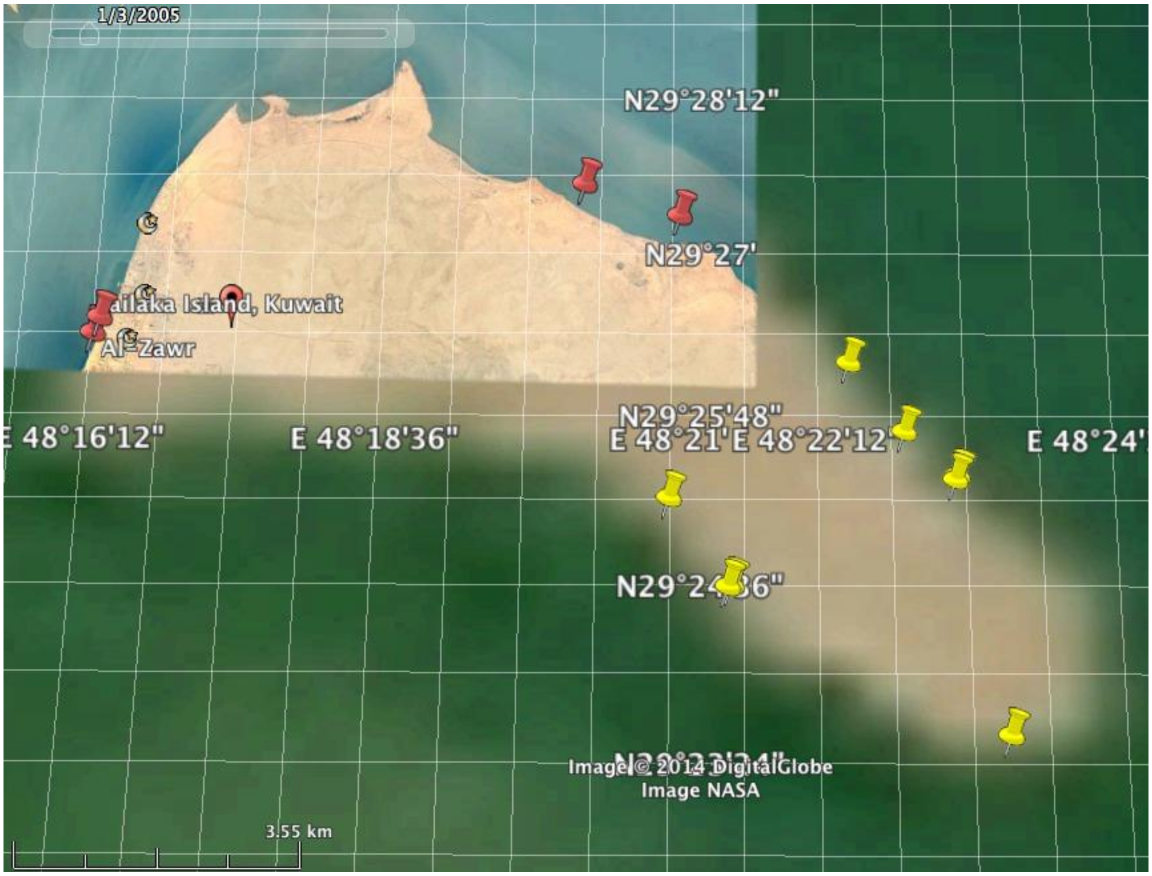

Figure B.4 Failaka Island, Kuwait showing the quality of satellite imagery available for 2005 and projection of the Google Earth grid view. Red pins represent weirs found during the original study for 2005, while yellow pins represent weirs found using imagery available after the survey was completed in 2012.

A. **B.**

Figure B.5 Ground truthing GPS coordinates from Garibaldi et al. (2014)

A. Ground truthing verifies that the satellite image provided by Garibaldi et al. (2014) is a remnant of a private boat anchoring system. GPS coordinates: +028.59040° / +048.39914°.

B. GPS coordinates provided by Garibaldi et al. (2014) in relation to the coordinates of Figure 5a. A different angle was necessary to capture the length of the structure.

Appendix C. Anecdote ranking questionnaire.

The appendix presents the anecdote ranking survey used in Chapter 5.

Using the table below, please assign a numerical value (0-5) to each of the 50 passages based on the perceived abundance of the species. If the text refers to multiple species, the preceding note indicates the species of interest to the study.

Species Abundance	Criteria for Classification
(5) Extremely Abundant	Detailed historical accounts lacks any evidence of human use or damage.
(4) Abundant	Human use with no evidence of reduced abundance
(3) Common	Human use and evidence of reduced abundance
(2) Occurs	Evidence of severe human impact
(1) Rare	Rarely observed and further use would have no further environmental effect
(0) Absent	No longer in existence

1. In reference to fish

"Fish are nowhere more plentiful or more delicious than here. The water also is pure wholesome and agreeable."

2. In reference to fish

"Fine edible fish seemed extraordinarily numerous off that coast, and all day long the fishermen were landing their heavy catches through the surf. They were very cheap, a boatload of splendid fish bringing only a few cents. Drying small fish for camel fodder was going on almost the whole length of the beach. I saw nothing else being carried here but fish and some dates…"

3. In reference to birds

"They here saw vast numbers of those birds called 'plongeons' or divers, because they dive into the water to catch fish. They killed there ten or fourteen of them with sticks, and might have killed as many as would have served the whole fleet, but would not lose the opportunity of a fair wind."

4. In reference to fish

"Along the beach lie all kinds of fish from hammerhead shark to giant ray; the nearer waters of the Gulf of Oman teem with fish and much is shipped from here to Europe as fertilizer."

5. In reference to sea-wolves (seal lions)

"Thirty of these large sea-wolves were lying two and sometimes three in the same hole or pit, full of mud and dirt, where they wallowed like hogs. M. de St. Simon singled out such as lay on dry ground, as it was more easy to remove them when dead, and less troublesome to skin them, in order to get their grease or lard for making oil. He killed eleven of them successively. Two others rather larger than the rest, being only wounded, though they had already lost twenty pints of blood, had strength enough to get out of their holes, and escaped to sea, where we soon lost sight of them."

6. In reference to fish

"Muscat Cove abounds in fish of which there is a greater variety and abundance than can perhaps be found in any other part of the world at times the surface of the water is kept in a perfect foam from the rush of the larger fish in pursuit of their prey "

7. In reference to fish

“The whole coast abounds in fish mullet in the back waters and creeks are caught with the casting net in great numbers

8. In reference to dolphins

"On the way to the next anchorage at the river *Granis* (probably the Rud-Hilleh), near which was a palace, a stranded whale fifty cubits in length was observed, 'attended by a great number of dolphins, larger than are ever seen in the Mediterranean."

9. In reference to porpoises

“A few hours before, some hundred porpoises, whose figure may be seen in the plate, made their appearance within pistol shot, and seemed as if they had come on purpose to amuse us. They sprang out of the water in an extraordinary manner. Several of them in cutting their capers, leaped at least three or four feet high, and turned round not less than three times in the air, as if they had been on a spit.”

10. In reference to shellfish

“We did not catch any beautiful shell-fish here; the only one deserving notice was a helmet shell, which was at least eight inches in diameter.”

11. In reference to sharks

“Our fishing was always accompanied with fear; on account of the sharks which very much infest this road. The sharks taken by us, a specimen of which is exhibited in the plates, were not of an extraordinary size; they were of that species called the dog-fish. On an attentive examination of their rows of teeth, we thought they amounted to seven in number, instead of six, which are generally attributed to them. They were flat, triangular, sharp, and their edges were serrated. They did not appear to be firmly fixed in the jaw like those of other animals. They were moveable, opening and shutting like the fingers, in such a manner that each row in recovering its situation lay over the next to it, so that the upper row bending towards the inner part of the gullet, filled up the vacuity or interval between the lower row of teeth. They are disposed like the slates of a roof, or perhaps, like the leaves of an artichoke.”

12. In reference to fish

"The 3rd May was held as a day of thanksgiving and prayer; and on the 21st they passed the tropic of Cancer, catching every where such abundance of fish, that, besides supplying their immediate wants, they salted and dried a considerable store."

13. In reference to fish

"On getting near the Açores, they found no more fish, and had to use those they had dried and salted; and by this food many distempers were produced among them, particularly the scurvy."

14. In reference to whales

"The 28th November, the navigators went over to the continent, or north side of the straits, seeing some whales at a distance, and observed a pleasant river, about which were some beautiful trees with many parrots."

15. In reference to whales

"On the 24th we saw eight or ten whales, a great number of birds, and a kind of sea-weed, which our mariners called Baudreu."

16. In reference to penguins

"They procured abundance of penguins and fish, at an island three miles south from Port Desire; killing to the number of 50,000 penguins, which are nearly as large as geese, and procured a vast quantity of their eggs, by which their people were greatly refreshed, and the sick restored."

17. In reference to penguins

"Both were frequented by great numbers of penguins, the flesh of which served the natives as food, and their skins for clothing."

18. In reference to mussels

“They were here much distressed by hunger and continual rains, and two of their men were slain by the savages, while gathering mussels, which formed their chief subsistence.”

19. In reference to penguins

“After weathering many storms in Meniste bay, and having several encounters with the savages, they set sail on the 17th, and were driven into Penguin bay, or Goose bay, three miles from Meniste bay, and receiving its name from the vast multitude of penguins found here.”

20. In reference to sawfish

"Among the dangers of the pearler in the Persian Gulf the dreaded sawfish may be mentioned as the chief enemy. This shark-like creature is furnished with a formidable weapon in the shape of a flat projecting snout reaching a length of perhaps six feet and armed along its edges with strong toothlike spines. In the presence of such a terrific weapon the diver is almost powerless and instances are recorded in which the poor fellows have been completely cut in two. Nor are the attacks of saw fishes and sharks the only sources of danger."

21. In reference to fish

"The city of Zafar lies in an isolated desert region, in which there is not a village, and it has no dependencies. The bazaar is outside the city in a suburb called al-Harja, and it is one of the dirtiest and fly-ridden bazaars, because of the quantity of fruit and dish sold in it. Most of the fish in it are the species called *sardin*, which are extremely fat there. It is a strange fact that their beasts have their sole fodder these sardines, and likewise their flocks, and I have never seen this any other place."

22. In reference to fish

"From Zafar we sailed towards Oman in a small vessel belonging to an inhabitant of the island of Masirah. On the day following out embarkation we alighted at he roadstead of Hasik, in which there are a number of arabs, who are fishermen and live there...The only means of livelihood for the inhabitants of this port from fishing, and the fish that they catch is called *lukham*, which is like a dogfish. It is cut open, dried in the sun, and used for food; their huts also are built with fish bones, and roofed with camel hides. We continued out journey from roadstead of Hasik for four days, and came to the Hill of

Lum'an, in the midst of the sea. On top of it is a hermitage built of stone, with a roofing of fish bones, and with a pool of collected rainwater outside it."

23. In reference to birds

"We resumed our voyage and after two days reached the Island of Birds, which is uninhabited. We cast anchor and went ashore on it, and found it full of birds like blackbirds, except that these were bigger. The sailors brought some eggs of those birds, cooked and ate them, and also caught and cooked some of the birds themselves without slitting their throats, and ate them."

24. In reference to fish

"We came next to the island of Masirah, to which the master of the shop that we were sailing belonged. It is a large island, whose inhabitants have nothing to eat but fish."

25. In reference to dugongs

"On the edge of the harbor, someone spotted the hump of a dugong taking a breather: a sea cow; placid, vegetarian and prosy, it did not look to my eyes at all like a mermaid. Dugongs are becoming rare now. Perhaps their dwindling numbers have given them their fata appetite for human company. At any rate, they seem to like the busy world of jetties, piles, and baots. They seek out pors, and slumber in the cool shady water at the sides of the dhows and tankers. Then the local fishermen beat them to death, cut them up and sell them cheap in the *souk*. It is a pecularily unkind fate for merpersons."

26. In reference to worms

"The sea appeared as red as blood, and some of the water being drawn up was found full of small red worms, that leaped out of it like fleas."

27. In reference to fish

"Then on the way along the coast to Oman, he describes the frankincense-tree and the manner in which the gum is obtained. In places the people of the coast lived entirely on fish, and even built their houses of fish-bones, using camel hides for roofs."

28. In reference to fish

“Bahreyn itself the fishery is abundantly copious and furnishes occupation to at least half the inhabitants of the island.”

29. In reference to fish

"But fish of all kinds scaly smooth and shelly load the market stalls I doubt if any spot of the entire globe can boast an equal abundance. Hence the principal nutriment of the Baharinah is fish.”

30. In reference to pearl oysters

"In this bay are the best the most copious pearl fisheries of the Persian Gulf and in addition an abundance almost beyond belief of whatever other gifts the sea can offer or bring It is from the sea accordingly not from the land that the natives of Katar subsist and it is also mainly on the sea that they dwell passing amid its waters the one half of the year in search of pearls the other half in fishery or trade.”

31. In reference to birds

" Sea birds are numerous in certain parts of the world but I never saw such myriads of the feathered tribe as were met here. At every few yards we disturbed vast numbers which rose screaming and twittering around us."

32. In reference to sharks

“Polypi, sea nettles, mollusks, and other marine monsters swarm in this Gulf; sharks too are very common so that a swimmer off shore at Barr Faris would do well to look before he plunges."

33. In reference to fish

"All along the coast is carried on a considerable fishery its special object consists in certain small fishes entitled Metoot very much like whitebait or diminutive anchovies in size and shape but not so delicate in flavour. They are eaten uncooked after having been simply salted and dried in the sun without any further preparation."

34. In reference to sharks

"The governor was very polite but by no means talkative; he offered us what hospitality the poverty of the island could afford and a dish of mutton at his table seemed quite a luxury after the shark's flesh off which we were accustomed to make our meals on board. Sharks are very common throughout the Gulf and nobody thinks himself above eating them."

35. In reference to sharks

"They are a nutritive but at best an unsavoury food; their name here is "Awwal" the Indian for "shark;" the genuine Arab denomination is "Kelb ol Bahr" or "sea dog." I was much amused on finding that Niebuhr himself with other travelers, through want perhaps of sufficient conversance with local technicalities, have taken the word Awwal for the name of a place, and have in consequence christened the island of Bahreyn by the fish in question—common, it is true, off those shores but not precisely identical with them. Hence Bahreyn has in some maps and books become "Awwal," or "shark;"

36. In reference to seaweed

"The 8th July they were in lat. 27° N. when they fell in with considerable quantities of sea-weed called Saragossa."

37. In reference to shellfish

"They live chiefly on shell fish, such as mussels, which they gather from off Rocks along the Sea Shore, and their Arrows are the Work of the Women."

38. In reference to penguin

"On the little island where our gentlemen killed so many of these animals, one of the females seized a penguin at the instant it fell by a musket-shot. The sea she-wolf carried it into the water, and devoured it so entirely in a moment that nothing remained but a slip of skin floating on the surface. M. le Roy had, the day before, brought one of these penguins on board, which was at least two feet and a half high.”

39. In reference to fish (thunnies and bonitos)

“We had seen, before the storm came on, shoals of thunnies and bonitos. They leaped out of the water, and made the sea foam, as if they were fighting with each other.”

40. In reference to fish

”During the night several flying fish dropped upon our deck. They were all of that species, which have fins, that serve them for wings, reaching to their tail.”

41. In reference to fish

“While we were in quest of game, two of our officers amused themselves with fishing with the hook from the cabin windows, and caught fish enough to furnish a dish for three successive meals. The angle-rod would supply an equal quantity every day, if the line was but thrown one hour before the meal.”

42. In reference to fish

“These three sorts of fish, which were the only ones we caught on board, are no more than between nine and ten inches long; they are usually from six to seven. But all of them are excellent, particularly that which has the head, and nearly the figure of a pike. They bite so freely, that they are caught as soon as you throw out your line. This fish was one resource, when the weather did not permit us to go shooting.”

43. In reference to whales

”An occasional stray specimen would sometimes visit Roy Cove, where I spent one winter, when the whalers Brought in a dead whale.”

44. In reference to birds (petrel)

“This is the only specimen of this petrel I ever saw, but I believe it nests in holes in the ground on some of the remote islands, being known locally as the 'fire bird.”

45. In reference to seals

“In 1778 a French sealer found the beaches of Saunders Island lined with fur-seals and sea-elephants. Forty-two years later when the Captain's son went to the island he found none, and gave up the voyage.”

46. In reference to seals

Indeed from 1830 onwards sealing at the Falklands, South Georgia, the Shetlands, and other islands was a decadent commerce. At South Georgia seals had been so persistently slaughtered that in 1885 the crew of the Connecticut schooner during the weeks of the breeding season (September to January) were able to find only two.

47. In reference to seals

“In the season of 1915 one solitary fur seal was observed on the beach near the eastern end of South Georgia. It followed the fate of all rare animals and birds, it was promptly killed --‘by mistake’- by some Norwegian whalers.”

48. In reference to seaweed

“Another beautiful seaweed, usually to be found in deep water, is known as the 'tree-fern kelp'. According to Sir Joseph Hooker this species is plentiful on the Falklands. I found it very scarce, only once seeing it growing on the rocks near Fox Bay at extreme low-water mark. I had long been searching for specimens of it to add to our collections, when one day I suddenly detected some fine specimens just awash in a deep gully. Watching for a favourable opportunity between the waves I managed to gather some. This is the only occasion I ever found it growing, although I have, on several occasions, gathered it along the shores.”

49. In reference to jellyfish (medusa)

“Once I managed to get as far as Sparrow Cove, Port William, and was rewarded by the capture of a medusa of a new genus and species which was, unfortunately never met with again.”

50. In reference to birds

“In the evening of the 23d we saw several birds, and some very long and large and well formed beds of fishes fry, of a reddish cast. Most of them extended beyond our sight in length, and some were about a hundred feet in breadth.”

Appendix D. Dugong anecdotes

This appendix presents dugong records (anecdotes) that were used to reconstruct changes in dugong abundance in distribution in Chapter 6.

Author	Year	Quote	Score
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	50 BC - 700 AD	"Tell Akaz, Kuwait (n=68), Age: 50 BC - 700 AD, Period: Pre-Islamic"	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	300 BC - 100 AD	"F5 Failaka, Kuwait (n=142), Age: 300 BC - 100 AD, Period: Hellenistic."	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	400 AD - 1600 AD	"Siraf, Iran (n=12), Age: 400 AD - 1600 AD, Period: Sasanian/Islamic."	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	400 AD - 1600 AD	"Qalat al-Bahrain, Bahrain, Site 519 (n=104), Age: 400 AD - 1600 AD, Period: Dilmun."	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	400 AD - 1600 AD	"Qalat al-Bahrain, Bahrain, Site 520 (n=7), Age: 400 AD - 1600 AD, Period: Dilmun."	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	400 AD - 1600 AD	" Saar, Bahrain (n=12), Age: 400 AD - 1600 AD, Period: Dilmun."	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	2600 - 2000 BC	"Umm an-Nar, Abu Dhabi, UAE (n=3000+), Age: 2600 - 2000 BC, Period: Umm an-Nar/Bronze age"	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	4769-3400 BC	"Akab, Umm al-Qaiwain, UAE (frequent), Age: 4769-3400 BC, Period: ?Ubaid/4th mill BC settlement, and later dugong mound c.3500 BC.'	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	4769-3400 BC	"Tell Abraq, Sharjah/Umm al-Qaiwain, UAE (n=78), Age: 4769-3400 BC, Period: Umm an-Nar/Iron age."	5

Author	Year	Quote	Score
Rice, M. (1994) *The Archaeology of the Arabian Gulf, C. 5000-323 BC,* Vol., Routledge.	300 BC	"They were largely a fishing people and amongst the debris of their occupation the remains of a dugong, or sea cow, have been found. It was evidently butchered at Umm al Nar to feed the settlers there."	5
Rice, M. (1994) *The Archaeology of the Arabian Gulf, C. 5000-323 BC,* Vol., Routledge.	300 BC	"They detected two phases on the site, the earlier one when fish were predominately represented in the remains and later one when mammal bones became significant and when meat evidently formed an important part of the diet of the site's occupants. The animals represented included the Bahrain hare, which still lives around the site, the dugong, the sea-cow which breeds in the bay between Bahrain and Qatar."	5
Potts, D.T. (1993) Rethinking some aspects of trade in the Arabian Gulf. *World Archaeology* **24,** 423-440.	300 BC	"K. Hojgaard's investigations of the teeth recovered from the third millennium (Umm an-Nar period) graves on Umm an-Nar island, located on the coast of the UAE near Abu Dhabi (1980:363, cf. 1984:202) and in the Wadi Jizzi, near Sohar on the Batinah coast of Oman (1984: 202-3, 1985: 151-6), have show that cereals played no role in the diet of these coastal populations, who were largely dependent on fish, turtle and dugong for their protein."	5
Tosi, M. (1974) Some data for the study of prehistoric cultural areas on the Persian Gulf. *Proceedings of the Seminar for Arabian Studies* **4,** 145-171.	300 BC	There are "[m]ainly fishermen and dugong hunters on the small island of Umm an-Nar on the west coast of the peninsula."	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	1200-800 BC	"Shimal, Ras al-Khaimah, UAE (n=10), Age: 1200 – 800 BC, Period: Iron Age."	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	5100 – 4500 BC	"DA11, Dalma island, Abu Dhabi, UAE (present), Age: 5100 – 4500 BC, Period: Ubaid/Late Stone Age."	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	5700 - 4400 BC	"MR11, Marawah island, Abu Dhabi, UAE (present), Age: 5700 - 4400 BC, Period: Ubaid/Late Stone Age."	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	5000-4000 BC	"JH57, Jazirat al-Hamra, Ras al-Khaimah,UAE (n=3), Age: ?5000 - 4000 BC, Period: ?Ubaid/Late Stone Age."	5
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	5000-4000 BC	"Al Markh, Bahrain (common in later phase), Age: ? 5000 - 4000 BC, Period: Ubaid/Late Stone Age."	3
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	1400-1900 AD	"MR4, Marawah island, Abu Dhabi, UAE (many), Age: 1400-1900 AD, Period: Later Islamic period"	3

Author	Year	Quote	Score
Beech, M.J. (2010) Mermaids of the Arabian Gulf: archaeological evidence for the exploitation of dugongs from prehistory to the present. *Liwa Journal of the National Center for Documentation and Research* **2,** 3-18.	300BC - 200AD	Ed-Dur, Umm al-Qaiwain, UAE (present but rare), Age: 300BC - 200AD, Period: Ed-Dur.	3
Newman, E., Harting, J.E., Distant, W.L., Finn, F. (1860) *Zoologist,* Vol. v. 18-19), J. Van Voorst.	1859	"From reliable information which I have obtained, I am enabled to state, with confidence, that they are still occasionally observed within the Persian Gulf, - rarely however in shoals, but generally one or two stragglers at a time. It may be concluded therefore, that a shoal of them may yet be now and then seen off the coast of Mekran, at the head of the Arabian Sea a little further to the east, where Nearchus and his fleet encountered them; and that a carcass may still occasionally be stranded on the same rarely visited coast, and the bones even yet be applied to like purposes by the scanty fish-eating population of that inhospitable woodless region."	4
Fewtrell, W.T. (1860) On some specimens of dugong oil. *American Journal of Pharmacy* **32,** 230-233.	1860	"A few years ago Dr Hobbs the health officer at Moreton Bay introduced the oil obtained from the dugong as a substitute for cod liver oil. This animal is one of the herbivorous cetacea and is found on the northern coast of Australia, in the Red Sea, the Persian Gulf, and also in the Indian seas *Dugong dugong* or dugong is a Malay word which signifies sea cow."	4
Murray, A. (1866) *The Geographical Distribution of Mammals,* Vol., Day and Son, London.	1866	"The commonest species, *Halicore cetacea*, ranges from about the mouth of the Zambesi, northwards all along the East African coast into the Red Sea, thence along the Persian shore to the East Indies"	4
Blanford, W.T., A.R.S.M., F.R.S. (1876) *Eastern Persia: The zoology and geology, by W. T. Blanford,* Vol., Macmillan & Company, London.	1871	"Whales and porpoises abound on the Makran coast and porpoises are equally common in the Persian Gulf but whales are much more rare. Still some occur for I found the vertebra of one on the island of Kishm. Formerly whales were possibly more numerous than they now are for in the Voyage of Nearchus V it is stated that the fish eating inhabitants of the Makran coast in the days of Alexander the Great used bones of whales to build their houses .Thanks to the researches of Mr. Blyth we know pretty well what the great whale of the Makran coast is but as regards the porpoises Delphinida. I can only suggest that several of the Indian species probably occur Conf Blyth's Catalogue of the Mammals in the Museum of the Asiatic Society Jerdon's Mammals of India."	4
Goldsmid, F.J., John, O.B.C.S., Lovett, B., Euan-Smith, C.B., Blanford, W.T. (1876) *Eastern Persia: An Account of the Journeys of the Persian Boundary Commission, 1870-71-72,* Vol. v. 2), Macmillan and Company, London.	1871	"I cannot learn with any certainty that the dugong *Halicore dugong* has been met with on the Persian coast. It is said to occur there by Murray Geoge Dist Mam but I do not know on what authority and consequently I do not include its name in the list. It has not so far as I am aware been observed on the west coast of India farther north than Canara and I cannot find it recorded from any part of Arabia east of Aden."	3
Bretschneider, E. (2013) *Mediaeval Researches from Eastern Asiatic Sources: Fragments Towards the Knowledge of the Geography and History of Central and Western Asia from the 13th to the 17th Century,* Vol. 1), Taylor & Francis.	1874	"The Chinese author had probably heard of the large cetaceous animal which is described in zoology under the name of dugong or dugong halicore cetacea. Tin's beast is found in the Indian ocean and also in the Red Sea and the Persian Gulf and frequents the shallow sea and the coasts where it feeds on the submarine sea grass pastures. The dugong has given rise in ancient times to many miraculous tabs circulating among the Arabs and Persians."	3

Author	Year	Quote	Score
Burton, R.F. (1878) *The Gold-Mines of Midian,* Vol., Dover Publications, Mineola.	1877	"Rüppell (Reise, p. 187) says that the Halicore, often caught in the waters of the gulf, is called by the people Nakat el- bahr, or 'she-camel of the Sea.'"	4
Ross, E.C., Residency, P.G.P., Agency, M.P. (1881) *Report on the Administration of the Persian Gulf Political Residency and Muscat Political Agency for the Year,* Vol., Foreign Department Press.	1881	"'sea -dog.' Colonel Miles writes, 'not common but good eating.'"	3
Kitto, J. (1881) *Evening series. Isaiah and the Prophets,* Vol. 6, Robert Carter and Brothers.	1881	"There are besides numerous of the largest species in the seas of the Levant and also the Arabian Gulf and the Red Sea as well as cetacea and species of halicore or dugong which are herbivorous animals intermediate between whales and seals."	3
Brehm, A.E. (1895) *Brehm's Life of Animals,* Vol. 1, A.N. Marquis & Company, Chicago.	1896	"The fishermen say that the Dugongs usually live couples and rarely in small families but this applies better to the Arabian Gulf than to parts of the Indian Ocean where they are said to have been seen in schools. The Arabian fishermen say that one always finds at least two Dugongs together in the Red Sea but not infrequently as many as ten."	4
Rihani, A.F. (1930) *Around the Coasts of Arabia,* Houghton Mifflin.	1930	"She saw it and wrote about it to the Royal Society. It had a head like a monkey's, a thorax like a human being's while the rest of the body was that of a fish. This was neither a mermaid nor merman, but a mermonkey, unknown, me thinks."	4
Harris, J.R. (1932) *Evergreen Essays,* Vol., W. Heffer & sons, Limited.	1932	"In the Persian Gulf the skins would be those of the seal or dugong, for which there was a ready market in Egypt."	4
Thesiger, W., Stewart, R. (2007) *Arabian Sands,* Penguin Books Limited, London.	1948	"Saw a very small one at Abu Dhabi in 1948, and that only occasion in all his experience though local people had told him not really so very rare."	3
Thesiger, W., Stewart, R. (2007) *Arabian Sands,* Penguin Books Limited, London.	1948	"Once they brought in a young dugong or sea-cow which they had caught in their nets. It was about 4 feet long, a pathetically helpless-looking creature, hideously ugly. They said its meat was good eating, and that its skin made sandals."	3
Sanger, R.H. (1970) *The Arabian Peninsula,* Books for Libraries Press.	1954	"The harbor is also used by fishermen who cast their nets from dugout canoes. The most-prized fish are seacows, which are captured in the Bazam Channel to the west of the town."	3

Author	Year	Quote	Score
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1965	"According to the fishers interviewed at Abu Dhabi, active dugong hunting ended some time after H.H. Sheikh Zayed bin Sultan Al Nahyan had acceded as ruler of Abu Dhabi Emirate in the late 1960s. He is reputed to have said that fishers should not deliberately hunt dugongs, and only those dugongs accidentally caught in nets should be sold."	3
Bibby, G., Phillips, C. (1996) *Looking for Dilmun,* Stacey International.	1969	"Four thousand years ago dugongs "must have been common enough . . . to be the staple of life for a coastal community" a conclusion reached after excavation near Abu Dhabi. He states an exceeding rareness now; also shown by special Press comment on single specimens".	2
Gallagher, M. (1976) The dugong dugong (sirenia) at Bahrain, Persian (Arabian) Gulf. *Journal of the Bombay Natural History Society* **73,** 211-212.	1969	"Skull of dugong found at Bahrain 14 Apr 1969 E. coast, near Askar."	3
Gallagher, M. (1976) The dugong dugong (sirenia) at Bahrain, Persian (Arabian) Gulf. *Journal of the Bombay Natural History Society* **73,** 211-212.	1969	"Skull of dugong found at Bahrain 27 Apr 1969 Ras al Bahr."	3
Gallagher, M. (1976) The dugong dugong (sirenia) at Bahrain, Persian (Arabian) Gulf. *Journal of the Bombay Natural History Society* **73,** 211-212.	1969	"Skull of dugong found 1969 Ras al Bahr."	3
Gallagher, M. (1976) The dugong dugong (sirenia) at Bahrain, Persian (Arabian) Gulf. *Journal of the Bombay Natural History Society* **73,** 211-212.	1970	"Skull of dugong found 29 April 1970 E. coast, near Durr."	3
Gallagher, M.D. (1976) The dugong dugong (sirenia) at Bahrain, Persian (Arabian) Gulf. *Journal of the Bombay Natural History Society* **73,** 211-212.	1970	"Skull of dugong found 29 April 1970 E. coast, near Durr."	3
Gallagher, M.D. (1976) The dugong dugong (sirenia) at Bahrain, Persian (Arabian) Gulf. *Journal of the Bombay Natural History Society* **73,** 211-212.	1970	"Skull of dugong found 22 Feb 1970 Ras al Bahr."	3
Gallagher, M.D. (1976) The dugong dugong (sirenia) at Bahrain, Persian (Arabian) Gulf. *Journal of the Bombay Natural History Society* **73,** 211-212.	1971	"Skull of dugong found 10 Feb 1971 E. coast, near Ras al Qarain"	3
Walker, H. (1998) *Fish: Food from the Waters,* Vol., Prospect Books.	1971	"In the 1970s between 60 and 70 dugong were sold in the Abu Dhabi Market each year. Occasional specimens were still being reported in the early 90's."	2
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1971	"This situation contrasts with the picture of 10 years ago when the fish seller with whom we spoke claimed he could sell one to two dugongs in a day at certain times."	2
Gallagher, M.D. (1976) The dugong dugong (sirenia) at Bahrain, Persian (Arabian) Gulf. *Journal of the Bombay Natural History Society* **73,** 211-212.	1972	"He had sent skulls from Bahrein to British Museum (Nat. Hist.) and he had once found a few dead in exceptionally cold weather."	3
Betram, G.C.L., Betram, C.K.R. (1973) The modern Sirenia: their distribution and status. *Biological Journal of the Linnean Society* **5,** 297-338.	1966	"One specimen reached British Museum (Nat. Hist.) deep-frozen as a rarity from Bahrein in 1966"	2

Author	Year	Quote	Score
Betram, G.C.L., Betram, C.K.R. (1973) The modern Sirenia: their distribution and status. *Biological Journal of the Linnean Society* **5,** 297-338.	1966	"Very rare but formally abundant in places."	2
Gallagher, M.D. (1976) The dugong dugong (sirenia) at Bahrain, Persian (Arabian) Gulf. *Journal of the Bombay Natural History Society* **73,** 211-212.	1974	"The animal is known to some Bahrainis as Baqarat al bahr (sea cow), and to some others as Baqara seit, but for the only reports of live animals I am indebted to the late Mrs Anne Khalifa and to Mr. J.H. Clingly, who have observed single specimens as recently as 1974 off the east coast of Bahrain Island, swimming and surfacing "like a slow dolphin"."	2
Gallagher, M.D. (1976) The dugong dugong (sirenia) at Bahrain, Persian (Arabian) Gulf. *Journal of the Bombay Natural History Society* **73,** 211-212.	1974	"…and to Mr R Pickersgill, who once saw one raise its head and shoulders above the water. From this evidence and the list of specimens which follows one may conclude that a small population continues to survive in the Gulf of Bahrain"	3
Bulliet, R.W. (1975) *The Camel and the Wheel,* Harvard University Press, Cambridge.	1975	"A reasonably contemporary refuse dump excavation on the Arabian coast of the Persian Gulf indicates that there wild camels were eaten but the more important food animal was the dugong or sea cow.""	2
Nair, R.V., Mohan, L., Rao, K.S. (1975) The Dugong Dugong dugon. Bulletin of the Central Marine Fisheries Research Institute.	1975	"Dugongs have been formerly stated to be abundant in the Arabian (Persian) Gulf but now they are very rare there."	2
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1975	"Although he used boats and helicopters he observed dugongs only three times and the largest number seen on any one occasion was about 50"	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1975	"These estimates were probably accurate as there was direct evidence that at least 24 dugongs had been brought into the market during part of the 1975-76 winter alone."	2
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1975	"Prior to this spill, in 1975 and 1976, a preliminary boat and helicopter survey of dugongs In the waters around Bahrain Ahad noted dugongs on only three occasions, and the largest number seen was about 50."	3
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1976	"In 1976, two members of the Emirates Natural History Group obtained separate estimates of 50–60 and 60–70 dugongs sold each year."	2
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1977	"On 14 February 1977 at least eight dugongs were landed at Butain, near Abu Dhabi city, and much of the meat was sold directly to local people, rather than going through the Abu Dhabi fish souk"	2

Author	Year	Quote	Score
United States National Oceanic and Atmospheric Administration. *Administration of the Marine Mammal Protection Act of 1972,* National Marine Fisheries Service, National Oceanic and Atmospheric Administration.	1977	"During 1977 the Service received informal sighting reports of dugongs off the coast of Bahrain in the Persian Gulf, but no comprehensive status reports or population surveys were done."	3
Raban, J. (1979) *Arabia: A Journey Through the Labyrinth,* Simon and Schuster, New York.	1979	"On the edge of the harbor, someone spotted the hump of a dugong taking a breather: a sea cow; placid, vegetarian and prosy, it did not look to my eyes at all like a mermaid. Dugongs are becoming rare now. Perhaps their dwindling numbers have given them their fatal appetite for human company. At any rate, they seem to like the busy world of jetties, piles, and boats. They seek out ports, and slumber in the cool shady water at the sides of the dhows and tankers. Then the local fishermen beat them to death, cut them up and sell them cheap in the souk. It is a peculiarly unkind fate for merpersons."	2
Kilner, P., Wallace, J. (1979) *Gulf Handbook,* Vol., The Book Service Ltd, Colchester.	1979	"Off Bahrain, the dugong or seacow still grazes on the grasses of the shallow sea bed."	3
Hill, M., Webb, P.A. (1984) *An Introduction to the Wildlife of Bahrain,* Ministry of Information, State of Bahrain.	1980	[A female dugong has well] "developed teats and, in a very human fashion, holds its single youngster, with a flipper, to the breast to feed. It is not really known how abundant these sea animals are. Some years very few are recorded, but in other years it is possible to find as many as thirty feeding on the extensive seagrass beds to the north of the Hawar archipelago. The male dugong is larger than the female and possesses small tusks. Young dugong have been seen in April around the Hawar Islands swimming alongside their mothers."	3
Anon. (1986) Dugongs return to Persian Gulf after fears of extinction. In: *New Scientist*. pp. 25-26.	1983	"In addition, observers have counted 50 carcasses of dugongs, an endangered relative of the manatee or sea cow. This may be the entire dugong population of the Gulf."	1
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1983	"Ironically, the number of dugongs killed during the oil spill was much greater than suspected at the time-- an estimated 150 following adjustment for areas not searched, the distribution of dugongs, and the dispersal pattern of the oil -- but the population of dugongs was also much greater than assumed".	2
Begley, S., Carey, J., Callcott, J. (1983) Death of the Persian Gulf. In: *Newsweek.* Vol. 102.	1983	"53 beached carcasses" were seen.	2
Heinsohn, G.E. (1986) Rare and endangered: world's only strictly marine sea cow threatened. *Australian Natural History* **21,** 530-531.	1983	"MEPA observers sighted two live dugongs in the Gulf of Salwah in late April 1983."	3
Heinsohn, G.E. (1986) Rare and endangered: world's only strictly marine sea cow threatened. *Australian Natural History* **21,** 530-531.	1983	"There is an as yet unconfirmed report that 30 live dugongs with a couple of calves were sighted off the UAE in October 1983."	3

Author	Year	Quote	Score
Heinsohn, G.E. (1986) Rare and endangered: world's only strictly marine sea cow threatened. *Australian Natural History* **21,** 530-531.	1983	"Seventy dugongs had also previously been sighted in Bahrain waters in November 1983."	3
United States National Oceanic and Atmospheric Administration. *Administration of the Marine Mammal Protection Act of 1972,* National Marine Fisheries Service, National Oceanic and Atmospheric Administration.	1983	"As a result of the Iraq-Iran war and the oil pollution problems created in the Persian Gulf by the damaging of three offshore oil wells in early 1983, the Service has attempted to collect information on the effects of this oil pollution on Gulf marine organisms. Because of the war situation, little on the spot research can be carried out. However, information from Bahrain indicates that at least 31 carcasses of dugong were observed along the Bahrain coastline at the end of March, 1983".	2
United States National Oceanic and Atmospheric Administration. *Administration of the Marine Mammal Protection Act of 1972,* National Marine Fisheries Service, National Oceanic and Atmospheric Administration.	1983	"…with one additional carcass observed near Kuwait".	2
United States National Oceanic and Atmospheric Administration. *Administration of the Marine Mammal Protection Act of 1972,* National Marine Fisheries Service, National Oceanic and Atmospheric Administration.	1983	"…and another off Saudi Arabia during the same time period. Whether these deaths were linked to the oil spill or some other cause has not been verified. The information is significant in that it indicates that the known dugong population south of Bahrain has been severely impacted."	2
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1983	"Dugongs were not hunted but they were caught in gill nets. Although he did not know how many dugongs were caught each year in his village, he felt that most of the dongs that we caught were released or discarded. He discussed the fates of 4 dugongs he had caught in his nets 3 years earlier. One of the dugongs was found dead in the net and was discarded. Another was too heavy to move and was released alive. The cow of a cow-calf pair was sold in the Doha souk and the calf was consumed at Al Ru'ays. He had not caught dugong in the 2 years prior."	2
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1983	"We learned of a similar case to this from a fisherman in Karzakkan in western Bahrain. In 1983 he caught a dugong while fishing in the UAE which he sold at the Abu Dhabi souk."	2
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1983	"However, two or three years earlier (1982-1983) four dead dugongs washed up near his camp (these could have been victims of the Nowruz oil spill incident)."	2
Heinsohn, G.E. (1986) Rare and endangered: world's only strictly marine sea cow threatened. *Australian Natural History* **21,** 530-531.	1984	"Two dead Dugongs were found on Gulf of Salwah beaches of Saudi Arabia between January and the end of May 1984 by staff of the University of Petroleum and Minerals, Dhahran, and a third dead dugong was reported but not located during this period."	2
Heinsohn, G.E. (1986) Rare and endangered: world's only strictly marine sea cow threatened. *Australian Natural History* **21,** 530-531.	1985	"During a 2 1/2 hour helicopter flight on 18 February 1985, covering the entire length of the Gulfs of Bahrain and Salwah, I saw one dugong between the Bahrain and Saudi Arabian coasts".	2

Author	Year	Quote	Score
Vousden, D.H.P. (1986) *The Bahrain Marine Habitat Survey Project Report,* Environmental Protection Committee, State of Bahrain, Manama.	1985	"Subsequently Vousden (1985) reassessed the dugong herds off the east coast of Bahrain and estimated a minimum population of 70 to 100 dugongs."	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1985	"Only one fisherman with whom we talked had ever caught a dugong along the north Saudi Arabian coast (north of Ras Tanura). He claimed to have caught a one metre animal, which he identified from our photos as a dugong, at Ras az Zawr in the winter of 1985. He had never seen nor caught any other dugongs and he did not know of any other fisherman ever catching a dugong."	2
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1985	"Fishermen at Al Mouda and Saffaniya had never seen a dugong."	1
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1985	"However, demand for dugong meat ensured a continued supply. In the mid-1980s between 70 and 100 dugongs were sold annually in the Abu Dhabi fish souk. This was an increase over the estimated dugong sales at the same souk a decade earlier."	2
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1985	"In the mid-1980s live dugongs were sometimes brought into the Abu Dhabi fish souk. During butchery, it was said that none of the gut contents must spill onto the meat, or it would be spoilt. The tail meat was the most favored, and the muscle, fat, and connective tissue of the facial disc was also highly desired. The flukes, flippers, viscera, and remaining head were discarded. The hide, which is very thick, was once used to make sandals […]. The meat was eaten fresh or salted, and some parts of the dugong were used medicinally […]. An average adult dugong carcass yields 100– 150 kg of usable meat […], which sold for much less than the cost of lamb and beef, so dugong was cheap red meat. Some restaurants in Bahrain bought dugong meat to use as an inexpensive source of beef ."	2
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1985	"Discussions with fish sellers at the Manama market confirmed that prior to this decree, one to two dugong were sold per month at the Bahrain central market."	2
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1985	"Prior to the Ministerial Decree, up to 20 dugongs were sold annually at the Manama Souk."	2
Aspinall, S. (2001) Environmental Development and Protection in the UAE. In: *United Arab Emirates: A New Perspective*. Trident Press, Bookcraft, pp. 277-304.	1985	"Individuals were still occasionally caught off Umm al Qaiwain in the mid-1980s (P. Hellyer pers. comm.)."	3
Heinsohn, G.E. (1986) Rare and endangered: world's only strictly marine sea cow threatened. *Australian Natural History* **21,** 530-531.	1985	"From September 1984 through January 1985, 8 separate sightings of 1 to 70 dugongs have been reported to D. H. Vousden (State of Bahrain Environmental Protection Organization), with the largest group, more than 70 dugongs, seen on 12 January 1985."	3

Author	Year	Quote	Score
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200	1985	"The fishermen interviewed a the seven fishing camps in the Gulf of Salwa gave the impression that dugongs were also scarce along the Saudi Arabian southern coast. Most of them had heard of dugongs, but had never seen one."	1
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200	1985	"One fisherman had lived and fished in the vicinity of his settlement all his life (40 years) and his father had fished there before him. He knew dugongs occurred in the area because his father had told him about them but had never seen one."	1
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200	1985	"Yet we found skeletal remains of two dugongs on the beach within 5 kilometres on either side of his camp."	2
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200	1985	"At another location where the fisherman claimed not to know about dugongs we found a dugong skull on the beach less than one kilometre from his home."	2
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200	1985	"Only at one coast guard station, Dawhat Hamah, had an officer ever seen a dugong."	1
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200	1985	"Since then he claims 2 to 3 dugongs wash up dead each year. He therefore believes dugongs are more common now than they were 10 years ago."	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200	1985	"The neighbouring fisherman (1 km further along the beach) had fished in the area for 15 years without catching a dugong. However, just 3 days before our visit he claimed to have had a dugong drown in one of his nets."	2
Anon. (1986) Dugongs return to Persian Gulf after fears of extinction. In: *New Scientist*. pp. 25-26.	1986	" A herd of them has been spotted near the Bahraini island of Hawar. Scientists in Saudi Arabia think it could contain as many as 500 animals."	3
Anon. (1986) Arabian dugongs. *Marine Pollution Bulletin* **17,** 285.	1986	"World Wildlife Fund (WWF) International reports the discovery of 300 to 500 dugongs in the region of Qatar and Bahrain. The herd was found during a helicopter survey as part of Saudi Arabia's Dugong Replacement Project sponsored by the Meteorology and Environmental Protection Administration (MEPA)."	3
Baldwin, R., Cockcroft, V.G. (1997) Are dugongs, Dugong dugon, in the Arabian Gulf safe? *Aquatic Mammals* **23.2,** 73-74.	1986	"During this survey, which included a large portion of the coast of the United Arab Emirates (UAE), a total of 24 dugong carcasses was recorded".	2
Baldwin, R., Cockcroft, V.G. (1997) Are dugongs, Dugong dugon, in the Arabian Gulf safe? *Aquatic Mammals* **23.2,** 73-74.	1986	"In 1986, a survey conducted by the Saudi Arabian Meteorological and Environmental Protection Administration (MEPA) established an estimated population of dugongs in the Arabian Gulf of 7307 +/- 1302 S.E. (Preen, 1989)."	4

Author	Year	Quote	Score
Loughland, R.A., K., A.-A. (2011) *Marine Atlas of the Western Arabian Gulf,* Vol., Saudi Aramco, Saudi Arabia.	1986	"There have been at least four die-offs of marine mammals in Gulf since the 1980s. Two were due to oil spills during wars in 1983 and 1991 (Preen 1989, 1991). The other two in 1986 and 1991 resulted in 415 and (Vine and Casey, 1992)."	2
Baldwin, R., Cockcroft, V.G. (1997) Are dugongs, Dugong dugon, in the Arabian Gulf safe? *Aquatic Mammals* **23.2,** 73-74.	1986	"UAE 41-27 degrees N; 686 dugong seen".	4
Baldwin, R., Cockcroft, V.G. (1997) Are dugongs, Dugong dugon, in the Arabian Gulf safe? *Aquatic Mammals* **23.2,** 73-74.	1986	"UAE 41-27 degrees N; 215 dugong seen".	3
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1986	"In previous decades demand for dugong meat was high and animals were captured by herding them into shallow water, where they were clubbed to death. By 1986, however, active hunting of dugongs had ceased (at least around Mirfa, on the mainland southeast of Marawah Island, and around Abu Dhabi Island), and the only dugongs captured were those accidentally entangled in fishing nets."	2
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1986	"In 1986, the fishers from Mirfa claimed that the one to two dugongs they caught each year were consumed locally."	3
Vine, P., Casey, P. (1992) *The heritage of Qatar,* Vol., Immel, London.	1986	"The gentle Dugong lives-on, and gathers from time to time in remarkably big herds. Early in 1986, for example, over six hundred Dugong were counted in a herd feeding between Bahrain and Qatar."	4
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	"He reiterated that there was no active dugong hunting in the area and that the animals are caught accidentally in gill nets. Up until about 1984, when 16 fishing dhows worked out of Al Khor, he estimated 2 to 3 dugongs were caught by the village fishermen each year."	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	"At the fish souk in Doha we were told by two fish sellers that only one dugong was sold in the previous year. Four fishermen at the souk estimated that 1 or 2 are sold annually. Al Khor was said to be the source of most of the dugongs."	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	"During our beach survey of east Qatar at the same time we retrieved two dugong carcasses."	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	"There is no longer any active hunting, but many dugongs are captured in gill nets set for fish. According to fishermen from Jaww and Askar it is customary for Bahrainis to eat Dugong. The elderly fisherman we talked with at Jaww believed that there are more dugongs now than in earlier years, before the discovery of oil, because dugongs were eaten by everyone then. In fact he described how on family tribe were the traditional dugong hunters for Bahrain and he estimated that hundreds of dugongs were killed annually."	3

Author	Year	Quote	Score
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	“One of the two fishermen we talked with at Askar village on the east coast of Bahrain had a good knowledge of dugong behaviour and ecology, and he said that dugongs are caught frequently enough for them to be the main cause of net damage. For this reason they are not a desired catch.”	4
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	“The fisherman we talked to at Jaww village had a less benign attitude to the dugongs. Any dugongs that get caught in his nets are clubbed to death or weighted down with cement blocks to drown. No dugongs are released. At different times in the conversation he claimed that 6-7 and 12-14 dugongs are caught annually by Jaww fishermen. Most of these are consumed within the village although occasionally they would take a calf to the Manama market.”	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	“Because dugong meat sold so cheaply, it was being purchased (according to fish sellers at the Manama Central Market) by restaurants in Bahrain to use as a source of inexpensive "beef".”	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	“The fishermen of Askar and Jaww were in agreement that dugongs were most abundant between Fasht Al Adm and the Hawar islands.”	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	“The fisherman from Jaww claimed to have seen a herd of 250-300 dugongs west of the Hawar islands one month before our interview.”	4
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	“The fisherman from Askar said dugongs tend to aggregate most in winter, and that sometimes they form into huge herds like an island of up to 500 dugongs. He believes that the aggregated dugongs sunbathe to warm up. He also believes that winter is the breeding season.”	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	“These observations suggest that our record of a herd of nearly 700 dugongs southeast of Bahrain in the winter of 1986 may not be as exceptional as the literature suggests.”	4
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	“In January 1986, the captain of the Gulf Tender, a merchant ship which maintains navigation beacons in the northern Gulf, found a dead dugong in Bandar Mishab, on the far north coast.”	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	“In April 1986 the captain of the Sea Rapier a supply vessel which does weekly runs between Ras Tanura and Marjab, Zuluf, Saffaniya, Berri and Aby Saafa oil fields reported seeing a group of 4 dugongs about 13 kilometres north of Abu Ali.”	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	“J.D. Miller (pers comm) spoke with a fisherman at Jubail in January 1986 who had caught and drowned a dugong at Fasht Dibal during the winter of 1985.”	3

Author	Year	Quote	Score
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1986	"In January 1986 a dugong was caught in a gill net on the west coast of Bahrain and kept captive for several days."	3
Rogan, E., Kwan, D., Donovan, G. (2004) Subsistence Hunting of Marine Mammals. In: *Fisheries and Aquaculture Vol. II*.	1986	"There is also evidence that dugongs were hunted in the Arabian Gulf and probably in the Red Sea approximately 4000 years ago. Prior to the discovery of oil in the Arabian Gulf, dugongs were a common food source in Bahrain with an annual harvest of hundreds. In 1986 and 1988 between 70-100 dugongs were reported to have been sold in Abu Dhabi."	3
Agius, D.A. (2009) *Seafaring in the Arabian Gulf and Oman: People of the Dhow,* Vol., Routledge, New York.	1987	"Some weigh about 200 to 300 kg yielding from 24 to 56 liters of oil, feed on marine algae and grasses, their skin is brown or grey (Ahmed 1987). Until a few hundred years ago fairly common. It was hunted because of its delicious meat and valuable oil. Its skin was used for waterproof roofing and it also served to cover the frame for the hull for a coracle like boat (Aspinall 1998)."	3
Preen, A. (1989) The status and conservation of dugongs in the Arabian Region Volume 1. MEPA coastal and marine management series, 200.	1983	"At least 37 dugong carcasses were recovered in the months after the Nowruz oil spill in the Arabian Gulf in 1983."	2
Preen, A. (2004) Distribution, abundance and conservation status of dugongs and dolphins in the southern and western Arabian Gulf. *Biological Conservation* **118,** 205-218.	1991	"There have been at least four die-offs of marine mammals in Gulf since the 1980s. Two were due to oil spills during wars in 1983 and 1991 (Preen 1989, 1991). The other two in 1986 and 1991 resulted in 415 and 71 carcasses along the east Qatar and Saudi Arabian coastlines (Preen 2004) and were thought to have been caused by morbillivirus."	2
Pierce, V. The effects of the Arabian Gulf oil spill on wildlife. Proceedings of the Annual Meeting of the American Association of Zoo Veterinarians, Calgary, Alberta, Canada, 1991, pp. 362-367.	1991	"On May 26 1991 there was a report of 60 dead dolphins and 11 dead dugong found on the beaches between al-Khobar and Salway in Saudi Arabia (over 200km of coastline)".	2
Bleakley, C., Kelleher, G., Wells, S. (1995) *A global representative system of marine protected areas. Vol. 3: Central Indian ocean, Arabian seas, East Africa and East Asian seas.,* Vol., World Bank, Washington, DC.	1991	"14 dugong [were] stranded along the Saudi coast of the Gulf of Salwa. This die-off coincided with the Gulf War oil spill, but occurred several hundred kilometers south of the most heavily polluted area."	2
Baldwin, R., Cockcroft, V.G. (1997) Are dugongs, Dugong dugon, in the Arabian Gulf safe? *Aquatic Mammals* **23.2,** 73-74.	1995	"In two days of searching, the remains of a total of 28 dugongs were found in, or in close proximity to, four fishing villages. Five of the 28 dugongs found were judged to have died more than two years previously and were excluded from any mortality estimates".	2
Baldwin, R., Cockcroft, V.G. (1997) Are dugongs, Dugong dugon, in the Arabian Gulf safe? *Aquatic Mammals* **23.2,** 73-74.	1995	"Drying meat, no more than two weeks old, and barrels of what appeared to be dugong oil, were found at two sites. The meat was suspended and drying in strips, alongside shark fins. Anecdotal evidence obtained from an interview with fishermen on Murawah Island suggested that dry dugong meat can be sold to neighbouring villages, or in fish markets, for the equivalent of US$7.5 per kilogram. An entire, freshly caught dugong apparently sells for US$ 210. This is comparable to figures quoted by MEPA that vary between US$0.30 and US$2.70 per kilogram (Preen, 1989)."	2

Author	Year	Quote	Score
Baldwin, R., Cockcroft, V.G. (1997) Are dugongs, Dugong dugon, in the Arabian Gulf safe? *Aquatic Mammals* **23.2,** 73-74.	1995	…"the estimated annual dugong mortality in only four fishing villages of the UAE approximates 0.16% (11.5 of 7000) of the total number of dugongs estimated to inhabit the Arabian Gulf (Preen, 1989). Assuming that catch levels of dugongs at other fishing villages in the Gulf are similar to those surveyed, then the catches by fishermen at as few as 50 villages would be unsustainable."	2
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1995	"These carcasses were in the same area where the remains of the 28 dugongs were reported in 1995."	2
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1998	"In 1998, 12 dugong carcasses were found tied under mangroves on Marawah Island near an area where large-meshed gillnets were set."	2
Aspinall, S. (2001) Environmental Development and Protection in the UAE. In: *United Arab Emirates: A New Perspective*. Trident Press, Bookcraft, pp. 277-304.	1999	"A repeat survey of Abu Dhabi waters was completed in 1999 by the Commission for Environmental Research, part of the Emirates Heritage Club, Abu Dhabi, and found no statistically significant change in the number of dugong occupying Abu Dhabi waters, with an estimated 2000 to 3000 individuals present (Preen, pers. comm.)."	4
Marsh, H. (2008) Dugong dugon. In: *The IUCN Red List of Threatened Species. Version 2014.3*.	1999	"In 1999, 11 dead dugongs (five females, two males and four unknown) were examined (al-Ghais, pers. comm. 2000). The vast majority of dead dugong remains have been found in, or near fishing villages and most of the stranded animals show clear evidence of having been caught by local fishers (Baldwin 1995). Fishers have admitted that dugongs get entangled in their nets at times. However, detailed information is not forthcoming, as fishers are aware of the law which bans dugong capture".	3
Preen, A., Das, H., Al-Rumaidh, M., Hodgson, A. (2012) Dugongs in Arabia. In: *Sirenian Conservation: Issues and strategies in developing countries*. (Eds. E. Himes, J. Reynolds, L. Aragones, A. Mignucci-Giannoni, M. Marmontel), University Press of Florida, Gainesville.	1999	"Based on the 1999 population estimate, the sustainable annual take of dugongs in the UAE is 54-107 (2-4%)".	2
Kwong, M. (2008) Abu Dhabi tries to save the dumpy lady of the sea. In: *The National*. Abu Dhabi.	1999	"By 1999, the same year the UAE enacted a federal law forbidding the harvesting or harassment of dugongs, that population had fallen to 2,691."	2
Keijl, G.O., van der Have, T.M. (2002) Observations on marine mammals in southern Iran, January 2000. *Zoology in the Middle East* **26,** 37-40.	2000	"A single individual was seen briefly in the Hara Protected Area (26°50'13"N 55°43'35"E) in a rather narrow muddy creek, approximately 15 m wide, only about three metres from the shore, on 29 January, 2000. When it first surfaced it was not identified, but when we approached the spot it suddenly surfaced about 5 m from the boat and then dived with a sudden splash, not to be seen again. When it surfaced near the boat the broad flattened snout was seen, and when it subsequently dived the tailstock and V-shaped flukes were seen very clearly. The length could not be estimated."	3

Author	Year	Quote	Score
Keijl, G.O., van der Have, T.M. (2002) Observations on marine mammals in southern Iran, January 2000. *Zoology in the Middle East* **26,** 37-40.	2000	“Interestingly, three Dugongs were again observed in the Hara Protected Area on 1 November 2000: one at the entrance of the mangroves and two in creeks approximately 20 m wide.	3
Keijl, G.O., van der Have, T.M. (2002) Observations on marine mammals in southern Iran, January 2000. *Zoology in the Middle East* **26,** 37-40.	2000	…”there have been no observations in the Khouran Straits since the early 1980s (B. SAEEDPUR, pers. comm.).”	1
ERDWA (2007) Marine and coastal environment of Abu Dhabi, United Arab Emirates.	2000	Estimated population 1861 (+/- 411) dugongs	3
Braulik, G.T., Ranjbar, S., Owfi, F.*, et al.* (2010) Marine mammal records from Iran. *Journal of Cetacean Research and Management* **11,** 49-63.	2000	“Green (2000) also described a sighting of three dugongs in the Hara Protected Area on 1 November 2000.”	2
Marsh, H. (2008) Dugong dugon. In: *The IUCN Red List of Threatened Species. Version 2014.3*.	2000	“The Environmental Research and Wildlife Development Agency (ERWDA) conducted summer and winter aerial surveys of UAE waters in the Arabian Gulf in summer 2000 and winter 2001 (al-Ghais & Das 2001). The survey was conducted in five zones over 34 transects covering 6075km2 in summer and 6697 in winter. The population of dugongs in the survey zones was estimated to be 1861 individuals in summer and 2185 in winter. No large groups were sighted during the survey. Nearly 40% of sightings were in seagrass beds, and over 50% in deep water. More than 80% of the population was sighted around the islands of Abu Al Abyad, Salalah, Marawah, Jananah, Al-Fayl, Al-Bazm and Bu Tinha (al-Ghais & Das 2001). These survey findings support Preen’s (1989a) earlier conclusions that dugongs predominantly occur in the Abu Dhabi emirates of the UAE. Dugongs were seen near Abu al Abyad Island, Merawwah, Jananah, Al-Bazm al Gharb and Bu Tinah, islands north of Al Hamriya (25º47'N, 050º43'E), and Jabal Dhannah in both 1986 and 2000 (Figure 2.4). In contrast, Preen (1989a) reported that the highest concentration of dugongs in the UAE was in the area between Merawwah and Bu Tinah. Dugongs have usually been sighted in small groups or as solitary individuals in UAE waters.”	2
ERDWA (2007) Marine and coastal environment of Abu Dhabi, United Arab Emirates.	2001	“Estimated population 2185 (+/- 382) dugong.”	2
Kwong, M. (2008) Abu Dhabi tries to save the dumpy lady of the sea. In: *The National*. Abu Dhabi.	2001	“Two years later, helicopters spotted, 2,185 dugongs and marine protected area in Marawah Island was declared to preserve a core habitat for the marine mammals.”	2
Williams, E.H., Mignucci-Giannoni, A.A., Bunkley-Williams, L.*, et al.* (2003) Echeneid–sirenian associations, with information on sharksucker diet. *Journal of Fish Biology* **63,** 1176-1183.	2002	“Video images of a herd of about 120 dugongs were taken in the Persian Gulf off the western portion of the United Arab Emirates”.	2
ERDWA (2007) Marine and coastal environment of Abu Dhabi, United Arab Emirates.	2004	“Estimated population 2291 (+/- 329) dugong.”	2

Author	Year	Quote	Score
Kwong, M. (2008) Abu Dhabi tries to save the dumpy lady of the sea. In: *The National*. Abu Dhabi.	2007	“Dugongs are very vulnerable to human threats such as oil spills and last year a team of field scientists found two dugongs trapped in an abandoned driftnet near Abu al Abyad Island.”	2
ERDWA (2007) Marine and coastal environment of Abu Dhabi, United Arab Emirates.	2009	“Estimated population 2501 dugong.”	2
ERDWA (2007) Marine and coastal environment of Abu Dhabi, United Arab Emirates.	2010	“Estimated population 2846 dugong.”	2
ERDWA (2007) Marine and coastal environment of Abu Dhabi, United Arab Emirates.	2011	“Estimated population 2465 dugong.”	2