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# Design for Sustainable Fisheries — Modeling Fishery Economics

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# Acronyms and abbreviations used in this report

BAU – Business as Usual

BFT – Bluefin Tuna

CEA – California Environmental Associates

CITES – Convention on International Trade in Endangered Species

EABT – East Atlantic Bluefin Tuna

FAO – Food and Agriculture Organization of the United Nations

GOM – Gulf of Mexico

GMFMC – Gulf of Mexico Fishery Management Council

ICCAT – International Commission for the Conservation of Atlantic Tunas

IFQ – Individual Fishing Quota

ITQ – Individual Transferable Quota

IUU – Illegal, Unreported, and Unregulated Fishing

LRFF – Live Reef Food Fish

MSY – Maximum Sustainable Yield

NOAA – National Oceanographic and Atmospheric Administration (US)

NPV – Net Present Value

RFMO – Regional Fisheries Management Organization

SCRS – Standing Committee for Research and Science

SPR – Spawning Potential Ratio

TAC – Total Allowable Catch

# Introduction

Fisheries provide employment for 180 million people worldwide and represent a significant percentage of the animal protein consumed globally, particularly in developing countries.[1] Fish and fishery products are one of the most widely traded agricultural commodities with exports worth more than $85 billion in 2008.[2] But marine fisheries today are under pressure. While fisheries in some developed countries are recovering, overfishing has impoverished the state of the marine ecosystem globally. According to Food and Agriculture Organization (FAO) data, 30 percent of fish stocks are currently considered overexploited,[3] with another 50 percent considered fully exploited.[4] In addition to being both a biological and a food-supply tragedy, the erosion and subsequent collapse of fisheries pose an immediate economic threat to fishers and others whose livelihoods depend on fishing. This threat extends beyond fishers to all participants along the value chain whose economic activity represents an estimated $500 billion per year.[5] There have been a number of studies highlighting the fact that the economic contribution from the world's marine fisheries is significantly smaller than it could be if fisheries were managed to their maximum sustainable yields. The World Bank estimates annual lost revenues to be $51 billion per year; other estimates range from $46–$90 billion per year.[6] Establishing biologically and economically sustainable fisheries is clearly desirable and necessary. However, achieving sustainable fishing practices is not a straightforward task as there are significant challenges that ultimately inhibit their realization, especially in making the transition to sustainability, as reducing catches and introducing new fishing practices to allow fish stock to recover are often necessary — which generally mean hardship for some stakeholders, albeit temporary.

That said, only a limited amount of research has been done to explore the challenges of a transition to sustainable fisheries in detail, particularly regarding the economic implications for the different players along the value chain. While there has been extensive biological modeling, there has been little work that focuses on the biological implications of a transition to sustainability and adds the economic modeling of different players in the value chain, enabling the exploration of scenarios that are realistic both biologically and economically. This report helps fill these gaps, presenting a methodology for identifying and evaluating pathways to sustainable fisheries.

The methodology is demonstrated by exploring the biological and economic impact of different pathways to sustainability for three different fisheries: East Atlantic bluefin tuna, Gulf of Mexico red snapper, and tropical grouper — each of which are either in imminent danger of collapse, or face significant challenges to achieving sustainability. This methodology could also be beneficial for understanding the economic value and sustainability of other fisheries.

The intention of this report is to engage all stakeholders in discussions that explore the best means of establishing sustainable fisheries around the world, based on a clear understanding of the options and their biological and economic implications. It is not the intention of this report to make recommendations.

1. FAO, *The State of World Fisheries and Aquaculture*, 2010.
2. Andrew J. Dyck and U. Rashid Sumaila, "Economic impact of ocean fish populations in the global fishery," *Journal of Bioeconomics*, 2010, Volume 12, Number 3, pp.227-243.
3. Overexploited refers to fisheries producing catches beyond their maximum sustainable limits, and fully exploited refers to fisheries where fishing levels are at or close to the maximum sustainable limits.
4. FAO, *The State of World Fisheries*, 2010. Analysis by CEA suggests that this may be an optimistic assessment of the state of global fisheries, with some assessments putting the level of overexploited fisheries as high as 70 percent. For a detailed review of the debate on the state of global fisheries and further academic references, see Chapter 1 of upcoming Design for Sustainable Fisheries report by CEA, 2011.
5. FAO, *The State of World Fisheries and Aquaculture*, 2010.
6. World Bank, *Sunken Billions* 2008. For additional references, see also: FAO 1993, Garcia and Newton 1997, Sanchirico and Wilen 2002, Wilen 2005.

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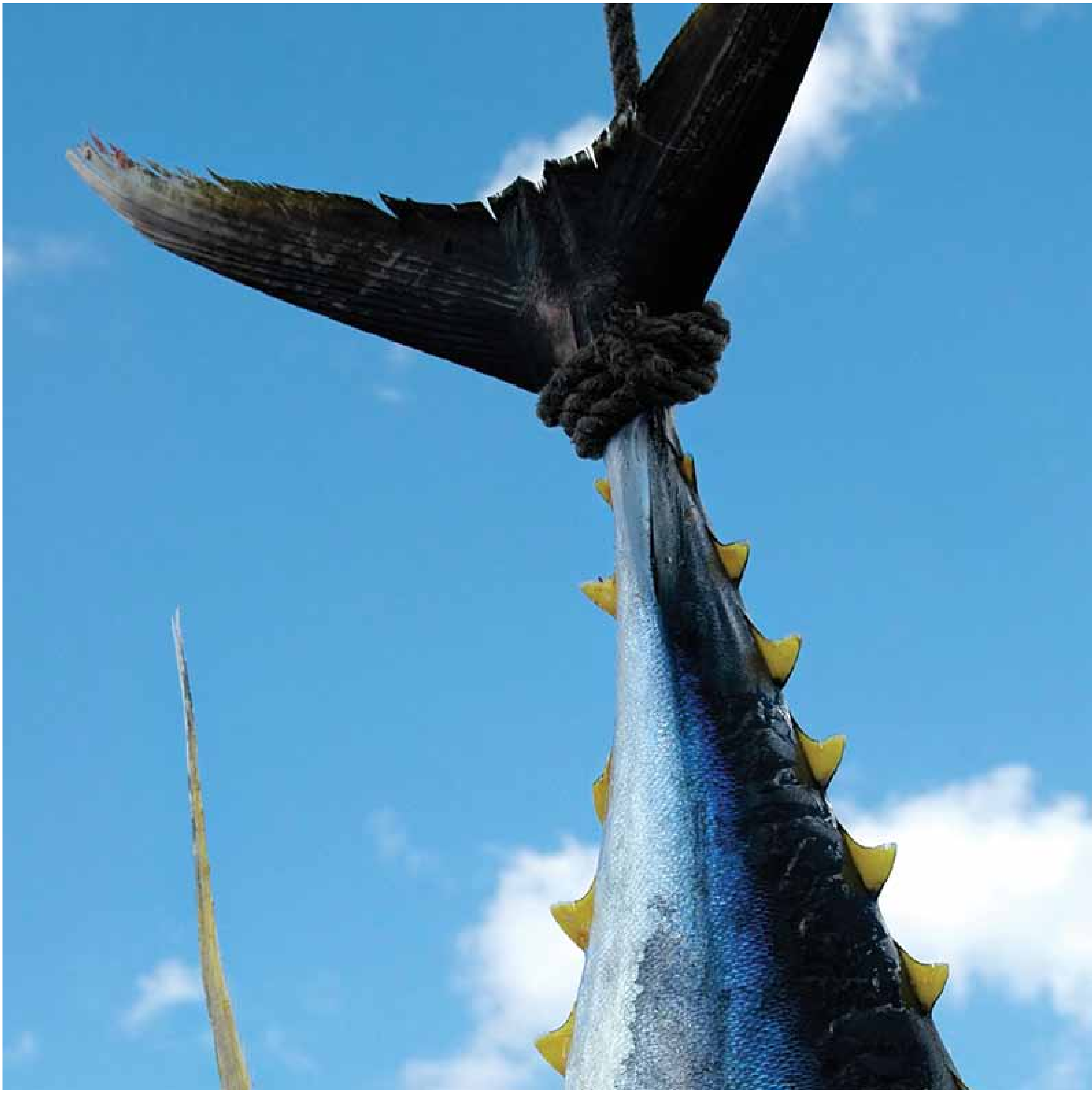
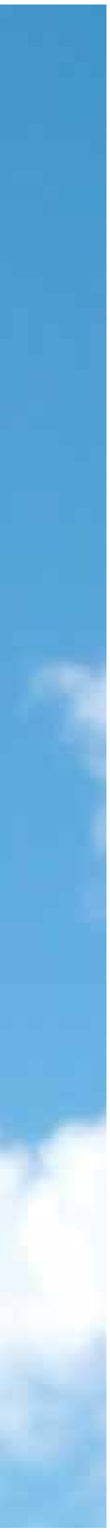


# Executive Summary



While transitioning to sustainable fisheries is crucial, there are at least three root causes that explain why it is so challenging. First, since achieving sustainable fishing typically requires a reduction in fishing effort and changes in fishing practices for some period of time, there are usually short-term financial losses throughout the value chain. Those players who — often for subsistence reasons resulting from a lack of alternative opportunities — place a higher value on short-term benefits may be less concerned about driving a fishery to collapse than about losing short-term harvests. Second, even when a fishery reaches a sustainable state, its economic and other benefits may not be evenly distributed among different players: in many cases fishery restoration creates winners and losers as some players will benefit from the long-term solution and others will carry an increased burden as a result of more sustainable practices. Third, data gathering and adequate fishery management are usually necessary to achieve sustainable fishing, however in many areas these are difficult to put into action . Without an indication of the health of the fish stock, even the fishers with the best intentions can overfish since they do not know when they are overfishing. Ineffective management of global fisheries is likely to result in the depletion of the shared resource, meaning unrecoverable ecological and economic losses.

To help address these challenges, we devised a methodology that can compare both the biological and economic impact of the different choices available for managing the different fisheries of the world. We collaborated with leading fishery experts from UC Santa Barbara and Eco-Analytics group to carry out the underlying biological modeling, and we led the overall analysis and contributed to the economic modeling for the bio-economic model. To illustrate the methodology and see how the model can provide a clear understanding of transition options to help stakeholders in their efforts to establish sustainable fisheries, we examined three fisheries in detail.

In each case outlined below, detailed field research was conducted to understand both the specific stakeholders concerned and the value chain dynamics. Using in-depth biological and economic modeling, we explored different potential future management scenarios, starting with a Business as Usual (BAU) scenario and comparing it with different transition paths to a sustainable state. By analyzing these scenarios, we could highlight the significantly different biological and economic outcomes.

- The study of the bluefin tuna (BFT) in the East Atlantic and Mediterranean provides an example of a fishery that is on the verge of collapse due to the species' high level of biological vulnerability, overfishing, and Illegal, Unreported, and Unregulated (IUU) fishing. We modeled three different scenarios: one in which current practices continue, a second where IUU fishing is eliminated, and a third where the fishery is closed completely to allow recovery. The first sees the collapse of the fishery within the next 2–5 years, along with the industry's profits. The second and third both return the bluefin tuna fishery to a sustainable path. Closure of the fishery brings about the fastest and most assured recovery of the bluefin tuna, but would be the most economically challenging transition path in the short term as both fishers and tuna ranches would see significant losses.

- The Gulf of Mexico red snapper case study provides an example of a fishery that has implemented an Individual Fishing Quota (IFQ) for its commercial sector and is on the road to recovery. But the speed of recovery and potential economic benefits are impeded by overfishing and dead discards in the recreational sector. The analysis examined five different scenarios, ranging from Business as Usual (BAU), to reducing the number of dead discards, and a combination of fewer discards and adherence to the Total Allowable Catch (TAC) limit imposed by the Gulf of Mexico Fishery Management Council (GMFMC). This target was set with the goal of reaching sustainability by 2032. The analysis showed that BAU would mean failing to meet the 2032 sustainability target. Full adherence to the TAC by all players and a 60 percent decline in the discard mortality rate could see the fishery reach sustainability in just five years, with all players benefiting.

- The third study is hypothetical due to lack of comprehensive biological and economic data on a tropical fishery. The case looks at a tropical grouper fishery using the biological characteristics of grouper and making assumptions on fishing practices based on data from a variety of fisheries in the Coral Triangle.[7] In this hypothetical case, the fishery starts in a relatively pristine state. However, a combination of overfishing and destructive fishing practices — due to a lack of management and appropriate incentives throughout the value chain — is driving the fishery and the eco-system to collapse. We looked at three different scenarios. The first assumes BAU, with only artisanal fishers fishing the waters. Nevertheless, the fishery collapses by 2029. The second models the entry of large-scale operators, which accelerates the collapse and sees short-term profits of local fishers halved within five years. The third excludes large-scale operators from tropical grouper fisheries at the same time as constraining harvests by artisanal fishers, helping the grouper fisheries return to economic and biological sustainability by eliminating destructive practices (such as the use of toxic chemicals) and maintaining fishing at a sustainable level. Under this scenario, profits for artisanal fishers are maximized in the long-term (20 years).

All three case studies had a number of issues that many fisheries have in common, including lack of data, IUU, overcapacity, and lack of ownership incentives.

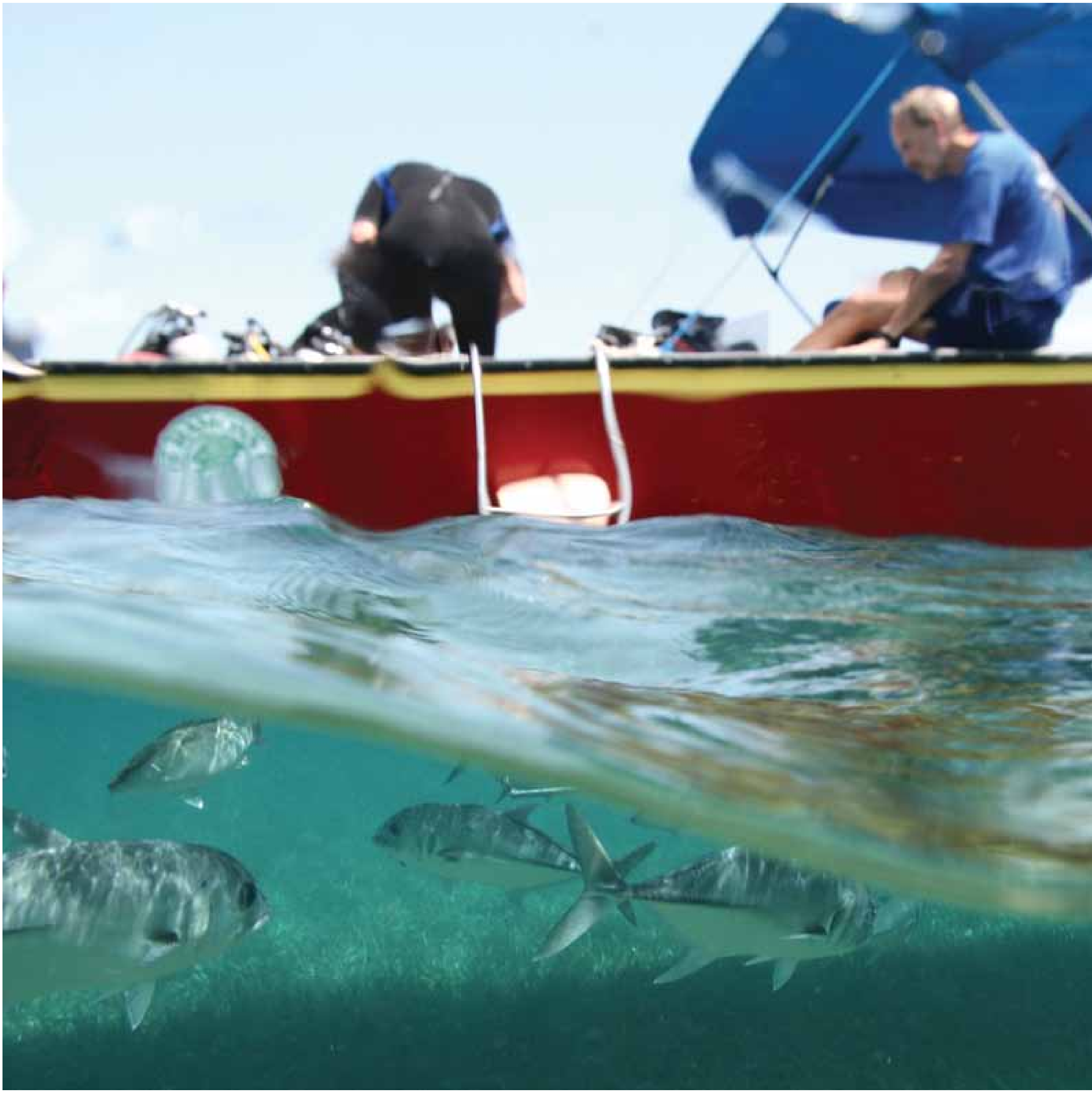
Three key insights arose, which can guide the future evolution of the methodology and its application in the context of fisheries management.

First, stakeholder dynamics and root causes of key issues within specific fisheries are not always obvious and both in-depth field research and economic modeling are required to understand them.

Second, there are many different pathways to achieving the biological objective of sustainability, and modeling can help in: (1) providing a holistic view of the winners and losers in the value chain during a transition; (2) comparing the biological and economic impact of different transition pathways; and (3) identifying new management solutions with the smallest burden on the involved players.

Finally, to perform the economic analysis and construct the most effective solutions, a variety of experts need to be engaged in the debate — biologists, NGOs, fishery managers, government, multilateral agencies, value-chain players, and others — who all bring different insights into the dynamics of a fishery.

7. The Coral Triangle refers to a geographic area in Southeast Asia encompassing Indonesia, Malaysia, Papua New Guinea, and the Philippines, considered to be one of the most important marine biodiversity hotspots in the world.



# Approach to Modeling

Modeling is a powerful tool for uncovering the underlying economics along the value chain, and for producing data on the implications of different transition paths and management solutions for discussions with stakeholders. But modeling can only be applied when the often complex interaction of stakeholders and the value chain in a specific fishery are understood in detail. To arrive at sound conclusions, we brought together a multidisciplinary group of experts to contribute to the analysis. Extensive field research and interviews were also part of the overall data collection.

To model fishery economics, we first took into account the underlying biology of the fish. We then added the economic parameters for selected key parties in the value chain. Finally, we created various scenarios that represented different management solutions to see how each intervention impacted the biology of the fishery and the economics of the different players involved. (Exhibit 1)

## Biological model

To develop the underlying biological model, we collaborated with leading academics Chris Costello and Steve Gaines of University of California Santa Barbara (UCSB) and Eco-Analytics. Their work looks to meld the skills of quantitative ecologists and economists to address key issues of design and implementation of market-based fisheries reform.[8] The model for each fishery is an age-structured model that describes the biomass[9] of the fishery as a function of different harvest efforts and management scenarios. (See sidebar: Age-Structured Model.)

Exhibit 1

**Bio-economic analysis — approach to the case studies**

← Biological Model → ← Economic Model →

| Biomass and yield calculations | Maximum Sustainable Yield (MSY) estimation | Fisher economics | Value chain economics | Insights on decision making |
|---|---|---|---|---|
| ▪ UCSB model to describe stock characteristics: Biomass of stock and projected future yields<br>▪ Determination of relationship between harvest effort and yield quantities for all management scenarios | ▪ Combine pricing dynamics with biological model to draw revenue curve<br>▪ Determine the Maximum Sustainable Yield (MSY) | ▪ Field research into economics of key players<br>▪ Fisherman costs and revenues for different players | ▪ Continue value chain assessment to determine most relevant down-stream players<br>▪ Determine costs and revenues for relevant players | ▪ Compare the biological and economic impact of different transition paths to recovery by modeling different management scenarios<br>▪ Identify potential economic barriers to transition based on model output and field research |

← Conduct economic assessment of the effects of transition on any relevant players →

SOURCE: McKinsey & Company

8. See http://sfg.msi.ucsb.edu/node/12 for more detailed information.
9. Biomass refers to the total mass of the particular fish stock under investigation.

The models assume the growth rate of the fish stock is dependent on the number of fish (density) that have the potential to spawn and the number of recruits, or harvested fish. At low fish population densities, the number of recruits-per-spawner is highest and decreases with increasing numbers of spawners. In other words, as the stock grows in density, its growth rate increases — up until the point when the fish begin to be crowded and the maximum carrying capacity of the ecosystem is reached. The number of spawners that produce maximum sustainable yield is the point at which the difference between the number of recruits-per-spawner and replacement (i.e. one recruit per spawner) is the greatest. When the biomass is at Maximum Sustainable Yield (MSY), the fishery has reached its highest potential growth rate, allowing the stock to be sustainably harvested at that level indefinitely. However, to be conservative, a yield slightly lower than MSY may be targeted. (Exhibits 2, 3)

## Economic model

In order to model the economics of the fisheries, we conducted field research to determine the dynamics of the value chain and the underlying economics of the key players. In all of the case studies, the model takes into account the economics of the fishers, including the revenues from harvests (volume multiplied by price) and their costs. We also looked at the economics of other key players who significantly influence the fishery, such as the tuna ranchers in the bluefin tuna fishery and traders in the tropical grouper case. Where useful, we incorporated pricing dynamics for fish caught under different fishing practices, for example for legally versus illegally caught fish, and for price variations at different markets.

In each of the case studies we've outlined the results both in terms of annual profits/losses as well as Net Present Value (NPV) of the results for different time periods. For the NPV calculations we used a discount rate ranging from 6-10% per annum, which represents the estimated cost of capital. The short-term annual profits/losses, and to some extent the 5-year NPVs are most relevant for those players who, due to uncertainty of future cashflows, may only look at the economic situation for the next few years to guide their behavior.

The longer term NPVs (20 years) are relevant for policy makers who have a long-term perspective, and for fishery players who have a more secure cashflow, for example based on catch shares or other forms of ownership rights.

## Management scenarios

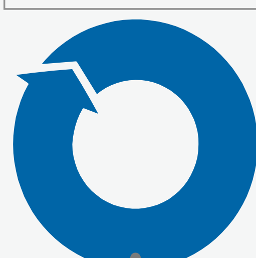
For this report, we chose scenarios ranging from the fastest path to recovery (typically closure of the overexploited fishery), to BAU (meaning no change from current practices), to highlight the significantly different biological and economic outcomes. The aim of this approach is to provide fishery managers and policymakers with a tool to explore their options for regulatory and incentive structures for establishing sustainable fisheries.

Exhibit 2

### Basic building blocks of the biological model

**Biological model**

**Stock**
- The stock model tracks a time series of biomass for any given harvest trajectory
- Life-history characteristics vary across species
- Various management scenarios explore recovery options



**Age structured model simulates biomass over recovery period**

**Stock dynamics**
- Model links biomass in period *t+1* to biomass and harvest in period *t*

**Parameterization**
- Model parameters derived to match stock assessments

**Management scenarios**
- Capture range of options (e.g. harvest restrictions or spatial closures)

**Recovery time**
- Will depend on species characteristics and management scenarios

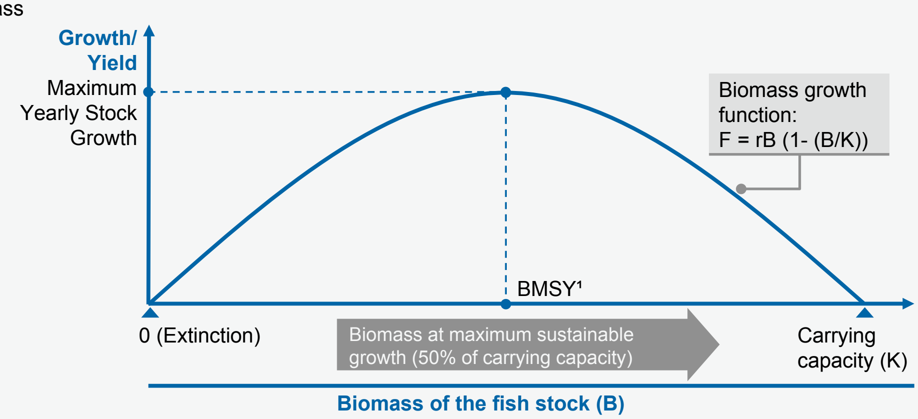
SOURCE: UCSB

The tool has to be seen as one element in a multi-faceted decision making process, which also takes many other factors (e.g. social and cultural considerations) into account.

Exhibit 3

## A fishery's ability to regenerate — as a renewable resource — is often estimated using a simple surplus production model

**Relationship between growth and stock level (surplus production model)**
t biomass




Note: F = Yield, B = Biomass of stock, K = Carrying capacity, r = Growth rate
1 Biological Maximum Sustainable Yield

SOURCE: Grafton et al (2006)

## Age-Structured Model

Most commercial and recreational fisheries target certain ages and sizes of fish. Whether a fish of a given size or age is likely to be captured or killed may depend on biological or environmental factors, gear restrictions, or management regulations. Age-structured and surplus-production models are two types of models that are often used to examine the population dynamics of exploited fish stocks.

Age-structured models keep track of the demographics of a population, usually by age or length bins. Thus they have a distinct advantage over simpler surplus-production models, which aggregate all of the animals in a given year — regardless of age — into a single number or biomass.

The age-structured model incorporates two important aspects of a fish population — somatic growth and differential vulnerability (or mortality) based on the size or age of a fish. For instance, if a fish lives to be 10 years old, but regulations only allow the killing of fish that are large enough to be considered five-years-old, then an age-structured model can account for this differential vulnerability when determining the size of future populations. Similarly, if young fish are more likely to die of natural causes than older fish, then age-structured models can account for this difference in natural mortality.

Age-structured models are particularly useful because they provide convenient frameworks for examining the consequences of age- or size-specific commercial and recreational fishing mortality. These models also allow us to account for the reproductive potential of different age classes. This is important, given that the exploitation of many populations result in smaller, less fecund fish. (Exhibit 3)

## Modeling Under Uncertainty

The economic model described in this report can be a powerful tool to inform policy decisions. Yet it is important to recognize the limits of economic models, which result from the uncertainties that are inherent in building abstract concepts. There are three main sources of uncertainty in the economic modeling of fisheries. First, different biological assumptions (including age distribution, natural mortality, and spawner-recruit relationships), will lead to a range of results. Second, uncertainty related to external environmental variability (such as impacts of climate change on ocean conditions), may influence the growth and distribution of fish stocks. Third, economic uncertainty (which can be caused by events such as the recent conflict in Libya and the tsunami in Japan), is likely to impact price and demand variables as well as the economic conditions under which fish are caught, processed, and distributed.

We have attempted to highlight the biological and economic variability in the modeling where we thought it was necessary. However in some instances environmental uncertainty has been excluded from our considerations as information related to environmental drivers and their impact on the fish stock is often limited or too complex for the type of model employed. In the bluefin tuna case study, for example, there does appear to be a lagged correlation between the stock and the North Atlantic Oscillation. However, given the uncertainty of this correlation and the complexity of introducing stochastic effects in the modeling, we have not included this effect. Introducing environmental variability into the models could be a next step for parties interested in taking the analysis further.

For the Gulf of Mexico red snapper and tropical grouper models, we have relied on published and currently accepted models used by fishery managers — so we have not added additional biological uncertainty. Given the near collapsed state of the bluefin tuna stock we chose to add biological variability by using 11 different biological scenarios, employing a variety of assumptions and population growth models (based on the literature) to study the sensitivity of our current fishing effort assumptions on the fish stock. For the economic analysis outlined in this report we selected the scenario that most closely reflects the average of the 11 scenarios. However, we still refer to the range in outputs of these scenarios when considering the time frame for recovery or collapse, as we consider it is prudent to do so under the precautionary principle.[10]

Finally, we have limited the modeling of economic uncertainty to an examination of the sensitivity of the economic outcomes for the critical value chain players under different prices, time frames, and discount rates. Again, for parties interested in taking this analysis further, we recommend an exploration of other sources of uncertainty, such as supply and demand relationships. In particular, more complex analyses of uncertainty in contexts where irreversibility exists (i.e. extinction of a fish stock) are in the early stages, but we would recommend the following papers for further reading on the topic:

M. Weitzman, “Fat-Tailed Uncertainty in the Economics of Catastrophic Climate Change,” REEP Symposium on Fat Tails, 2011;

M. Weitzman, “GHG Targets as Insurance Against Catastrophic Climate Damages,” Harvard University, 2010;

E. Li, “Option Value of Harvesting: Theory and Evidence,” *Marine Resource Economics*, 1998, Volume 13, Number 2;

C. Hepburn, “Behavioral Economics Hyperbolic Discounting and Environmental Policy,” *Environmental and Resource Economics*, 2010, Volume 46, Number 2, pp. 189-206.

10. The common principle in international environmental law, introduced through the Rio Declaration in 1992, indicates that lack of scientific certainty is no reason to postpone action to avoid potentially serious or irreversible harm to the environment.

# Case studies

Three case studies were selected to provide insight into different fishery archetypes. The case study selection was made with the objective of providing examples of fisheries with different geographies, biological characteristics, management structures and types of fishers (and other players) involved in the value chain. The studies focus on the following fisheries:

- **East Atlantic and Mediterranean Bluefin Tuna:** an example of a fishery that is on the verge of collapse due to the species' high level of biological vulnerability, overfishing, and Illegal, Unreported, and Unregulated (IUU) fishing.

- **Gulf of Mexico Red Snapper:** an example of a fishery that has implemented an Individual Fishing Quota (IFQ) for its commercial sector and is on the road to recovery, but the speed of recovery is impeded by overfishing and dead discards in the recreational sector.

- **Coral Triangle Tropical Grouper (Hypothetical):** an example of a fishery in the Coral Triangle where a combination of overfishing and destructive fishing practices — due to a lack of management and appropriate incentives throughout the value chain — is driving the fishery and the eco-system to collapse.

# East Atlantic and Mediterranean Bluefin Tuna

## Overview of current situation

The fishery of the East Atlantic and Mediterranean bluefin tuna,[11] considered to be one of the ocean's most valuable species, is on the verge of collapse.[12] While the fishery is relatively small, with an official catch quota of just 13,500 tons in 2010, its market value is more than $300 million. More than 80 percent of all tuna caught in the East Atlantic and Mediterranean is destined for Japan. With its high fat content and cultural appeal, good quality tuna can be sold for high prices on the Japanese fish auction market. At the beginning of 2011, a single, 342 kilogram tuna sold for almost $400,000,[13] placing the value of the fish at almost $1,200 per kilogram. However, it should be noted that this doesn't not reflect the average price. Rather, it reflects the significant cultural importance Japanese consumers place on the fish and in particular, on the first fish of the season.[14]

Bluefin tuna is caught in the East Atlantic and Mediterranean by purse seiners, longline fishing vessels, traps and bait boat fishing vessels — most of which come from France, Spain, and Italy — and by traditional tuna traps or 'almadrabas' in the Mediterranean. While under most methods bluefin tuna are killed in the fishing process itself, purse seiners keep their catches alive and the fish are transferred to tuna ranches, which are floating cages mainly utilized in the Mediterranean. This process allows tuna caught during the summer months at spawning aggregation sites to be fattened over a period of six to nine months, and then killed as needed and transferred to the Japanese tuna market, where it is sold either fresh or frozen. (Exhibit 4)

Ranching was developed in the late 1960s and 1970s in Australia to supply the Japanese tuna market with Southern bluefin tuna; it was introduced in the Mediterranean in the early 1990s. Purse seiners and tuna ranchers are somewhat symbiotic in that purse seiners are able to sell tuna that have sub-optimal fat content to

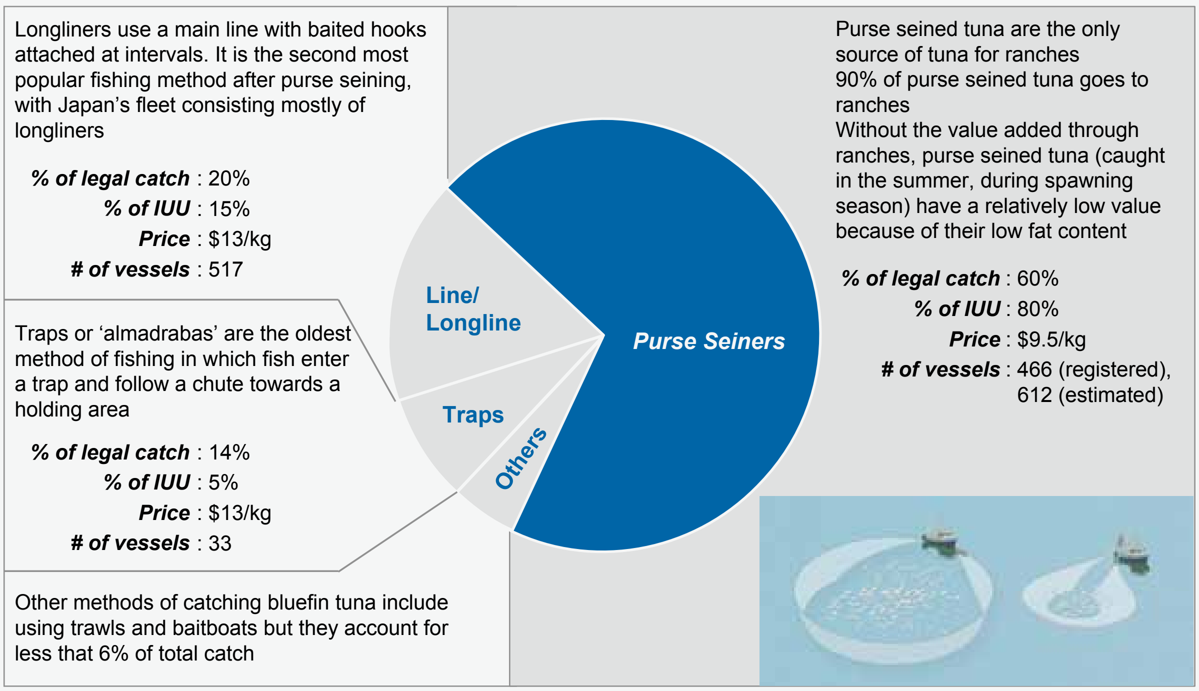
11. Considered to be a part of the Northern bluefin tuna species, the East Atlantic and Mediterranean bluefin tuna and the closely related Western Atlantic bluefin tuna are treated as separate stocks because they are considered to be sub-populations with distinct spawning grounds.
12. Collapse here is defined as reaching less than 10 percent of the sustainable biomass, or the biomass that delivers the maximum sustainable yield. For the East Atlantic bluefin tuna, this was determined to be approximately 350,000 tons.
13. For more details see: http://planetgreen.discovery.com/travel-outdoors/bluefin-tuna-sells-for-396000.html.
14. See CITES COP15, Proposition 19, http://www.cites.org/eng/cop/15/prop/E-15-Prop-19.pdf. For a more informal discussion, see also: http://www.nytimes.com/2010/06/27/magazine/27Tuna-t.html.

Exhibit 4

**East Atlantic bluefin tuna fishing overview**

PRELIMINARY

Included in analysis




SOURCE: ICAAT, Greenpeace, WWF, ATRT, Bjorndal

ranchers during the summer, and tuna ranchers are then able to provide Japan with a year-long supply as the tuna fatten in their cages throughout the year. Summer is the ideal time for purse seiners to catch tuna because tuna aggregate at spawning sites during this time, allowing purse seiners to minimize marginal cost per fish. Without tuna ranches, these tuna would not fetch the highest market prices because they would create a glut in the market, and their fat content would be at its lowest. Catching tuna during spawning and transferring them to tuna ranches allow fishers to catch the fish at the lowest cost and still fetch the highest possible price under the most favorable market conditions. Several major distributors of bluefin are also investors in many of the bluefin tuna ranches in the Mediterranean. (Exhibit 5)

## Management of the fishery

The East Atlantic and Mediterranean bluefin tuna are highly migratory, known to move between their spawning grounds in the Mediterranean and East Atlantic to as far as the Gulf of Mexico before returning again each year. Since the fish travel between the waters of several nations and through high seas, the fishery is managed by a Regional Fisheries Management Organization (RFMO), in this case the International Commission for the Conservation of Atlantic Tunas (ICCAT), as prescribed by the United Nations Convention on the Law of the Sea and the UN fish stocks agreement.[15]

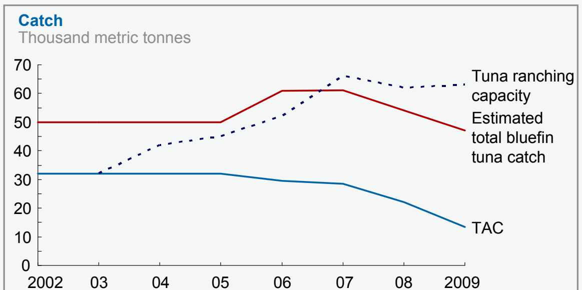
The primary management method employed by the organization is a (TAC) quota, currently 12,900 tons per

15. ICCAT was established in 1996 and is an intergovernmental organization, with member countries participating in the conservation and management of the East Atlantic and Mediterranean bluefin tuna. For more information on ICCAT see: http://www.iccat.es/en/.

Exhibit 5

**Although legal limits on EA bluefin tuna catch have fallen over the past 5 years, tuna ranching capacity continues to be ramped up**

E. Atlantic bluefin tuna, Estimated catch, Total Allowable Catch (TAC) quota, recommended TAC, 2002 - 2010




The International Commission for Conservation of the Atlantic Tuna (ICCAT) has consistently set the TAC in excess of the scientifically recommended quota in past years

SOURCE: ICAAT SCRS, 2008, 2010; Greenpeace, WWF, ATRT

year, which is an overall restriction on the volume of fish that can be caught, allocated to each member country. Member countries are in turn advised to distribute these quotas between individual vessels. In practice, however, it is mostly only European member states that make these reallocations as many developing nations do not have the institutional structures to manage or monitor fishing vessels independently.

Until 2010, the TAC was established by a vote of representatives of the member countries. In recent years, the TAC has often exceeded the recommendations of ICCAT's Standing Committee for Research and Science (SCRS). In 2010, the conference of parties of ICCAT agreed to follow the SCRS's recommendations. However, current suggested TACs made by the SCRS have moved away from past recommendations. As recently as 2009, the scientific advisers were calling for a complete closure of the fishery to give the stock sufficient time to recover. However, in 2010, the SCRS recommended only a four percent reduction in the TAC for 2011 from the previous year's number.

ICCAT is currently tasked with ensuring that bluefin tuna recover to a sustainable biomass — defined as the biomass at which the tuna stock provides the maximum sustainable yield. In the current recovery plan for the bluefin tuna, ICCAT member countries have established 2022 as the year by which the stock needs to recover with a 60 percent probability. (See sidebar: Uncertainty.)

## Analysis of underlying causes: the perfect storm

Following the introduction of tuna ranches, tuna harvests reached a peak of almost 60,000 tons before falling to 47,000 tons in 2008 (the last year for which data was available). These harvest levels were consistently above the TACs set by ICCAT due to significant IUU fishing. Assuming 2008 harvest levels are sustained, the biological modeling shows that the bluefin tuna stock is likely to collapse[16] sometime between 2012 and 2015, with important ecologic and economic consequences.

ICCAT has been attempting to actively manage the East Atlantic bluefin tuna through a variety of fishing efforts and compliance measures. The combination of biological vulnerability of the fish, overfishing, and significant IUU fishing has made it very difficult for ICCAT to effectively manage the fishery.

**Biological vulnerability**

The East Atlantic and Mediterranean bluefin tuna is considered to be easy to catch because it aggregates in large numbers during each spawning season, which occurs at predictable times. Before the introduction of purse seining in the tuna fishery, these aggregations were harder to exploit, but newer technology allows fishers to capture a large number of fish with relative ease. In fact, the additional effort required to catch each incremental fish is very low. As a result, fishers are not exposed to any change in their fishing cost or effort even as the overall stock declines. This lack of a stock effect essentially means fishermen will not notice a difference in the catch volume until the fish stock has collapsed (i.e. catch volume will not indicate a decline in stock).

16. Collapse here is defined as less than 10 percent of the sustainable biomass, or the biomass, which delivers the maximum sustainable yield. For the East Atlantic Bluefin Tuna, this was determined to be approximately 350,000 tons.

**Overfishing**
The high value of the fishery has driven a significant amount of overcapacity and overcapitalization within the purse seining fleet. Current estimates of total purse seine capacity are 50,000–60,000 tons. The combined effect of significant overcapacity in the tuna fishing fleet (not just among purse seiners), the progressively shorter fishing seasons (due to declines in fish stocks from previous years) and a lack of ownership of the rights to fishing quotas for individual fishers creates a race to fish each season. The lack of certainty for many fishers about their catch in future years and the lack of widely distributed quotas lead fishers to fish for as much tuna as possible within a given period. This uncontrolled catch is further exacerbated by the fact that there are only a limited number of observers on ships. Additionally, there is no real-time monitoring of the number and size of fish being caught, nor are there any international enforcement mechanisms on the high seas.

**Illegal, Unreported, and Unregulated fishing (IUU)**
For a number of years, the high value of the fishery has driven a significant amount of Illegal, Unreported, and Unregistered fishing (IUU). In fact, the black market value of bluefin tuna across the value chain was estimated at $4 billion last year.[17] Both the volume and value of IUU fishing are reported to be five to ten times higher than the legal trade of bluefin tuna.

Overcapacity in purse seiners combined with the rapid and unmanaged expansion of tuna ranches is seen by some to function as a laundering mechanism for illegally caught bluefin tuna. Managing live bluefin tuna is an inherently difficult task, because it can be a challenge to estimate the number of fish caught within a purse seine. Since there are limited means of ensuring compliance, fish in excess of quotas or below size limits are transferred to tuna ranches. Tuna ranches in turn are able to certify the origin of the tuna as required by the ICCAT under the bluefin catch documentation program by employing a variety of tactics, including assuming high growth rates of tuna within the ranch, and a certain amount of reproduction taking place within the cages. The ICCAT compliance committee accepts these high growth rates, but many scientists have questioned them.

**Management issues**
It is especially difficult for the ICCAT to deal with this coincidence of factors in the tuna fishery situation because it has a limited mandate and relies on its member countries to implement and enforce policies and measures developed through the negotiating process. For instance, the ICCAT strongly recommends that member countries apportion the TAC limits it sets among individual vessels. Doing so would build confidence that limits would be adhered to, and that it was in the fishers' interests to participate in ensuring the long-term sustainability of the fishery. However, according to an independent review commissioned by ICCAT on it's own management effectiveness, only the quota distributed to the European Union is effectively managed at a vessel level. This means that almost 50 percent of the TAC is only imposed at national levels.

Finally, the ICCAT has traditionally only managed the fishing part of the value chain, not upstream activities, such as ranching and distribution, where a major concentration of power and influence lies. Today, more than 60,000 tons of tuna ranching capacity is held by 70 tuna ranches — more than four times the total allowable catch this year.

## Biological and economic analysis
To inform discussion of potential management solutions for the fishery, we looked at the economic and biological effects of three different management scenarios, which we selected based on our interviews and research.

**Scenario 1: Business as Usual (BAU)**
Under a Business as Usual scenario, harvest levels are assumed to remain constant, while overcapacity in both purse seiners and tuna ranches continues to drive significant levels of IUU fishing. That is because both players require larger volumes of fish than the TAC currently allows in order to remain financially viable in the short term. Under this scenario, the bluefin tuna fishery is projected to collapse between 2012 and 2015.

Purse seiners will continue to earn enough revenue to remain profitable for the next year or two, but according to the model, with the collapse of the stock, long-term

17. International Consortium of Investigative Journalists, "Looting the Seas," 2010.

revenues will fall and the fleet will quickly become unprofitable. The Net Present Value (NPV) of the fishery over the next five years is $80 million, but the NPV over the next 15 years falls to about $5 million as several years of losses essentially eliminate any profits captured in the short term.

Ranchers, on the other hand, appear to be unprofitable already.[18] Early profits appear to have led to a ‘ranching bubble’, as many rapidly invested in capacity. As a result, the increased demand driven by overcapacity in the ranches caused harvests to not only quickly surpass legal limits of the TAC, but also go well beyond even the most optimistic estimates of maximum sustainable yield.

Today, tuna ranching capacity is in excess of 60,000 tons. Even when adjusted for the growth of tuna within the tuna cages, this capacity is almost four times the TAC for 2011. The modeling shows that declining tuna volumes have resulted in the overall fishery operating at a loss, as ranchers must pay higher prices for a declining volume of tuna. The ranchers’ profits have been further eroded by a drop in demand from an apparently saturated Japanese market, which results in ranchers having to retain quantities of bluefin tuna from one year to the next, at an added cost. There are no alternative uses for the excess ranching capacity. We estimated the ranchers have a negative 5-year NPV of $950 million and a negative 15-year NPV of $2.4 billion. (Exhibit 6)

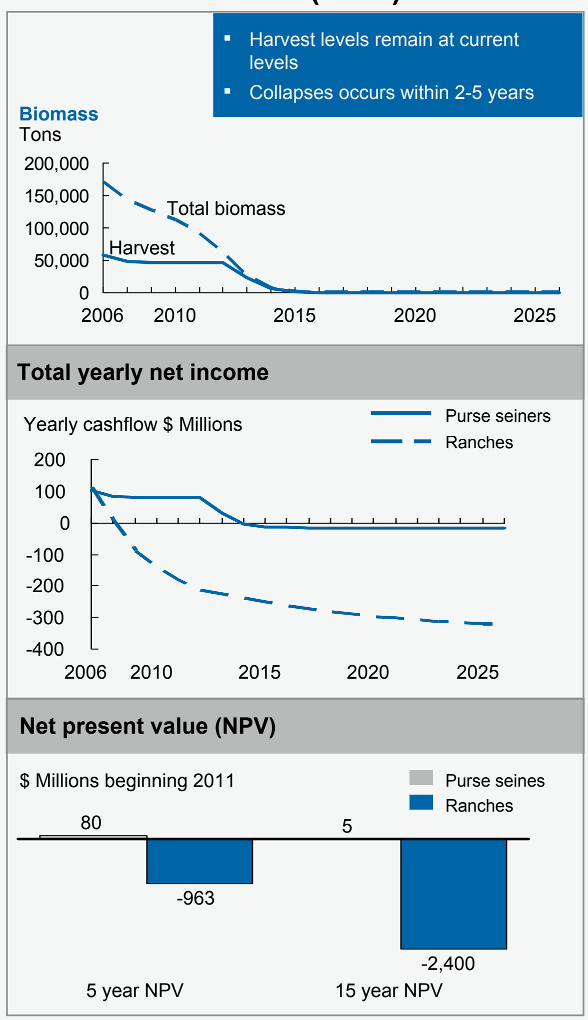
**Scenario 2: No Illegal, Unreported and Unregulated (IUU) and strict enforcement of Total Allowable Catch (TAC)**

In this case, we assume that there is no Illegal, Unreported, and Unregulated fishing and that the current TAC of 12,900 tons per year is maintained and strictly enforced until the fishery recovers.

Under this scenario, the model projects that the fishery recovers by 2023.[19] In this case, fishers generally fare better than under the BAU scenario, commanding an NPV over five years of $98 million versus $80 million. Our field analysis revealed a 40–60 percent pricing differential between legally and illegally caught tuna. This scenario assumes that shifting towards the completely legal trade of bluefin tuna allows fishers to capture a higher price for their catch from tuna ranches and that this more than offsets the reduction in catch volume over the short term. In addition, we believe that supplies would be guaranteed

Exhibit 6

## EA Bluefin tuna scenario 1: Business as Usual (BAU)




SOURCE: McKinsey & Company

18. Ranching economics data is based on expert interviews and business plans developed to support tuna ranching activity provided by ATRT
19. But, recovery is not guaranteed because of uncertainty in the biology of the species. (See sidebar: Uncertainty.)

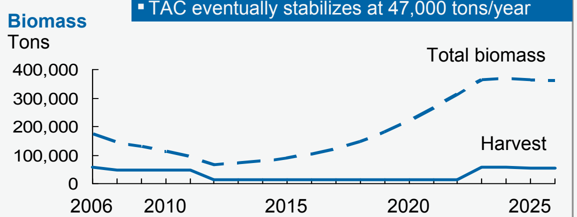
for a much longer period and this is reflected in the 15-year NPV of $412 million the scenario yields. (Exhibit 7)

In this and the third scenario rancher's NPV's are even lower as they must sustain a greater loss in the earlier years while the supply of tuna is further restrained and illegal supplies are eliminated. Even after the fishery is reopened to a sustainable catch level, the ranching sector as a whole remains unprofitable unless some capacity can be taken offline.

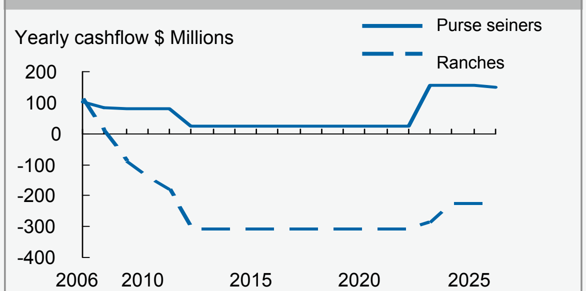
Exhibit 7

## EA Bluefin tuna scenario 2: No IUU and TAC enforced

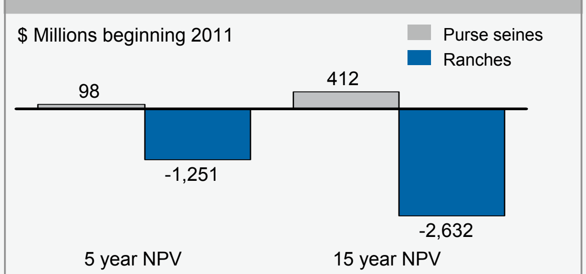
- Illegal, Unreported and Unregulated fishing eliminated from 2011
- Current Total Allowable Catch of 12,900 until 2022 but with higher uncertainty[1]
- TAC eventually stabilizes at 47,000 tons/year




**Total yearly net income**




**Net present value (NPV)**




1 Under certain biological assumptions the fishery could still collapse
SOURCE: McKinsey & Company

**Scenario 3: Closure of the fishery until recovery**
Under this scenario, the fishery is closed until it recovers. The model indicates this would occur within eight years.

During the recovery period, both fishers and tuna ranches would see significant losses, with purse seiners facing a negative five-year NPV of $60 million. However, over a 15-year period, fishers could capture slightly higher value than under scenario two. Under the closure scenario, they would command a 15-year NPV of $470 million versus a $412 million under the second scenario. The additional fish caught following the closure compensate for the short-term losses. However, these short-term losses for purse seiners of about $100 million are significant during the closure period. (Exhibit 8) On the other hand, only this scenario would ensure recovery with very low uncertainty.

## Summary of the bluefin tuna case analysis

Without reform of the bluefin tuna fishery, the model predicts that it is likely to collapse within the next 2–5 years, and both the purse seiners and ranching industry will suffer from significant losses. But the models also show that bluefin tuna fishery can be returned to a sustainable biomass to provide maximum harvest levels. The models show, however, that this can only be achieved if IUU fishing is eliminated, either through extensive monitoring and enforcement or by closing the fishery altogether. Closing the fishery completely would lead to the fastest and most assured recovery of the bluefin tuna, but it is the most economically challenging in the short term. (Exhibit 9)

Although the models show that enforcement of TAC and elimination of IUU could lead to recovery, recovery by this strategy is not guaranteed because of uncertainty about the biology of the species. (See sidebar: Uncertainty.) To offset this uncertainty, it would be preferable to reduce the TAC if the second scenario is implemented.[20] Eliminating

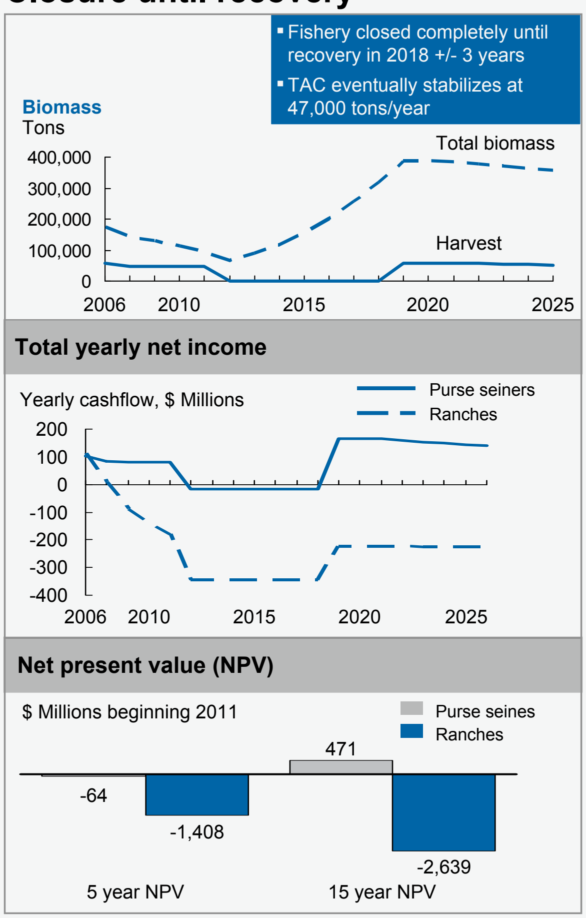
20. The precautionary principle with respect to fisheries management refers to taking a cautious approach to fishery management and choosing to apply the most conservative actions in managing fish stocks. It was developed in response to the significant amount of uncertainty related to stock characteristics and the difficulty of guaranteeing the sustainability of a specified level of exploitation.

IUU requires eliminating the root causes of IUU, i.e. overcapacity and overcapitalization. Other measures to reduce overfishing such as limiting fishing in spawning aggregation areas and better aligning the incentives of fishers through some form of rights-based management, should also be explored. Closure, on the other hand, would require the implementation of strong trade barriers. Those could include a Convention on International Trade in Endangered Species (CITES) Appendix I[21] listing. (See sidebar: Endangered Species.)

Under both scenarios, players incur losses in the short term, so decision makers will need to evaluate the impact on affected players and weigh the pros and cons of each option before deciding on an optimum management plan. One way to protect industry players could be to consider various incentive schemes, such as redirecting subsidies to those legal players who would suffer the most during the transition period.

Exhibit 8

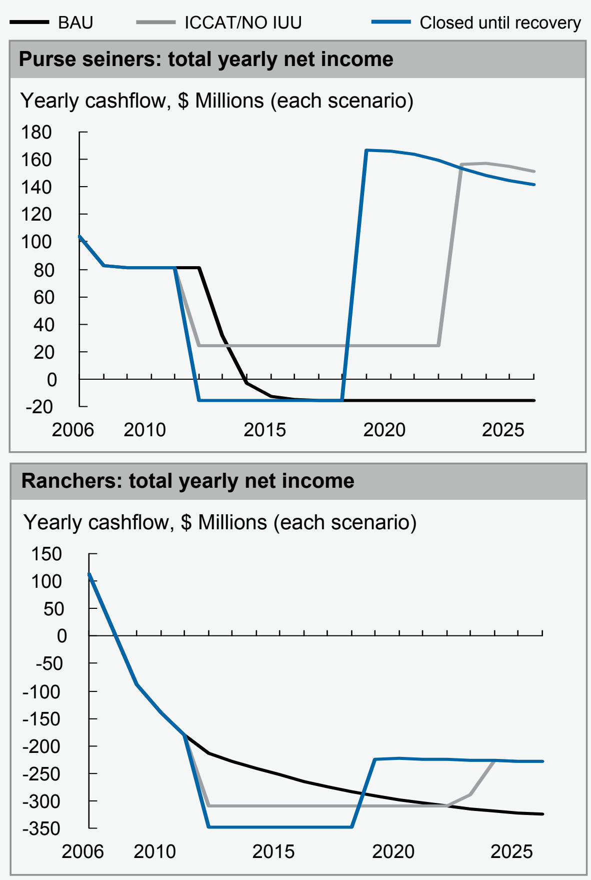
## EA Bluefin tuna scenario 3: Closure until recovery




SOURCE: McKinsey & Company

Exhibit 9

## Summary of scenarios for East Atlantic bluefin tuna




SOURCE: McKinsey & Company

21. An Appendix 1 listing on the Convention on International Trade in Endangered Species of Wild Flora and Fauna would forbid the trade of bluefin tuna between signatory countries.

## Bluefin Tuna Biological Model

We use an age-structured model similar to the one developed by MacKenzie et al. (2009) for making projections of the East Atlantic Bluefin Tuna (EABT) biomass. We treat the estimates of historical population size up to 2006 as known quantities and project the population biomass forward, using biological parameters described by MacKenzie and ICCAT (2009).[22] From MacKenzie, we use the numbers-at-age in 2006 to project the age-structured model forward. EABT are subject to numerous types of fisheries and fishing gears. Rather than include a commercial age-selectivity function for each fishery and gear type, we use a single selectivity curve described by MacKenzie.

Information on the maturity-at-age and weight-at-age (used for calculating spawning biomass) and natural mortality was taken from the ICCAT report (table 1, page 3). We estimated the parameters for three spawner-recruit relationships — Ricker, Beverton-Holt, and hockey stick — based on the spawning-biomass and recruitment data from the ICCAT report. The hockey stick model assumes an average number of recruits over the historical range of spawning biomass (i.e. a constant recruitment) and a constant ratio of recruits-to-spawning biomass for spawning biomasses less than what has been historically observed (i.e. a line with a constant slope between the origin and average number of recruits). First, we would describe the base-case scenario similar to one described by MacKenzie. The base-case scenario uses age-specific natural mortality, weight-at-age, and maturity-at-age (as described in table 1 of the ICCAT report) and the 2006 numbers-at-age, commercial selectivity, and the hockey-stick spawner-recruit relationship (as described by MacKenzie). Two alternative models would use the Beverton-Holt or Ricker spawner-recruit relationships. Each of these relationships assumes that the population would recover more quickly from small spawning-biomass due to their assumptions that the highest recruits-per-spawner occur when the stock size approaches zero. Another possible scenario would be to include a constant natural mortality of 0.2 for all ages. This is the default for most marine fishes. The other scenarios that we previously described were not scenarios that were included in either the ICCAT or MacKenzie documents, but ones that we looked at to determine whether the population dynamics of the model provided reasonable results.

## Bluefin Tuna – Endangered Species?

Over the past couple of years, attempts have been made to list the bluefin tuna as an endangered species. While different listings would yield varying results, the primary objective has been to limit or even close the bluefin tuna fishery entirely.

In March 2010, countries meeting at the Convention on International Trade in Endangered Species (CITES) voted against a proposal by Monaco to include the fish on the Appendix 1 listing, which would result in a complete ban on the international trade of the species. While countries would be able to consume catches within their national territories, a large part of the supply to Japan would be eliminated as Japan consumes approximately 80 percent of the bluefin tuna, but only accounts for 10 percent of all reported East Atlantic bluefin tuna caught today.

Countries including Monaco, the United States, Norway, Kenya and the UK supported the proposal, whilst a number of developing countries and others like Japan and Libya argued that the ICCAT was in the best position to manage the fishery.

Most recently, the United States' National Oceanographic and Atmospheric Administration (NOAA) decided against listing the bluefin tuna for protection under the Endangered Species Act, a move which would have closed the US fishery. Although in recent years the NOAA has supported a closure of the fishery at the ICCAT, in this case it has decided to hold off making a decision until the results of the next stock assessment are released in 2013.

22. MacKenzie, Mosegaard & Rosenberg. Impending collapse of bluefin tuna in the northeast Atlantic and Mediterranean. Conservation Letters, Volume 2. 2009.

# Gulf of Mexico Red Snapper

## Overview of current situation

The Gulf of Mexico is the ninth largest body of water in the world and contains some of the most productive fisheries. In 2008, it was estimated that 590,000 tons of fish and shellfish valued at $661 million were harvested commercially. The Gulf of Mexico is also a historically important fishery to recreational fishers, with more than three million fishers taking about 24 million fishing trips in 2008. Red snapper is an especially significant species in the Gulf of Mexico, both in terms of volume and value. It yields the third highest value of commercially caught species and is the sixth most caught species by volume in the Gulf. Red snapper is also the fourth most recreationally caught species in the Gulf of Mexico. There is such heavy demand for red snapper in the Gulf region that only about 10 percent of commercial red snapper is shipped elsewhere. Within the Gulf region, the value of red snapper is multiplied three to nine times between the time it is harvested and when it is sold at retail, so red snapper has a significant economic impact.

Together, these factors have meant that there is significant demand for red snapper, and consequently significant fishing pressure. In combination with the heavy demand, the traditional management approach of setting an overall limit on how much fish can be harvested and allowing fishers to compete for the largest possible share has led to a 'race to fish', in which intense competition leads to overharvesting and individual fishers have no incentives to practice good stewardship. Consequently, the fishery has been subjected to high levels of fishing pressure and overexploitation.

## Management of the fishery

In response, the Gulf of Mexico Fishery Management Council (GMFMC), which manages the fishery, set a target for the fishery to reach sustainability by 2032. Sustainability was defined as achieving a Spawning Potential Ratio[23] (SPR) of 26 percent, and put red snapper under a Total Allowable Catch (TAC) limit, which in 2009 was 1,134 tons. The commercial sector was allotted 51 percent of the TAC and the recreational sector was allotted the remaining 49 percent. As of

23. The spawning potential ratio refers to the number of eggs that could be produced by an average fish in a fished stock, divided by the number of eggs that could be produced by an average fish in an unfished stock. This is a measure used by NOAA to determine the health of the stock.

2007, the commercial sector has been operating under an Individual Fishing Quota (IFQ) system. The IFQ is a form of 'catch share', which is a management system that allocates private shares or rights to a percentage of the total harvest, to individuals or cooperatives. Real-time data that indicates how much fish is caught and by whom, allows commercial fishers to fish at their own pace without overshooting their collective allocation. The IFQ in the commercial sector has essentially created a year-round fishing season for commercial fishers and has eliminated the 'race to fish'. Thus, the commercial sector has consistently adhered to its collective allocation and operates under an effective, data-rich system. Proponents of catch-share management say that catch shares also create incentives for commercial fishers to help expand the size and health of the entire fishery.

Management of the recreational sector has however been more challenging. The recreational sector is composed of three major groups — charter boats, head boats (or party boats), and private anglers. Charter boats and head boats are referred to as the for-hire sector, since they make a profit from taking recreational fishers onto the water, whereas private anglers do not make a profit from their fishing activity. While the sector is managed under a single TAC and a uniform set of regulations, these different players have disparate interests, and management of the sector has not been as successful as that of the commercial sector, leading to a fractured system. (Exhibit 10)

While recreational fishers have a strong desire to preserve the fishery, they currently do not have the tools or appropriate management guidelines to do so. From 1991 to 2008, the recreational allocation was overshot 13 out of

Exhibit 10

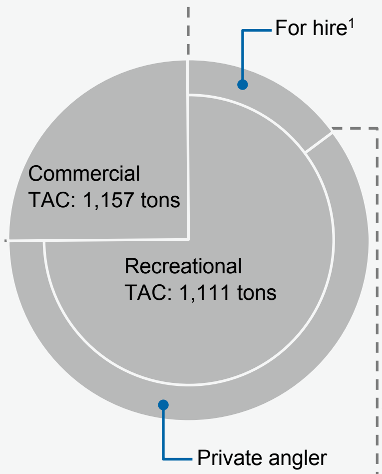
## Gulf of Mexico Red Snapper fishing overview

**Commercial:**
Uses vertical line with multiple hooks and a weight attached. Vessels usually around 14 meters with 313 hp engines. Average fishing trip lasts 4-5 days. Under-harvesting since the IFQ system was put in place in 2007

***Estimated catch*** : 1,074 tons
***Dead discard rate*** : 1-3% of total catch
***Price*** : $10.00/kg
***# of vessels*** : 80

**Head boats (or party boats):**
Take 20-100 people on trips that last from half a day to overnight. Many directly provide fishing licenses to customers and cook red snapper for customers after trips. Profits also generated from food and drinks sold on board

***Estimated catch*** : 185 tons
***Dead discard rate*** : 120% (all recreational)
***Bag Limit*** : 2 per person per day
***Price per angler*** : $178
***# of vessels*** : 79




**Charter boats:**
Take 5-6 people per trip and often request that customers have licenses beforehand. Charter boats usually take half or full day trips.
They charge for fuel

***Estimated catch*** : 517 tons
***Dead discard rate*** : 120% (all recreational)
***Bag Limit*** : 2 per person per day
***Price per angler*** : $120-$140 + fuel costs
***# of vessels*** : 1,187

**Private anglers:**
Individuals who fish on their own vessels for recreational purposes. Their expenditures are considered to be a major contributor to the Gulf economy. They are represented at a national level by groups such as the Congressional Sportsmen's Caucus

***Estimated catch*** : 899 tons
***Dead discard rate*** : 120% (all recreational)
***Bag limit*** : 2 per person per day – limited enforcement

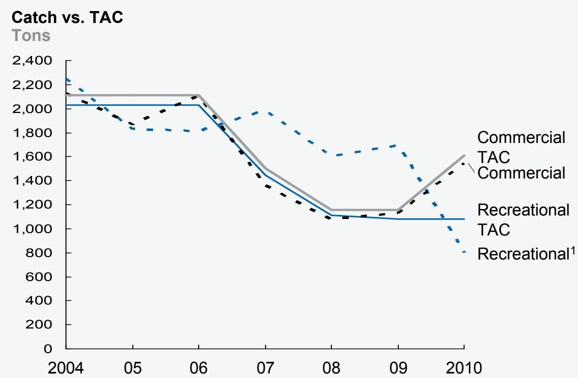
1 For hire sector consists of head boats and charter boats
SOURCE: NOAA, GMFMC, Liese et al., Holland et al.

18 years and in 2008, the recreational TAC was exceeded by almost 100 percent, excluding dead discards. In addition to the difficulty recreational fishers face in adhering to the TAC, there continues to be a high discard mortality rate in this sector, which exacerbates threats to the fishery by driving up overall fishing mortality. Consequently, despite the improvements in the commercial sector, the model predicts that under the current circumstances, in which the recreational sector is not engaged in efforts to curb harvest, the Gulf of Mexico red snapper fishery will fail to meet its target for sustainability. (Exhibit 11)

Exhibit 11

### Harvest data suggests the commercial sector is now well managed while the recreational sector continues to face challenges

GoM Red Snapper, Actual Harvest, Total Allowable Catch (TAC) quota [Commercial and Recreational]




- The recreational TAC has been exceeded significantly in the past
- In 2010 harvest dipped below usual levels because of the Deepwater Horizon oil spill which led to closures of many fishing areas
- Commercial fishers have consistently fished at, or just under, their allotted TAC

1 2009 and 2010 recreational harvest numbers are estimates

SOURCE: NOAA, GMFMC

## Analysis of underlying causes

Reaching the SPR target is impeded by two main causes in the recreational sector — overharvesting of red snapper and an extremely high discard mortality rate. Lack of real-time data is also a contributing factor.[24]

Currently, there are unintended incentives within the management structure that lead to ever increasing fishing activity by recreational fishers. For example, the GMFMC uses limited seasons as a way to reduce fishing pressure on red snapper. However, uncertainty about the length of the following year's season creates a derby fishing mentality — a contest to catch as many fish as quickly as possible — among recreational fishers. This, in turn, leads the GMFMC to further shorten seasons, which leads to even more competitive fishing derbies. Revenues for the for-hire sectors depend primarily on the number of days available to take customers fishing, so participants are motivated to fish as much as possible in a short time, especially since they have no way of knowing how other players will affect their next season.

The GMFMC has also implemented a combination of low bag limits[25] and high minimum size requirements in order to protect red snapper. However, these measures have also had unintended consequences in the fishery. Although fishers can only keep two fish per day, there is no way to know how many fish are thrown back (mostly dead) before two are taken home. The minimum size requirement also forces fishers to throw fish back even if they may otherwise have kept them and stopped fishing for the day. Limited knowledge regarding proper release of red snapper in order to reduce mortality from barotrauma is a further contributor to the dead discard problem.[26] Some fisheries require venting[27] as a way

24. A data-rich fishery is one in which real-time data regarding fishery behavior, harvest, associated by-catch, discards, mortality, etc. are available to those accessing and managing the fishery.
25. Bag limits refer to the number of fish that a private angler can retain at the end of a fishing day (i.e. number of fish that can be landed).
26. Barotrauma refers to the shock a fish can receive from the rapid change in pressure when it is brought up to the surface from deep waters; this often leads to the fish not being able to swim after being released. One symptom of such a shock is an inflated stomach.
27. Venting is a procedure in which a fisher makes a small incision in a fish's protruding stomach (caused by being brought up to the surface rapidly) to release the gases within the stomach until the fish can swim in its original depth of water. The effectiveness of this procedure has been debated, and although it is required in the Gulf of Mexico, it is discouraged in California.

to stop the fish from dying when released, while others strongly urge fishers to use venting as a last resort. Further research may help to establish best practices for private anglers.

Lastly, the lack of real-time data for the recreational sector combined with sparse monitoring and enforcement of private anglers has led to consistent overharvest.

## Biological and economic analysis

To inform discussion of potential management solutions for the fishery, we looked at the economic and biological effects of five different management scenarios.

**Scenario 1: Business as Usual (BAU)**

In the Business as Usual scenario, we assume that the commercial sector operates under its current IFQ and that it adheres to its allocation, while the recreational sector collectively overshoots its allocation by approximately 100 percent. We used an estimated rate of discard mortality of approximately 1.2 times the weight of harvested red snapper, based on interviews with experts and fishers in the region. (See sidebar: Reducing Dead Discards.) We use an allocation rule which assumes that the management council will increase the TAC by 3 percent if the SPR increases by at least 3 percentage points between evaluation periods (three years).[28] The recreational sector continues to fish in a 54-day season. Under BAU, we find that the stock fails to reach the recovery target by 2032. In this scenario, profits of commercial and head boats flat line, while charter boats continue to operate at a loss, as they do currently. (Exhibit 12)

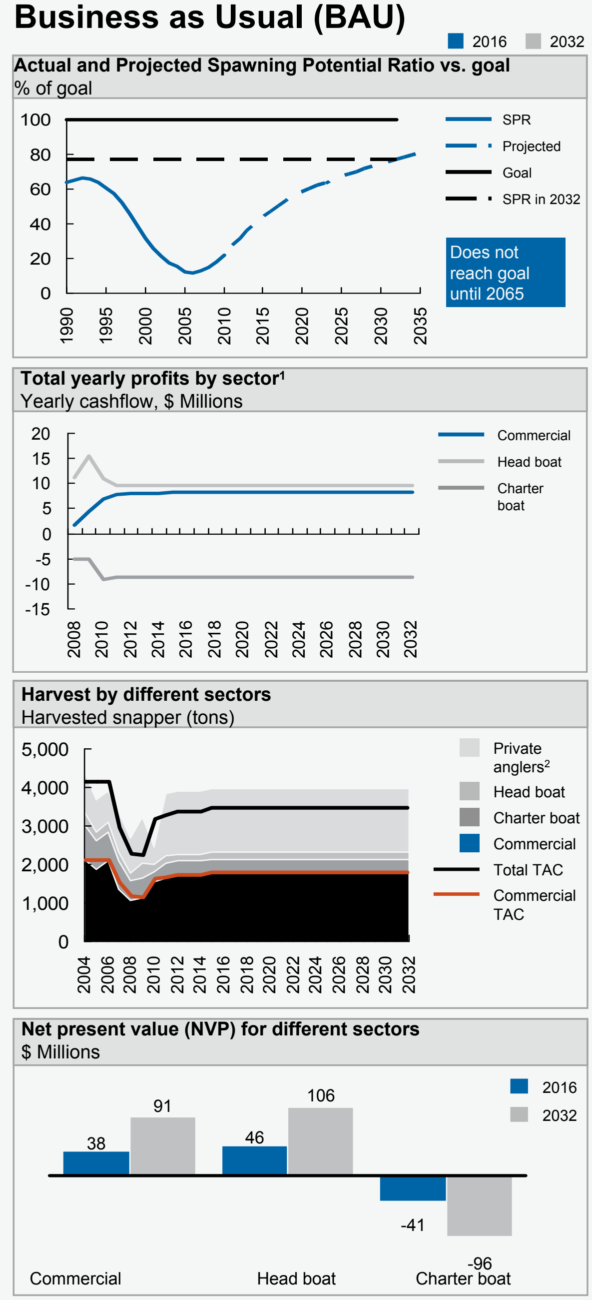
**Scenario 2: Individual Fishing Quota (IFQ) for the For-Hire Sector**

The second scenario analyzes the impact of implementing an IFQ in the for-hire sector. We assume that the for-hire sector, equipped with the appropriate tools to keep track of its collective activity, adheres to its allocation while private anglers continue to harvest under BAU conditions. We assume an allocation of the recreational TAC of 30 percent to the charter boat

28. The SPR raise of 3% acts as a trigger to be able to raise the TAC.

Exhibit 12

### GoM Red Snapper scenario 1: Business as Usual (BAU)




1 Profits of the for-hire sector depend on number of days that they are on the water

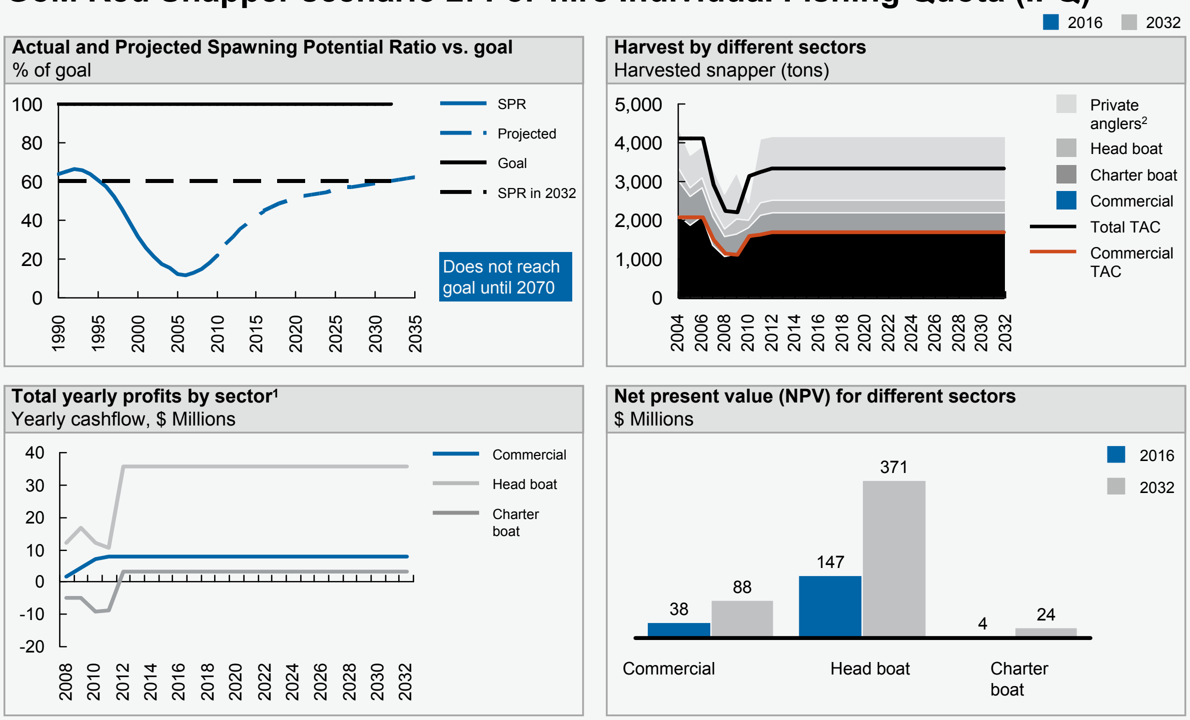
2 Season length for private anglers is 54 days

SOURCE: McKinsey & Company

sector, and 20 percent to the head boat sector.[29] We find that the stock does worse biologically under these conditions than under BAU because the for-hire sector catches a larger percentage of the recreational TAC than they currently do under BAU, but the private anglers continue to overshoot their allocation. Thus, even though more fish are being accounted for, more fish are also being caught per year. The commercial fishers do not get as much of an increase in the TAC as a result and thus, they suffer a small financial loss of about $0.3 million a year, relative to BAU. Note that this financial loss could be absent if we do not assume that a large portion of the recreational allocation is given to the for-hire sector, which has accountability under an IFQ system. Regardless, the financial situation for the for-hire sector improves markedly. The revenue stream of the for-hire sector is mostly dependent on the number of days participants are allowed on the water, Under the second scenario the charter boats have the opportunity to fish their allocation in approximately 90 days, while the head boats fish their allocation in approximately 200 days. In a span of five years, the NPV of the fishery increases by up to $101 million for head boats and by $45 million for charter boats compared with the BAU scenario. This scenario demonstrates that engagement of the recreational sector in finding ways to improve the biological and economic performance of the fishery may be critical. (Exhibit 13)

Exhibit 13

## GoM Red Snapper scenario 2: For-hire Individual Fishing Quota (IFQ)




1 Profits of the for-hire sector depend on number of days that they are on the water
2 Season length for private anglers is 54 days

SOURCE: McKinsey & Company

29. This assumption is an estimation based on the historical levels of the catch.

**Scenario 3: Reduction in Recreational Dead Discard Rate**

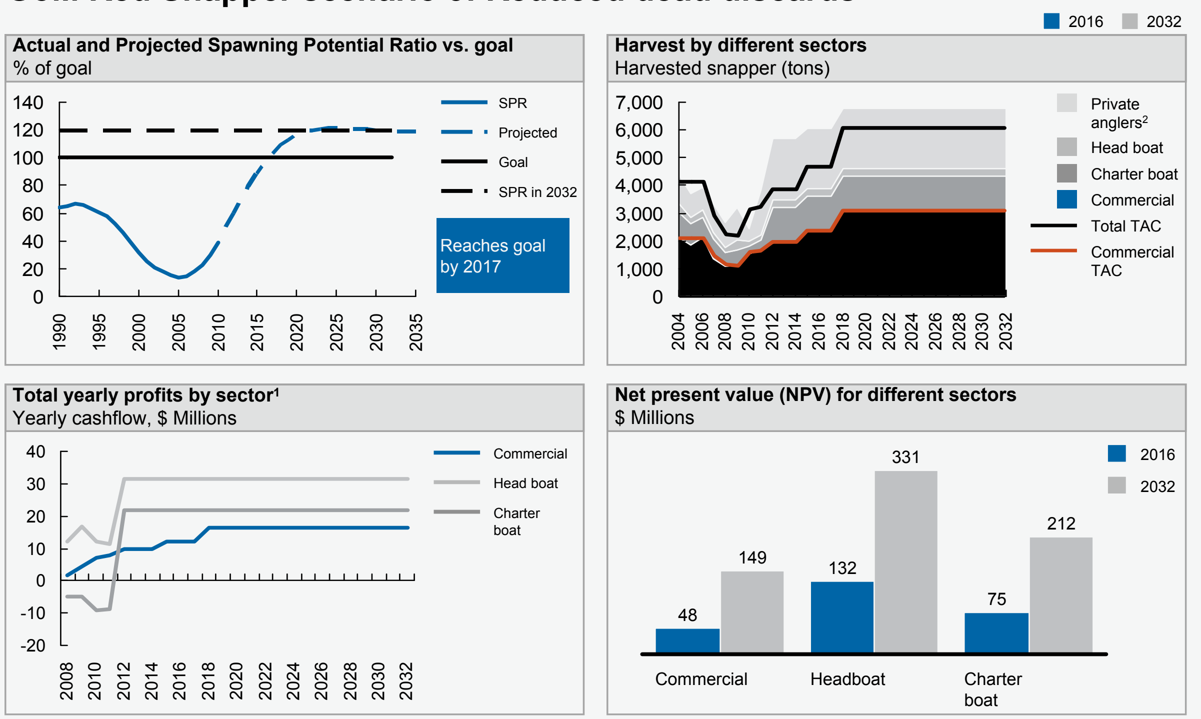
This scenario analyses the impact on the red snapper fishery of recreational fishers using best practices and as a result, reducing the dead discard rate. (See sidebar: Reducing Dead Discards). If we assume that the dead discard rate decreases from 1.2 times the weight of harvested snapper to 0.5 times the weight of harvested snapper, with all other conditions under BAU remaining the same, the recovery target can be reached in six years (by 2017). We further find that all players have more time on the water and are significantly more profitable. With the significantly lower discard mortality rate, there would be leeway to increase the TAC by 30 percent. This increase in TAC would effectively enable a year-round season for the recreational sector.[30] The NPV of the fishery to 2016 increases by $9.5 million over BAU for the commercial sector, as more snapper may be harvested and sold. NPV for head boats and charter boats increases by $86 million and $116.5 million, respectively, in the same time period, compared with BAU. (Exhibit 14)

**Scenario 4: Adherence to Total Allowable Catch (TAC) across Recreational and Commercial Sectors**

If red snapper are too sensitive to barotrauma and cannot be fished without suffering a high dead discard rate, other means may need to be considered to address

Exhibit 14

## GoM Red Snapper scenario 3: Reduced dead discards



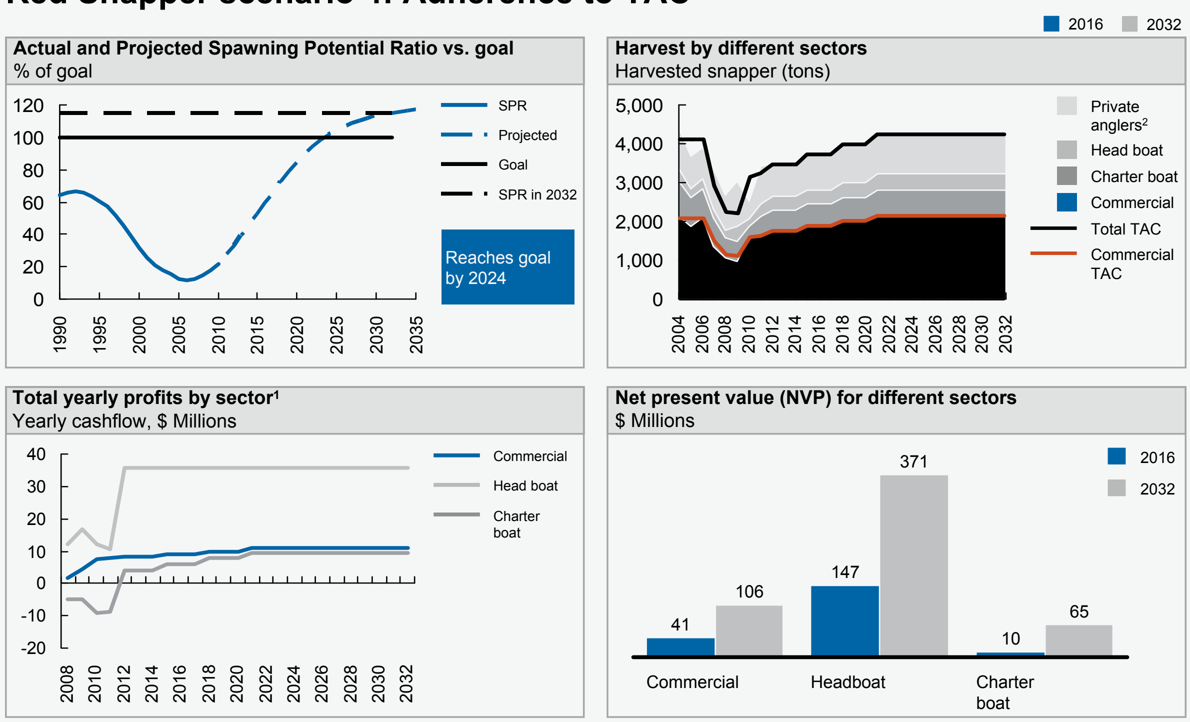

1 Profits of the for-hire sector depend on number of days that they are on the water
2 Season length for private anglers is 365 days

SOURCE: McKinsey & Company

30. We've assumed, based on historical levels, that given a year-round season, charter boats would use approximately 200 days and head boats would use approximately 170 days.

Exhibit 15

## Red Snapper scenario 4: Adherence to TAC




1 Profits of the for-hire sector depend on number of days that they are on the water
2 Season length for private anglers steadily increases and plateaus at 200 days per year
SOURCE: McKinsey & Company

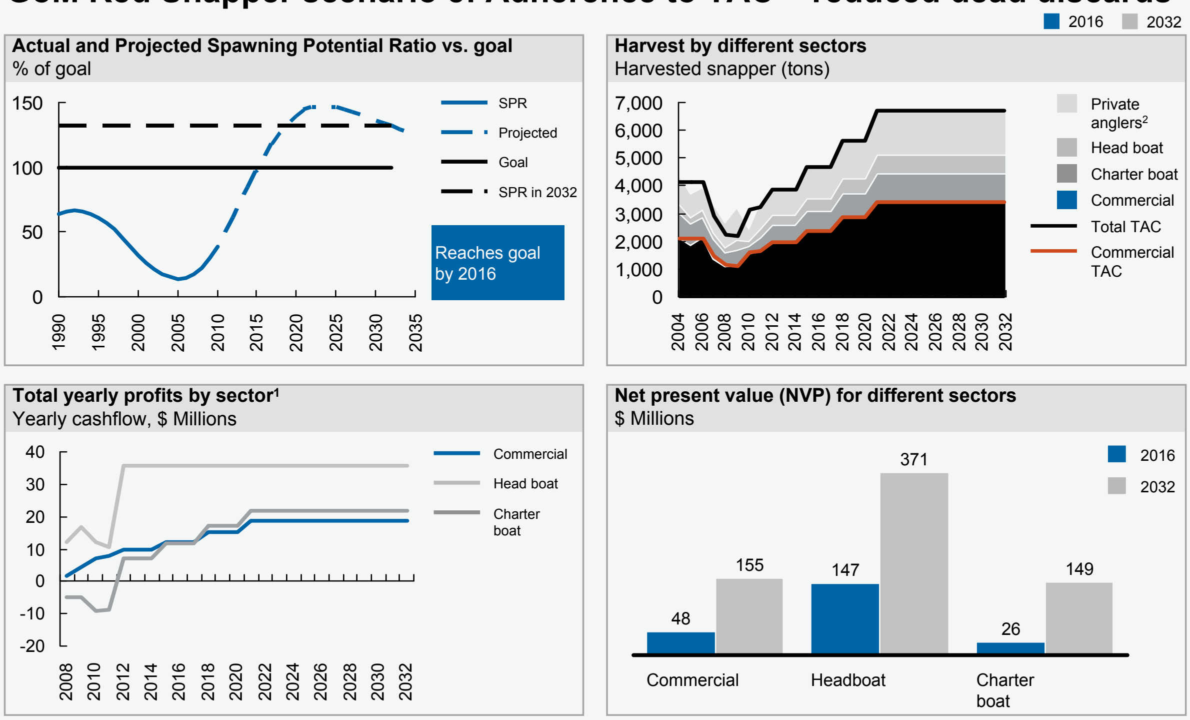
excess mortality of red snapper. In the fourth scenario, we assume a continued high dead discard rate of 1.2 times the weight of harvested red snapper and analyze the effects of the recreational sector having access to real-time data and full accountability. We assume that head boats receive 20 percent of the TAC, charter boats receive 30 percent, and private anglers receive 50 percent. We assume an IFQ system is the best way to have 100 percent accountability in the for-hire sector, while increased enforcement, real-time data, and best practices can lead to accountability in the private angler sector. We find that under these conditions, the management council would be able to increase the TAC by 7 percent. The fishery reaches its recovery target by 2024 and all players benefit. Charter boats can spend approximately 100 days on the water, head boats spend about 200 days on the water, and private anglers spend about 150 days on the water.[31] NPV of the fishery to 2016 increases by approximately $2.2 million over BAU for the commercial sector, as a larger amount of snapper may be harvested and sold. NPV for head boats and charter boats increases by $101 million and $51.5 million, respectively, in the same time period. (Exhibit 15)

**Scenario 5: Reduction in Dead Discards Rate and Adherence to Total Allowable Catch (TAC)**
The fifth scenario analyzes the impact on the fishery and all players when there is real-time data

31. The number of days are calculated based on historical catch levels per day.

Exhibit 16

## GoM Red Snapper scenario 5: Adherence to TAC + reduced dead discards




1 Profits of the for-hire sector depend on number of days that they are on the water
2 Season length for private anglers steadily increases to a full-year season
SOURCE: McKinsey & Company

in the recreational sector,[32] full adherence to the TAC by all players, and a 60 percent decline in the discard mortality rate. Under these conditions, the management council could increase the TAC by 20 percent. The fishery reaches its recovery target by 2016, in only five years, and all players benefit. Charter boats can spend approximately 120 days on the water, head boats spend about 200 days on the water, and private anglers spend about 175 days on the water. NPV to 2016 increases by approximately $9.5 million for the commercial sector compared with under BAU, as more snapper may be harvested and sold. NPV for head boats and charter boats increases by $101 million and $67 million, respectively, in the same period.

Thus, this appears to be the optimal scenario for the red snapper stock, as well as for commercial boats and charter boats. Head boats experience no difference in impact between this scenario and scenarios two (IFQ for the for-hire sector) and four (adherence to TAC by all players). Private anglers benefit more from this scenario than from all the others except for scenario three (reduced dead discards). In this scenario, they may fish year round as long as they reduce the discard mortality rate significantly. (Exhibit 16)

In all of the above scenarios, we added a feature to the model which allows us to see the impact of a charter boat sector with reduced capacity. While there is no impact

32. The assumption is that real-time data enables fishers to know when the quota is met, and thus stop fishing. Today, since there is a lag in receiving data, fishers in the recreational sector do not know when they have gone over the quota until after they have already fished more than their quota.

on the biological characteristics of the fishery, there are significant positive economic impacts to this sector when capacity is reduced by approximately 50 percent. This suggests that there is currently overcapitalization in the charter boat sector.

## Summary of analysis

The overall dynamics of the Gulf of Mexico red snapper fishery are such that the recreational sector has incentive to participate in derby fishing that leads to overfishing, and their practices contribute to creating a very high dead discard rate for the fishery. If this situation continues, the analysis shows that under a BAU scenario, the recovery target is not reached by 2032. The fish stock remains at a low SPR, while the economics of all players remain sub-optimal.

One potential solution that is under consideration is an IFQ for the for-hire sector. While there is currently no IFQ system for the for-hire sector, there is already a lot of data for the sector, and it could easily adopt such a system and gain longer fishing seasons. The model indicates, however, that even with an IFQ system in place for the for-hire sector, the recovery target is not reached by 2032. Thus, it will be necessary to engage private anglers to participate in a management strategy in order to reach the current sustainability goal. The different incentives for the for-hire sector and private anglers suggest that the two groups might best be managed separately, according to the incentives that influence their behaviour.

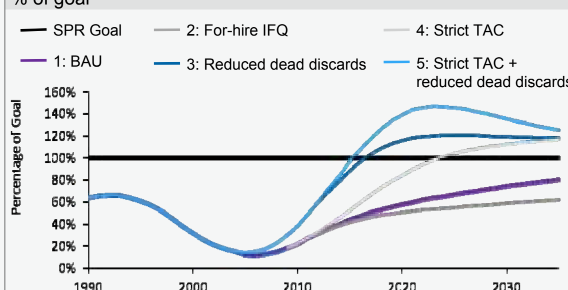
The analysis also reveals the importance of addressing the dead discard rate in the fishery. Reducing this rate has a significant impact. The model indicates that even without the collection of real-time data or strict adherence to allocations, there can be a significant positive biological and economic impact on the entire fishery (and all groups that use it) if recreational fishers take the initiative to improve their catch and release practices to lower the dead discard rate. (See sidebar: Reducing Dead Discards.)

Finally, if the management council can provide tools and incentives to the recreational sector that will increase accountability and promote adherence to the TAC, the biological objective can still be met, even if the high discard mortality rate cannot be lowered. In addition to a positive biological impact on the fishery, this would have a positive economic impact on the for-hire sector. The private anglers would also benefit from significantly longer seasons each year. If the dead discard rate is also improved, the benefits for all parties would increase even further. (Exhibit 17)

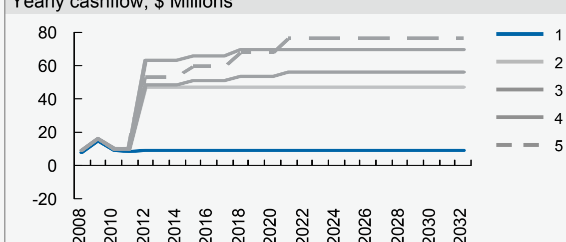
Exhibit 17

### Summary of scenarios for GoM Red Snapper

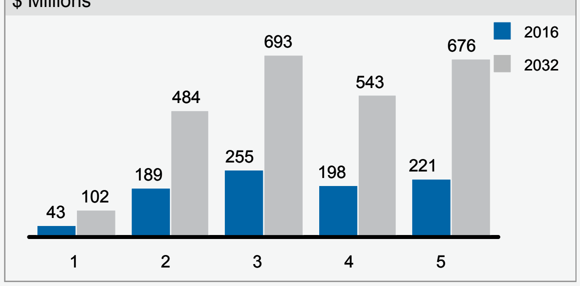
**Actual and Projected Spawning Potential Ratio vs. goal**
% of goal




**Total yearly profits overall[1]**
Yearly cashflow, $ Millions




**Net present value (NPV) for different sectors**
$ Millions




1 Profits of the for-hire sector depend on number of days that they are on the water

2 Season length for private anglers steadily increases and plateaus at 200 days per year

SOURCE: McKinsey & Company

In addition to the technical challenges inherent in these potential solutions, there are also political challenges. As illustrated in the second scenario, splitting the for-hire sector from the private anglers can have positive economic effects for the for-hire sector since its fishing season is no longer subject to early closure due to excess effort in the private angling sector. More days on the water translates into increased profits for the for-hire sector. However, the various groups involved have different interests at stake, so a sector split is not necessarily straightforward.

## Gulf of Mexico Red Snapper Biological Model

We use an age-structured model for projecting biomass of the red snapper population in the waters off the southeastern United States. This model was based on a paper by Murdoch MacAllister (2004) and uses data from 1880–2004. Biomasses beyond 2004 are based on user-defined harvest, by-catch,[33] and discard levels as discussed in the scenarios. The primary objective of this model is to account for the mortality from four distinct fishing sectors: commercial, shrimp, private-recreational, and commercial-recreational (commonly referred to as head boats).

One of the main concerns in the red snapper fishery is discard rates. Both the recreational and commercial fishery have a minimum size limit. It is hypothesized that discards occur in two ways: either fish are below the legal size limit and must be discarded, or smaller fish are discarded after the fishers reach their bag limit but continue to catch larger fish. The MacAllister model uses an age-specific discard rate for the commercial and recreational fishery. The original MacAllister paper looked at a single recreational fishery. The model distinguishes between the different components of the recreational fishery, which include head boats, charter boats, and private anglers. The shrimp fishery does not have a discard rate because only fish up to a year old are caught in it, and all the fish that are discarded are assumed to die. Our field research suggests that the MacAllister paper may have underestimated the discard rates observed in the commercial and recreational fisheries. To account for this, we added a switch to the spreadsheet that allows the user to define the discard rate for the commercial and recreational fisheries; however, unlike the MacAllister model, ours assumes that the user-defined discard rate is constant for all ages.[34]

**Limitations of the model**

For the purposes of this exercise, we have treated the Gulf of Mexico red snapper fishery as an isolated, single species fishery, while taking into account by-catch taken by shrimpers operating in the Gulf of Mexico. We assume that approximately 2,700 metric tons of snapper are taken by shrimpers initially and that the amount of snapper caught by them increases as the stock's biomass increases. The model does not take into consideration changes in biomass as a result of fishing for other species typically found in the Gulf of Mexico. Such species include grouper species, lobster, crab, and red drum. Biomass of the red snapper stock is also affected by changes in temperature, and the dead discard rate also heavily depends on the depth at which recreational fishers are fishing. This model does not capture all of the nuances of the actual fishery. However, it is meant to provide high-level insights into the biological and economic dynamics of the different players in the fishery.

33. Species of fish or other animals that are caught in the process of fishing for other target species.
34. McAllister, Murdoch K. "A population dynamics model for Gulf of Mexico red snapper that uses a historically extended catch time series and alternative methods to calculate MSY", SEDAR7-AW-11, August 9, 2004.

## Reducing Dead Discards

There are four potential methods of reducing dead discards: prohibition of high grading, using release weights, using coochum traps, and venting. (Exhibit 18)

We hypothesize that the current high discard rate is not simply an inherent characteristic of the recreational sector, but that it is also a response to current regulations. Changes in the regulations such as minimum size requirement, bag limit, and season length may have the potential to drastically reduce the discard rate in the recreational sector. There may in fact be an inverse relationship between heavy regulations and limitations, and the discard rate.

Exhibit 18

### Potential methods for reducing red snapper discard mortality

| | Prohibition of high-grading | Release weights | Coochum traps | Venting |
|---|---|---|---|---|
| **Description** | Fishers throw back the least desirable fish. Thus fishers are capable of being in compliance with the law without following the spirit of it | A hook is placed through the jaw of the fish and a weight is attached so that the fish will be brought to a depth where it can swim free | A coochum trap uses the same concept as release weights. Can use any non-floating crate used to push a fish back to its original depth | Puncturing of swim bladder to allow fish to return to their original depth; it can lead to fatal damage to other internal organs |
| **Prevalence** | Reduced in the commercial fishery through programs like Gulf Wild but difficult to manage in the recreational sector | Just started becoming available through tackle outlets | Used in Southern California for the past 15-20 years | The Gulf of Mexico requires that fishers carry and use venting tools; California encourages decompression but not venting |
| **Potential options** | While it is difficult to monitor and enforce, dead discards may potentially decrease if bag limits and minimum size requirements increase | A pilot program for release weights in the Gulf of Mexico could be run and subsidies could be provided if successful | A pilot program could be run and if successful the Gulf Council could promote the use of coochum traps | Better studies on effects of venting for red snapper. Certification for fishers who know how to vent properly |

SOURCE: Expert interviews

# Coral Triangle Tropical Grouper (Hypothetical)

## Overview of current situation

Grouper fisheries in the Coral Triangle are relatively low volume compared with other fisheries in the region. However, they are important to local human populations because the high prices that the species commands in the Asian Live Reef Food Fish (LRFF) trade provide an important source of income. Beyond the revenue from the LRFF, the sale in local markets also provides a source of animal protein and means of subsistence for local fishers. Although the size of harvests in the region are poorly documented, United Nations Food and Agriculture Organization (FAO) data from three major countries involved in marine capture grouper fisheries — Indonesia, the Philippines, and Malaysia — suggest that grouper species represent about one percent of total regional marine capture fisheries production.[35] The value of the species is much higher since because grouper can sell for very high prices in the LRFF trade. Fishers involved in the LRFF trade may earn four to six times the average income in the Philippines.[36]

The number of fishers in the LRFF trade is also very large. In Indonesia alone, there are 7,000 to 8,000 LRFF fishers. There are more than 35,000 LRFF fishers in the Coral Triangle, and the number fishing for grouper for local consumption is likely to push the total number fishing for grouper higher, according to California Environmental Associates.[37]

## Management of fishery

Typically, fisheries in this area have fragmented — if any — local, regional, or national control, which leaves the grouper fisheries in the region largely open to anyone. Government efforts to implement conservation measures to both limit fishing mortality and ecosystem destruction at the local, regional, and national level have focused on constraining fishing capacity, eliminating destructive gear, and protecting large areas from fishing — including spawning grounds and sensitive habitats. However, these regulations have done little

35. FAO, Global Production Statistics 1950-2009 Database (accessed May 16, 2011), http://www.fao.org/fishery/statistics/global-production/query/en.
36. Lida Pet-Soede and Mark Erdmann, "An overview and comparison of destructive fishing practices in Indonesia", *SPC Live Reef Fish Bulletin* Volume 4, April 1998, pp. 28-36.
37. California Environmental Associates, "The Live Reef Food Fish Trade (LRFFT): A Supply Chain Review and Market Intervention Analysis", A Project of the Kingfisher Foundation in cooperation with WWF 2001, pp. 1-40.

to limit or reduce fishing mortality as they are largely disregarded and unenforced.

In addition to the government, both nongovernmental organizations and the private sector have led efforts to protect fish stocks from overexploitation. Organizations such as the World Wildlife Fund, Conservation International, and the Sustainable Fisheries Partnership have, along with local organizations, have had some success in establishing sustainable fisheries management in a few select communities. Some traders, who act as middlemen by brokering sales and transferring grouper to end markets, have also promoted sustainable management, although this practice is very limited.

There are a few notable examples of additional regulatory actions. In the Philippines export quotas have been introduced. However, their success has been limited due to continued illegal trade and a lack of knowledge of the regulations.[38] Management within Australia has been relatively successful; catch limits and individual quotas are used to ensure biological sustainability and the continued economic performance of reef fish fisheries.

Nevertheless, overfishing and destructive fishing practices have threatened and will continue to threaten the sustainability of grouper stocks and the incomes derived from their harvesting. If harvesting continues at current rates, overfishing will continue to drive serial stock depletion, characterized by the movement of a fishery from one stock to another as each becomes uneconomical. This dynamic will be accelerated by the use of destructive gear. Without management, the model indicates that stocks can be depleted by small scale artisanal fishers alone. Additional pressure from more organized, medium- to large-scale operations can further deplete fisheries, particularly if non-selective gear is used and spawning aggregation areas are targeted. (Exhibit 19)

Exhibit 19

## Grouper harvesting and middlemen

| | Small scale harvesters | Medium to large-scale harvesters | Middlemen (traders, etc.) |
|---|---|---|---|
| **Description** | Individual fishermen, generally from local villages, target species for subsistence and local and export markets. Motor use is limited.<br>▪ Utilize destructive and 'non-destructive' gear<br>– Cyanide and dynamite are illegal, but provide high catch per unit effort of live fish<br>– Hook and line, longline spear, traps and trawl are less effective and produce more dead fish | Groups of fishermen organized to travel long distances to capture live reef fish using motorized vessels<br>▪ Often utilize destructive gear<br>▪ Cyanide is preferred due to high catch per unit effort of live fish | Middlemen act as buyers, exporters, lenders, and aqua-culturists for the live fish trade<br>▪ Fund fishing activities in exchange for exclusive access to harvests<br>– Organized groups of fishermen for longer trips<br>– Provide cyanide, gear and motors to individuals<br>▪ Fund and build grow out facilities<br>– Live grouper kept in cages awaiting transport<br>– Undersized fish are grown to marketable sizes<br>▪ Purchase from local fishermen and export to lucrative markets |
| **Challenges** | There are few alternatives and the live fish trade is lucrative relative to other activities | Often fish in waters far from their communities with little incentive to limit destruction. Wages for crew are higher than most alternative activities | Traders have multiple communities providing live fish, and can easily repurpose investments to new under-exploited areas. Traders appear to use reefs as a depletable resource and are indifferent to local collapse/depletion |

SOURCE: Pet et al. 1999, Ainsworth et al. 2008, Koeshendraiana et al. 2006

38. Michael Fabinyi and Dante Dalabajan, "Policy and practice in the live reef fish for food trade; A case study from Palawan, Philippines", *Marine Policy*, 2011, Volume 35, Number 3, pp. 371-378.

## Analysis of underlying causes

Lack of management coupled with increased fishing pressure from population growth, lucrative markets for LRFF, greater per trip profits from destructive practices, and lack of resource ownership are the primary drivers of overfishing and destructive practices.

Small-scale artisanal fishing pressure, fueled by high prices for live grouper, is a major contributor to harvest levels above those which the stock can sustain. In addition, large-scale operations have the capacity to rapidly harvest large quantities of the species. The stock effect (the increase in cost to find and harvest fish as stocks decline) is not large because grouper can be targeted easily during spawning aggregations, further increasing their susceptibility to overfishing.

Middlemen, or traders, play an important role by providing access to lucrative markets. This access to markets accelerates the fishery's depletion that is already underway as a result of largely open access fisheries. In addition, players further up the LRFF value chain are likely to be indifferent to local depletion because, historically, there have always been more fishing grounds from which to obtain fish for the LRFF trade. Middlemen, unlike small-scale fishers, have also been able to move from fishing ground to fishing ground. However, as the abundance of grouper decreases regionally and opportunities elsewhere dwindle, the economics of middlemen and harvesters may be beginning to align.

While high demand for products and promotion of unsustainable practices by traders accelerate stock decline, the key problem lies in the lack of management to control harvests. Lack of management could be in part fuelled by a lack of urgency, as there is a perception that the marine environment is inexhaustible. Given the paucity of stock assessments, there is little data to help refute this misconception.

Besides by lack of management, unsustainable levels of fishing are driven by a lack of resource ownership by users. This, in turn, drives competition for greater individual catches. Facilities designed to grow out undersized grouper in order to obtain higher prices create markets for all sizes of fish, threatening the ability of any individual fish to make it to an age at which spawning can occur. Lastly, coastal development puts pressure on grouper fisheries as new participants enter and target the high value species.

Destructive fishing practices, such as the use of sodium cyanide,[39] do not account for as much of the grouper harvest as hook and line or methods using other kinds of gear. However, the use of the chemicals greatly reduces the health and resilience of grouper stocks and of coral reef ecosystems in general.

## Biological and economic analysis

Since this is a hypothetical case, we used published levels of abundance and catch from sample areas as reference points for abundance of grouper, harvest rates, and population density of fishers.[40] For this case, we assume that the fishery starts out at a relatively pristine state. Many fisheries in this area, however, are already closer to fully exploited or overexploited, so we would expect collapse to occur more rapidly in those fisheries than in the hypothetical model. For simplicity of analysis, we assume the fishery represents a reef area of approximately 1,000 square kilometers, which may be smaller or larger than any given coastal fishery in the area. It should be noted, however, that a change to the reef area acts as a scalar to the outputs; it does not mean that results cannot be compared between models.

**Scenario 1: Business as Usual (BAU)**

The Business as Usual scenario assumes artisanal fishermen are the sole cause of fishing mortality. Fishing mortality is determined by: the number of fishing participants operating on an area of coral reef, the catch

39. Sodium cyanide is used to harvest groupers for the live food fish trade. Harvesters squirt sodium cyanide from squirt bottles to stun target fish. This allows the harvester to easily collect the fish and transfer it to a vessel's holding tank. Doses necessary to stun large groupers often kill smaller fish, invertebrates, and hard corals. Sodium cyanide is used by both small-scale fishers and larger operations.

40. Cameron H. Ainsworth, Divya A. Varkey and Tony J. Pitcher, "Ecosystem simulation models of Raja Ampat, Indonesia, in support of ecosystem based fisheries management", in *Ecological and Economic Analyses of Marine Ecosystems in the Bird's Head Seascape, Papua, Indonesia: Part II,* ed. Megan Bailey and Tony J. Pitcher, Fisheries Centre Research Reports, 2008, Volume 16, Number 1, p.186.

per trip, and the number of trips each individual takes. The number of trips is assumed to be constant. The model includes a small stock effect, causing catch per trip to decrease as stocks decline. (Definitive evidence does not confirm or refute this assumption. Grouper aggregate to spawn, making them easy targets, however evidence suggests there may be a small impact on catch per trip as stocks decline.[41])

The number of fishers is driven by population growth. Initial fisher density is assumed to be 0.37 per square kilometer of coral coverage or approximately 370 fishers initially. This figure is based on studies of communities and fisheries in Raja Ampat, an archipelago located in eastern Indonesia, which at the time of the studies had low population densities relative to Indonesia and the region as a whole. In 2009, population growth rates for Indonesia, Malaysia, and the Philippines were 1.1 percent, 1.7 percent, and 1.8 percent, respectively.[42] However, since some studies show that population growth may be higher in some coastal areas,[43] we assume a population growth rate of two percent. We assume that 40 percent of artisanal fishers' catch is sold to traders in the live fish trade, while the remaining 60 percent is consumed for subsistence or sold in local markets.

Price per kilogram is determined by the market to which the product is destined and the size of fish. Fish destined for live reef fish market command higher prices per kilogram, and there is a premium for particularly large fish. Middlemen in the live reef fish trade earn a margin on each fish that passes through the value chain.

Under BAU, we find that the stock collapses — i.e. declines to 10 percent of carrying capacity — by 2029.[44] In this scenario, profits of artisanal fishers decline in relation to the stock, as both catch per trip and average size of each fish harvested decrease. The profits for middlemen decrease as harvests decline and zero out at collapse. When this occurs, it is assumed that middlemen can redirect their investments and obtain fish from other locations. (Exhibit 20)

**Scenario 2: Destructive practices drive fishery to immediate collapse**
In this scenario, small-scale fishers continue to operate as under BAU, however large-scale operations using less selective gear enter the fishery four years after the modeling begins, in 2010. Large-scale operations are oriented to sell to traders in the live reef fish trade, and can rapidly deplete stocks of grouper and other species due to their scale and use of technology, such as motors and assisted diving systems. While estimates vary, large-scale grouper operations appear to be able to harvest more than two tons of fish per trip. Here, we model the entry of three such operations conducting trips twice each month. Under this model, the stock would collapse by 2017.

The NPV of profits for small-scale harvesters calculated from 2011 decrease by more than half in the short term (five years) and to one quarter of the original value in the longer term (20 years) as compared to the BAU. Large-scale operators would earn more than small scale fishermen in this scenario under both time frames. But it is the middlemen who would see their NPV tripling in the short term and increasing by 60 percent in the long term. This boost to short-term profits and less concern for local stocks could explain why middle men often assist in the introduction of large-scale operators in these regions. Furthermore, large-scale operators and middlemen can presumably redirect investments to other geographical locations with similar species. Because these opportunities exist, fixed costs — such as vessels for harvesting and transporting — are not presumed to be lost if the fishery ceases to produce grouper. (Exhibit 21)

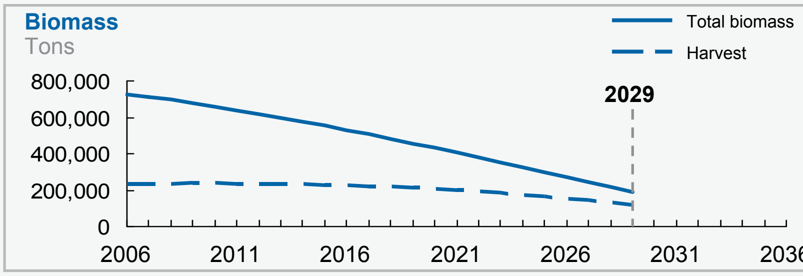
**Scenario 3: Maximum Sustainable Yield (MSY)**
Under this scenario, the model assumes a reduction in the number of fishing vessels to the level that would, at current catch per trip and trips per year rates, harvest the Maximum

41. Helen Scales, Andrew Balmford and Andrea Manica, "Impacts of the live reef fish trade on populations of coral reef rish off northern Borneo", *Proceedings of the Royal Society B* 274, 2007, pp.989–994.
42. World Bank, "Population growth (annual %)", (accessed May 21, 2011), http://data.worldbank.org/indicator/SP.POP.GROW.
43. See Bailey et al, 2008.
44. For all scenarios, we assume the starting biomass of the fishery is 38.75 percent of carrying capacity. Regionally, grouper stocks are likely to be below their Biological Maximum Sustainable Yield (around 50 percent of carrying capacity). However, individual stocks may range from untouched to fully depleted. The hypothetical stock we model sits somewhere in the middle, or perhaps slightly closer to untouched.

Exhibit 20

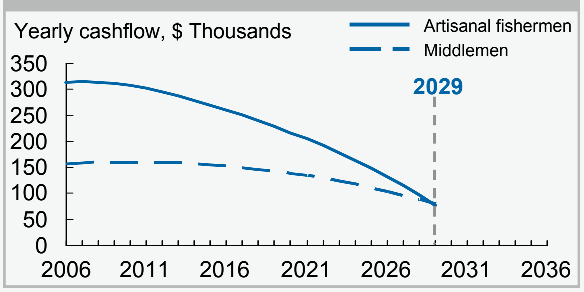
## Grouper scenario 1: Business as Usual (BAU) — excl. commercial fishers

**Scenario 1: BAU**

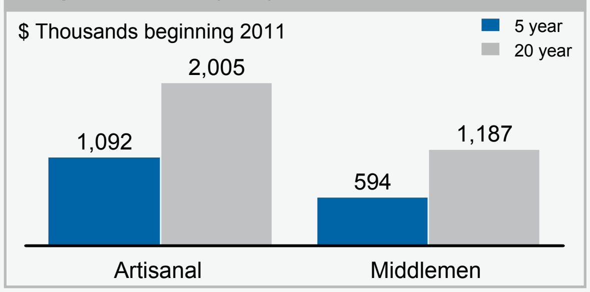



- **Collapse occurs in 2029**

**Total yearly net income**




**Net present value (NPV)**

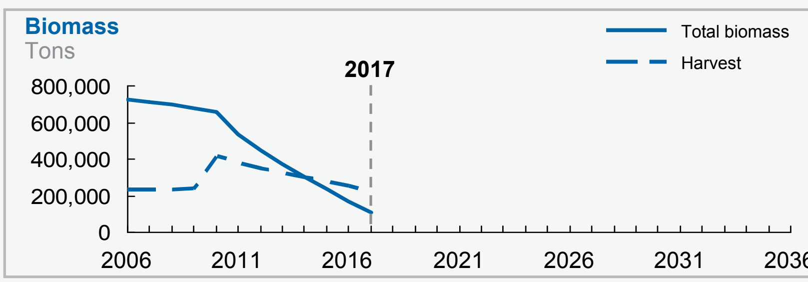



SOURCE: McKinsey & Company

Exhibit 21

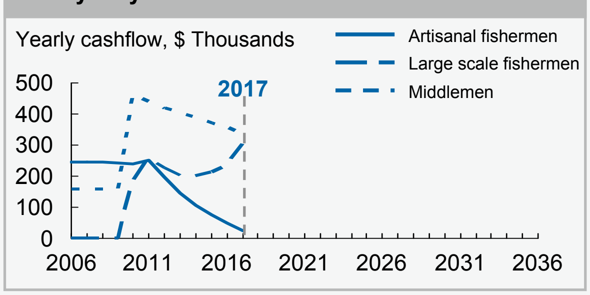
## Grouper scenario 2: Business as Usual (BAU) — incl. commercial fishers

**Scenario 2: Rapid depletion**

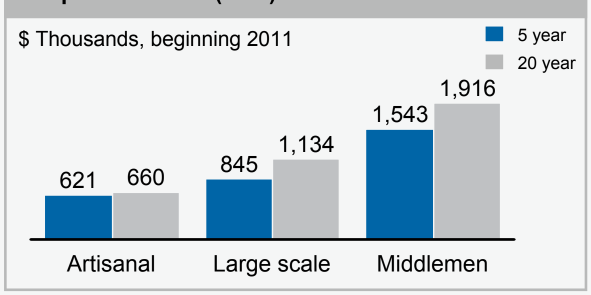



- **Collapse occurs in 2017**

**Total yearly net income**



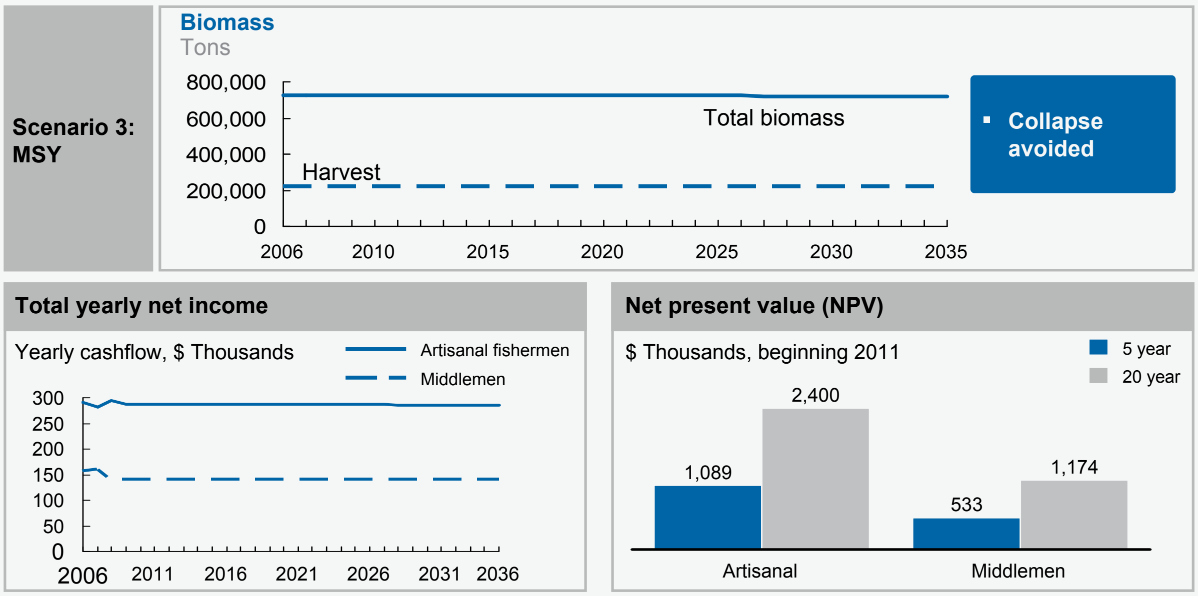

**Net present value (NPV)**




SOURCE: McKinsey & Company

Exhibit 22

**Grouper scenario 3: Maintaining Maximum Sustainable Yield (MSY)**




SOURCE: McKinsey & Company

Sustainable Yield. Large-scale operations are excluded from the fishery. Small-scale operators gain an additional 20 percent on the long term NPV through the sustainable management of the fishery. Middlemen profits remain relatively unchanged or slightly reduced as compared to the BAU. (Exhibit 22) As the modeling effort begins with a relatively intact stock, the true value of comparing the BAU with this scenario will only be seen over a longer period of time. In fact, as previously mentioned, many grouper stocks are already overfished, which would suggest that small scale operators would stand to gain even more than what has been described under this scenario through sustainable fishery management.

## Summary of analysis

Our analysis suggests that the fishery will collapse even with just artisanal fishing, but will collapse even faster if commercial fishers are included in the model.

This suggests that large-scale operators will have to be excluded from tropical grouper fisheries, and harvests by artisanal fishers will have to be constrained to ensure the economic and biological sustainability of the grouper fisheries. In both scenarios in which fishing mortality is not constrained, the fishery collapses. Under BAU, this occurs by 2036. When large-scale operators enter the fishery, collapse occurs within five years.

Under the MSY scenario, which bars large-scale operators, profits for artisanal fishers are maximized. Profits for middlemen are slightly reduced compared to the BAU scenario — but significantly lower than what they could earn under the rapid depletion scenario.

Sustainable practices in the fishery may be promoted in a number of ways. Potential solutions include: bans on destructive practices (such as the use of cyanide), obtaining better data, establishing demand side efforts (as discussed below), as well as better aligning the interests of fishers with the long-term sustainability of the fishery.

Governments need to have information of the condition of the fisheries in order to understand the implications of the losses and of non-action. There are a number of creative solutions that are being developed to help management in data-poor fisheries.[45] Given the lack of basic information on the fish stocks in the region, obtaining such data could be very valuable.

Demand side efforts such as the establishment of certification of sustainable products or consumer awareness campaigns rely on providing incentives to improve fishing practices through price premiums. Alternatively, they can provide disincentives for unsustainable practices by reducing demand for such products. Bans, moratoriums, or trade regulations can also be used. However, disincentives largely rely on increased monitoring and penalties, and often reduce the economic performance of fisheries. Demand side efforts may not address the market for local products and they carry a risk of continued depletion if more direct management is not also pursued.

The most promising solutions align incentives of users with the interests of long-term sustainability. In grouper fisheries of the Coral Triangle this could be achieved, for example, through a combination of community-based TURFs (territorial use rights in fisheries) and reserves that would provide fishers with long-term, secure, and exclusive privileges to marine areas — to offer an assurance that the benefits of conservation measures taken today will accrue to them in the future.

45. Kristen Honey, Jerry Moxley and Rod Fujita, "From Rags to Riches: Data-Poor Methods for Fishery Managers", California Sea Grant College Program, 2010, and Ashley Apel "Assessment Methods for Data Poor Stocks", Environmental Defense Fund, October 2010.

## Live Reef Food Fish Trade

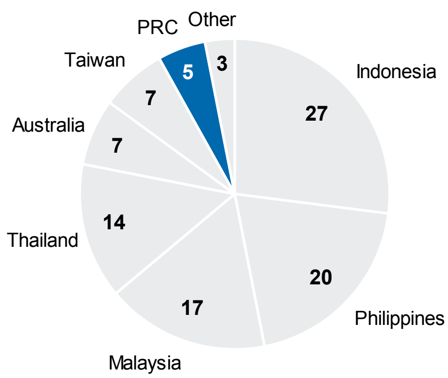
The live reef food fish trade is a small but lucrative sector of the seafood industry in Asia. Wild Live Reef Food (LRFF) fisheries are concentrated in the Coral Triangle countries of Indonesia, the Philippines, and Malaysia, and are driven largely by demand in Hong Kong and mainland China. Analysis by California Environmental Associates (CEA) determined that the value of the live reef food fish trade increased from approximately $1 billion to $2 billion in the last 10 years. Demand is expected to increase as the main importers become wealthier.

Given the high prices fetched by some species, including tropical grouper, the LRFF trade has contributed to fueling fishing effort in the region, resulting in overexploitation and depletion of targeted stocks. Further exacerbating fishing pressure on tropical grouper is the fact that less vulnerable species which fetch a lower price in the market do not serve as substitutes for critically endangered species. The LRFF trade has also been associated with destructive fishing practices, in particular the use of cyanide.

Exhibit 23

**Source of fish imports into Hong Kong**

Share of volume of Hong Kong's total imports by source country in 2009
%, 100% = 10,500 tons




SOURCE: CEA

While there are efforts to reduce the pressure, notably the WWF Coral Triangle Network Initiative, LRFF is a very difficult commodity to influence. An analysis by CEA suggested that the major segments of the industry — consumers, producers, and traders — are resistant to change and consumers in the end market for LRFF (mainly individual restaurants in China and Hong Kong) are unlikely to be willing to pay more for environmentally preferable options or to avoid using LRFF in order to achieve more sustainable LRFF. The issue for producers or fishers is that there is a systemic failure of fishery management. Regarding traders, CEA notes that the industry is largely defined by rampant unreported and often illegal trade. Without any demand for change from buyers or mechanisms to improve fishery management on the water, the supply chain is helping to drive LRFF fisheries toward exhaustion. In summary, LRFF trade remains a threat to coral reef ecosystems and biodiversity in the region, with serial overfishing occurring in many or most regions, and destructive fishing practices compounding the damages. (Exhibit 23)

## Tropical Grouper Biological Model

We use an age-structured model for projecting biomass of the grouper population in the Coral Triangle. The primary objective of this model is to account for the unique life history of the grouper.

Grouper are a long-lived reef fish with a unique life history known as protogynous hermaphroditic, which means that the fish transitions from female to male as it grows older. This life history makes the fish particularly vulnerable to overfishing since the greatest egg production is concentrated in fish aged 4 to 7, when the majority of the fish in those age classes are reproductive mature females.

The age-structured models account for the protogynous hermaphroditic grouper by modeling the proportion of fish at a given age that are likely to be male versus female. In addition, the model has commercial selectivity parameters by age, which allows us to evaluate alternative age/size selective harvest policies and the outcomes on the egg production of the population. This is a fishery where simply conserving the older, larger fish in the population may not be optimal if the majority of those are males that do not produce offspring.

# Summary of Insights

There are a number of common factors that underlie overfishing and threaten the sustainability of fisheries worldwide. They include high market prices for specific species, illegal fishing, inadequate or a total absence of fisheries management, scarce or non-existent data, and lack of ownership incentives. Biological characteristics of any particular species, combined with these economic and institutional factors, can make certain species especially vulnerable.

While these common factors are the root causes of threatened fisheries, they play out differently in every fishery, depending on the specific mix of stakeholders involved and unique characteristics of the fishery. In order to develop strategies for averting a fisheries collapse and restoring sustainability, it is useful for policy makers to understand the unique set of forces operating in any given fishery. To illustrate how the common factors that lead to fishery collapse play out in particular fisheries and to determine a range of potential solutions, we modeled scenarios for three fisheries — those of the East Atlantic bluefin tuna, Gulf of Mexico red snapper and the tropical grouper.

The scenarios do not lay out complete solutions for restoring the fisheries discussed to sustainability. Rather, they illuminate the factors that inhibit transitions to sustainability and provide indications of what strategies could be looked into to surmount those obstacles. Additional work needs to be done to arrive at manageable solutions.

Some of the scenarios that were explored showed potential solutions that seemed theoretically achievable but would require large changes to current practices and potentially significant short-term losses to key players. This would need to be addressed to develop manageable solutions. It appears that the bluefin tuna fishery, for example, could be returned to sustainability through the elimination of Illegal, Unreported and Unregulated (IUU) fishing. This would probably require enlisting the participation of those that drive the demand for tuna. These include about 70 tuna ranchers and the small number of distributors who are said to manage the bulk of the fish that is sold in Japan — by far the largest market for bluefin tuna. The fact that tuna ranchers as a whole are already unprofitable because of overcapacity could provide the basis for their participation in a solution.

It would be useful to gain a greater understanding of the economic impact of this path on the ranchers and distributors. This information could both give a better idea of what it would take to succeed on this path, and how stakeholders at the top of the value chain might be enlisted in preserving the viability of the fishery in the long run.

As challenging as shutting down IUU may be, the alternative course — closing down the bluefin tuna fishery for six to eleven years — may be even more difficult since it would completely eliminate a source of livelihood for tuna fishers for that time period.

The case of the tropical grouper also shows the differing interests at stake and indicates that the various players would need to be enlisted in finding solutions, from middlemen to the Live Reef Food Fish (LRFF) trade along with its end customers. While the interests of fishers and middlemen are beginning to align as they feel the impacts of declining stocks, the end customers seem to show no signs of concern.

In addition to the middlemen and end customers participating in a solution, there would have to be a reduction of fishing by small-scale fishers — the artisanal fishers — who sell grouper in local markets for their livelihoods. While establishing some kind of ownership arrangement for small grouper fishers appears to be a promising strategy for reducing overfishing, exactly what mechanisms and how they would be implemented remain to be determined.

The case of the Gulf of Mexico red snapper, meanwhile, illustrated a fishery whose recovery appears more within reach, although still highly challenging due to many different parties being involved. Imposing and enforcing individual fishing quotas on the for-hire sector could have immediate beneficial effects for this sector. Adverse economic consequences for the commercial sector could be limited enough to be manageable. The other facet of the solution — significantly reducing the number of dead discards among private anglers — presents a management challenge. While there are established practices for reducing dead discards, they need to be made compelling for private anglers. This could be feasible since it does not entail adverse economic consequences for those private anglers.

Although unique sets of circumstances define the scope of potential recovery strategies for specific fisheries, approaches that work in one fishery may at the same time be suggestive of solutions for other fisheries.

The case studies reconfirm some key patterns in fisheries management, for example, that while high prices in markets for the three fish species considered are a powerful force in driving overfishing, market players — given the right incentives and under the appropriate circumstances — will adhere to quotas. The Gulf of Mexico red snapper fisheries are a case in point. There, commercial fishers have adhered to quotas for years, and even undershot them on some occasions. Further, IUU does not appear to be a major factor in this fishery. Meanwhile, in the bluefin tuna fishery, TACs are consistently and significantly surpassed, largely as a result of IUU. The explanation for this is likely to lie in the international nature of the bluefin market and the overcapacity in purse seiners and tuna ranchers.

Similarly, while the tropical grouper and Gulf of Mexico red snapper fisheries are, literally, a world apart, overfishing by the smallest-scale fishers in each fishery appears to be aggravated by lack of data. Further exploration of how the required data could be made available may inform solutions for both fisheries.

The case studies enabled us to identify stakeholder dynamics, root causes, and new management solutions. We were able to compare the biological and economic impact of different transition pathways, and provide a holistic view of the winners and losers in the value chain during a transition. The case studies also provide a better understanding of what it would take to overcome the barriers to achieving sustainable fisheries and present ideas about how to further apply and develop the introduced methodology.

# References

In addition to the references footnoted in the text of the report, we relied on the following sources for context and data in the development of the individual case studies:

**East Atlantic and Mediterranean Bluefin Tuna Case Study**

Bjorndal & Brasao, Bjorndal & Brasao. The East Atlantic bluefin tuna fisheries – stock collapse or recovery? SNF Working Paper No. 34/05. June 2005.

Campbell, Kennedy & McIlgorm. Conservation and optimum utilization of Southern bluefin tuna. 2002.

ClientEarth. Legal requirements to protect bluefin tuna under EU law – implications for ICCAT negotiations. October 2010.

CITES. Proposal to include Atlantic bluefin tuna on Appendix I of CITES in accordance with Article II of the Convention. October 2009.

Crockett. Protecting bluefin tuna: domestic and international solutions. Pew environment group. November 2010.

Economic Performance of Selected European Fishing Fleets. Annual Economic Report 2005. 2006.

ECORYS. T*he socio-economic impact of possible commission proposals pertaining to the conservation of Atlantic bluefin tuna.* 2010

Gates. Investing in our future: the economic case for rebuilding mid-Atlantic fish populations. Pew environment group. 2009.

Gentner consulting group. Domestic economic impacts of a CITES appendix I listing for bluefin tuna. September 2009.

Greenpeace & ATRT. *Tuna! Tuna! Tuna!* 2007.

Greenpeace. *Facts about five major tuna suppliers*. 2008

ICCAT. Panel 2: Northern temperate tunas. ICCAT 2010 conference presentation. 2010.

ICCAT. Report of the standing committee on research and statistics, SCRS. October 2010.

ICCAT. Report of the 2010 Atlantic bluefin tuna stock assessment session. September 2010.

ICCAT. Report of the standing committee on research and statistics, SCRS. 2008.

Joseph. Managing fishing capacity of the world tuna fleet. FAO fisheries circular no. 982. 2003.

Kell. Projections for Eastern Atlantic and Mediterranean bluefin tuna. ICCAT SCRS. 2010.

Kurota, Oshima, Abe, Takeuchi & Nakano. Current and future Atlantic bluefin stock status relative to CITES listing criteria using an updated 2008 virtual population analysis. ICCAT SCRS. 2010.

MacKenzie, Mosegaard & Rosenberg. Impending collapse of bluefin tuna in the northeast Atlantic and Mediterranean. Conservation Letters, Volume 2. 2009.

Mielgo Bregazzi, R., *The plunder of bluefin tuna in the Mediterranean and East Atlantic in 2004 and 2005 – uncovering the real story*. WWF. May 2006

Mielgo Bregazzi, R., *Fishing capacity of the Bluefin tuna purse seine fleet inside the Mediterranean Sea*. 2008

Mielgo Bregazzi, R., *Requiem for a Bluefin Tuna*. 2009

Miyake, Guillotreau, Sun & Ishimura. Recent developments in the tuna industry: stocks, fisheries, management, processing, trade and markets. FAO fisheries and aquaculture technical paper 543. 2010.

Oceanic Développement, Poseidon Aquatic Resource Management Ltd and MegaPesca Lda (2005). "Economic Situation, Prospects and Analysis of the Impact of the Liberalization of Trade". Study on the European Tuna sector. 2005.

Pew environment group. Conserving Atlantic bluefin tuna with spawning sanctuaries. Ocean science series. October 2010.

Pew environment group. Finding sustainability: recommendations to ICCAT 17th special meeting of the commission. 2010.

Sumaila, U.R. and L. Huang. "Managing Bluefin Tuna in the Mediterranean Sea." Economic Research Forum. 2010.

Sustainable fisheries partnership (2010): Sousa. Recovering bluefin tuna position statement. Sustainable fisheries partnership. March 2010.

Tietze, Prado, Le Ry & Lasch. Techno-economic performance of marine capture fisheries. FAO fisheries technical paper 421. FAO. 2001.

WWF. Technical analysis of the outcomes of the 21st meeting of ICCAT with respect to Eastern Atlantic bluefin tuna. 2009.

WWF. On the brink: Mediterranean bluefin tuna, the consequences of collapse. 2007.

WWF. Position paper: East Atlantic and Mediterranean bluefin tuna. 2010.

WWF. Media backgrounder: how fisheries regulation has so far failed the bluefin tuna. 2010.

WWF & ATRT S.L. *The plunder of bluefin tuna in the Mediterranean and East Atlantic in 2004 and 2005: Uncovering the real story.* 2006.

WWF. *Spatial management to support recovery of the Atlantic bluefin tuna in the Mediterranean*. 2008.

**Red Snapper Case Study**

Association, National Oceanic and Atmospheric. Annual Commercial Landing Statistics. http://www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings.html (accessed February 2011).

Federal Register. NOAA Fisheries Service, Southeast Regional Office. March 30, 2010. http://sero.nmfs.noaa.gov/sf/pdfs/Red%20Snapper%20Proposed%20Rule.pdf (accessed March 18, 2011).

Gulf of Mexico Fishery Management Council. Gulf of Mexico Fishery Management Council. May 6, 2010. http://www.gulfcouncil.org/Beta/GMFMCWeb/downloads/recbrochure2009-10.pdf (accessed February 2011).

Liese, C., and D.W. Carter. "Collecting Economic Data from the For-Hire Fishing Sector: Lessons from a Cost and Earnings Survey of the Southeast U.S. Charter Boat Industry." The Angler and the Environment (American Fisheries Society), 2011: 14.

National Oceanic and Atmospheric Association. Recreational Fishery Statistics Time Series Query. http://www.st.nmfs.noaa.gov/st1/recreational/queries/catch/time_series.html (accessed February 2011).

S.M., Holland, and A.J. Fedler. "The Operations and Economics of the Charter and Head Boat Fleets of the Eastern Gulf of Mexico and South Atlantic Coasts." Texas A&M University. 2011. http://essm.tamu.edu/people/msorice/ditton/Projects/docs/HollandFedlerMilon.PDF (accessed February 2011).

Southeast Data, Assessment, and Review. Stock Assessment of Red Snapper in the Gulf of Mexico. Update assessment, Miami: Southeast Data, Assessment, and Review, 2009.

Southeast Data, Assessment, and Review. Stock Assessment Report of SEDAR 7: Gulf of Mexico Red Snapper. Stock assessment, Charleston: Southeast Data, Assessment, and Review, 2005.

**Tropical Grouper Case Study**

Ainsworth, Cameron, Divya Varkey and Tony Pitcher, "Ecosystem simulation models of Raja Ampat, Indonesia, in support of ecosystem based fisheries management," in *Ecological and Economic Analyses of Marine Ecosystems in the Bird's Head Seascape, Papua, Indonesia: Part II,* ed. Megan Bailey and Tony J. Pitcher, Fisheries Centre Research Reports, 2008, Volume 16, Number 1, p.186.

Burke, Lauretta, Elizabeth Selig and Mark Spalding, "Reefs at Risk in Southeast Asia," *World Resources Institute* (2002): 1-73

California Environmental Associates, "The Live Reef Food Fish Trade (LRFFT): A Supply Chain Review and Market Intervention Analysis," A Project of the Kingfisher Foundation in cooperation with WWF 2001, pp. 1-40.

Fabinyi, Michael and Dante Dalabajan, "Policy and practice in the live reef fish for food trade; A case study from Palawan, Philippines," *Marine Policy*, 2011,Volume 35, Number 3, pp. 371-378

FAO, Global Production Statistics 1950-2009 Database (accessed May 16, 2011), http://www.fao.org/fishery/statistics/global-production/query/en.

Hirason Huruondono and Lida Pet, "Assessment of Conservation Solutions for the Togean Islands, Sulawesi, Indonesia," *Conservation International and The Conservation and Community Investment Forum* (2003): 1:23

Johnston, Brian, ed., "Economics and market analysis of the live reef-fish trade in the Asia–Pacific region," *ACIAR Working Paper* 63 (2007)

Pet-Soede, Lida and Mark Erdmann, "An overview and comparison of destructive fishing practices in Indonesia," *SPC Live Reef Fish Bulletin* Volume 4, April 1998, pp. 28-36.

Sadovy, Yvonne and Michael Domeier, "Are aggregation-fisheries sustainable? Reef fish fisheries as a case study," Coral Reefs 24 (2005): 254–262

Sadovy, Yvonne and Min Liu, "Report on Current Status and Exploitation History of Reef Fish Spawning Aggregations in Eastern Indonesia," Western Pacific Fisher Survey Series: Society for the Conservation of Reef Aggregations 6 (2004): 1-41

Sunjaya, Jared Hardner, Dessy Anggraeni, Christo Hutabarat, A. Ruwindrijarto, Scales, Helen, Andrew Balmford and Andrea Manica, "Impacts of the live reef fish trade on populations of coral reef fish off northern Borneo," Proceedings of the Royal Society B 274, 2007, pp.989–994.

World Bank, "Population growth (annual %)", (accessed May 21, 2011), http://data.worldbank.org/indicator/SP.POP.GROW

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