THE HIDDEN COST OF OVERFISHING TO COMMERCIAL FISHERMEN: A 2009 SNAPSHOT OF LOST REVENUES

Final Report

Report to The Pew Charitable Trusts

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LIST OF ACRONYMS

ACL	Annual Catch Limit
CC	Cape Cod
FSSI	Fish Stock Sustainability Index
GB	Georges Bank
GMFMC	Gulf of Mexico Fishery Management Council
GOM	Gulf of Maine
gw	gutted weight
lw	live weight
MA	Middle Atlantic
MSA	Magnuson-Stevens Fishery Conservation and Management Act
MSY	maximum sustainable yield
NAC	Northwestern Atlantic Coast
NEFMS	New England Fishery Management Council
NMFS	National Marine Fisheries Service
NOAA	National Ocean and Atmospheric Administration
OFL	overfishing level
OY	optimum yield
SAFMC	South Atlantic Fishery Management Council
SNE	Southern New England
ww	whole weight

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EXECUTIVE SUMMARY

Ocean fish populations are a vital renewable resource for human populations, providing food, employment and recreation, as well as contributing to global biodiversity. Unfortunately, due to overfishing, environmental degradation, climate change and other stressors, many fish stocks worldwide are in considerable decline.

Biological overfishing occurs when fishing rates exceed population growth rates. The resulting declines in fish populations can impact the economy at large. This study analyzes one important component of the costs of overfishing: forgone revenues from lost commercial fisheries harvests due to years of continued stock depletion, or historic overfishing. It estimates the present annual forgone revenue of overfishing for three regions in the United States: New England, the South Atlantic and the Gulf of Mexico. These regions were chosen for analysis because they are grappling with the effects of historic overfishing and therefore have a significant number of overfished stocks. The 20 stocks included in this analysis are federally managed stocks particular to each region that are included in the Fish Stock Sustainability Index and are currently classified by the National Marine Fisheries Service as “overfished.” A stock that is classified as overfished is defined as having a biomass level below a biological threshold specified in its fishery management plan.

Overfishing means fewer fish are available to catch in future years. The annual forgone revenue of historic overfishing, therefore, is an estimate of the value of lost catch in a given year due to overfishing. To arrive at the catch loss for each fishery, we first estimated the potential landings of each overfished stock as if it were at healthy levels, and compared those estimates directly to current landings values. We measured potential landings for each fish stock on the basis of optimal yield, and examined four approximations of optimal yield. Our estimates of commercial catch losses are for 2009, the most recent year for which all necessary data were available.

Based on our estimates, **the aggregate catch loss summed over all three regions in 2009 was $164.2 million.** Under a less-conservative approximation of optimal yield, commercial catch loss across all three regions in 2009 was estimated at $222.5 million. **Across all three regions, we demonstrated that only 20 to 29 percent of potential landings in 2009 were realized in actual landings.** We found the commercial catch loss ($149 million) to be greatest in New England, where there are more overfished species than in any other region in the United States. In the Gulf of Mexico and South Atlantic regions, where large catch allocations are apportioned to recreational fishing, and therefore not accounted for in this analysis, commercial catch losses were lower but still significant. Commercial catch loss in the Gulf of Mexico and the South Atlantic regions were $12.3 million and $2.9 million, respectively.

Our estimates of losses resulting from historic overfishing apply to commercial landings only, and do not account for the backward-linked economic impacts of commercial harvest, nor the forward-linked economic activity that would have resulted from the processing and retail sale of these potential catches. Additionally, there are further economic losses beyond the commercial sector in other industries, such as recreational fishing, and there are costs associated with negative impacts to food security, biodiversity and other ecosystem services that are not addressed in this analysis. Commercial catch losses are one significant component of the total economic costs of overfishing. Estimates of commercial catch loss we find in this study provide a strong economic argument in support of maintaining healthy fish populations and avoiding delays in rebuilding stocks currently subject to overfishing and/or classified as overfished.

1. INTRODUCTION

Fish stocks are a vital resource to human populations. Not only are they a renewable resource, but they provide a variety of benefits including food and recreational pleasure, as well as supporting livelihoods. At present, however, pressures from illegal and/or unsustainable fishing, coupled with climate change, changing land-use patterns, population growth and other stressors, are contributing to declines in fish stocks. Fishing efforts globally have remained relatively constant with only slight increases, while the global production of marine fisheries has declined (Food and Agriculture Organization of the United Nations [FAO], 2010). Many have declared this period from the latter half of the 20th century to the present as the most crucial stage in fishing history (Srinivasan *et al.,* 2010 citing Grainger and Garcia, 1996; Pauly *et al.*, 2002; Myers and Worm, 2003; Millennium Ecosystem Assessment, 2005; Lotze *et al.*, 2006; Worm *et al.*, 2006).

Biological overfishing, the standard definition of overfishing, occurs when fishing depletes fish stocks faster than they can reproduce. Overfishing over time can result in consistent, substantial losses in commercial landings. Catch levels that exceed prescribed fishing levels can yield higher than sustainable profits in the short-term, but such harvesting eventually results in biologically overfished fisheries (i.e., fisheries that have a biomass level below a biological threshold specified in their fishery management plans). These fisheries are also economically inefficient because the extra effort required to locate and harvest catch can exceed the additional benefits. Economic overfishing occurs at a harvest rate that fails to maximize the long-term net sustainable rate of return from the fishery. The loss of ecosystem services resulting from fish stocks in decline further adds to the costs of overfishing. But a rebuilt, or never overfished, healthy fishery can provide abundant landings for the long-term.

Several studies have demonstrated the potential economic benefits of maintaining or rebuilding healthy fish stocks. In a 2009 assessment of more than 200 stocks and stock complexes, the National Oceanic and Atmospheric Administration (NOAA) estimated that rebuilding U.S. fish stocks would increase the current ex-vessel value by 54 percent annually, from $4.1 billion to $6.3 billion (NOAA, 2011). This potential increase could generate an additional $31 billion in sales and support an additional 500,000 jobs (Schwaab, 2011). Fully rebuilt U.S. fish populations in commercial and recreational fisheries could generate $216 billion in annual sales and support 2.5 million full- and part-time U.S. jobs.[1]

Examining a subset (17 stocks) of federally managed overfished stocks, Sumaila and Suatoni (2005) estimated that the combined net present value ($567 million) from rebuilding stocks according to their respective rebuilding plans would be three times greater than values derived from recent catch scenarios ($194 million). Their estimates are derived from a partial valuation; they represent only a fraction of the total potential benefits associated with rebuilding federally managed overfished ocean fish stocks.

Our study analyzes one component of the losses associated with overfishing: forgone revenues from lost commercial fishery harvests due to historic overfishing. It estimates the value of lost harvests in federally managed commercial fisheries that are currently classified as overfished in New England, the South Atlantic and the Gulf of Mexico regions. The analysis, based on 2009 data, provides a snapshot of the potential losses from overfishing and the potential benefits of maintaining or rebuilding healthy fish populations that in turn will support commercial fisheries.

2. PROJECT OVERVIEW

This study answers the following question: What are the present annual forgone revenues due to historic overfishing? Overfishing means fewer fish are available for harvest in future years due to reduced population levels. The annual forgone revenue of historic overfishing, therefore, is an estimate of the value of the lost harvest in a given year due to years of stock depletion from overfishing. Our analysis targets federally managed commercial fisheries that have been classified as overfished in the New England, South Atlantic and Gulf of Mexico regions. We provide estimates for a single year, 2009, the

[1] These numbers are a summation of the estimated impacts of rebuilding from Schwaab (2011) and the comparable commercial and recreational estimates from NMFS (2008).

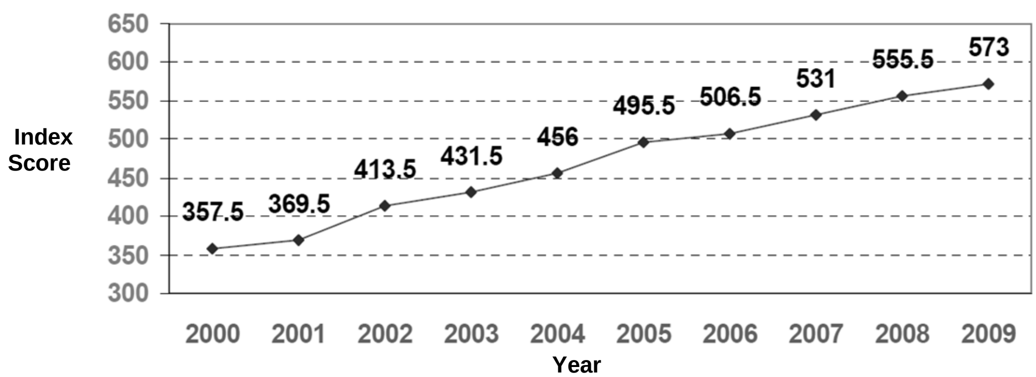
most recent year for which all necessary data were available, providing a snapshot in time, as compared with an analysis of the historic net present value of overfishing over a longer period.[2]

NOAA's National Marine Fisheries Service (NMFS) reports annually to Congress on the status of fisheries under the Magnuson-Stevens Fishery Conservation and Management Act (MSA) (Sec. 304[e][1]). In 2009, 522 individual fish stocks and stock complexes were reviewed by NMFS (NMFS, 2010a). NMFS characterizes stocks as unknown, healthy, or "subject to overfishing" or "overfished." A stock may be both subject to overfishing and overfished at the same time. Stock assessments are carried out often, although the frequency with which assessments occur varies by stock.

According to NMFS, a stock is subject to overfishing if its fishing mortality rate exceeds the level that provides for maximum sustainable yield (MSY). MSY is considered the largest average catch that can be taken from a stock on a continuing basis under prevailing environmental conditions without impairing its long-term productivity. NMFS defines a stock that is overfished as having a biomass level below the biological threshold specified in its fishery management plan. A fishery management plan is a set of science-based recommendations aimed at achieving specified management goals for a fishery. When a stock is classified as overfished, the MSA requires fishery managers to take actions to rebuild stocks and implement a plan to end overfishing.

NMFS measures progress in the management of national fisheries through the Fish Stock Sustainability Index (FSSI).The FSSI will increase if additional assessments are conducted, or if overfishing ends and stocks rebuild toward the level that provides MSY. Key stocks are selected for their importance to commercial and recreational fisheries. Since 2000, the index has increased nearly 60 percent (see Figure 1).[3]

Figure 1. FSSI Score 2000-09



Source: adapted from NMFS (2010a)

In this study we targeted three of the eight fishery management council regions: New England, South Atlantic and the Gulf of Mexico. These regions were chosen because they are grappling with the effects of historic overfishing and consequently have a significant amount of overfished stocks. For these three regions, we considered only fish stocks included in the FSSI and classified as overfished in the first quarter assessment report for the NMFS Status of U.S. Fisheries, 2011. Table 1 displays the 20 stocks included in our analysis by region.

[2] The net present value of historical overfishing would represent the discounted net flow of both the short-term gains made in the initial years where landings exceeded sustainable rates and the longer-term losses due to dwindling populations.

[3] The maximum possible FSSI score is 920 points. The most recent FSSI score is 583, as reported in the first quarter update for 2011, which also explains the scoring methodology (NMFS, 2011). To reach the maximum score would require the stock to grow roughly another 58%; however, there are 298 additional stocks that currently are not considered in the FSSI. The statuses of these additional stocks are largely "not defined," "not applicable" or "unknown."

Table 1. List of Targeted Stocks for This Study

	New England
1	Atlantic cod–Georges Bank
2	Atlantic halibut
3	Ocean pout
4	White hake
5	Windowpane–Gulf of Maine/Georges Bank
6	Winter flounder–Georges Bank
7	Winter flounder–Southern New England/Middle Atlantic
8	Witch flounder–Northwestern Atlantic Coast
9	Yellowtail flounder–Cape Cod/Gulf of Maine
10	Yellowtail flounder–Georges Bank
11	Yellowtail flounder–Southern New England/Middle Atlantic

	South Atlantic
1	Black sea bass
2	Red grouper
3	Red porgy
4	Red snapper
5	Snowy grouper

	Gulf of Mexico
1	Gag
2	Gray triggerfish
3	Greater amberjack
4	Red snapper

All of the overfished stocks listed above are also classified as subject to overfishing, except Atlantic halibut, ocean pout and yellowtail flounder–Georges Bank in New England; and red porgy in the South Atlantic (NMFS, 2011).

It is important to note that Table 1 is not a comprehensive list of all overfished stocks in each of the three regions. There are four additional overfished stocks in the New England region—smooth skate, thorny skate, Atlantic salmon and Atlantic wolffish. However, we could not find the necessary data for smooth and thorny skates,[4] and the latter two stocks are not FSSI stocks due to Atlantic salmon's listing under the Endangered Species Act and Atlantic wolffish's relatively lower commercial landings. It is conceivable that years of overfishing, combined with other factors, resulted in a significant decline of the commercial contribution of each of these stocks, precluding FSSI designation at the outset. More information regarding the tragedy of Atlantic salmon is presented in historical detail by Montgomery (2003). As for Atlantic wolffish, there are recent concerns that the stock may be rapidly headed toward extinction (Conservation Law Foundation, 2008).

As of the beginning of 2011, there are two stocks in the New England region and four in the South Atlantic that are determined to be subject to overfishing but are not classified as overfished. These are: Atlantic cod–Gulf of Maine and windowpane–Southern New England/Mid-Atlantic in New England; and in the South Atlantic, gag, speckled hind, tilefish, vermillion snapper and Warsaw grouper. Additionally, three New England stocks are no longer classified as subject to overfishing or overfished but are still undergoing rebuilding efforts. These are Acadian redfish–Gulf of Maine/Georges Bank, American plaice–Gulf of Maine/Georges Bank and barndoor skate–Georges Bank/Southern New England.

In the South Atlantic region, pink shrimp are classified as overfished as outlined by the stock's biological definition; however, the pink shrimp fishery is decidedly different from groundfish fisheries and will not be considered in this analysis.[5]

Beyond the stocks displayed in Table 1 and the aforementioned exceptions, there are no additional overfished fisheries in the three targeted regions; however, there are several FSSI and non-FSSI stocks for which overfished status is either unknown or undefined in New England (two), the South Atlantic (74) and the Gulf of Mexico (41). For a detailed list of these unknown or undefined stocks, please see

[4] Smooth skates may no longer be designated as overfished, according to new survey data collected through 2010, although at this time thorny skates will probably remain classified as overfished (Thompson, 2011).

[5] The South Atlantic pink shrimp stock is officially considered an annual crop, eliminating the requirement of a rebuilding plan (NMFS, 2010b). The South Atlantic fishery management plan for shrimp states that with favorable environmental conditions, high fecundity enables pink shrimp to rebound from a very low population size to a high population size in a short period (SAFMC, 1996). The Shrimp Review Advisory Panel recently concluded that the parent stock was in decline, not because of overfishing but rather environmental and climatic factors (NMFS, 2010b). It would seem that if favorable environmental conditions keep the stock relatively impervious to crashing, then a decline due to environmental factors should require attention.

Appendix A. In the five council regions and the Highly Migratory Species management division outside the scope of this study, an additional total of 23 FSSI and non-FSSI stocks are classified as overfished as reported in the first quarter of 2011.

3. DATA COLLECTION AND METHODS

To conduct our analysis, we first identified the fish stocks for which adequate data were available (see Section 2, Table 1). For each stock, we then assembled the following data:

- Scientifically determined MSY reference points.
- Enforced or proposed commercial vs. recreational allocations (where available).
- Commercial price per pound in 2009.
- Commercial landings (pounds) in 2009.

Sources for these data are referenced in Table D.1 in Appendix D and consist of NMFS data, individual stock assessments, regional council documents and personal communication with council staff. All estimates are reported in 2009 dollars unless otherwise noted.

To estimate catch losses from overfishing, we needed to compare the current commercial harvest level for each fishery to *potential* commercial landings if the fishery were not overfished. Potential landings could be estimated on the basis of optimal yield (OY) or MSY. The MSA (Section 3 [33] MSA, 2007) defines OY as the amount of fish that:

> (a) will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems;
>
> (b) is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor; and
>
> (c) in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the maximum sustainable yield in such fishery.

OY is typically found by determining the yield that corresponds to a given percentage decrease in the fishing rate that achieves the MSY of a healthy fish stock. The estimate of MSY is instrumental to determining OY, though the actual calculation of OY varies widely depending on biological, economic and social factors particular to the stock in question. There are often two types of OY estimates: a longer term "equilibrium OY," based on the stock at healthy, equilibrium biomass levels; and shorter-term "rebuilding OY" set at low levels to facilitate successful rebuilding of overexploited fisheries with legally required rebuilding plans. Estimates of OY in the latter case are more like moving targets that would increase as the stock rebuilds.

Many have debated the appropriateness of using MSY or OY as a management tool for fisheries (Roughgarden and Smith, 1996; Jennings *et al.,* 2001; Heneman, 2002; Walters *et al.,* 2005; Legovic *et al.,* 2010). MSY, however, is still the most "readily understood and operational" concept within fisheries management (Mace, 2004). Potential landings based on MSY rather than OY are larger and, in our analysis, would lead to higher estimates of catch losses. We chose, however, to base our estimates of catch losses on OY, on the grounds that MSA requires fishery councils to set management levels at OY, since fishing directly at MSY is neither biologically nor economically optimal.[6]

As discussed, estimates of OY vary according to fish stock but are typically based on a reduction of the harvest rate associated with MSY. However, current equilibrium OY levels specific to each fish stock in

[6] Economically, while it may appear initially that harvesting at the MSY would garner the largest profit, this is not necessarily true. A harvesting rate that is less than MSY, where marginal revenue equals marginal cost, is actually where economic rents are maximized (Christy and Scott, 1965). The economic rent is the difference between the value of the catch and the cost of that catch. Grafton, Kompass and Hilborn (2007) support a lower harvesting rate, too, showing that under reasonable prices, costs and discount rates, it is not economic to exploit fisheries to extinction and that an economically optimizing biomass is above that supporting MSY.

our analysis could not be determined, nor could we estimate them with the provided information; therefore, we estimated OY as a direct percentage of MSY.[7] Healthy fish stocks may have equilibrium OY levels that typically represent 70 to 100 percent of estimated MSY, while overfished stocks have rebuilding OY levels ranging from 0 to 100 percent of MSY depending on specific management plans and goals. Furthermore, some of the stocks in our analysis are currently assigned very low OYs under their respective rebuilding plans; higher OYs would apply if stocks were returned to the healthy equilibrium levels we assume for our catch loss analysis. For these reasons, our analysis assumes that potential landings based on OY represent 75 percent of potential landings based on MSY. We chose 75 percent of MSY as a conservative proxy for OY for each stock given that our catch loss estimates assume healthy stocks. The given equilibrium OY levels we did find for specific stocks in our analysis exceeded 75 percent of MSY (see Appendix C), however, New England stock assessments indicate that the OY in the New England stocks may be closer to 75 percent. We recognize that 75 percent of MSY may not be the most accurate proxy for OY for each stock considered, and catch losses estimated based on alternative proxies of OY (65 percent, 85 percent and 95 percent of MSY) are also presented in this study.

In our analysis, we did not assume that 100 percent of the OY would be allocated for commercial fishing. In the South Atlantic and Gulf of Mexico regions, where recreational fishing of many overfished species is popular, recreational fishing may have a larger economic impact than commercial fishing (Griffin *et al.*, 2009; Gentner, 2011). In these regions, we determined the commercial allocation percentages we applied in our analysis from official council decisions, where available, as referenced in Appendix D. Because the South Atlantic red snapper and red grouper fisheries had no previously designated allocations, we took as the commercial allocations the proportion of commercial landings to total landings reported by Southeast regional staff from 2009.[8] In New England, annual catch limits do not include a specific allocation between commercial and recreational harvesting. After consulting with New England Fishery Management Council representatives, we assumed that 100 percent of OY goes to the commercial fishing sector.

To estimate catch loss from overfishing, we estimate the difference between maximum revenue obtainable from the fishery and the actual revenue obtained in 2009. The lost economic revenue for each stock (LER_s) is calculated in four steps. First, the MSY (*M*) of that stock is multiplied by 75 percent to produce the proxy value of OY, which is then multiplied by the allocation (*A*) to commercial fishing, multiplied again by the current commercial price per pound (*P)* for that stock, minus the value of current commercial landings (*PxL*).

$$LER_s = \left(M(.75)AP\right) - \left(PL\right)$$

For a specific region (*r*) considered in the analysis, the estimate of lost economic revenue per region (LER_r) can be calculated as the sum of the estimates of LER_s for this region over all stocks (*S*) or:

$$LER_r = \sum_{s \in S} LER_s$$

The estimated lost economic revenue (LER_{TOT})) for all stocks ($s \in S$) considered in this analysis is therefore:

$$LER_{TOT} = \sum_{r \in R} LER_r = \sum_{r \in R} \sum_{s \in S} LER_s$$

[7] We present the current OY levels used for stocks considered in this analysis (where available) in Appendix C.

[8] It is notable that in 2010, harvest of South Atlantic red snapper was prohibited for both commercial and recreational fishing sectors.

Using these calculations and the aforementioned assumptions, we conducted an analysis that compares the value of actual 2009 commercial landings with estimated commercial landings if the fisheries had not been overfished.[9]

4. RESULTS

Results presented in this section and summarized in Table 2 assume OY levels that are equivalent to 75 percent of MSY. In Section 4.2, we present a wider range of catch loss estimates based on alternative approximations of OY. In Section 5, we briefly discuss the broader economic implications of catch losses and overfishing.

4.1. Forgone Landings—Direct Value

Table 2 presents the results of our catch loss analysis for targeted stocks in each of the three study regions. The aggregate catch loss summed over all three regions in 2009 was estimated at $164.2 million. Of all stocks and all regions, the New England Atlantic cod–Georges Bank fishery is estimated to have the largest single stock catch loss, estimated at $46.3 million in 2009. This is followed by the New England winter flounder–Georges Bank fishery and the New England Atlantic halibut fishery, both with estimated catch losses of approximately $26.5 million in 2009. The highest estimated catch loss in the South Atlantic in 2009 was the black sea bass at $1.2 million; in the Gulf of Mexico in 2009, the red snapper stock was the largest estimated catch loss at $10.3 million.

The catch loss value for the New England region as a whole ($149 million) far exceeded the regional catch losses in the South Atlantic ($2.9 million) and Gulf of Mexico ($12.3 million). The New England region manages more stocks classified as overfished than any other region in the country. In addition, estimates of commercial catch losses in the Gulf of Mexico and South Atlantic may be smaller than in New England because of the large allocations to recreational fishing. In the South Atlantic and Gulf of Mexico regions, our analysis does not capture catch losses associated with recreational fishing.

The last column in Table 2 displays the percentage of estimated potential landings realized by current landings. For example, in New England, winter flounder–Georges Bank landings were approximately $6.4 million, compared with a $9.6 million estimated potential; thus, approximately 66 percent of potential landings were realized. This measure allows for interesting comparisons. In the New England region, for example, winter flounder–Georges Bank had the highest percentage of landings realized, though its catch loss was not the smallest. In New England, ocean pout and windowpane–Gulf of Maine/Georges Bank had the lowest percentage of landings realized, zero each, though again, their respective catch losses were among the smallest.

Generally, current harvests in the South Atlantic and Gulf of Mexico seem to realize a greater portion of potential landings than those in New England. As mentioned previously, this is most likely affected by the different commercial allocations among the regions. The Gulf of Mexico gray triggerfish stands out with only 8 percent realized.

The New England region overall had the lowest percentage of landings realized, 21 percent, compared with the South Atlantic and Gulf of Mexico totals of 57 and 48 percent, respectively. The sum total constitutes only 25 percent of potential landings over all stocks in all regions.

[9] Commercial prices vary with landings. Healthier stocks and larger commercial landings typically lead to lower commercial prices, holding all other factors constant. Because our analysis was specific to 2009 landings, we applied 2009 commercial prices.

Table 2. Estimated Catch Loss by Region (2009)

New England	MSY (1000 lb lw)	75% OY (1000 lb lw)	% to com-mercial	Potential landings (1000 lb lw)	Potential value (1000 $)	2009 $/lb	Total landed (1000 lb lw)	Current value (1000 $)	Estimated catch loss (1000 $)	% value real-ized
Atlantic cod–GB	68,694	51,520	100%	51,520	*$65,880*	$1.28	15,340	$19,615	$46,265	30%
Atlantic halibut	7,716	5,787	100%	5,787	*$26,959*	$4.66	99	$461	$26,499	2%
Ocean pout	8,276	6,207	100%	6,207	*$3,645*	$0.59	0	$0	$3,645	0%
White hake	12,787	9,590	100%	9,590	*$9,232*	$0.96	4,070	$3,918	$5,314	42%
Windowpane–GOM/GB	1,543	1,157	100%	1,157	*$508*	$0.44	4	$2	$507	0%
Winter flounder–GB	7,716	5,787	100%	5,787	*$9,626*	$1.66	3,823	$6,358	$3,267	66%
Winter flounder–SNE/MA	21,477	16,108	100%	16,108	*$26,792*	$1.66	172	$286	$26,506	1%
Witch flounder–NAC	5,185	3,889	100%	3,889	*$7,512*	$1.93	2,028	$3,918	$3,594	52%
Yellowtail flounder–CC/GOM	3,792	2,844	100%	2,844	*$3,814*	$1.34	1,197	$1,606	$2,209	42%
Yellowtail flounder–GB	20,723	15,543	100%	15,543	*$20,846*	$1.34	2,147	$2,880	$17,966	14%
Yellowtail flounder–SNE/MA	13,448	10,086	100%	10,086	*$13,528*	$1.34	218	$293	$13,235	2%
								SUBTOTAL	**$149,008**	**21%**

South Atlantic	MSY (1000 lb ww)	75% OY (1000 lb ww)	% to commer cial	Potential landings (1000 lb ww)	Potential value (1000 $)	2009 $/lb	Total landed (1000 lb ww)	Current value (1000 $)	Estimated catch loss (1000 $)	% value realiz ed
Black sea bass	2,778	2,083	43%	896	*$1,994*	$2.23	363	$808	$1,185	41%
Red grouper	1,110	833	60%	500	*$1,372*	$2.75	431	$1,183	$189	86%
Red porgy	626	469	50%	235	*$342*	$1.46	165	$240	$102	70%
Red snapper	2,431	1,823	35%	638	*$2,289*	$3.59	362	$1,298	$991	57%
Snowy grouper	313	235	95%	223	*$674*	$3.02	89	$270	$404	40%
								SUBTOTAL	**$2,872**	**57%**

Gulf of Mexico	MSY (1000 lb ww)	75% OY (1000 w lb ww)	% to commer cial	Potential landings (1000 lb ww)	Potential value (1000 $)	2009 $/LB	Total landed (1000 lb ww)	Current value (1000 $)	Estimated catch loss (1000 $)	% value realiz ed
Gag	4,270	3,202	39%	1,249	*$4,151*	$3.32	843	$2,802	$1,350	67%
Gray triggerfish	1,638	1,229	21%	258	*$270*	$1.05	19	$20	$249	8%
Greater amberjack	5,039	3,779	27%	1,020	*$1,059*	$1.04	601	$624	$435	59%
Red snapper	14,960	11,220	51%	5,722	*$18,224*	$3.18	2,500	$7,962	$10,262	44%
								SUBTOTAL	**$12,296**	**48%**
								GRAND TOTAL	**$164,176**	**25%**

4.2. Alternate Assumptions—Direct Value

The results in Table 2 closely align with current management practices; however, catch loss estimates are sensitive to changes in underlying assumptions about potential catches. In Table 3, we present three additional sets of estimates of commercial catch loss based on different assumptions about potential catch. In Scenario A, 95 percent of MSY is available for commercial fishing allocations. In Scenario B, potential catch is based on 85 percent of MSY as OY. In Scenario C, OY is equal to 75 percent of MSY; this is the scenario that produced the results in Section 4.1 and Table 2 above. Finally, in Scenario D, potential catch is based on a low estimate of OY; OY is equal to 65 percent of MSY. We apply the same commercial allocation percentages and prices across each scenario.

Table 3. Estimated Catch Loss by Region Under Varied Scenarios (2009)

	New England		South Atlantic		Gulf of Mexico		GRAND TOTAL	
Scenarios	Catch loss	% value realized	Catch loss	% value realized	Catch loss	% value realized	Catch loss	% value realized
A. 95% of MSY to be respectively allocated to commercial fisheries	$199.2 million	16%	$4.7 million	45%	$18.6 million	38%	**$222.5 million**	**20%**
B. 85% of MSY to be respectively allocated to commercial fisheries	$174.1 million	18%	$3.8 million	50%	$15.5 million	42%	**$193.3 million**	**22%**
C. 75% of MSY to be respectively allocated to commercial fisheries	$149.0 million	21%	$2.9 million	57%	$12.3 million	48%	**$164.2 million**	**25%**
D. 65% of MSY to be respectively allocated to commercial fisheries	$123.9 million	24%	$2.0 million	66%	$9.1 million	56%	**$135.0 million**	**29%**

Not surprisingly, estimates of catch losses are significantly higher (about $222.5 million) if we assume that a higher portion (95 percent) of MSY is available for commercial fishing allocations. As shown in Appendix C, this scenario may be more representative of management practices for the South Atlantic and Gulf of Mexico. Higher catch loss estimates do not indicate that fishery allocations should be made on these bases. The ecological and economic impacts associated with various management regimes have to be carefully considered and weighed (see Appendix B).

These catch loss estimates imply that only small fractions of potential values are currently realized; only in three instances throughout all four scenarios (the South Atlantic in Scenarios C and D, and the Gulf of Mexico in Scenario D), do the current landings values realize more than half of estimated potential commercial values. It is important to note again that there are additional losses incurred in the recreational fisheries in the Gulf and South Atlantic regions not accounted for here.

The differences among catch loss estimates from the four scenarios are substantial, in total and by region. However, all four scenarios, from the least to most conservative assumptions, agree that approximately 71 to 80 percent of potential landings are currently not being realized due to historic overfishing. Furthermore, broader economic impacts of overfishing should not be overlooked, such as associated economic losses in backward- and forward-linked industries (see Appendix E for a brief discussion on this and overfished stocks globally).

5. CONCLUSION

The losses resulting from historic overfishing are significant. We analyzed 2009 estimated catch losses to commercial fisheries in the New England ($149 million), South Atlantic ($2.9 million) and Gulf of Mexico ($12.3 million) regions. The aggregate catch loss summed over all three regions in 2009 was estimated at $164.2 million, but could be as high as $222.5 million under less-conservative assumptions about potential catch size.

Catch loss estimates are based on forgone gross revenues from landings of overfished stocks as compared to landings values of these stocks at healthy levels. They do not account for forgone benefits from other potential economic activity in industries related to commercial harvesting, such as bait and tackle shops, commercial processing, seafood retail and throughout the economy at large. Overfishing also contributes to losses in other industries, such as recreational fishing, which this study did not capture. Finally, overfishing leads to critical losses in biodiversity, ecosystem services, and food security, the sum total impact of which may well exceed the value of lost output by commercial fisheries.

Catch losses are but one important component of the total economic costs of overfishing. Nevertheless, the estimates of catch loss provided by this study provide a strong economic argument in support of maintaining healthy ocean fish populations and continuing efforts to rebuild stocks currently subject to overfishing or classified as overfished.

APPENDIX A: List of Stocks with Overfished Status Unknown or Undefined[10]

If definitions exist but do not apply to certain stocks or are not available, the stock is listed as *undefined*. If there is no basis for making a determination, the stock is listed as *unknown*.

New England	FSSI Stock?	Overfishing?	Overfished?
Red deepsea crab–Northwestern Atlantic	Yes	No	Unknown
Winter flounder–Gulf of Maine	Yes	Unknown	Unknown
South Atlantic			
Gray triggerfish	Yes	No	Unknown
Hogfish	Yes	Unknown	Unknown
Scamp	Yes	No	Unknown
Speckled hind	Yes	Yes	Unknown
Warsaw grouper	Yes	Yes	Unknown
White grunt	Yes	No	Unknown
Wreckfish	Yes	No	Unknown
Little tunny–Gulf of Mexico	Yes	No	Undefined
Goliath grouper–Southern Atlantic Coast /Gulf of Mexico	Yes	No	Unknown
Caribbean spiny lobster–Southern Atlantic Coast /Gulf of Mexico	Yes	No	Unknown
Black corals (*Antipatharia*)	No	No	Undefined
Fire corals (*Milleporidae*)	No	No	Undefined
Hydrocorals (*Stylasteridae*)	No	No	Undefined
Soft corals (*Octocorallia*)	No	No	Undefined
Stony corals (*Scleractinia*)	No	No	Undefined
Golden deepsea crab	No	Unknown	Unknown
Jonah crab	No	Undefined	Undefined
Red deepsea crab	No	Undefined	Undefined
Almaco jack	No	Unknown	Unknown
Atlantic spadefish	No	Unknown	Unknown
Banded rudderfish	No	Unknown	Unknown
Bank sea bass	No	Unknown	Unknown
Bar jack	No	Unknown	Unknown
Black margate	No	Unknown	Unknown
Black snapper	No	Unknown	Unknown
Blackfin snapper	No	Unknown	Unknown
Blue runner	No	Unknown	Unknown
Blueline tilefish	No	Unknown	Unknown
Bluestriped grunt	No	Unknown	Unknown
Coney	No	Unknown	Unknown
Cottonwick	No	Unknown	Unknown
Crevalle jack	No	Unknown	Unknown
Cubera snapper	No	Unknown	Unknown
Dog snapper	No	Unknown	Unknown
French grunt	No	Unknown	Unknown
Grass porgy	No	Unknown	Unknown
Gray snapper	No	No	Unknown
Graysby	No	Unknown	Unknown
Jolthead porgy	No	Unknown	Unknown
Knobbed porgy	No	Unknown	Unknown
Lane snapper	No	No	Unknown
Lesser amberjack	No	Unknown	Unknown
Longspine porgy	No	Unknown	Unknown
Mahogany snapper	No	Unknown	Unknown
Margate	No	Unknown	Unknown

[10] Summary of Stock Status for FSSI and Non-FSSI Stocks—Fourth Quarter 2010 (NMFS, 2010b)

Misty grouper	No	Unknown	Unknown
Nassau grouper	No	No	Unknown
Ocean triggerfish	No	Unknown	Unknown
Porkfish	No	Unknown	Unknown
Puddingwife	No	Unknown	Unknown
Queen snapper	No	Unknown	Unknown
Queen triggerfish	No	Unknown	Unknown
Red hind	No	Unknown	Unknown
Rock hind	No	Unknown	Unknown
Rock sea bass	No	Unknown	Unknown
Sailors choice	No	Unknown	Unknown
Sand tilefish	No	Unknown	Unknown
Saucereye porgy	No	Unknown	Unknown
Schoolmaster	No	Unknown	Unknown
Scup	No	Unknown	Unknown
Sheepshead	No	Unknown	Unknown
Silk snapper	No	Unknown	Unknown
Smallmouth grunt	No	Unknown	Unknown
Spanish grunt	No	Unknown	Unknown
Tiger grouper	No	Unknown	Unknown
Tomtate	No	Unknown	Unknown
Whitebone porgy	No	Unknown	Unknown
Yellow jack	No	Unknown	Unknown
Yellowedge grouper	No	No	Unknown
Yellowfin grouper	No	Unknown	Unknown
Yellowmouth grouper	No	Unknown	Unknown
Wahoo	No	Unknown	Unknown
Cero–Southern Atlantic Coast/Gulf of Mexico	No	Unknown	Unknown
Ridged slipper lobster–Gulf of Mexico	No	Undefined	Undefined
Gulf of Mexico			
Red drum	Yes	No	Undefined
Hogfish	Yes	Unknown	Undefined
Nassau grouper	Yes	No	Undefined
Snowy grouper	Yes	Unknown	Undefined
Yellowedge grouper	Yes	Unknown	Undefined
Stone crabs (*Menippe spp.*)	Yes	No	Undefined
Bluefish	No	Unknown	Unknown
Black corals (*Antipatharia*)	No	No	Undefined
Fire corals (*Milleporidae*)	No	No	Undefined
Hydrocorals (*Stylasteridae*)	No	No	Undefined
Soft corals (*Octocorallia*)	No	No	Undefined
Stony corals (*Scleractinia*)	No	No	Undefined
Almaco jack	No	Unknown	Undefined
Anchor tilefish	No	Unknown	Undefined
Banded rudderfish	No	Unknown	Undefined
Blackfin snapper	No	Unknown	Undefined
Blackline tilefish	No	Unknown	Undefined
Blueline tilefish	No	Unknown	Undefined
Cubera snapper	No	Unknown	Undefined
Dog snapper	No	Unknown	Undefined
Dwarf sand perch	No	Unknown	Undefined
Goldface tilefish	No	Unknown	Undefined
Gray snapper	No	Unknown	Undefined
Lane snapper	No	Unknown	Undefined
Lesser amberjack	No	Unknown	Undefined
Mahogany snapper	No	Unknown	Undefined
Misty grouper	No	Unknown	Undefined

Queen snapper	No	Unknown	Undefined
Red hind	No	Unknown	Undefined
Rock hind	No	Unknown	Undefined
Sand perch	No	Unknown	Undefined
Scamp	No	Unknown	Undefined
Schoolmaster	No	Unknown	Undefined
Silk snapper	No	Unknown	Undefined
Speckled hind	No	Unknown	Undefined
Tilefish	No	Unknown	Undefined
Warsaw grouper	No	Unknown	Undefined
Wenchman	No	Unknown	Undefined
Yellowfin grouper	No	Unknown	Undefined
Yellowmouth grouper	No	Unknown	Undefined
Seabob	No	Unknown	Undefined

APPENDIX B: MSY and OY

Maximum sustainable yield (MSY) is the absolute maximum number of fish that can be removed from the ecosystem at a rate that leaves the existing stock size the ability to replace the removal. It has been argued by many, however, that harvesting at the rate associated with MSY is not the most biologically or economically optimal rate.

MSY has been the standard reference point in fishery management for more than five decades and continues to be so today, despite calls since the late 1970s to change it (Larkin 1977, for an example). May *et al.* (1979) highlight the need to recognize the important interactions among species as opposed to the single-species focus of calculating MSY. These concerns are still present in recent literature. Heneman (2002) points out the inherent contradiction between "maximum" and "sustainable" within MSY and calls for a completely new fisheries management model. Walters *et al.* (2005) and Legovic *et al.* (2010) fear that the reliance on MSY will ultimately result in the extinction of a large number of fish species due to the inability of MSY-based management methods to account for the large degree of complex interdependence between species in marine ecosystems.

MSY continues, however, to be defended and utilized in management practices. Despite falling out of favor for a while in the 1980s after heavy criticism, the MSY concept underwent a sort of reincarnation, bringing it back to the forefront of current fisheries management (Mace, 2001; Punt and Smith, 2001). While MSY had been described as a target harvest level to achieve, it is now seen more as an absolute harvest limit, which if surpassed may result in overfishing. In fact, the term overfishing limit is used more and more in recent stock assessments and official NOAA/NMFS documents, directly defined as corresponding to MSY. For a more thorough review of the controversy over MSY, see Punt and Smith (2001).

There are always uncertainties in MSY calculations and risks of unforeseen shocks to the fishery populations such as natural and man-made disasters and unpredictable levels of illegal or unregulated catch, among others. Biological models show that any reduction in the population corresponding with MSY for any reason will crash the stock, driving it to extinction; harvesting just below MSY at an economically favorable rate that corresponds with a smaller population size is also viewed as ecologically unstable and may result in a feedback loop that ultimately drives the stock to extinction (Roughgarden and Smith, 1996; Jennings *et al.*, 2001). Therefore, ecologists and biologists strongly advocate a harvesting rate below MSY, implying a larger corresponding population size (Milner-Gulland and Mace, 1998). These arguments additionally demonstrate that over time, harvesting at the prescribed rates below MSY maximizes long-term revenue in an uncertain and variable environment (Roughgarden and Smith, 1996).

While many uncertainties are still inherent in the calculation and utilization of MSY, it is the most "readily understood and operational" concept within fisheries management overall (Mace, 2004). But in consideration of the varied, serious concerns about MSY-based management, safeguards have been put in place, such as requiring fishery managers to plan and operate using OY statistics and the mandate of implementing annual catch limits, which are required to be significantly less than the estimates of MSY.

Economically, while it may appear initially that harvesting at the MSY would garner the largest profit, this is not necessarily true. A harvesting rate that is *less* than MSY, where marginal revenue equals marginal cost, is actually where economic rents are maximized (Christy and Scott, 1965). The economic rent is the difference between the value of the catch and the cost of that catch. Grafton, Kompass and Hilborn (2007) support a lower harvesting rate, too, showing that under reasonable prices, costs and discount rates, it is not economically efficient to exploit fisheries to extinction and that an economically optimizing biomass is above that supporting MSY.

Economic overfishing occurs at a harvest rate that does not maximize the long-term net sustainable rate of return from the fishery. This "economic overfishing" can result in a higher level of effort for a smaller stock size. Many economists recommend operating commercial fisheries at a lower level of fishing effort. Lowering fishing effort, however, is not necessarily the same as decreasing fishing costs. Lower aggregate fishing costs, from favorable subsidies or technological innovation, may increase fishing effort and may encourage economic and biological overfishing (Arnason *et al*., 2009).

Preventing the overexploitation of fish stocks is the goal of considerable fisheries regulations and management. The aforementioned issues of uncertainty, risk, ecological equilibriums and maximizing consistent economic efficiency have led the MSA to legally require fishery management and harvesting allowances at levels of OY, as opposed to MSY. OY is legally defined as the amount of fish that:

> (a) will provide the greatest overall benefit to the Nation, particularly with respect to food production and recreational opportunities, and taking into account the protection of marine ecosystems;
>
> (b) is prescribed as such on the basis of the maximum sustainable yield from the fishery, as reduced by any relevant economic, social, or ecological factor; and
>
> (c) in the case of an overfished fishery, provides for rebuilding to a level consistent with producing the maximum sustainable yield in such fishery.
>
> (Section 3 [33] MSA, 2007)

OY is typically found by determining the yield that corresponds to a given percentage decrease in the fishing rate that achieves the MSY of a healthy fish stock. The estimate of MSY is instrumental in determining OY, though the actual calculation of OY varies widely depending on a stock's biological, economic and social factors. There are often two types of OY estimates: 1) a longer-term "equilibrium OY," based on the stock at healthy, equilibrium biomass levels; and 2) shorter-term "rebuilding OY" set specifically at low levels to facilitate successful rebuilding of overexploited fisheries with legally required rebuilding plans. Estimates of OY in the latter case are more like moving targets that would be expected to increase as the stock rebuilds.

This lower allowable harvest at OY as compared to MSY corresponds with a higher biomass level. Framed within a broader ecosystem approach, OY may better satisfy both biological sustainability and economic rent-maximizing objectives.

APPENDIX C: Current OY Levels

Table C.1 displays currently determined levels of OY for the stocks considered in this analysis, and the percentage of MSY the OY level constitutes. As discussed, estimates of OY vary according to fish stock but are typically based on a reduction of the harvest rate associated with MSY. However, current equilibrium OY levels specific to each fish stock in our analysis could not be determined, nor could we estimate them with the provided information; therefore, we estimated OY as a direct percentage of MSY.

Table C.1. Current Optimum Yield Values

South Atlantic	MSY (ww lb.)	OY (ww lb.)	OY % of MSY
Black sea bass	2,777,825	2,742,551	**98.7%**
Red grouper	1,110,000	1,064,000	**95.9%**
Red porgy	625,699	587,901	**94.0%**
Red snapper	2,431,000	2,425,000	**99.8%**
Snowy grouper	313,056	303,871	**97.1%**

Gulf of Mexico	MSY (ww lb.)	OY (ww lb.)	OY % of MSY
Gag	4,269,960	4,170,000	**97.7%**
Gray triggerfish*	1,638,000	567,000*	**34.6%***
Greater amberjack*	5,039,000	1,870,000*	**37.1%***
Red snapper	14,960,000	13,350,000	**89.2%**

* OY for these species are not an equilibrium OY level; they have specifically been set low to achieve rebuilding goals.

Sources for OYs: Respective Stock Assessments, SAFMC Amendments 15A (2007) and 17A (2010), and GMFMC Amendment 30A (2008)

New England stock assessments indicate that the OY for New England stocks may represent a lower percentage of MSY than the South Atlantic and Gulf of Mexico stocks. We recognize that taking a set percentage (75 percent, as presented in the main analysis) of MSY to estimate OY may not be the most accurate proxy for OY for each stock considered, and catch losses estimated based on alternative proxies of OY (65 percent, 85 percent and 95 percent of MSY) are also presented in this study.

APPENDIX D: Data Source Reference Table by Stock

Table D.1. Data Sources by Stock

New England	Source MSY	% to Commercial Fisheries	2009$/LB	Total Landed
Atlantic cod–GB	NEFMC Amendment 16 2009	NEFMC Framework Adjustment 44 2010	NMFS 2009	Northeast Preliminary Fisheries Statistics, NMFS 2010c
Atlantic halibut	NEFMC Amendment 16 2009	NEFMC Framework Adjustment 44 2010	NMFS 2009	NMFS 2009
Ocean pout	NEFMC Amendment 16 2009	NEFMC Framework Adjustment 44 2010	NMFS 2009	Northeast Preliminary Fisheries Statistics, NMFS 2010c
White hake	NEFMC Amendment 16 2009	NEFMC Framework Adjustment 44 2010	NMFS 2009	Northeast Preliminary Fisheries Statistics, NMFS 2010c
Windowpane–GOM/GB	NEFMC Amendment 16 2009	NEFMC Framework Adjustment 44 2010	NMFS 2009	Northeast Preliminary Fisheries Statistics, NMFS 2010c
Winter flounder–GB	NEFMC Amendment 16 2009	NEFMC Framework Adjustment 44 2010	NMFS 2009	Northeast Preliminary Fisheries Statistics, NMFS 2010c
Winter flounder–SNE/MA	NEFMC Amendment 16 2009	NEFMC Framework Adjustment 44 2010	NMFS 2009	Northeast Preliminary Fisheries Statistics, NMFS 2010c
Witch flounder	NEFMC Amendment 16 2009	NEFMC Framework Adjustment 44 2010	NMFS 2009	Northeast Preliminary Fisheries Statistics, NMFS 2010c
Yellowtail flounder–CC/GOM	NEFMC Amendment 16 2009	NEFMC Framework Adjustment 44 2010	NMFS 2009	Northeast Preliminary Fisheries Statistics, NMFS 2010c
Yellowtail flounder–GB	NEFMC Amendment 16 2009	NEFMC Framework Adjustment 44 2010	NMFS 2009	Northeast Preliminary Fisheries Statistics, NMFS 2010c
Yellowtail Flounder–SNE/MA	NEFMC Amendment 16 2009	NEFMC Framework Adjustment 44 2010	NMFS 2009	Northeast Preliminary Fisheries Statistics, NMFS 2010c
South Atlantic				
Black sea bass	SEDAR SAR 2005	SAFMC Amendment 17B 2010b	NMFS 2009	pers comm. Jack McGovern 2/21/12
Red grouper	SEDAR 19 SAR 2010	% to commercial over total landed 2009	NMFS 2009	pers comm. Jack McGovern 2/21/12
Red porgy	SEDAR SAR 2006a	SAFMC Amendment 15B 2008	NMFS 2009	pers comm. Jack McGovern 2/21/12
Red snapper	SAFMC Amendment 17A 2010a	% to commercial over total landed 2009	NMFS 2009	SAFMC Amendment 17A 2010a
Snowy grouper	SEDAR 4 SAR 1 2004	SAFMC Amendment 17B 2010b	NMFS 2009	pers comm. Jack McGovern 2/21/12
Gulf of Mexico				
Gag	SEDAR SAR 2007	pers comm. Jack McGovern 2/21/11	NMFS 2009	pers comm. Jack McGovern 2/21/12
Gray triggerfish	SEDAR 9 SAR 1 2006c	pers comm. Jack McGovern 2/21/11	NMFS 2009	pers comm. Jack McGovern 2/21/12
Greater amberjack	SEDAR 9 SAR 2 2006b	pers comm. Jack McGovern 2/21/11	NMFS 2009	pers comm. Jack McGovern 2/21/12
Red snapper	SEDAR SAR 2009	pers comm. Jack McGovern 2/21/11	NMFS 2009	pers comm. Jack McGovern 2/21/12

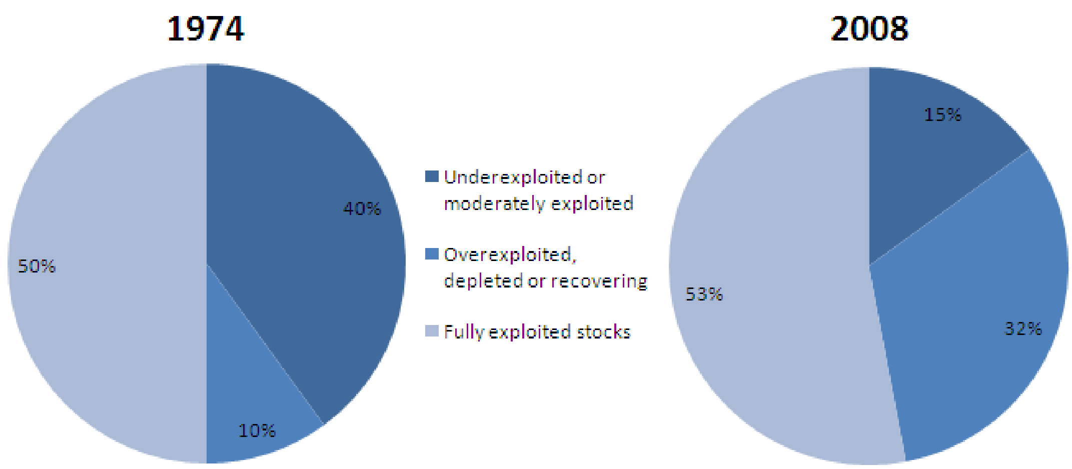
APPENDIX E: Broader Economic Impacts of Overfishing

Beyond the value lost in direct commercial landings due to overfishing, there are associated losses in both "backward" and "forward" linkages in the respective supply chains. Backward links refer to the labor, gear and other operating suppliers that support commercial fishing efforts. Forward links refer to the processing, wholesale and retail industries that purchase and add value to commercial landings harvests. The economic value of commercial landings contributes to additional indirect and induced effects in backward-linked industries. Indirect effects refer to the money spent by commercial fishermen on bait, gear, fuel, equipment maintenance and related operating costs that support commercial fishing efforts. Induced effects represent the boost to the economy provided by the overall spending by fishermen, their crews and the employees of the indirect industries, made possible by the earnings from commercial landings. The value of indirect and induced effects are typically determined using economic multipliers. Multipliers appropriate to these fish stocks and these regions could be applied to our estimates of catch losses to derive a fuller estimate of the economic impacts of historic overfishing in these regions.

Catch losses due to historic overfishing result in additional economic losses at forward links in the value chain beyond commercial harvesting. NMFS produces an annual fisheries statistics report that includes an economic value-added model for commercial fisheries (NMFS, 2009). The model calculates the value added at each forward step in the value chain, beginning with commercial harvest and ending at the point of final sale to consumers, thus estimating the total direct economic impact of the commercial fishing industry on the U.S. economy. Thus, our catch loss estimates at the harvesting level imply further losses in seafood processing and retail as well.

Catch losses in the New England, South Atlantic and Gulf Coast regions are perhaps best understood in the context of overexploited, depleted or recovering fish stocks worldwide. Globally, the proportion of fish stocks identified as overexploited, depleted or recovering has more than tripled, from 10 percent in 1974 to 32 percent in 2008 (FAO, 2010) (see Figure 2). Fully exploited stocks remain moderately consistent, while under- or moderately exploited stocks fell from 40 percent of the assessed stocks in 1974 to 15 percent in 2008, the lowest percentage yet recorded (FAO, 2010). The FAO terms "overexploited" and "depleted" roughly correspond with the NMFS terms "overfished" or "subject to overfishing" used throughout this report.

Figure 2. FAO Assessed Global Stocks Percentage Breakdown



The lost economic benefits from overharvesting global marine fisheries are estimated to be about $50 billion annually, or a cumulative $2 trillion over the past three decades, as published in a recent World Bank report on the economic justification for fisheries reform (Arnason *et al.,* 2009). These losses represent the difference between the estimated potential and the actual net economic benefits from global marine fisheries; the annual estimate of $50 billion is likely to be a conservative estimate. It includes only the direct value of commercial landings and excludes losses to recreational fisheries, marine tourism, fishery-dependent industries and global biodiversity, and does not consider the losses attributable to illegal fishing or compromise of the ocean carbon cycle. Thus, it is very likely that global economic losses from unsustainable exploitation of fish stocks substantially exceed $50 billion a year.

In addition, Arnason *et al.* (2009) identify massive overcapacity in the global fishing fleet and harmful subsidies resulting in stagnant productivity, severe economic inefficiency and fishery resource stocks performing well below their economic optimums. Economically healthy fisheries require biologically healthy fish stocks. To begin to address these issues and start on a path of economic recovery, the World Bank report recommends a serious decrease in global fish mortality and dedicated rebuilding of fish stocks.

Global marine catch losses from overfishing directly affect global food insecurity. Srinivasan *et al.* (2010) examined 11,804 fish stocks and estimated global potential catch losses due to historic overfishing. They then estimated levels of undernourishment that could have been avoided had the catch losses been realized. The results from their midlevel scenario suggested that in 2000, approximately 20 million people could have avoided undernourishment had fisheries not been overfished (Srinivasan *et al.*, 2010). The authors estimated potential catch losses by utilizing MSY levels, from which they subtracted actual recorded catch. Final results were summed over stocks, over years (1954–2004) to determine total global catch loss estimates, which were then converted into potential food energy amounts to determine country-specific estimates of the number of people for whom sustainable fishing might have alleviated hunger. The study of Srinivasan *et al.* (2010) is unique in its approach to analyzing the consequences of overfishing in the direct context of food security. They astutely remind us that fisheries are worth more than the economic output produced by commercial fishing.

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