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The potential for blue growth in marine fish yield, profit and abundance of fish in the ocean

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ABSTRACT

The oceans provide food, employment and income for billions of people. We analyzed data from scientific stock assessments, and from a statistical model for other fish stocks, to summarize the past and present status, and the potential catch, abundance and profit for 4713 fish stocks constituting 78% of global fisheries. Three major scenarios of future trends are considered; business as usual (BAU) in which largely unmanaged fisheries move towards bioeconomic equilibrium but where well-managed fisheries maintain their management, maximum sustainable yield (MSY) in which fisheries are managed to maximize yield, and fisheries reform (REF) where the competitive race to fish is eliminated and fisheries are managed to maximize profit. The future prospects differ greatly based on region of the world and product type. This analysis forecasts that yield in major tuna and forage fish species will remain roughly the same as current levels under all three scenarios, while there does appear to be potential for increased yield of whitefish. There is considerable room for increased profit in most of these fisheries from better management. Increased yield will come from rebuilding overexploited stocks, reducing fishing mortality on stocks that are still abundant but fished at high rates, and surprisingly from fishing some stocks harder. Indeed in Europe and North America the primary potential for increased yield comes from fully exploiting stocks that are now lightly exploited. Asia provides the greatest opportunity for increased fish abundance and increased profit by fisheries reform that would lead to reduced fishing pressure.

1. Introduction

Fishing is one of the most widespread, important, and impactful human activities affecting the world's oceans. Capture fisheries employ tens of millions of people [1] and fish are the most traded of food products in the global economy. The economic, social and nutritional importance of capture fisheries is especially great in the poorest countries [2] where capture fisheries may provide over 50% of the animal protein consumed locally and account for 50% of export earnings. The total landed value of capture fisheries is estimated at $80 billion [3] and including processing and retailing, the total value was estimated to be $200 billion. While the total economic value of fishing in the oceans is relatively small compared to oil and gas and marine transport, the importance for employment is far greater, and the role in food security is of the utmost importance. Thus capture fisheries are one of the most significant human activities in the oceans, and necessarily play a central role in the blue economy and blue growth.

So what is the potential of the oceans to produce more food, more jobs and more profit? Global capture fisheries volume as reported to the Food and Agriculture Organization of the United Nations (FAO) has been around 80 million tons while including discards [4] the estimates have reached over 100 million tons. Theoretical estimates of the potential harvest have ranged from a low of 22 million tons to a high of 1400 million tons [5–9]. These calculations are largely theoretical, and are based on assumptions that most of the potential was harvested regardless of the economics.

Sethi et al. [10] showed that new fisheries development has slowed dramatically and most new fisheries in recent decades have been targeting small stocks; though there are certainly large resources in the oceans that are unexploited, especially krill and mesopelagic stocks [11] which might have the potential to double global fish production. However, stocks that are currently unexploited are generally not economically viable to harvest, and under current fishing methods will likely remain unharvested. Thus the first step in analyzing the potential of capture fisheries to contribute to blue growth is to explore the status and potential of stocks that are currently fished.

Costello et al. [12] used data from 4713 fisheries worldwide,

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representing 78% of global reported fish catch, to estimate the status, trends, and benefits of alternative approaches to produce yield and profit from fisheries in addition to estimating the impact of alternative management approaches on the abundance of the species in the ocean. The three primary policy scenarios were (1) Business As Usual (BAU) in which current management approaches continue, (2) Yield maximization (FMSY) in which fishing mortality for each stock was set at the value that would produce long term maximum yield and (3) Fisheries Reform (REF (called "rights-based fishery management" in that paper)) in which fishing pressure was managed to maximize long term economic value. This paper uses the same set of models and data.

Costello et al. used two primary methods to estimate stock status and potential productivity. For stocks for which scientific assessments are publicly available in the RAM Legacy Stock Assessment Database (www.ramlegacy.org), the current abundance and fishing mortality rate were taken from the published stock assessments, and the potential productivity was either taken from the published assessment where available, or estimated using the methods of Worm et al. [13]. Stocks in the RAM Legacy database contain estimates of catch, biomass and recruitment over time, and are the result of detailed species by species analysis by scientific teams. For stocks where no scientific assessment was available, a new approach that combined a panel regression method (modified from Costello et al. [14]) with a biological model (modified from Martell and Froese [15]) was used. This model used a range of measures of catch trend and biological traits of the species to estimate the stock status. The parameters of the regression model were estimated from stocks in the RAM Legacy database which have scientifically derived values for stock status. This panel regression model provided an estimate of the current stock size, current fishing mortality rate, and the potential productivity under different harvest patterns. Profit was calculated using an economic model where operating costs were a function of fishing mortality rate, and allowed for price to depend on total global production.

At a global scale, Costello et al. estimated that under fisheries reform, catch could be increased by 14%, biomass by 37% and profit by 79% compared to 2012 levels. While most assumptions in the model were chosen to be conservative, there are two key assumptions in the Costello et al. analysis that may make their estimates optimistic. First, they assumed that each stock could be individually managed in such a way to either maximize yield (FMSY) or profit (REF). This ignores the fact that many stocks are caught in mixed fisheries and each stock cannot be individual managed. More generally, when there is considerable management imprecision, even if agencies have the objective and funding they may not precisely achieve either yield or profit maximization. Second, their analysis does not explicitly consider trophic interactions between species (though they do reduce MSY of forage fish by 25% to partially account for food web effects). Thus, in their analysis, rebuilding high trophic level predators would not systematically decrease the productivity of lower trophic levels, and rebuilding stocks at any trophic level would not impact their competitors productivity.

Despite these and other limitations, the Costello et al. paper does provide a useful first attempt to examine the potential to increase fisheries yield and profit at a stock specific level. Many of their results are surprising and robust to the limitations in the analysis. In their paper the results were presented either globally aggregated, or only for a small range of countries exclusively in Asia. This paper is motivated by the observation that, at present, there are striking differences in the management and status between regions around the world. The most important regions of the world in terms of catch reported to FAO are in descending order China, Korea, Japan and Pacific Russia (FAO Region 61 referred to as NE Asia), Western South America (primarily Peru and Chile FAO Region 87), SE Asia (FAO Regions 71 and 57), European Atlantic (FAO Region 27) and the NE Pacific (Primarily Alaska FAO Region 67). In recent decades, both the US and European Atlantic fisheries have been reformed and had pronounced declines in exploitation rates. Stock rebuilding has occurred for most of the assessed stocks. In contrast, stocks in Western South America, and almost all of Asia have not been reformed nor shown significant rebuilding. Thus it may be expected that the potential benefits of changing management practice, either to FMSY or to reform, will differ considerably by region.

Costello et al. separated out two major scenarios. In the "conservation concern" scenario, reforms were targeted only at stocks with current biomass less than biomass at maximum sustainable yield (B < BMSY) and/or current fishing mortality greater than fishing mortality at maximum sustainable yield (F > FMSY). Thus, that scenario did not consider fishing harder on currently underexploited fisheries. The second scenario applied reforms to all fisheries. In that scenario, large gains in catch (and often, profit) could be attained by fully exploiting the currently under-exploited stocks. Because this paper seeks to examine the potential of *all* global fisheries, this paper focuses on the latter scenario, and so will be able to distinguish between a fishery that can attain higher catches by fishing *less* vs. a fishery that can attain higher catches by fishing *more*. It turns out that large gains can be made in both categories, but how this plays out differs tremendously around the world. While many may find it surprising that large gains can be made from higher exploitation rates on some stocks, almost all published analyses of exploitation rates [13,16–19], show many stocks are exploited well below the level that produces maximum sustainable yield; our results are consistent with these earlier findings.

But fishery management does not just vary geographically, it also varies by the type of fish being caught. Thus, this paper will also explore the benefits of changed fisheries management for specific types of fish. The most abundant category of fish is small pelagic fishes, which includes anchovy, sardine, herring, mackerel, capelin and their relatives. The harvest of these species goes to a mix of feed for aquaculture and to human consumption, and in many countries provides a vital part of food security for some of the poorest people of the world. A number of these fisheries have undergone reform over the past decade or so, and these species generally are quick to respond to management efforts. Some of the most valuable fisheries of the world are the cods, hakes, haddocks and pollock, often called whitefish, and a very high fraction of these stocks have been reformed. Tunas and their relatives provide a contrast because they are found primarily beyond national exclusive economic zones (EEZs) and are managed by Regional Fisheries Management Organizations (RFMOs). Generally few of these fisheries have been reformed. Other major categories of fish stocks are compared because of their importance to global production are miscellaneous coastal fishes (much of Asia's fisheries fall in this category), miscellaneous demersal fisheries (again Asia is the major producer), squids and their mollusc relatives (cuttlefish and octopus), and shrimps.

This paper evaluates the potential for blue growth in different regions of the world and for different types of fish from implementing alternative fishery management actions. The potential growth (or loss) in yield and profit (and the associated change in fish stock biomass) are evaluated and how much of the potential growth in yield arises from reducing fishing pressure, and how much comes from increasing exploitation on underexploited resources are calculated.

2. Materials and methods

The stock-level results from Costello et al. are tabulated to compare catch, abundance, and profit in 2012 vs. 2050 for the three scenarios (BAU, FMSY, and REF). Each stock is classified into one of two groups, those where the fishing mortality rate in 2050 (under the REF) scenario was higher than in 2012 (these fisheries require fishing harder than current practice), and those where the fishing mortality rate in 2050 was lower than in 2012 (these fisheries require fishing less than current practice). For example, a stock that is currently experiencing severe overfishing would be categorized as a stock that would require "fishing less" to achieve better outcomes. But there are two classes of fisheries that would require "fishing more" to achieve better outcomes. The most

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