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Status and Solutions for the World's Unassessed Fisheries

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Recent reports suggest that many well-assessed fisheries in developed countries are moving toward sustainability. We examined whether the same conclusion holds for fisheries lacking formal assessment, which comprise >80% of global catch. We developed a method using species' life-history, catch, and fishery development data to estimate the status of thousands of unassessed fisheries worldwide. We found that small unassessed fisheries are in substantially worse condition than assessed fisheries, but that large unassessed fisheries may be performing nearly as well as their assessed counterparts. Both small and large stocks, however, continue to decline; 64% of unassessed stocks could provide increased sustainable harvest if rebuilt. Our results suggest that global fishery recovery would simultaneously create increases in abundance (56%) and fishery yields (8%-40%).

When sustainably managed, marine fisheries provide a major source of food and livelihoods for hundreds of millions of people worldwide (*1*). When poorly managed, these benefits to people and ecosystems are severely compromised (*2*). Despite this tremendous global significance, there is considerable debate among conservation and fisheries scientists about the status of global fisheries [e.g., (*3*) *and references therein*]. To date, assessing the biological status of fisheries has relied either on detailed stock assessments, which combine structural population models with data to estimate a species' population size and trajectories under different harvest scenarios, or on local knowledge and less formal analysis (*4*). A recent synthesis of global fisheries with formal assessments reveals that although 63% have a biomass below what would produce maximum sustainable yields (MSY), nearly half of these (45%) have lowered exploitation rates sufficient for recovery (*3*). A complementary analysis by the FAO found that 32% of 441 studied stocks are either overexploited (28%), depleted (3%), or recovering (1%) (*4*). However, it is unclear whether these results extend to the remainder of global fisheries; while 20% of global catch comes from assessed species (*5*, *6*), <1% of species have assessments, largely owing to intensive data requirements and cost. Here we explore the status of thousands of previously unassessed fisheries and use the estimates to inform the challenges and benefits surrounding global fisheries recovery.

The scientific literature includes widespread speculation on global fisheries status because of considerable ecological, social, and food security implications. One approach relies on indirect measures of fishery status (e.g., fraction of fisheries with declined catch, mean trophic level of catch, percentage of primary production appropriated by fishery catches) (*2*, *7*–*12*), but these approaches have many potentially confounding explanations. For example, declining catch is a necessary but not sufficient indicator of collapsed fisheries, resulting in unreliable estimates of stock status (*13*). A different approach uses status estimates from a smaller collection of "data-rich" fisheries (with formal assessments) as indicators for all fisheries (*13*), which also leads to unreliable predictions if data-rich fisheries differ fundamentally from unassessed fisheries (*3*).

Building on this literature, we developed a multivariate regression approach to identify predictors of stock status (B/B_{msy}) from assessed fisheries and use these models to estimate the status of unassessed fisheries (*14*). We couple the compilation of existing stock assessments (*5*) to an extensive database of characteristics of each unassessed fishery, such as time series of catch and fishery development (*6*) and species' life history traits (*15*). Building on fishery science, our method assumes that the status of a population is a function of its life history traits and harvest history, and the manner in which these variables collectively affect fishery status is consistent across species with similar characteristics.

Our approach utilizes the same kinds of variables (life history, fishery catch, etc.) as do stock assessments. Yet the approach departs fundamentally from traditional stock assessment because we never specify a structural

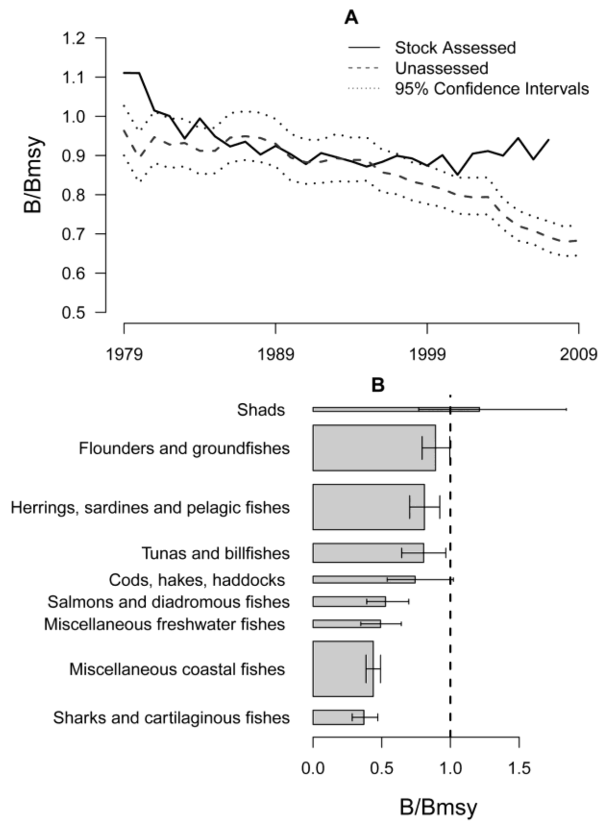

Fig. 1. (**A**) Time trend of median B/B_{msy} for stock assessed and unassessed fisheries. (**B**) Histogram of median predicted B/B_{msy} in 2009 for species categories of unassessed fisheries. Bar widths are proportional to the number of fisheries in each category.

Fig. 2. Time trend of median B/B_{msy} for unassessed fisheries (red) and assessed fisheries (black) with small landings (i.e., lifetime landings for a fishery is less than the median lifetime landings for all fisheries; solid line) and large landings (dashed line).

model linking these variables to stock status and we have no indices of abundance trends. By building a panel (i.e., longitudinal dataset), our approach captures both time series effects (e.g., how long the fishery has operated) and cross sectional effects (e.g., anchovies and sharks may respond differently to the same series of catch). This approach does not produce precise estimates for individual fisheries and therefore is not a substitute for formal assessment. However, it does provide a method for estimating the status of collections (including the global status) of previously unassessed stocks.

Regression models estimating $\log(B/B_{msy})$ predict stock status for assessed fisheries; we use six models of varying complexity (*14*) that are consistent with the scientific literature [e.g., (*16*–*18*)]. Specifically, B/B_{msy} is higher when catch shows an upward trajectory, and lower when current catches are consistently lower than historic levels. Small, quickly maturing species that can recover rapidly from mismanagement have higher B/B_{msy} than slow-growing species that take longer to reach sexual maturity and have lower sustainable exploitation rates.

To predict the status of unassessed fisheries, we compiled a companion database of 7,721 marine fisheries from the FAO landings database (*6*). There are strong caveats around aspects of these data (*19*), but they remain the best source of global fisheries catch records. This database determines the finest resolution for analysis—species caught by a country within an FAO region (fig. S2). After focusing exclusively on finfish and aggregating across countries for highly mobile species, our final dataset contains 1,793 distinct unassessed marine fisheries from around the world, comprising 23% of global landings (*6*). For each unassessed fishery, we applied the most data rich model possible, yielding time series estimates of B/B_{msy} for each fishery.

We found that 64% of unassessed fisheries have a stock biomass less than B_{msy} (*14*)—nearly identical to the comparable statistic (63%) for assessed fisheries (*3*). We also found that 18% (CI: 0.17-0.20) of unassessed stocks are collapsed (i.e., $B/B_{msy} < 0.2$), which is intermediate to other estimates [5% by (*17*), 14% by (*3*) and 30% by (*7*)]. Overall, we predict a median B/B_{msy} of 0.64 (CI: 0.60-0.68) for the world's unassessed fisheries in 2009—substantially lower than the median value of 0.94 exhibited by assessed fisheries in 2007, the nearest year for which data are available (Fig. 1A). Trends in assessed and unassessed stocks diverged in the mid-1990s; one possible explanation is a shift of effort from assessed (and well-managed) fisheries to unassessed ones (*20*).

We used our model to estimate status by categories such as species category, fishery size, socioeconomic conditions of the host nation, and geographic region. Although most species categories would benefit from management reform, small schooling fish such as herrings and sardines have relatively higher biomass than many slow-growing large-bodied fishes such as sharks (Fig. 1B). Larger than average unassessed fisheries have a median biomass near MSY (B/B_{msy} = 1.00; CI: 0.92-1.10; Fig. 2). Smaller stocks, which are critically important for biodiversity and small-scale seafood security, tend to be in much worse condition (B/B_{msy} = 0.49; CI: 0.45-0.53). These effects of fishery size hold over time, and both groups show continuing declines in biomass. We found that unassessed fisheries in the developing world (B/B_{msy}=0.70, CI: 0.60-0.80) may have higher stock biomasses, on average, than those in developed countries (B/B_{msy} of 0.56, CI: 0.51-0.62; supplementary online text). Geographically, the eastern Indian Ocean, including India, southern Indonesia, and Western Australia, have relatively high B/B_{msy}, while the Northwestern Atlantic, including the Northeastern United States and Canada, has among the lowest median B/B_{msy} (Fig. 3). In general there are stark contrasts between the median status of assessed and unassessed stocks, even in regions noted for well managed assessed stocks (e.g., New Zealand and Alaska; Fig. 3). However, our data coverage in some regions is low (Fig. 3) and thus geographical comparisons warrant caution.

We used five approaches to validate the accuracy of model predictions, including within sample validation for assessed fisheries, bias tests for fishery size and data errors, jackknife analyses, comparisons with FAO assessments, and comparisons with B/B_{msy} estimates from inside and outside more than 50 marine reserves around the world. Each of

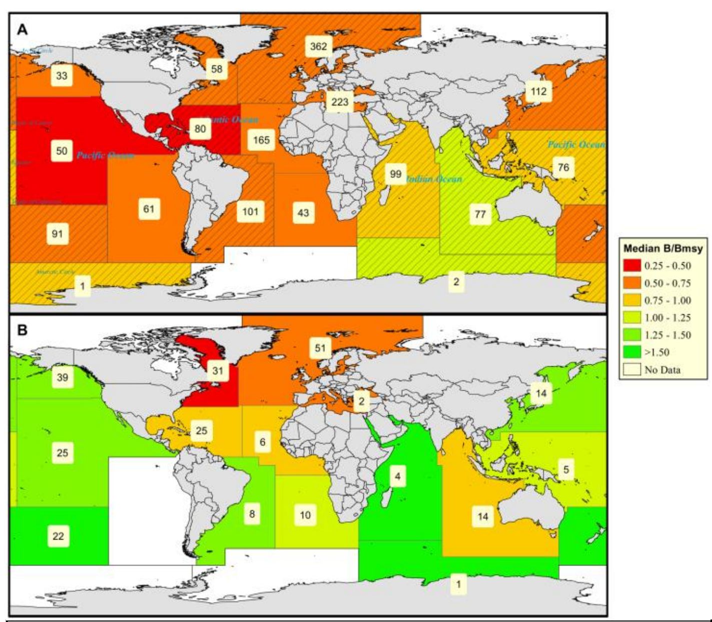

Fig. 3. Map of median B/B_{msy} of (**A**) unassessed fisheries in 2009 and (**B**) stock assessed fisheries (2000-2007) for FAO regions. Hashing indicates the model accounts for less than 40% of total reported landings in that region.

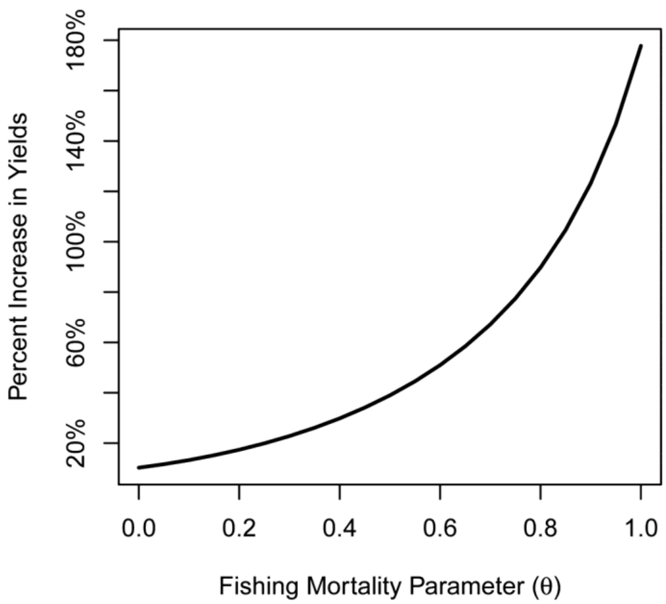

Fig. 4. Percent increase in fishery yields from moving to B_{msy} across a spectrum of possible fishing mortality rates. θ measures the fractional difference between fishing mortality to hold current biomass in steady state and fishing mortality at collapse.

these validations generally supported the value of this new assessment tool (supplementary online text).

The ability to estimate the status of thousands of unassessed stocks allows us to address a number of globally important policy questions. An immediate consequence of $B/B_{msy}<1.0$ is the increase in fishery yield and fish biomass that would result from recovery. Using B_{msy} as a target for rebuilding fisheries, the percentage increase in stock biomass that would result from reform is simply: $\%Increase=100*(B_{msy}/B-1)$. For example, recovering the median fishery in our analysis ($B/B_{msy}=0.64$) would generate a 56% increase in biomass left in the ocean.

Fishery recovery also ultimately increases yields. Many regions of the world with low B/B_{msy} also face pressing food security challenges, which will increase dramatically given projected changes in human populations and wealth in the coming decades (*21*). We find that in some fisheries, yields could more than double (supplementary online text), although it is worth noting that total global seafood production is dominated by a small number of large stocks. Forecasting the potential response for the median fishery requires estimating the current fishing mortality. Using the very conservative assumption that current mortality would stabilize B/B_{msy} at its current value, recovering the median fishery would increase yield by 15% and recovering all fisheries would increase yield by 8%. The continued declines in biomass for both large and small unassessed stocks, however, suggest current mortality is substantially higher. If instead we assume that unassessed fisheries are 50% closer to the fishing effort that would lead to their collapse, the predicted increase in yield from recovery is 51% for the median fishery and 40% globally (Fig. 4; supplementary online text).

Our analysis suggests large potential conservation and food benefits from improving the management of the world's unassessed fisheries. To realize these benefits requires successful approaches for fisheries reform. Limiting entry and using individual transferable quotas have been shown to benefit data-rich fisheries within developed countries (*22*). These approaches, however, may prove more challenging to implement for unassessed fisheries in developing countries, because they inherently require strong governance, rule of law and monitoring. Rather, approaches such as territorial user right fisheries (TURFs) (*23*), fisheries cooperatives (*24*), TURFs coupled with no-take reserves (*25*), and co-management approaches (*26*) are likely to be more broadly appropriate tools. In addition, coupling recent advances in data poor assessment (*27*) with these management instruments will be critical to success.

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Supplementary Materials
www.sciencemag.org/cgi/content/full/science.1223389/DC1
Materials and Methods
Supplementary Text
Figs. S1 to S13
Tables S1 to S12
References (*28*–*32*)

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