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Systematic distortions in world fisheries catch trends

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Over 75% of the world marine fisheries catch (over 80 million tonnes per year) is sold on international markets, in contrast to other food commodities (such as rice)[1,2]. At present, only one institution, the Food and Agriculture Organization of the United Nations (FAO) maintains global fisheries statistics. As an intergovernmental organization, however, FAO must generally rely on the statistics provided by member countries, even if it is doubtful that these correspond to reality. Here we show that misreporting by countries with large fisheries, combined with the large and widely fluctuating catch of species such as the Peruvian anchoveta, can cause globally spurious trends. Such trends influence unwise investment decisions by firms in the fishing sector and by banks, and prevent the effective management of international fisheries.

World fisheries catches have greatly increased since 1950, when the FAO of the United Nations began reporting global figures[3]. The reported catch increases were greatest in the 1960s, when the traditional fishing grounds of the North Atlantic and North Pacific became fully exploited, and new fisheries opened at lower latitudes and in the Southern Hemisphere. Global catches increased more slowly after the 1972 collapse of the Peruvian anchoveta fishery[4], the first fishery collapse that had repercussions on global supply and prices of fishmeal (Fig. 1a). Even taking into account the variability of the anchoveta, global catches were therefore widely expected to plateau in the 1990s at values of around 80 million tonnes, especially as this figure, combined with estimated discards of 16–40 million tonnes[5], matched the global potential estimates published since the 1960s (ref. 6). Yet the global catches reported by the FAO generally increased through the 1990s, driven largely by catch reports from China.

These reports appear suspicious for the following three reasons: (1) The major fish populations along the Chinese coast for which assessments were available had been classified as overexploited decades ago, and fishing effort has since continued to climb[7,8]; (2) Estimates of catch per unit of effort based on official catch and effort statistics were constant in the Yellow, East China and South China seas from 1980 to 1995 (ref. 9), that is, during a period of continually increasing fishing effort and reported catches, and in contrast to declining abundance estimates based on survey data[7]; (3) Re-expressing the officially reported catches from Chinese waters on

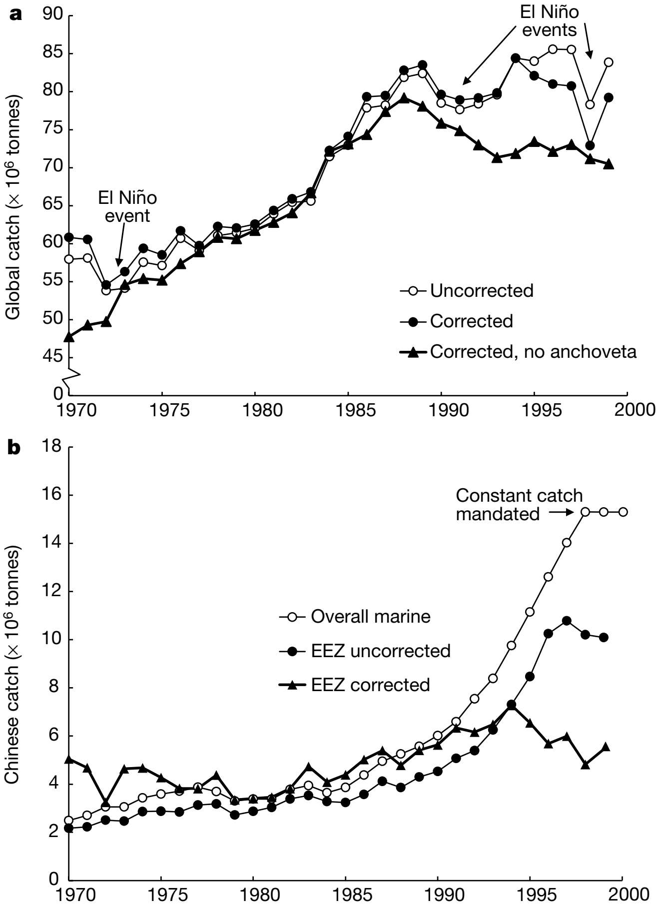

Figure 1 Time series of global and Chinese marine fisheries catches (1950 to present). **a**, Global reported catch, with and without the highly variable Peruvian anchoveta. Uncorrected figures are from FAO (ref. 3); corrected values were obtained by replacing FAO figures by estimates from **b**. The response to the 1982–83 El Niño/Southern Oscillation (ENSO) is not visible as anchoveta biomass levels, and hence catches were still very low from the effect of the previous ENSO in 1972 (ref. 4). **b**, Reported Chinese catches (from China's exclusive economic zone (EEZ) and distant water fisheries) increased exponentially from the mid-1980s to 1998, when the 'zero-growth policy' was introduced. The corrected values for the Chinese EEZ were estimated from the general linear model described in the Methods section.

a per-area basis leads to catches far higher than would be expected by comparison with similar areas (in terms of latitude, depth, primary production) in other parts of the world.

We investigated the third reason in some detail by generating world fisheries catch maps on the basis of FAO fisheries catch statistics for every year since 1950 (see Fig. 2a for a 1998 example). A statistical model was used to describe relationships between oceanographic and other factors, and the mapped catch. Most high-catch areas of the world were correctly predicted by the model. These areas typically had very high primary productivity rates driven by coastal upwellings, like those off Peru, supporting a large reduction fishery for the planktivorous anchoveta *Engraulis ringens*[4]. The exception was the waters along the Chinese coast. Here, the high catches could not be explained by the model using oceanographic or other factors. Yet the catch statistics provided to FAO by China have continued to increase from the mid-1980s until 1998 when, under domestic and international criticism, the government proclaimed a ‘zero-growth policy’ explicitly stating that reported catches would remain frozen at their 1998 value (Fig. 1b)[10].

Mapping the difference between expected (that is, modelled) catches and those mapped from reported statistics showed large areas along the Chinese coast that had differences greater than 5 tonnes $\mathrm{km}^{-2}\,\mathrm{year}^{-1}$. Overall, the statistical model for 1999 predicted a catch of 5.5 million tonnes, against an official report of 10.1 million tonnes (see Fig. 1b for earlier years). Although China was not the only FAO member country reporting relatively high catches, their large absolute value strongly affects the global total.

For a number of obvious reasons, fishers usually tend to underreport their catches, and consequently, most countries can be presumed to under-report their catches to FAO. Thus we wondered why China should differ from most other countries in this way. We believe that explanation lies in China’s socialist economy, in which the state entities that monitor the economy are also given the task of increasing its output[11]. Until recently, Chinese officials, at all levels, have tended to be promoted on the basis of production increases from their areas or production units[11]. This practice, which originated with the founding of the People’s Republic of China in 1949, became more widespread since the onset of agricultural reforms

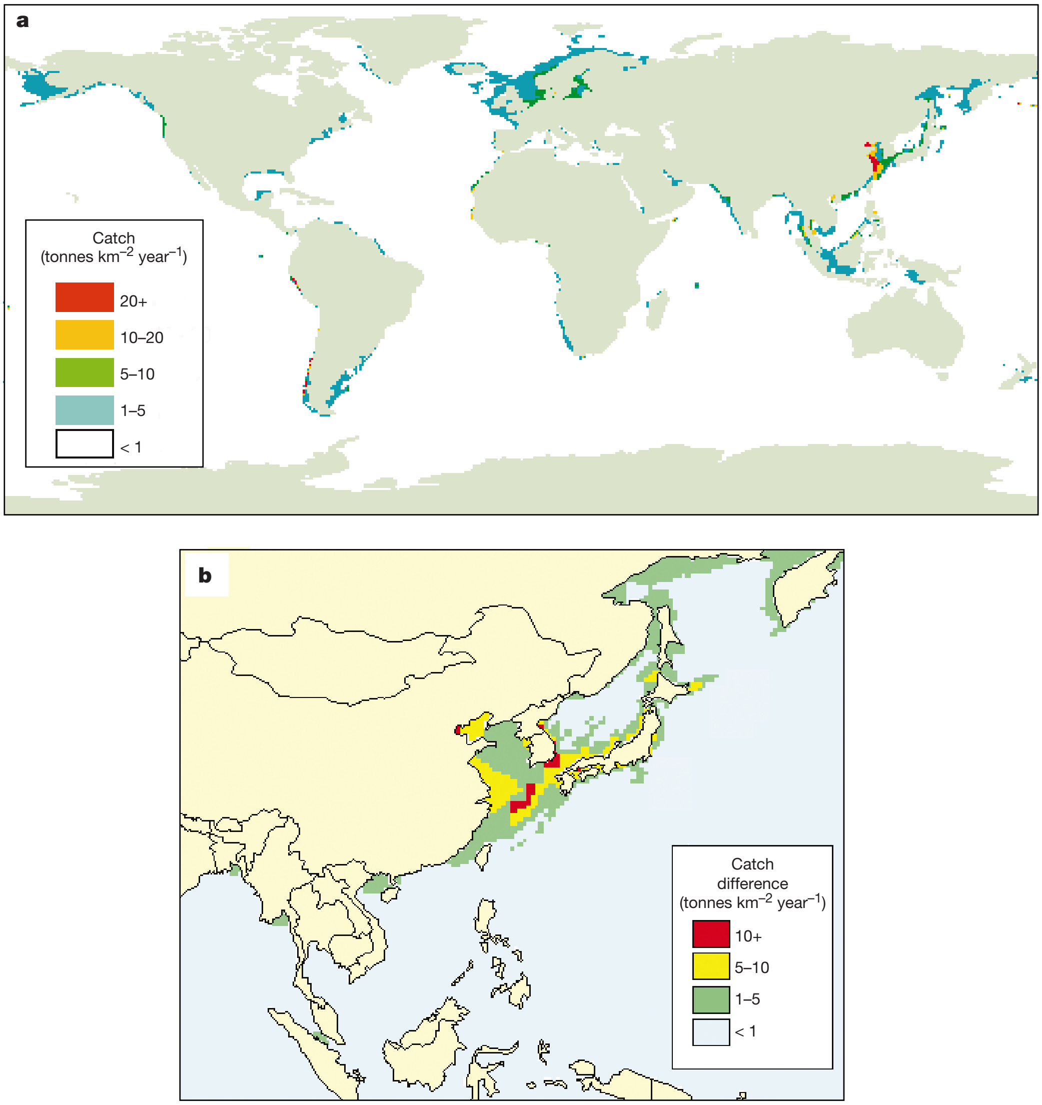

Figure 2 Maps used to correct Chinese marine fisheries catch in Fig. 1b. **a**, Map of global catches reported by FAO for 1998, generated by the rule-based algorithm described in the Methods section. We note the anomalously high values along the Chinese coast, comparable in intensity (not area covered) to the extremely productive Peruvian upwelling system. **b**, Map of differences in southeast and northeast Asia between the catches reported in **a** and those predicted by the model described in the Methods section.

that freed the agricultural sector from state directives in the late 1970s (refs 10, 11).

The Chinese central government appears to be well aware of this problem, and its 1998 'zero-growth policy' was partly intended to prevent over-reporting. Thus, the official fisheries catches for 1999–2000 are precisely the same as in 1998 (Fig. 1b), and will be for the next few years. Such measures, although well motivated, do not inspire confidence in official statistics, past or present.

The substitution of the more realistic estimated series of Chinese catches into the FAO fisheries statistics led to global catch estimates which, although fluctuating, have tended to decline by 0.36 million tonnes year^{-1} since 1988 (rather than increase by 0.33 million tonnes year^{-1}, as suggested by the uncorrected data). The global downward trend becomes clearer when the catches of a single species, the Peruvian anchoveta, which is known to be affected by El Niño/Southern Oscillation events, is subtracted (see Fig. 1a). In this case, a significant ($P < 0.01$), and so far undocumented downward trend of 0.66 million tonnes year^{-1} becomes apparent for all other species and fisheries. This is consistent with other accounts of worldwide declines of fisheries[12,13].

Ironically, it is likely that, at the lowest levels (individual fishers), catches are under-reported in China as elsewhere in the world. The production targets caused these reports to be exaggerated. At some times these two distortions may perhaps have cancelled each other out, and an accurate report of catches may have been submitted to FAO. Since the early 1990s, however, the exaggerations have apparently far exceeded any initial under-reporting.

The greatest impact of inflated global catch statistics is the complacency that it engenders. There seems little need for public concern, or intervention by international agencies, if the world's fisheries are keeping pace with people's needs. If, however, as the adjusted figures demonstrate, the catches of world fisheries are in general decline, then there is a clear need to act. The oceans should continue to provide for a substantial portion of the world's protein needs. The present trends of overfishing, wide-scale disruption of coastal habitats and the rapid expansion of non-sustainable aquaculture enterprises[14], however, threaten the world's food security. □

Methods

Data processing involved a disaggregation of global fisheries catch statistics firstly into detailed taxonomic groups, and then into fine-scale spatial cells (a half-degree of latitude by a half-degree of longitude), using a variety of databases and systematic rules[15]. The spatially disaggregated catches provided the basis for a general linear model of fisheries catches (see below). The model predicted the likely catches in the spatial cells in the Chinese exclusive economic zone (EEZ), thus providing an estimate of Chinese catches (including Hong Kong and Macau, but excluding Taiwan).

Data sources

Fisheries catch statistics were provided by the FAO (FishStat[3] and 'Atlas of Tuna and Billfish Catches', http://www.fao.org/fi/atlas/tunabill/english/home/htm). The spatial cells were described by depth (US National Geophysical Data Center), primary productivity (Joint Research Centre of the European Commission Space Applications Institute—Marine Environment Unit, http://www.gmes.jrc.it/download/kyoto_prot/glob.marine.pdf), biogeochemical provinces[16], the presence of ice (US National Snow and Ice Data Center, http://www.nsidc.org), surface temperature (NOAA's Marine Atlas, http://www.nodc.noaa.gov/OC5/data_woa.html), and an upwelling index calculated for each cell by multiplying negative deviations in surface temperature (from the average for that latitude and ocean) by the primary productivity in that cell. Fishing access rights were determined using maps of the exclusive economic zones (EEZ) of coastal states[17] and a database of fishing access agreements[18].

Taxonomic disaggregation

The fisheries statistics of several nations commonly include a large fraction of catches in 'miscellaneous' categories. Chinese catches so reported were disaggregated on the basis of the breakdown provided by its two nearest maritime neighbours with detailed marine fisheries statistics (Taiwan and South Korea)[15]. Assigning catches to lower taxa allowed the use of biological information in the spatial disaggregation process.

Spatial disaggregation

A database of the global distribution of commercial fisheries species was developed using information from a variety of sources including the FAO, FishBase[19] and experts on various resource species or groups. Some distributions were specific; others provided depth or latitudinal limits, or simple presence/absence data. The spatial disaggregation process determined the intersection set of spatial cells within the broad statistical area for which the statistics were provided to FAO, the global distribution of the reported species, and the cells to which the reporting nation had access through fishing agreements[15]. The reported catch tonnage was then proportioned within this set of cells.

Catch predictions

A general linear model was developed in the software package S-Plus[20]. The model relates log fisheries catch (in tonnes $\text{km}^{-2}\,\text{year}^{-1}$) for each cell (the dependent variable) to depth, primary productivity, ice cover, surface temperature, latitude, distance from shore, upwelling index (the continuous predictor variables), 33 oceanic biogeochemical provinces and one global coastal 'biome'[16] including most of the area covered by the world's EEZs, including China's (the categorical predictor variables). Fishing effort was not used in the prediction and catches were assumed to be generally close to their maximum biologically sustainable limits. The additive and variance stabilizing transformation (AVAS) routine of S-Plus[20] was used to identify transformations ensuring linearity between the dependent and explanatory variables, and the model was then used to predict the catch from each spatial cell. Those from Chinese waters were combined, then compared with the catches obtained from the rule-based spatial disaggregation described above.

Trend analyses

The estimates of recent trends of global catch were estimated by linear regression of catch versus year, for the period from 1988 (highest catches, anchoveta excluded) to 1999 (last year with FAO data), for uncorrected global marine catches, global marine catches adjusted for Chinese over-reporting, and adjusted catches minus the catch of Peruvian anchoveta.

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