Evolution of global marine fishing fleets and the response of fished resources

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Previous reconstructions of marine fishing fleets have aggregated data without regard to the artisanal and industrial sectors. Engine power has often been estimated from subsets of the developed world, leading to inflated results. We disaggregated data into three sectors, artisanal (unpowered/powered) and industrial, and reconstructed the evolution of the fleet and its fishing effort. We found that the global fishing fleet doubled between 1950 and 2015—from 1.7 to 3.7 million vessels. This has been driven by substantial expansion of the motorized fleet, particularly, of the powered-artisanal fleet. By 2015, 68% of the global fishing fleet was motorized. Although the global fleet is dominated by small powered vessels under 50 kW, they contribute only 27% of the global engine power, which has increased from 25 to 145 GW (combined powered-artisanal and industrial fleets). Alongside an expansion of the fleets, the effective catch per unit of effort (CPUE) has consistently decreased since 1950, showing the increasing pressure of fisheries on ocean resources. The effective CPUE of most countries in 2015 was a fifth of its 1950s value, which was compared with a global decline in abundance. There are signs, however, of stabilization and more effective management in recent years, with a reduction in fleet sizes in developed countries. Based on historical patterns and allowing for the slowing rate of expansion, 1 million more motorized vessels could join the global fleet by midcentury as developing countries continue to transition away from subsistence fisheries, challenging sustainable use of fisheries' resources.

fishing capacity | effort | CPUE | artisanal | industrial

Marine fisheries support global food security (1), human livelihood, employment (2), as well as global trade (3) and will continue to do so in the foreseeable future with the benefit of wise management.

Understanding fishing capacity is paramount to its management (4) and failure to manage fisheries compromises all of the services these vital resources offer. Although the importance of knowledge of fish stocks is undeniable, it cannot be disassociated from the fishing processes themselves. Catch per unit of effort (CPUE) is still a widely used measure of the well being of a fished stock (5), which cannot be estimated without some measure of the fishing capacity, defined hereafter in its simplest form—the number of existing fishing boats. Although there has been significant work to collect global fishing fleet data, most notably by the United Nation's Food and Agriculture Organization (FAO), gaps in the data are nontrivial, and no satisfying method has been found that fills them and allows for comparison or prediction without major and often flawed assumptions (6).

Although progress has been made toward reconstructing the historical size and power of the global fishing fleet (6, 7), several inconsistencies are apparent in the results. This is partially because public records aggregate disparate fishing fleets into one component as if they were easily interchangeable units. It is, however, well understood that global fishing fleets consist of, at least, two separable components: "artisanal" and "industrial," the former comprising both motorized and unmotorized elements. These components of the fleet, although interacting, are different in their scope and aims (8) and vary vastly in their regional definitions. The industrial fleets are better documented and reported than artisanal fleets (9), specifically how they developed to exploit often distant fish stocks, which could not be fished efficiently by artisanal fishers. Recent technological progress, particularly in electronic monitoring systems, has provided a substantial volume of information on the composition and behavior of the larger components of the industrial fleet (10). In contrast, the extent and impact of the artisanal fishing fleet is underestimated in the literature. This paper aims to strengthen the knowledge of the global marine fishing fleets by reconstructing the number and engine power of artisanal and industrial fishing vessels.

For centuries, fishing vessels used sails and oars as propulsion methods. The introduction of steam-powered trawlers and the subsequent improvements in propulsion had a dramatic effect on the efficiency of fishing vessels, their spatial reach, and on landings; perhaps best documented in the Northern Atlantic (11). Whereas the focus nowadays is on industrial fishing operations, a vast portion of global fishing still occurs at artisanal levels (12, 13). Furthermore, as the research on fisheries is biased toward the developed world, the impact of the unpowered artisanal fishing fleet is often overlooked in academic studies. As up to a quarter of fishing vessels are unmotorized globally (1), neglecting this component of the fleet and its transition through technological advances results in vast underestimates of the impact of fishing, particularly, in the poorest parts of the world. Improved understanding of the motorization of the fishing fleet and taking a step back from focusing almost exclusively on detailed industrial fleets are fundamental for both reconstructing

Significance

We independently reconstructed vessels number, engine power, and effort of the global marine fishing fleet, in both the artisanal and industrial sectors. Although global fishing capacity and effort have more than doubled since 1950 in all but the most industrialized regions, the nominal catch per unit of effort (CPUE) has comparatively decreased. Between 1950 and 2015 the effective CPUE, among the most widely used indicator to assess fisheries management and stocks well being, has decreased by over 80% for most countries. This paper highlights the large differences in the development of sectorial fishing fleets regionally. This detailed paper empowers future exploration of the drivers of these changes, critical to develop sector and regionally specific management models targeting global fisheries sustainability.

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the past and for predicting the future evolution of fishing fleets. In this paper, we compiled data from various sources to fill in the gaps in the knowledge of global marine fishing fleets, particularly, their history and level of motorization, the separation to artisanal (both motorized and unmotorized, referred hereafter as "powered-artisanal" and "unpowered-artisanal") and industrial sectors, and their fishing effort.

Results

The Size and Power of the Global Fishing Fleet. The number of vessels in the global marine fishing fleet doubled from 1.7 in 1950 to 3.7 million in 2015 (Fig. 1*A*). This increase is heterogeneous across the globe with a drastic increase in the size of the fishing fleet of Asia (defined hereafter as the countries in East Asia and the Indian Peninsula and excluding the Middle East, which were grouped instead with the Maghreb under "Arab World"), only slightly compensated by a fleet reduction in developed countries, such as observed in North America and Western Europe in the 1990s.

The magnitude of changes across the three sectors differs substantially. Although the unpowered-artisanal fleet declined by 0.2 million between 1950 and 2015, the motorized fleet, both powered-artisanal and industrial, increased more than six times over the same period (Table 1), accompanied by an increase in the mean engine power (Fig. 2 *D*–*F*). In 2012, we estimate that the global number of marine fishing vessels was 3.7 million, of which 68% were motorized (Fig. 2*A*–*C*). Our estimates agree with FAO estimates of 3.2 million and 70%, respectively (14). Parenthetically, although the 2018 State of World Fisheries and Aquaculture (SOFIA) report (1) estimates 4.6 million vessels globally in 2016, this includes the inland fishing fleet, excluded from our analysis. A simple proportionality rule with regard to the last disaggregated data indicates that, based on FAO data, the number of marine vessels decreased to 3.1 million in 2016, compared with our estimates which increased to 3.7 million in 2015. Similar differences are observed in the unmotorized marine fleet in 2015/16, estimated from SOFIA 2018 to be under 1 million, compared with our estimate of 1.2 million. Our estimates of the total engine power, however, is only half of that given by previous global studies (*SI Appendix*, Fig. S13).

The motor power of the entire global fishing fleet increased quasiexponentially from 1950 to the 1990s followed by a period of slower growth up to 2015 (Fig. 1*C*). Until the 1980s, the growth of both industrial and powered-artisanal engine power followed similar trends (Fig. 1 *E* and *F*). In the past three decades, however, the growth of industrial fleets has slowed considerably, and now the total engine power of the powered-artisanal sector is equal to that of the industrial. It is important to note, however, that the vastly varying definitions of artisanal fishing globally imply a certain level of uncertainty and overlap.

Regionally, the power of European, North American, and Australian fleets more than doubled from the 1950s to the 1980s, followed by a drastic reduction in the 2010s (Table 1). Their share of the global fleet, however, dropped drastically, especially its unpowered-artisanal component. By contrast, the Asian share of the global fleet and their total engine power have increased four times since 1950. This increase is particularly striking in Southeast Asian countries where their relative share of the power increased over 10 times in the period.

Powered-artisanal and industrial sectors aside, a strong heterogeneity in the different power classes was evident. Small powered vessels now make up a vast portion of the global motorized fleet in numbers but do not represent a large portion of the engine power (Fig. 1 *B* and *D*). In contrast, the large powered vessels represent less than 5% of the fleet but account for a third of the total engine power. The regional and temporal differences are equally striking with the developed world fleet drastically reducing their capacity of both smaller and larger vessels, whereas the same components of the Asian fleet vastly expanded. Further details can be found in the *SI Appendix*.

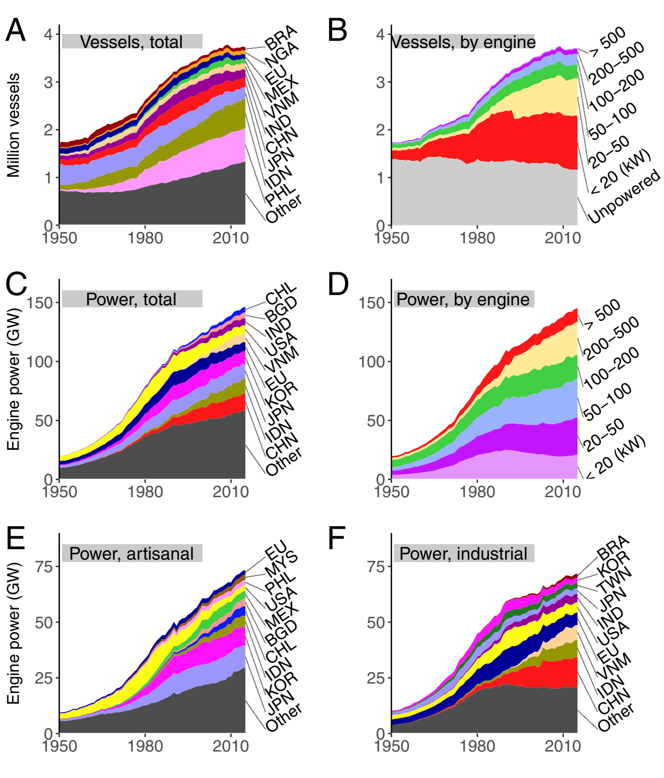

Fig. 1. Number of vessels in the global fishing fleet by country (*A*) and power class (*B*), total engine power of the global fishing fleet by country (*C*), power class (*D*), powered-artisanal (*E*), and industrial (*F*) sectors 1950–2015. Country labels [except for the European Union (EU)] are expressed in ISO 3166–1 standards.

CPUE. The global nominal and effective effort increased steadily from 1950 to 1980 across all regions and sectors (Fig. 3). Since the 1980s, however, some variability has been observed. Although the nominal effort of both the European industrial sector and the North American (United States and Canada) fleet (both sectors) decreased, the effective effort stabilized in recent years due to the increase in technological efficiency. Although the European and Northeast Asian (China, Taiwan, Japan, and Korea) nominal artisanal effort stabilized, the corresponding effective effort continued to increase.

The European and Oceanian industrial fishing effort was consistently greater than the artisanal effort throughout the time range studied, whereas the North American and Southeast Asian industrial effort overtook their artisanal counterparts in the 1980s and 2000s, respectively. The artisanal and industrial efforts of the Indian Peninsula and Northeast Asia have been closely matched, although the artisanal effort of Africa, the Arab World, and Latin America was consistently greater than their industrial counterparts.

Sectorial and regional variabilities were greater in the CPUE (Fig. 4 and *SI Appendix*, Fig. S12). Although the nominal CPUE of Asian fleets consistently decreased relative to 1950 and Oceania's increased throughout the same period, other regions showed some variability. Latin America had a steep increase in the 1960s, followed by an equally fast decline in the early 1970s, whereas the fall in the European nominal CPUE occurred throughout the 1980s. Of all regions, only Europe and the Indian Peninsula showed a trend in the total indexed nominal CPUE that closely followed that of the industrial sector in both amplitude and variability (*SI Appendix*, Fig. S12).

The relative effective effort followed a general downward trend due to the added effect of the yearly technological efficiency creep. Over the period of 2000–2015, the nominal CPUE of Europe and North America increased on average by 2.5% and

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Table 1. Number of fishing vessels and associated motor power by regions, by fishing sector, at various years

Region	Number of vessels (1000)									Motor power (GW)					
	Unpowered			Powered, artisanal			Powered, industrial			Artisanal			Industrial		
	1950	1980	2015	1950	1980	2015	1950	1980	2015	1950	1980	2015	1950	1980	2015
Magreb and Middle East	50	70	65	5	28	134	1	5	11	0.2	1	5.6	0.2	1.1	3
Sub-Saharan Africa	68	113	266	2	32	97	1	2	4	0.2	0.9	3.1	0.2	0.9	1.8
Europe*	187	34	8	53	96	80	19	40	30	1.6	3.6	3.5	4.3	16.8	9.5
Oceania†	65	28	39	6	15	45	1	3	4	0.3	0.8	1.7	0.8	1.7	2.4
North America	46	6	1	76	126	41	12	21	19	5.2	11.8	4.4	2	5.2	5
Central America‡	45	58	80	7	33	130	1	6	5	0.4	1.8	6.5	0.4	2.2	2.4
South America	123	97	54	7	26	166	0.2	3	8	0.3	1.3	9.7	0.1	1.2	3.4
Indian Peninsula§	108	185	87	6	17	156	0	14	73	0.1	0.5	7.2	0	1.1	5.6
South East Asia	230	596	536	17	231	877	0.7	15	171	0.2	3.3	11.9	0.2	2.7	18.5
North East Asia¶	450	199	23	113	441	387	20	57	115	1	8.6	19.8	2.1	12.2	20.7
World	1371	1385	1161	293	1045	2113	56	167	440	9.4	33.7	73.4	10.2	44.9	72.5

*Including Russia.
†Australia, New Zealand, and Pacific Islands Nations.
‡Including Mexico and the Caribbean.
§India, Pakistan, Sri Lanka, Maldives, and Bangladesh.
¶China, Japan, Taiwan, and Korea.

2.1% per year, respectively, whereas that of the Indian Peninsula, Southeast Asia, and Latin America dropped by 1.3%, 2.1%, and 4.1%, respectively (Fig. 5*A*). The rate of change in nominal CPUE in the rest of the world was stable over the same period with less than 0.3% a year (increase or decrease). Although some variability in the relative abundance is observed (Fig. 4), its decrease since 1950 follows patterns bounded by the nominal and effective CPUE in most regions but Asia where the decrease in indexed abundance from stock assessment data was not observed until the 1980s.

Past, Present, and Future of the Global Fishing Fleet

Data Availability and Credibility. Reconstructing the number of vessels in the world's fishing fleet presents multiple challenges. Data are often biased toward industrial vessels and underestimate the numbers of artisanal vessels. It is not uncommon for national fishery departments to report only their industrial fleets (e.g., Albania) or even a portion of it (e.g., Pacific Islands Nations reported only tuna vessels, whereas Peru reported only fleets targeting their anchoveta stock), despite the prevalence of smaller powered-artisanal vessels (1). (For the literature and data sources on specific countries hereafter, please refer to the tables and explanatory documentation in the *SI Appendix*.) Studies and country reports sometimes focus exclusively on registered, licensed, or officially active vessels, each a subset of the total fishing fleet. This, in turn, can lead to strong underestimates of the national fishing fleet and its effort (6, 7), which, if not taken into account by policies and effective management, can, in turn, lead to economic losses, increase in levels of illegal, unreported, and unregulated (IUU) fishing or discrepancies in stock assessments. A further implied consequence of misreporting fleets is that, if and when catches or fish stocks collapse, it appears to an external observer as if the fishing fleet has simply collapsed with it. Although it is undeniable that the disappearance of a target stock will heavily impact the number of fishing vessels over the years (as seen, for instance, after the collapse of the Peruvian anchoveta stock in the 1970s), vessels do not disappear without a trace from 1 y to another. In the years it takes for management to deal with a surplus of unused vessels, the fleet will typically move on to other stocks and locations (15). The misinterpretation that the active fleet is actually the total number of fishing vessels in a country is, in turn, cited in further studies, and the distorted unreported statistics are further perpetuated.

Lack of governmental transparency presents further obstacles to the availability of trustworthy data. Data were limited or falsified during the Soviet era, the dictatorship in Chile under Pinochet, and for a handful of African nations. Some countries have been known to adjust their marine catch statistics (16), and it is expected that such artifacts also exist in their reports of fishing capacity. Although the FAO has taken steps in recent years to reduce the propagation of misreporting, historical databases can still present easily perpetuated biases.

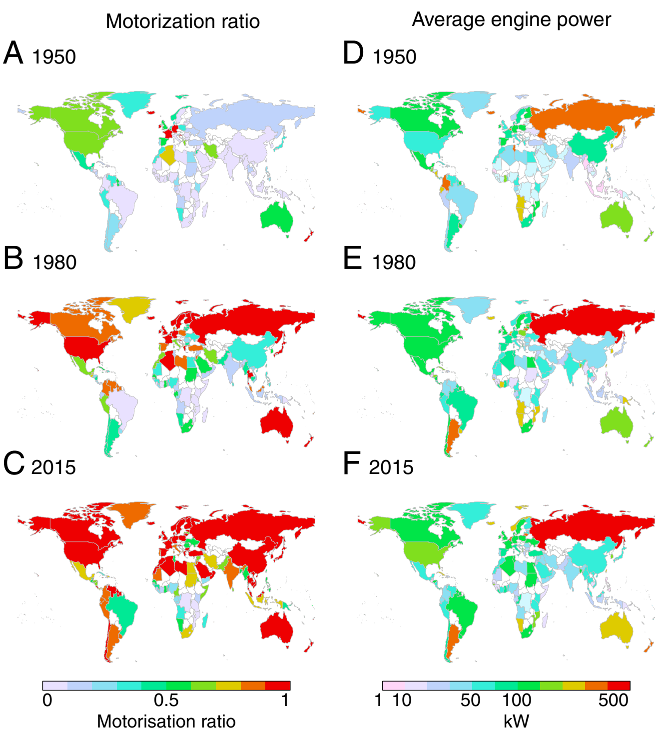

Fig. 2. Snapshots of the ratio of motorization (*A*–*C*) and average engine power in kilowatts (*D*–*F*) of the national motorized fishing fleet in 1950, 1980, and 2015, respectively. Motorization levels in European countries in 1950 might be overestimated due to the lack of data post-World War II. No data for the unmotorized fleet of Finland was found, but it was assumed that the motorization level was close to 100% since the 1970s, similar to other Scandinavian countries.

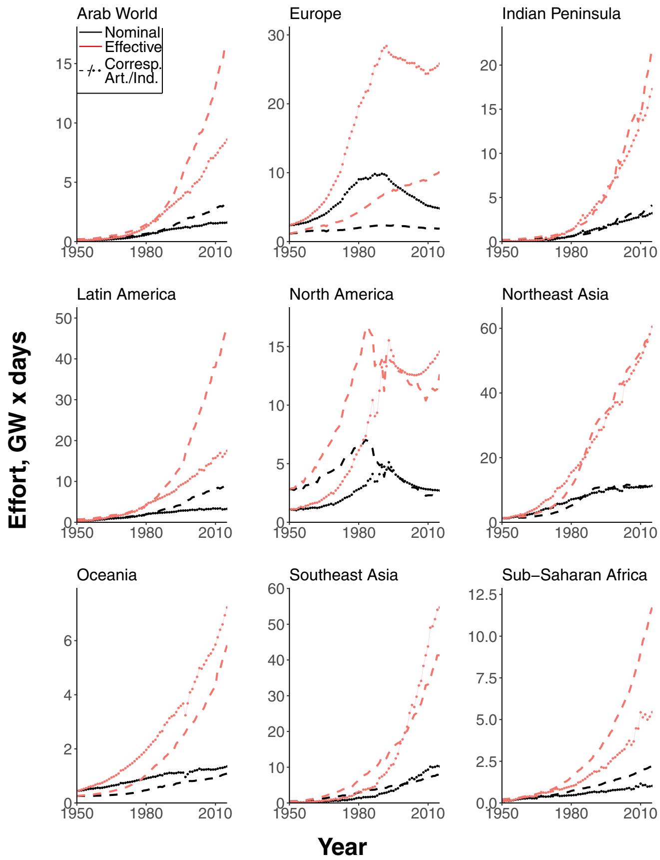

Fig. 3. Yearly nominal (black) and effective (red) fishing effort by region and sector, 1950–2015. The effective effort assumes a 2.6% increase in technological creep per annum. The dashed lines represent the artisanal fishing sector (including powered and unpowered), and the dotted lines represent the industrial sector.

Quantifying Fishing Sectors. Lack of historical data and the use of gross domestic product (GDP) as a proxy for motorization leads to uncertainty in both the size of the historical unmotorized fleet and the rate at which motors have replaced oars and sails, particularly, in the richest countries. The latest SOFIA report (1) states that the number of nonmotorized vessels has increased in recent years due to improved reporting but, as it does not disaggregate inland and marine fisheries, it is unclear whether their observation supports our results. The size of the unpowered-artisanal fleet could be higher, and the global motorization levels lower than we estimated here. Indeed, this is suggested by the lack of information found for the unpowered-artisanal fleet of the Arabic peninsula and the contradictions in the fleet reported by Small Island Nations. We argue, however, that the effect of the unmotorized fleet on fishing grounds, although potentially high locally and on specific species targeted for subsistence, is often minimal compared with the motorized segments as shown by our CPUE calculations (*SI Appendix*, Figs. S8 and S9).

Although the industrial fishing fleet is often better reported, some of these concerns also apply to the powered-artisanal sector. The number of boats retrofitted with engines is difficult to assess, although censuses are more abundant for this sector than the unmotorized one and allow for cross-validation and sharper estimates. Their impact on fishing grounds, however, is far from negligible as can be seen, for instance, in the Philippines municipal fisheries.

It is important to note that no distinction was made among artisanal, small scale, subsistence, and traditional sectors in this paper. Any vessel which fell under country-specific definitions was considered artisanal (further details in the *SI Appendix*).

Our paper shows that artisanal fleets already have total power levels comparable with industrial fleets and, although the sector is receiving less fuel and capacity subsidies (17), it is also less restricted and monitored. The fishing effort of the artisanal fleet is in all regions but Europe and Oceania equal or larger than the industrial effort, suggesting that the artisanal sector could play an important role in global overfishing. Scarcity of data and lack of a unified definition of what is artisanal, however, suggest caution when comparing data across regions. In particular, the measure of the CPUE is difficult to separate by sector. Although the industrial catch is often clearly reported, not only is the artisanal underdocumented, but also studies and countries use their own definitions of what the artisanal catch is, which might not be directly compatible with either legal definitions or definitions used in other studies. For instance, although one might separate the artisanal catch from the industrial with depth and distance to shore (13), a large portion of the legally industrial fleet of the EU (i.e., the vessels over 12 m in length) are known to fish in coastal waters (18), effectively leading to overlaps between sectorial CPUE.

This use of country-specific definitions for the artisanal/industrial sectors rather than a blanket one, however, hinders the meaning of a direct comparison of the sectors of countries with different definitions. The FAO (1) circumvents this issue by using vessel length classes (under 12 m and over 24 m), although we prefer to compare engine power, which is more meaningful for future examination of the energy intensity of fleets and associated fuel use and greenhouse gas production and allows for the separation of the artisanal sector into unpowered and powered. Although this approach is extendable

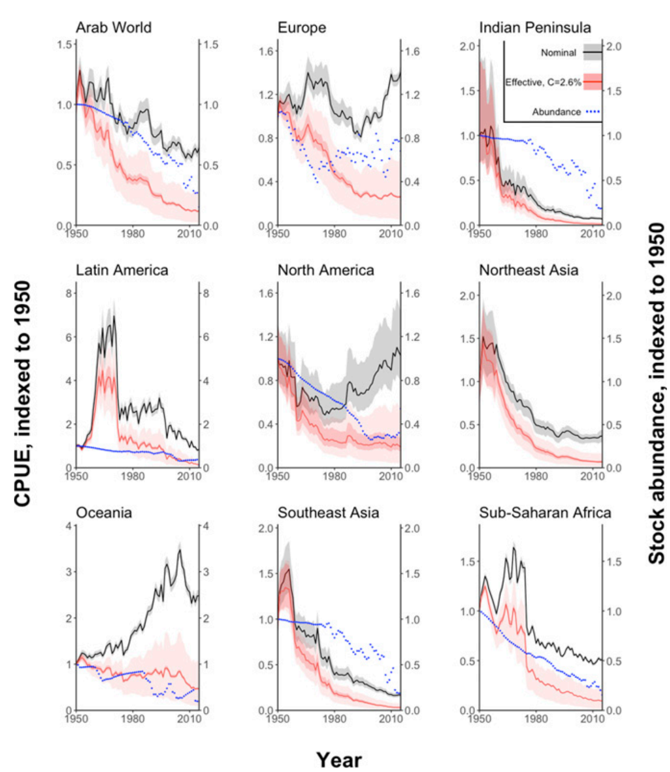

Fig. 4. Yearly change in nominal (black) and effective (red) CPUE and stock abundance (dotted blue) by region, 1950–2015, indexed to 1950. The effective CPUE assumes a 2.6% increase in technological creep per annum. The gray and dark pink shaded areas correspond to one SD error (68% confidence interval) based on the uncertainty of the engine power alone, the light pink shaded area corresponds to one SD error based on the uncertainty of the engine power and technological creep combined. Abundance was expressed in terms of the total assessed biomass or spawning biomass. The *y* axes were aligned to facilitate comparison.

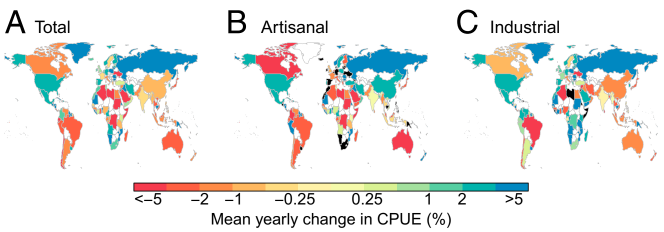

Fig. 5. Mean yearly change in nominal CPUE per country between 2000 and 2015, total (*A*) and for the artisanal (*B*) and industrial (*C*) sectors. Countries in black do not have enough information to meaningfully calculate the rate of change according to sectors.

to the fishing effort, catch data are not yet disaggregated to allow for a comparison of the CPUE between classes of engine power.

Recreational Fisheries are absent from our paper but are by no means unimportant. Over half a million recreational vessels are present in Australia alone (19), over 50 times that of artisanal and industrial fishing vessels combined with the catch of comparable levels or sometimes exceeding the commercial sector (20). This is common in developed countries (21).

Although our estimates of the number of vessels agrees with other studies (1), our estimates of the engine power and, thus, the effort starkly contrast with previous ones (6) (*SI Appendix*, Fig. S12). The separation of the fleet by sector is a fundamental difference in our methodology and explains a vast portion of the difference. Furthermore, the use of "similar countries" to estimate the average engine power of data-poor countries, although limited in its depth, is an improvement over using data from developed technologically advanced countries (e.g., EU fleet register) and extrapolating this to the quite dissimilar fleets of developing countries.

Modernization of Fleets and Management. Technology transfer and improvement in engine design have vastly impacted the motorization of the global fleet. The developed countries' fleet started their motorization in the first part of the 20th century by developing coal-powered vessels. This technology has been rendered mostly obsolete with massive improvement in the cost efficiency of petroleum-based motors. In particular, the development of portable motors was a game changer in fisheries. In the developing world, outboard motors have become more and more prominent and allow for more flexibility in the development of the fleet. Most of the vessels equipped with an outboard motor remain artisanal, but it is not uncommon to see boats retrofitted with motors of over 50 kW. This is particularly true in Southeast Asia where hundreds of thousands of vessels equipped with outboard motors are present. Retrofitting likely has a considerable effect on the sustainability of (powered) artisanal fisheries with increased pressure on stocks and a rise in greenhouse gas emissions from fuels. The increased pressure that this motorization has had on fishing stocks is particularly felt in Africa and Southeast Asia, reflected in the drop in CPUE since 1950, both nominal and effective (Fig. 6). This pattern mirrors what has been seen elsewhere, such as in North America, where the rapid motorization of the fishing fleets in the 1950s was likewise accompanied by a decrease in the relative nominal CPUE in both regions.

Our analysis shows that the effective effort increased at a much faster rate throughout the world than the corresponding catch, although signs of a stabilization appeared for Europe and North America since the 1990s. Although the effective CPUE of Oceania decreased, the observed rate is comparatively lower than the rest of the world. This indicates that, although a general reduction in abundance is observed throughout the world (Fig. 4), the observed stabilization in North America and Europe and the slower rate of decline in Oceania are consistent with the impact of fisheries' management in these regions (22). Although biomass is a good indicator of the stress of fisheries on the oceans, the data are often limited to developed countries, and, as such, the relative abundance of stocks, particularly in Asia and Africa, might be overestimated (Fig. 4). It is further difficult to fully entangle the measure of abundance from the CPUE as stock assessment can be based on the latter.

In contrast, using the effective CPUE as a simple direct measure of stock abundance paints a dark picture of the oceans' resources. The rapid decrease in the relative effective CPUE, however, is fundamentally linked to estimates of the technological creep. A creep of 2.6% per year corresponds to a fivefold increase in fishing efficiency over a 65 y period. As a measure of the increased efficiency of fishing techniques, the uncertainty on this parameter is consequential and translates to vastly incremental uncertainties on the CPUE. Although no distinction is found between the creep of the artisanal and the industrial fleets (23), available data for its calculation is almost exclusively sourced from developed countries, making calculated trends elsewhere less reliable (further details in the *SI Appendix*). Our findings that Europe and North America had a rate of change in nominal CPUE over the last 15 y over 2% per year indicates that only these regions are adapting their fisheries' management strategies to a sufficient extent to account for an increase in technological efficiency. In Southeast Asia, Latin America, and the Southern Mediterranean, the drop in nominal CPUE over the same period indicates that the expansion of the fisheries occurred at a much faster rate than fish stocks could support. Combined with the high uncertainty on the increase in technological efficiency, particularly, its temporal and regional variations, additional management measures seem urgently warranted. This decline is of particular importance in regions where the artisanal fleet sustains a considerable portion of the population, such as Southeast Asia. As agricultural systems connect on both land and seas (24), overfishing and an imminent decline, marked by uncertainties on the sectorial CPUE and potentially underestimated landings, could ripple throughout the economy and impact future food security.

The highly variable geopolitical map and its impact on fishing fleets further complicates our understanding of the evolution of fleets and their management. European colonial empires explain the high mean power in Africa in the 1950s and 1960s and the reduction in subsequent decades, even though the mean generally increased elsewhere. It is uncertain, however, how much of this effect lingered as old segments of their fleet might have been "left behind." By contrast, the independence of Timor-Leste from Portugal and then Indonesia led to the quasitotal destruction of their fleets. The instability and economic disparity in the Middle East can be seen through various levels of motorization with strict policies and management explaining the leveling of the Emirates fleet, whereas conflicts in other countries have greatly reduced the capacity (25). Although EU countries are at different economic levels, there is a common push from the Union to reduce the fishing fleet (26), effectively prompting the reduction of the fleet even in the poorest countries of the block. The bottom line is that, although countries will reach a peak fishing fleet, the drivers for this are a

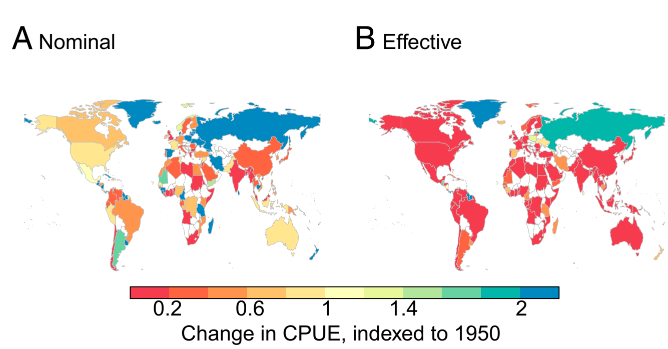

Fig. 6. Snapshots of the 2015 relative change in nominal (*A*) and effective (*B*) CPUE, indexed to 1950. The technological creep estimated at 2.6% per annum.

composite of local biology, climate, management, economics, and politics (2) and remain both complex and incompletely explained.

Some variation of the CPUE can be similarly directly linked to specific occurrences in fishing history. Our data clearly show the rise and fall of the Peruvian anchoveta fleet in the 1960s (Fig. 4), whereas the dent in the relative nominal CPUE in Europe around 1990 can be linked to the dissolution of the USSR and the resulting drop in catch.

Although indexed CPUE is often used as a proxy of the relative well being of stocks, we suggest caution when comparing it to 1950 as the accuracy and completeness of fleet data of the period is questionable. Conversely, one can think of 1950 as a semipristine state of the world's fisheries, and the drop in CPUE in the following decades was a consequence of unchecked modernization and expansion.

Conclusion

Despite decreasing global catches (12), falling CPUE, and relative abundance, we have shown that the global fishing fleet has kept on increasing. If past trends continue with a 1:1 ratio for the motorization, up to another million powered vessels could appear in the global fishing fleet over the next few decades with the potential for changes in access rights and catch reallocation, increased stress on ocean resources, and increased fuel emissions contributing to climate change.

Furthermore, the mean engine power of the fishing vessels per country is still increasing.

Recent signs of stabilization in the effective CPUE were observable for most developed countries, although these still represent the minority of locations. This might evolve in the near future, however, as fuel efficiency becomes paramount in discussions on mitigating climate change and management of the fleet in reaching a sustainable use of the marine resources.

Finally, previous reconstruction methods have attempted to extrapolate global data from a subset of the European fleet, leading to inflated results. We distanced ourselves from this bias in the calculation of the engine power, but further work is required to quantify the impact of sociocultural factors on the evolution of fishing fleets beyond simple reconstruction. The importance of regionally varied rates of technological change, if present, could vastly affect the global fishing effort, but the literature remains sparse. A deep understanding of both the size and the motorization of the artisanal and industrial fishing fleets is needed to estimate the global fishing effort and its impact on ecosystems, livelihood, and employment. In particular, this paper opens up the space for future work on comparing global CPUE assessment to CPUE-independent biomass assessments. Quantifying these is a necessary step toward understanding global fleet dynamics and their integration into more holistic models of global fisheries required to safeguard vital ocean resources.

Materials and Methods

The marine fishing fleet data from 149 sovereign states along with Taiwan, Greenland, and the Faroe Islands were collected. National and international databases were used along with official (governmental) literature and any scientific or gray literature providing either the number or the engine power of fishing vessels. Fishing fleet data were separated into three sectors: unpowered-artisanal, powered-artisanal, and industrial vessels using either data-specific or legal definitions of artisanal fishing. The number of vessels in each sector and country was interpolated with a (double) sigmoidal fit. An autoregressive integrated moving average model was then used to extrapolate to 1950 and/or 2015 whenever necessary. For missing data on the unpowered-artisanal fleet, it was assumed that the subsector increased proportionally with population (27) before a threshold based on GDP and decreased thereafter at a rate similar to the observed increase in powered fleets.

Both motorized sectors were divided into classes of engine power, each with a yearly ratio to the total number of vessels and a mean power per vessel (PPV). The ratios and PPVs of countries with sufficient data were determined with generalized additive models. The average engine power of vessels in countries with limited or no data were reconstructed by comparing to similar countries.

Days at sea (7) were used to estimate nominal fishing effort per country, year, engine power class, and sector. The effective effort was calculated using a 2.6% increase per annum in technological efficiency (creep), relative to 1950. Independent landings' data (13, 28) were used to calculate the CPUE, which was compared with the abundance index estimated from the stock assessment database (https://www.ramlegacy.org). Detailed information on data sourcing and analysis can be found in the *SI Appendix*.

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