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*Research*, part of a Special Feature on Managing local and global fisheries in the Anthropocene

# On the creeping increase of vessels' fishing power

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ABSTRACT. This contribution presents a synthesis, via a semilogarithmic regression, of estimates of the slow increase of technological efficiency, or "creep factor," as estimated by various authors for a number of demersal and pelagic fisheries. This factor is used in fisheries science to adjust for the gradual increase in the effectiveness of fishing gear resulting from the successive introduction of technological improvement to fishing gear and vessels. Altogether, 51 estimates of this creep factor, mostly around 2–4%/yr and covering periods from 4 to 129 yr, were assembled or newly calculated from secondary data and shown to decrease as the period covered increased. This finding is compatible with the hypothesis that creep factors are usually estimated and published to correct for the introduction of an effective new technology over a short period of time. We suggest that estimates obtained in this fashion cannot be applied to long-term analyses and propose instead our empirical relationship, derived from estimates of creep factor and the number of years covered in a study. Also, our study confirms that technology creep must be included in all analyses involving time series of fishing effort, particularly if they exceed one decade in temporal coverage.

Key Words: *effectiveness of fishing gear; fishing power; technological efficiency; technology creep factor*

## INTRODUCTION

People have been fishing for millennia and they have always tried to improve their methods (von Brandt 1964), both to increase their catch and to compensate for the declining catch per unit effort (CPUE) due to diminishing abundance of the underlying resources that fishing causes (Engelhard 2016). Since the late 19th century, following the introduction of steam trawlers in England, which marks the start of industrialized fishing, the improvement of technology has been relentless; the current vessels are much more powerful than steam vessels of similar tonnage (Engelhard 2008, Thurstan et al. 2010, Engelhard 2016).

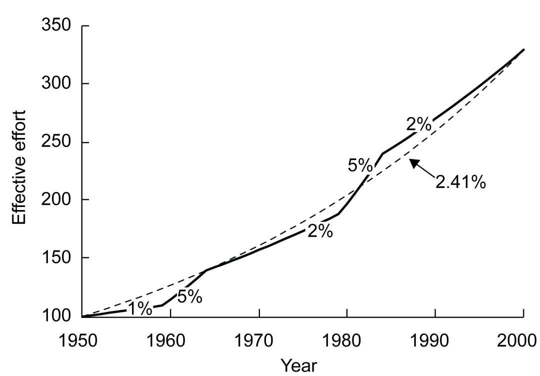
The relationship between fishing mortality and fishing effort is $F = f \times q$, where $F$ is the fraction of the fish population that dies from fishing during a unit of time (conventionally one year); $f$ is a measure of fishing effort (e.g., boats/d or fishing-h/d of a certain type of fishing vessel); and $q$ is the catchability coefficient (Beverton and Holt 1957, Arreguín-Sánchez 1996).

Technological creep ($C$) can be conceived as either a dimensionless change in catchability ($q$) or a dimensionless change in some aspect of nominal effort (Gulland 1956, Sanders and Morgan 1976). Either way, it affects fishing mortality. Conversely, if $F$ is to be kept at a given level, effective effort will increase due to technological creep, and nominal effort must be reduced accordingly.

Technological improvement can be conceptually separated into two groups: (1) major improvements in gear design, fish finding, and catch handling resulting in massive increase in effective fishing effort when they are implemented throughout a fleet within a few years; and (2) small background alterations in the rigging of a vessel or the skill of skippers at handling new technology or applying information technology, etc. (see Marchal et al. 2006). Technology creep factors receive far too little attention from fisheries scientists and even less from fisheries managers, for example, when they attempt to freeze the amount of fishing effort at a certain level but fail to account for the increase in effective effort of the vessels whose number is frozen. A similar problem occurs when subsidizing fleet retirement programs that allow decommissioning funds to be applied for the purchase of new, more efficient vessels (Munro and Sumaila 2002 and references therein, Pauly et al. 2002). Most studies of the creep factor refer to cases of the first type because the effect is strong and visible and thus justifiably attracts scientific and management attention. However, because of the cumulative effect, the changes of the second type are also important; they occur relentlessly, even when no major technology improvements appear to be taking place.

Engelhard (2016) emphasizes the general lack of quantitative information allowing for the estimation of the speed at which changes in fishing power happen over time and encourages more research on the topic. Our contribution's aims, therefore, are to present a number of estimates of this creep factor (both previously published and newly estimated) and, based on those, to propose an empirical relationship derived to allow inferences on long-term values of creep factor by combining both types of technologial improvements (Fig. 1).

**Fig. 1.** Simulated increase in effective effort over a 50-yr period comprising a mixture of background rates (% technological creep = 1 and 2%) and rapid increases (5%) due to technological improvements. The average rate of technological creep (2.41%; dotted line) is obtained by comparison of the beginning and end estimates of effective effort but can be approximated by an average rate of increase weighted by the number of years (2.42%).

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## MATERIALS AND METHODS

A literature search to update the data of Pauly and Palomares (2010) was conducted (originally in 2013 and updated in 2017), targeting estimates of time series trends of fishing power or fishing efficiency available from online resources. We searched the Aquatic Sciences and Fisheries Abstracts (ASFA), Web of Science (WS), and Google Scholar (GS) using the search terms "fishing power" and "fishing efficiency" occurring in the title. This search yielded 127, 45, and 155 hits for fishing power and 127, 31, and 133 hits for fishing efficiency in ASFA, WS, and GS, respectively. Of these records, 24 contributions contained usable time series data of fishing power (51 case studies; see Table 1) from which estimates of the annual increase of fishing power or fishing efficiency were obtained.

Though straighforward, the methods used to transform the source data to percentage annual increase in fishing power (*C%*) differed because the source data were heterogeneously expressed as: annual rate of change (Ward 2008), annual compounding increase (Hannesson et al. 2008, Thorson and Berkson 2010), average increase in fishing power (Brown et al. 1995, Zhou et al. 2015), fishing power in smack units (Engelhard 2008), increase in catchability coefficient (Atmaja and Nugroho 2011), change in technology coefficient (Gelchu and Pauly 2007) or efficiency (Hutton et al. 2003), change in loading capacity (Ruiz-Luna et al. 1997), average trend in fishing power (Marchal et al. 2002), or chain of total factor productivity (Squires 1994). Details of these transformations are provided in Table 1. In cases for which the source data were from comparisons of fishing power or efficiency from different vessel types fishing in parallel, the instantaneous rate of technological creep (*C*; $yr^{-1}$) was obtained, and the corresponding annual percentage increase (*C%*) is reported (Table 1) along with the resulting regression statistics (see Gascuel et al. 1993, Gelchu and Pauly 2007, Engelhard 2008).

## RESULTS

The first result we obtained is a series of 51 estimates of *C* (Table 1). We first comment in detail on two sets of these estimates. We then continue with their analysis.

Our first case, based on portions of the data in Table 1, presents estimates of *C* (Fig. 1) in English trawl fisheries for cod and plaice based on the classical method for fishing power estimates (Gulland 1956) for trawlers fishing in parallel. This time series, extending from 1880 to 2005, was reported by Engelhard (2008: table 1). Here, all ranges were replaced by the corresponding mid-ranges, and a few points were identified as outliers (e.g., those representing sailing vessels; see Fig. 2). The resulting slopes of the plot (Fig. 2, Table 1) provide relatively low estimates of *C* for cod and plaice, respectively, pertaining to an extraordinarily long time series of 129 yr.

Our second case is the result of an informal workshop reported by Fitzpatrick (1996; see Table 2), whose main result was that, over a period of 30 yr, the participating skippers of a wide range of vessel types perceived an increase in the efficiency of fishing gear, i.e., fishing power, equivalent to *C%* = 4.43%/yr ± 0.00255. Details of this exercise are not available, which would enable the results from the different fisheries included therein to be discussed separately. Thus, the entire exercise contributed only one estimate to our analysis (Table 1, Fig. 3).

**Fig. 2.** Increase in fishing power of English demersal trawl fisheries for cod (top) and plaice (bottom) based on data from Engelhard (2008:table 1).

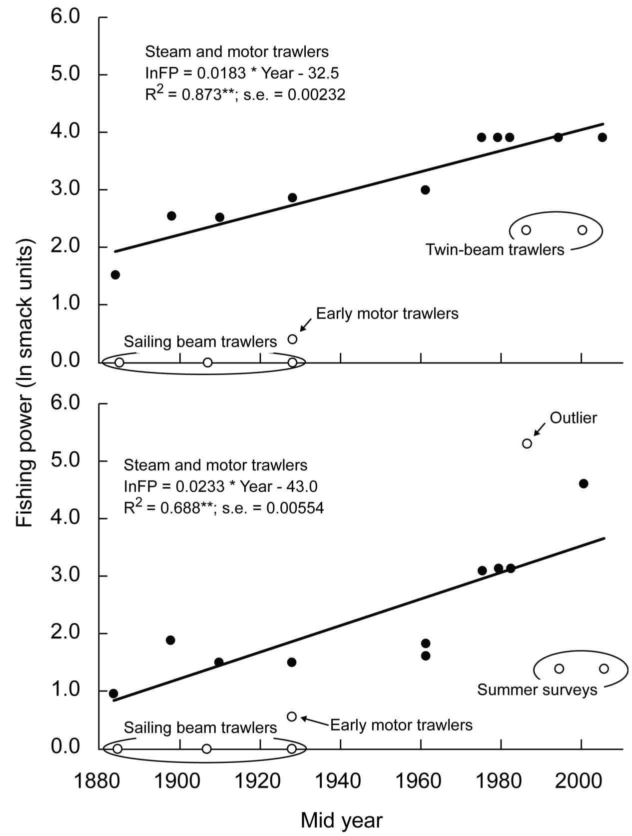


**Fig. 3.** Relationship between technological creep and the period to which the estimate applies. *C%* = percent change in technological creep per year; ln(*C%*) = 2.625 − 0.511 × ln(Year) ($r^2$ = 0.153, r = −0.3906, df = 49, $P$ < 0.0046). The X on the regression line indicates an average fishing power increase of 3.4% for the average period of 15 yr; dashed lines indicate the 95% confidence limits.

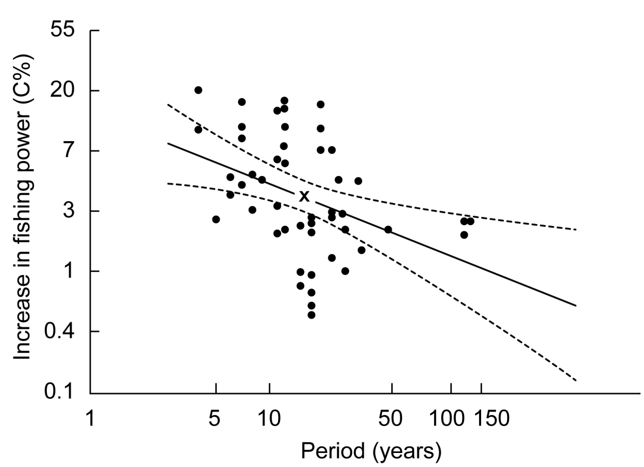

**Table 1.** Technological creep estimates for various fisheries and periods. *C* = technological creep; CPUE = catch per unit effort, FP = fishing power, GPS = global position system, IFP = index of fishing power, TC = technology coefficient, TFP = Tornqvist index of total factor productivity.

| Number | Fishery or species | Years | $C$ (yr$^{-1}$) | Standard error of $C$ | Estimation method and source |
|---|---|---|---|---|---|
| 1 | Lofoten cod (*Gadus morhua*) fishery | 1860–1988 | 0.0233 | 0.0426 | Based on 2.3% annual compounding increase estimated by Hannesson et al. (2008:table 4) |
| 2 | British North Sea Atlantic cod trawl fishery | 1886–2005 | 0.0183 | 0.00232 | Change in FP (smack units); based on data from Engelhard (2008:table 1) with ln(FP) = 0.0183 × Year − 32.5 (Fig. 2) |
| 3 | British North Sea European plaice (*Pleuronectes platessa*) trawling | 1886–2005 | 0.0233 | 0.00554 | FP (smack units); based on data from Engelhard (2008:table 1) with ln(FP) = 0.0233 × Year − 43.0, $r^2$ = 0.688**, df = 8 (Fig. 2) |
| 4 | Japan distant-water pelagic long liners | 1954–1998 | 0.02 | 0.0155 | Annual mean rate of change for mako shark, blue marlin, and bigeye, yellowfin, and skipjack tunas; based on Ward (2008: table 2) |
| 5 | Java Sea purse seine fishery for small pelagic fishes | 1976–2007 | 0.0143 | N/A | Based on Atmaja and Nugroho (2011) estimating an increase of 58% of the 2007 catchability coefficient from the 1976 coefficient |
| 6 | Wide range of vessel types (Table 2) | 1965–1995 | 0.0443 | 0.00255 | Change in TC; based on data from Gelchu and Pauly (2007: table 2.5) based on Fitzpatrick (1996; see Table 2) with ln(TC) = 0.0443 × Year − 87.7, $r^2$ = 0.893**, df = 36 |
| 7 | Australian silver-lipped pearl oyster (*Pinctada maxima*); GPS-aided fishery | 1984–2009 | 0.0101 | N/A | Based on Hart et al. (2011) estimating an increase of FP by 30% due to the introduction of GPS |
| 8 | Gulf of Mexico fisheries | 1981–2006 | 0.02 | N/A | Based on Thorson and Berkson (2010:table 4) for gag grouper (*Mycteroperca microlepis*), red grouper (*Epinephelus morio*), red snapper (*Lutjanus campechanus*), mutton snapper (*L. analis*), king mackerel (*Scomberomorus cavalla*), and greater amberjack (*Seriola dumerili*) fisheries |
| 9 | Australian northern prawn fishery | 1987–2011 | 0.026 | N/A | Based on average FP increase of 2.6% estimated by Zhou et al. (2015) for banana prawn (*Fenneropenaeus merguiensis*) |
| 10 | Pacific ocean perch (*Sebastes alutus*) trawl fishery, Vancouver Island, Canada | 1953–1976 | 0.0458 | N/A | Based on 2% increase reported by Kimura (1981) |
| 11 | Thread herring (*Opisthonema* spp.) fishery, Sinaloa, Mexico | 1972–1993 | 0.0737 | 0.0125 | IFP based on data from Ruiz-Luna et al. (1997:table 1; CPUE = $a$ × [loading capacity]$^b$); result was ln(FP) = 0.0737 × Year − 0.786, $r^2$ = 0.684**, df = 16 |
| 12 | Western rock lobster (*Panulirus cygnus*) shallow waters, Western Australia | 1971–1992 | 0.0125 | N/A | Mean of FP increase: 0.005–0.02; Brown et al. (1995) |
| 13 | Western rock lobster deep waters, Western Australia | 1971–1992 | 0.025 | N/A | Mean of FP increase: 0.01–0.04; Brown et al. (1995) |
| 14 | Pacific cod (*Gadus macrocephalus*) Butterwort ground fishery, Canada | 1960–1981 | 0.0271 | 0.009649 | FP increase based on data from Westrheim and Foucher (1985: table 6), with ln(FP) = 0.0271 × Year − 53.0, $r^2$ = 0.282*, df = 20 |
| 15 | Norwegian gillnet fishery, North Sea | 1980–1998 | 0.075 | 0.0457 | Mean trend in IFPs for cod, haddock, and saithe; based on data from Marchal et al. (2002:table 6) |
| 16 | Norwegian longline fishery, North Sea | 1980–1998 | 0.16 | 0.01 | Mean trend in IFPs for cod, haddock, and saithe; based on data from Marchal et al. (2002:table 6) |
| 17 | Norwegian otter trawl fishery, North Sea | 1980–1998 | 0.106 | 0.0438 | Mean trend in IFPs for cod, haddock, and saithe; based on data from Marchal et al. (2002:table 6) |
| 18 | Norwegian bottom trawl cod fishery, Barents Sea | 1971–1985 | 0.0214 | 0.2189 | Based on Skjold et al., *unpublished manuscript:* http://ices.dk/sites/pub/CM%20Doccuments/1996/P/1996_P3.pdf |
| 19 | European fisheries | 1985–1999 | 0.01 | N/A | TC; Banks et al. (2001) and Kirkley et al. (2001) |
| 20 | Greek bottom trawl fishery | 1994–2008 | 0.00791 | N/A | Annual *C* estimated by Damalas et al. (2014:table 3) for hakes, mullets, shrimps, squids, and sharks |
| 21 | Danish cod gillnet fishery, Baltic Sea | 1987–1998 | 0.06 | N/A | Increase of IFP; Marchal et al. (2001:table 3) |
| 22 | Danish cod trawl fishery, Baltic Sea | 1987–1998 | 0.02 | N/A | Increase of IFP; Marchal et al. (2001:table 3) |
| 23 | Danish gillnet fishery, North Sea | 1987–1998 | 0.147 | 0.0788 | Mean trend in IFPs for cod, plaice, and sole; based on data from Marchal et al. (2002:table 6) |
| 24 | Danish otter trawl fishery, North Sea | 1987–1998 | 0.08 | 0.04 | Mean trend in IFPs for cod and plaice; based on data in Marchal et al. (2002:table 6) |

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| 25 | Danish seine fishery, North Sea | 1987−1998 | 0.11 | 0.02 | Mean trend in IFPs for cod and plaice; based on data in Marchal et al. (2002:table 6) |
| 26 | Hake (*Merluccius merluccius*) fixed net fishery | 1986−1997 | 0.06 | N/A | Mean rate of change in FP; Morizur and Carn (2000) |
| 27 | French sole (*Solea vulgaris,* Soleidae) fixed net fishery | 1986−1997 | 0.17 | N/A | Annual rate of change in FP; Morizur and Carn (2000) |
| 28 | French-Ivoirian-Senegalese yellowfin tuna (*Thunnus albacares*) fishery | 1980−1990 | 0.1416 | 0.0334 | FP; based on data from Gascuel et al. (1993:fig. 5a) with ln(FP) = 0.1416 × Year − 12, $r^2$ = 0.666**, df = 9 |
| 29 | Spanish purse seine yellowfin tuna fishery; Eastern Atlantic | 1980−1990 | 0.0636 | 0.0178 | FP; based on data from Gascuel et al. (1993:fig. 5b) with ln(FP) = 0.0636 × Year − 5.746, $r^2$ = 0.586**, df = 9 |
| 30 | Torres Strait tiger prawn trawl fishery | 1989−1999 | 0.01872 | N/A | FP increase; O'Neill et al. (2003:table 3) |
| 31 | North Sea English fleets | 1990−2000 | 0.0297 | N/A | Estimated annual technological efficiency increase by Hutton et al. (2003) for otter trawl (IFP = 0.005), pot (IFP = 0.024), and *Nephrops* (IFP = 0.06) fleets |
| 32 | Pacific Coast ground fish trawl fishery | 1981−1989 | 0.0460 | 0.0139 | TFP; based on data in Squires (1994:table 3) with ln(TFP) = 0.0460 × Year − 91.3, $r^2$ = 0.610*, df = 7 |
| 33 | Dutch beam trawl fishery, North Sea | 1991−1998 | 0.05 | 0.0785 | Mean trend in IFPs for cod, plaice, and sole; based on data from Marchal et al. (2002:table 6) |
| 34 | Pacific Coast ground fish trawl fishery | 1982−1989 | 0.0279 | N/A | TFP; Squires (1994:table 1) |
| 35 | French spider crab (*Maja squinado*) fixed net fishery | 1992−1998 | 0.11 | N/A | Mean rate of increase; Morizur and Carn (2000) |
| 36 | Western rock lobster fishery, Australia | 1983−1989 | 0.165 | 0.0512 | Catch rate increase by period, testing four technology factors for legal-size lobsters; Fernandez et al. (1997:table 2) |
| 37 | Faeroese haddock longline fishery | 1996−2002 | 0.09 | N/A | Annual FP increase estimated by Eigaard et al. (2011) |
| 38 | Faeroese cod longline fishery | 1996−2002 | 0.043 | N/A | Annual FP increase estimated by Eigaard et al. (2011) |
| 39 | UK English Channel otter trawler fleet | 1993−1998 | 0.048 | N/A | Annual FP increase estimated by Pascoe et al. (2003) |
| 40 | UK English Channel pot fleet | 1993−1998 | 0.036 | N/A | Annual FP increase estimated by Pascoe et al. (2003) |
| 41 | Australian northern prawn (*Penaeus esculentus, P. semisulcatus*) fishery | 1988−1992 | 0.0235 | 0.00230 | Annual estimates of FP; based on data from Robins et al. (1998: fig. 3), with ln(FP) = 0.02352 × Year − 46.75, $r^2$ = 0.972**, df = 3 |
| 42 | Western rock lobster fishery, Australia | 1989−1992 | 0.105 | 0.0298 | Catch rate increase by period, testing four technology factors for legal-size lobsters; Fernandez et al. (1997:table 2) |
| 43 | Brixham demersal trawl fishery, UK | 1965−1968 | 0.201 | N/A | Annual change in FP; Houghton (1977) |
| 44 | Eastern king prawn (*Melicertus plebejus*) trawl fishery (all depths), Queensland, Australia | 1988−2004 | 0.0225 | 0.00154 | Annual change in FP; based on O'Neill and Leigh (2007:table 2) with ln(FP) = 0.02249 × Year − 44.73, $r^2$ = 0.934**, df = 15 |
| 45 | Eastern king prawn (shallow) trawl fishery, Queensland, Australia | 1988−2004 | 0.0245 | 0.00130 | Annual change in FP; based on O'Neill and Leigh (2007:table 2) with ln(FP) = 0.02452 × Year − 48.75, $r^2$ = 0.960**, df = 15 |
| 46 | Eastern king prawn (deep) trawl fishery, Queensland, Australia | 1988−2004 | 0.0195 | 0.00261 | Annual change in FP; based on O'Neill and Leigh (2007:table 2) with ln(FP) = 0.01948 × Year − 38.79, $r^2$ = 0.789**, df = 15 |
| 47 | Red spot king prawn (*Melicertus longistylus*) trawl fishery, Australia | 1988−2004 | 0.00583 | 0.00202 | Annual change in FP; based on O'Neill and Leigh (2007:table 2) with ln(FP) = 0.005831 × Year − 11.55, $r^2$ = 0.356*, df = 15 |
| 48 | North Queensland tiger prawn (*Penaeus esculentus*) trawl fishery, Australia | 1988−2004 | 0.00715 | 0.000928 | Annual change in FP; based on O'Neill and Leigh (2007:table 2) with ln(FP) = 0.007154 × Year − 14.28, $r^2$ = 0.798**, df = 15 |
| 49 | Southern Queensland tiger prawn trawl fishery, Australia | 1988−2004 | 0.00703 | 0.00185 | Annual change in FP; based on O'Neill and Leigh (2007:table 2) with ln(FP) = 0.007034 × Year − 13.98, $r^2$ = 0.491**, df = 15 |
| 50 | Endeavour prawn trawl fishery, Australia | 1988−2004 | 0.00957 | 0.00168 | Annual change in FP; based on O'Neill and Leigh (2007:table 2) with ln(FP) = 0.009573 × Year − 19.08, $r^2$ = 0.685**, df = 15 |
| 51 | Saucer scallop (*Amusium balloti*) trawl fishery, Queensland, Australia | 1988−2004 | 0.0049 | 0.00138 | Annual change in FP; based on O'Neill and Leigh (2007:table 2) with ln(FP) = 0.004788 × Year − 9.515, $r^2$ = 0.444**, df = 15 |

*$P < 0.05$, **$P < 0.01$.

Other estimates that were obtained from secondary data are documented (Table 1). Overall, these estimates of $C$ range from 0.0049 to 0.201 $yr^{-1}$, with a group of suspiciously low values (0.0049–0.0245 $year^{-1}$) published by O'Neill et al. (2003) and O'Neill and Leigh (2007), who studied fishing power in various Australian invertebrate fisheries (see numbers 30 and 44–51 in Table 1).

When the estimates of $C$ in Table 1 are converted to ln($C\%$) and plotted against the logarithm of the number of years for which they were estimated, the result is the significantly negative relationship ($P < 0.005$; Fig. 3) summarized by the equation:

$$C\% = 13.8 \times Y^{-0.511} \quad (1)$$

**Table 2.** Estimated technology coefficients of fishing vessels by vessel type (data from Fitzpatrick 1996), modified from Gelchu and Pauly (2007:table 2.5).

| Vessel type | Vessel length (m) | Technology coefficient (relative to 1980 = 1) | |
|---|---|---|---|
| | | 1965 | 1995 |
| Super trawler | 120 | 0.6 | 2.5 |
| Tuna seiner | 65 | N/A | 1.6 |
| Freeze trawler | 50 | 0.7 | 2.0 |
| Tuna longliner | 65 | 0.5 | 2.3 |
| Purse seiner | 45 | 0.6 | 2.0 |
| Stern trawler | 35 | 0.6 | 1.9 |
| Longliner | 35 | 0.4 | 2.8 |
| Multipurpose vessel | 25 | 0.6 | 2.5 |
| Shrimp trawler | 25 | 0.5 | 2.2 |
| Gillnetter | 15 | 0.4 | 1.5 |
| Trawler | 13 | 0.5 | 1.8 |
| Fast potter | 10 | 0.3 | 1.4 |
| Pirogue (canoe) | 10 | 0.6 | 1.3 |
| Mean (± 2 standard deviations) | | 0.53 ± 0.23 | 1.98 ± 0.93 |

which links *C%* to the duration of the period (*Y*, in years) for which *C%* was estimated. The average fishing power increase was 3.4% for the average period of 15 yr (Fig. 3). The regression relationship is not very tight, but given the heterogeneous nature of the data that went into the point estimates and of the underlying models (general linear models, chains of comparisons of successive trawler type, subjective assessments, etc.), a better fit probably cannot be expected.

Our results can be used in a practical way for a specific fishery or for global fisheries (see Anticamara et al. 2011) for which there is no other estimate of technological creep. The following equations can be used to calculate increase in effort (*E*) or decrease in CPUE as indicators of abundance.

$$E_{(t)} = E_{(t=0)} \times (1 + pd)^{t} \quad (2)$$

where *t* is the time in years after *t* = 0 and *pd* is the percentage creep reexpressed as a decimal fraction, i.e., *C%*/100. The multiplier for correcting CPUE is then:

$$\mathrm{Corr}_{(t)} = (1 - pd)^{t} \quad (3)$$

$$\mathrm{CPUE}_{\mathrm{Corr}(t)} = \mathrm{CPUE}_{(t)} \times \mathrm{Corr}_{(t)} \quad (4)$$

where the first value of CPUE is treated as *t* = 0, which leads to $\mathrm{Corr}_{(t=0)} = 1$.

These equations are now part of the CMSY method (a Monte Carlo method for estimating maximum sustainable yield) as originally presented by Froese et al. (2017) but whose implementation code is now modified to include an option for accommodating technological creep in the CPUE data that can be used as constraints (see http://oceanrep.geomar.de/33076/).

## DISCUSSION

Eq. 1 provides estimates of *C%* values of 1.3% for 100 yr, 1.9% for 50 yr, 4.3% for 10 yr, and 6.1% for 5 yr. No pattern could be identified for the data (Table 1) that would have allowed for specific fisheries (pelagic vs. demersal, large scale vs. small scale) to be identified (except for the low values of O'Neill and collaborators [2003, 2007]).

Our results also have a deeper societal aspect related to the rapid decline, in the Anthropocene, of global biodiversity (Butchart et al. 2010), particularly in the oceans (Worm et al. 2006). This decline is due, in large part, to the terrible efficiency of the technology that we deploy to torture what we want from soils (e.g., through fertilizers applied to irrigated monocultures) or from the oceans (e.g., by deploying thousands of trawlers, which destroy sea-floor communities). The problem is that we do not really notice this because of shifting baselines (Pauly 1995): To us, a tractor plowing a field in the 21st century looks like a tractor at the beginning of the 20th century, and a trawler plowing the sea in the 21st century looks like a trawler at the beginning of the 20th century. However, the newer technologies are profoundly different in that they have much greater environmental impacts than do the older ones. We will be in trouble as a species if we do not account for this difference.

## CONCLUSION

When analyzing time series of CPUE obtained from commercial vessels (as opposed to research vessels, whose rigging and operations are standardized and are supposed to remain similar over decades), Eqs. 2–4 can be used in the absence of any knowledge about the technological creep in a given fishery. This method also should apply to the effort used in stock assessments in surplus production modeling (Schaefer 1954), CMSY (Froese et al. 2017), or related methods.

*Responses to this article can be read online at:*
http://www.ecologyandsociety.org/issues/responses.php/11136

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