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Response to Palomares and Pauly. 2019. "On the creeping increase of vessels' fishing power"

The risk of underestimating long-term fisheries creep

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Palomares and Pauly (2019) provide an insightful review of studies assessing the rate of technological creep (*C*) in fisheries, emphasizing the importance of including technological creep when considering timescales exceeding one decade. Their analysis suggests that the rate of increase is negatively correlated with the length of the investigated time period, because of a selection bias of study targets toward particularly effective new innovations, concluding that the long-term value of *C* is actually quite low (1.3% y^{-1} over 100 y). We would like to raise two cautionary issues with regard to this conclusion. First, a conceptual consideration stemming from the inconsistent definition of technological creep across studies is important to keep in mind when comparing *C* across multiple analyses. Second, because of the difficulty of precisely observing *C*, the values of *C* relevant for long-term studies could be significantly higher than 1.3% y^{-1}.

The conceptual issue is linked to inconsistent definitions of *C*. As stated by the authors, *C* can be conceived either as a change in catchability (q) or some aspect of nominal effort (f), and the important quantity is the resultant product fq. Yet in most of the reviewed case studies, the effect of *C* is measured in terms of the catching power of a given unit of nominal effort, including only the increase in the catchability parameter q and therefore not assessing parallel changes in f. The unit used to measure f can vary significantly (Ricker 1975), from vessel time, fisher time, engine power, or vessel tonnage to number of hooks, hauls, net-meters, or traps. Importantly, the choice of nominal effort unit determines which aspects of technological creep are accounted for in f or q.

To illustrate, consider the differences if nominal effort is defined as either (a) fisher time (labor), or (b) the number of hooks. If choosing fisher time as a base unit for effort, q would incorporate all embodied and disembodied technical effects that improve the catch rate of fish per human hour invested (Squires and Vestergaard 2013), including mechanization, vessel features, gear, and knowledge. By comparison, when using hook number as the unit of effort, q would incorporate features of the hooks, vessels, and knowledge that increase the fraction of fish caught per hook, but ignore innovations that increase the possible number of hooks deployed per hour of labor, such as the invention of monofilament lines and power winches. Thus, the less inclusive unit of hooks would lead to a lower estimate of *C*, all else being equal. For individual studies, the choice of unit is not necessarily a problem, but a value of *C* estimated in one study is not assessing the same aspects of creep as one that uses a different nominal effort unit.

Apart from this conceptual issue, there are methodological limitations that can bias the relationship between *C* and length of time period suggested by the authors. Often, the methodologies of the long-term studies leave out some kinds of technological progress, especially those of the second kind described by Palomares and Pauly (small background alterations in the rigging of vessels or skill of skippers to handle and apply new technologies). For example, the base vessel method by Engelhard (2008) cannot identify creep stemming from technologies that are adopted by both the base vessel and the other vessel (see Bishop 2006), such as synthetic fibres, fish finding devices, GPS, or accumulating knowledge. Further, Ward (2008) sums the measured catchability improvements of many different processes, but lacks estimates for some, notably the effects of fish finding equipment and communication systems. Hart et al. (2011) estimate only the effect of the introduction of the GPS, so creep due to all other innovations over the 25-year study period is left out. Thus, we argue that many of the long-term *C* values are bound to be underestimated.

Further, as the authors underline, the uncertainty in the relationship is substantial (keeping in mind the logarithmic axes), and the R^2 is only 0.15. Additionally, Palomares and Pauly exclude the technological progress brought about by the advent of steam powered boats in the estimates by Engelhard (2008). Including the total increase in fishing power stated by Engelhard (50 times for cod, 100 times for plaice) increases the estimated *C* from 1.8 and 2.3% yr^{-1} to 3.3 and 3.9% yr^{-1}, respectively, in the 120-year study. Altogether, these cautionary issues leave open the possibility that the long-term value of *C* is not actually lower than the shorter term averages, especially not for more inclusive units of nominal effort.

We would also mention that, in a modeling study of global fisheries, a fleet-average *C* of about 5% yr^{-1} can explain the first-order trends in the historical development of the global fishery, whereas a 2% yr^{-1} rate underestimates the observed rate of change (Galbraith et al. 2017). Importantly, this result concurs with Palomares and Pauly, as well as Steneck and Pauly (2019), that the creeping increase in fishing power is a primary cause for global overfishing and biomass depletion. Because this type of broadly defined, fleet-average *C* is used to estimate long-term changes in catch efficiency (catch-per-unit-effort), which is used to assess fish abundance and overfishing (see, e.g., Watson et al. 2013 and Rousseau et al. 2019), finding an accurate *C* that fits the context is critical. Underestimating the long-term value of *C* would lead to an underestimate of fisheries impacts, and undervalue both the importance of incorporating creep into

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fisheries management and the feasible future impacts of further technological progress.

In conclusion, we strongly agree that inclusion of technological creep in fisheries management is essential for long-term fisheries sustainability. Future work on this important process could develop clearer definitions that better support application across diverse fisheries and timescales, and aim to better constrain the long-term and large-scale rate of technological creep. To paraphrase Palomares and Pauly, we believe that we are already in trouble as a species because we do not appropriately account for technological creep.

Responses to this article can be read online at:
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