



Reply

Ground-truthing the ground-truth: reply to Garibaldi *et al.*'s comment on "Managing fisheries from space: Google Earth improves estimates of distant fish catches"

Dalal Al-Abdulrazzak* and Daniel Pauly

Sea Around Us, Fisheries Centre, University of British Columbia, 2202 Main Mall, Vancouver, BC, Canada V6T 1Z4

*Corresponding author: tel: +1 917 373 4450; e-mail: d.alabdulrazzak@fisheries.ubc.ca

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There has been a growing interest in the potential of Google Earth for scientific inquiries, and our previous paper (Al-Abdulrazzak and Pauly, 2014. Managing fisheries from space: Google Earth improves estimates of distant fish catches. ICES Journal of Marine Science, 71: 450–454) on weirs and their catch in the Persian Gulf is a case in point. Garibaldi *et al.* (2014. Comment on: "Managing fisheries from space: Google Earth improves estimates of distant fish catches" by Al-Abdulrazzak and Pauly. ICES Journal of Marine Science), while agreeing in principle with using Google Earth for fisheries-related purposes, criticized the assumptions, data, methodology, and results of this paper. Here, we refute their criticisms, notably by showing that the "derelict weirs" that they thought they had "ground-truthed" are not weirs at all, but another type of fishing gear in one case, and debris from a boat anchoring system in the other. We develop the theme that ground-truthing requires local knowledge, and provide recommendations for using Google Earth images in fisheries management.

Keywords: Google Earth, ground-truth, fisheries.

Introduction

A major reason why, throughout the world, the food provisioning role and ecosystem impacts of small-scale fisheries are thought to be negligible is that catch data for these fisheries are hard to come by, especially data produced in the context of rigorous sampling designs as traditionally required by fisheries scientists (Pauly, 1995). However, not accounting for the catch of small-scale fisheries will generally be far more misleading than using conservative estimates derived from anecdotal estimates (Zeller *et al.*, 2006). Thus, a call for incorporating non-traditional sources of data into fisheries science (Pauly, 1995) has resulted in a number of studies that have attempted to estimate missing or underrepresented fisheries sectors using a diversity of methods, including household surveys, interviews with fishers, historical records, and, more recently, Google Earth (Saenz-Arroyo *et al.*, 2005; Zeller *et al.*, 2007; Jacquet *et al.*, 2010; Le Manach *et al.*, 2012; McClenachan and

Kittinger, 2013; Al-Abdulrazzak and Pauly, 2014; Al-Abdulrazzak *et al.*, in press).

Weirs have been a common feature on the coast of the Persian Gulf for decades (Figure 1), and even centuries (MacIvor, 1881), but their actual impact was not considered until recently. To assess the impact of weirs, it was necessary to accept the possibility that many relatively simple fishing gears can have, in aggregate, effects similar to that of industrial fishing gear. Indeed, weirs, given their relatively low construction cost, will tend to proliferate where the physical and social conditions are appropriate. However, the latter conditions may not favour catch monitoring and, hence, their role may be unappreciated, and even their existence denied, e.g. because, in some countries, the complex rules regulating their beneficial ownership may not fit into the top-down administrative structure of fisheries management. Multiple examples of this can be found in the Asia-Pacific region, where many countries, for a long time, pursued centralizing policies that they inherited from earlier colonial masters. These policies often



Figure 1. Three Blackburn B-101 Beverley heavy transporters flying over weirs off the coast of Bahrain. A reference to the (British) Royal Air Force squadron 84 suggests this photo was taken c. 1964.

suppressed traditional community-based management and resulted in a reduction on the contribution of local fish catches to livelihoods and diets of people in rural areas (Ruddle, 1993). In situations such as this, Google Earth-based studies can be invaluable, as they can generate compelling existential and quantitative data on fisheries. Garibaldi *et al.* (2014), while endorsing the use of such studies in principle, criticize the assumptions, methodology, statistics, results, and conclusions of Al-Abdulrazzak and Pauly (2014), primarily based on what they contend is a ground-truthing exercise which, however, only revealed (i) a lack of local knowledge, and (ii) insufficient reflection on the concept and nature of “ground-truthing”.

The key issue with the concept of “ground-truthing” is that it contains the word “truth”, which is always a problem in Science, given that in practice, we only deal with evidence that either supports or contradicts hypotheses (Popper, 2005). Ground-truthing satellite imagery is therefore not a matter of concocting a story about what may be happening on the ground, as the second author painfully discovered when the Chinese “trawlers” he thought he had ground “truthed” in a much reproduced photograph (Van Houtan and Pauly, 2007) turned out to show anchored vessels operating like weirs against tidal currents. Rather, ground-truthing, as is all of evidence-based science, is a matter of formulating and testing hypotheses, i.e. processes for which both local expertise and restraint in the face of uncertainty are needed. As we will show, lack of local knowledge, in this case, completely invalidated the ground-truthing intended by Garibaldi *et al.* (2014).

Rebuttal to the criticisms levied by Garibaldi *et al.*

We address the objections of Garibaldi *et al.* in what we think is a logical progression, although this is not the sequence in which they were presented in their comment.

(1) Garibaldi *et al.* criticize our use of only three estimates for the daily catch of weirs, obtained from a thorough literature review and interactions with local experts in each Gulf country. These three catch rates were the only estimates available. We accommodated this data scarcity—which we admitted is real—as best we could, by accepting large confidence intervals, i.e. using the Monte-Carlo method to explicitly account for uncertainty. This, it seems to us, is more constructive than entirely ignoring a fishing gear because

of data scarcity. We consider it telling that, despite their own local contacts, and access to Governments and national databases in the Gulf region, Garibaldi *et al.* (2014) did not present any alternative estimates.

(2) Garibaldi *et al.* (2014) write, “daily catch of weirs can differ substantially according to season, area, shape of gear, fish migration, ocean currents, weather conditions, etc.”. While this seems reasonable, we point out that these alleged relationships are hypotheses, and that hypotheses are tested with data—which they do not present. Accounting for the relationship between weir catch rates and any of the factors listed by Garibaldi *et al.* (2014; which can be straightforwardly incorporated into the Monte Carlo approach we used) could have improved our results. In fact, we did record the sizes of the three different components of each weir we encountered (Al-Abdulrazzak and Pauly 2014; see Table 2) and, thus, if/when data on catch per weir of different sizes become available, we will be able to consider them, along with the effect of tides and seasons.

(3) Garibaldi *et al.* (2014) consider that “when only a portion of a weir is visible it is in fact due to the weir being only partially present through either disrepair or abandonment”. This statement is refuted by Figure 2, which shows that the physical conditions encountered when an image is taken has a strong influence on the visibility of weirs. We assume that weirs that fall into such a state of disrepair that they are not fishing (or ghost fishing, which would be equivalent here) would not be standing and therefore not visible from Google Earth. Thus, not accounting for suboptimal visibility obscuring some weirs would have rightly been considered a source of downward bias. However, this correction for underestimation only added 6% to the total weirs that were actually counted.

(4) Both Figure 2a and b of Garibaldi *et al.* (2014), which are supposed to support their assertion [addressed in (3)] that we may have included derelict weirs in our estimate, do not, in fact, illustrate a derelict weir. Rather, Garibaldi *et al.* (2014) have mistaken a *maskar*, an entirely different gear, for a weir (Arabic: *hadrah*). *Maskars* are low stone barriers used in Qatar (and to a lesser extent the United Arab Emirates) that run parallel to shore allowing fish to swim over the top at high tide and require active fishing at low tide (Serjeant, 1978; Carter and Killick, 2010). *Hadrachs*, on the other hand, are made from bamboo poles and chicken wire (or historically, woven date palm fronds) and run perpendicular to shore (Figure 3). The obvious differences in appearance, orientation, and materials between *hadrahs* and *maskars* make it possible to differentiate between them solely from the satellite images. Because of these differences, and others (e.g. effort, catch composition, fishing season), *maskars* were not included in our study. However, this identifies another stationary gear whose impact could be monitored using Google Earth.

(5) Garibaldi *et al.* (2014) suggest that we “introduced positive biases” by needlessly inflating the number of estimated weirs when accounting for the low resolution of some of the satellite images that we used. Figure 4, which depicts Failaka Island, off Kuwait, for which we had only a partial area of sufficient resolution available to us at the time of the study, illustrates how certain areas of the coast which are likely to have weirs present may not have sufficient imagery resolution to detect them. At the time that we conducted our survey, only the north part of Failaka Island had sufficient resolution, which enabled us to detect four weirs in this area. However, imagery for 2012 (which only became available after our survey was completed) indicates that indeed eight additional weirs were present in the southern part of the island. We accounted for low resolution by counting the number of coastal

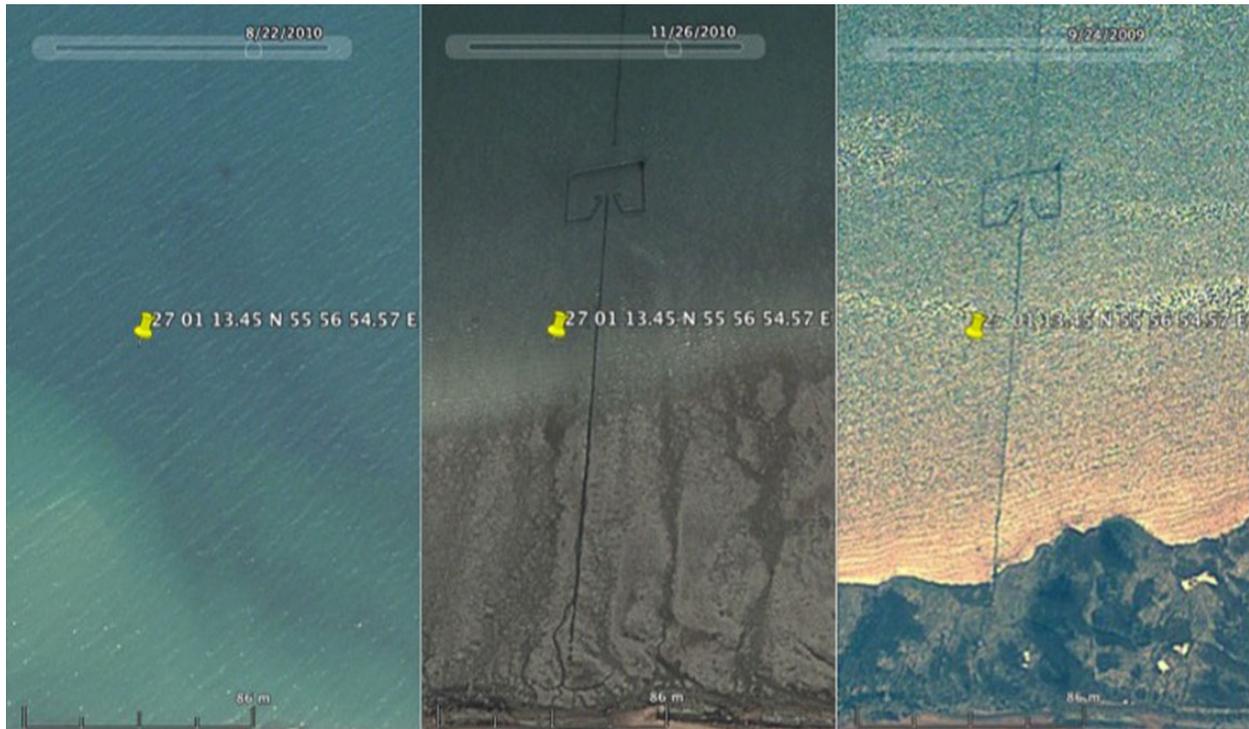


Figure 2. A single weir off the coast of Iran under three different conditions to illustrate the effect of physical conditions on visibility. Pin represents GPS coordinates.



Figure 3. Ground photograph of weir to contrast the image provided by Garibaldi *et al.* (2014) purported to be a weir but which is actually a maskar.

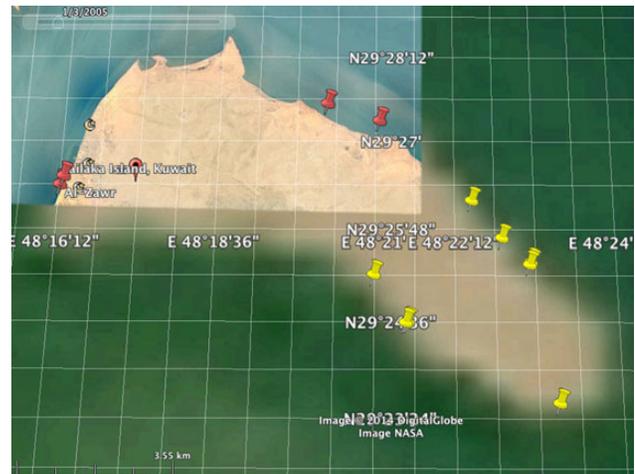


Figure 4. Failaka Island, Kuwait showing the quality of satellite imagery available for 2005 and projection of the Google Earth grid view. Red pins represent weirs found during the original study for 2005, while yellow pins represent weirs found using imagery available after the survey was completed in 2012.

grid squares in each country with and without available imagery, and raising the total number of weirs by the percentage of missing imagery. This method adds only an additional 8% to the total weirs counted in the Gulf. Obviously, this correction would not have been necessary if we had access to images with better resolution. However, since such was not available to us at the time, we applied what we contend is a reasonable correction to the poor resolution images.



Figure 5. (a) Ground-truthing verifies that the satellite image provided by [Garibaldi et al. \(2014\)](#) is a remnant of a private boat anchoring system. GPS coordinates: $+028.59040^{\circ} / +048.39914^{\circ}$. (b) GPS coordinates provided by [Garibaldi et al. \(2014\)](#) in relation to the coordinates of (a). A different angle was necessary to capture the length of the structure.

(6) Serendipitously, the GPS coordinates that [Garibaldi et al. \(2014\)](#) provided to illustrate a “weir fragment” in Kuwait corresponds to the coastal area directly in front of the first author’s home (Figure 5a). Having lived in this house for over two decades, she can state with certainty that the dark line in question was never a weir, but a remnant from a boat anchoring system that her father installed in the 1980s. That system was destroyed in the 1990/1991 Gulf War. However, the two 1 t weights and the lead line remain, creating a dark line in the satellite image that was mistaken by [Garibaldi et al. \(2014\)](#) for a derelict weir (Figure 5b).

(7) Beyond the coincidence described in (6), there are easily observable features in Google Earth that make it possible to determine that the object in the images is not a derelict weir. (i) The Google Earth time slider tool makes it possible to scan images of the same area taken in years before and after 2005. Doing so demonstrates that the dark line was never part of the “wing” section of a weir. (ii) The location of the sandbar in the middle of the “weir” would not allow fish to swim into the pocket during the receding tide, since weirs require gradually sloping seabeds. (iii) Examining nearby (<1 km) weirs reveals that all eight weirs in the area were well maintained from 2004 to 2013, indicating that the region is a productive fishing area and making it unlikely that one single weir in the same area would have been left derelict.

All the preceding dealt with technical matters. The following points deal with data and transparency issues.

(8) [Garibaldi et al. \(2014\)](#) state that we erroneously assert that “the FAO database” does not separate Saudi Arabia’s catch data from the Gulf and the Red Sea, and they point to the Gulf Regional Commission for Fisheries (RECOFI) database having such disaggregated data. We do not doubt that databases exist in which this differentiation is made. The FAO Fishstat database, which is the one we referred to, does not.

(9) [Garibaldi et al. \(2014\)](#) refer to an “unpublished document for domestic inter-organizational purposes” as something we should have consulted. They also state that we ignored the RECOFI. However, this organization does not widely disseminate the data it holds, and its decision on minimum data reporting standards (i) does not include catches by weirs ([FAO, 2013](#)); (ii) is based on

each member country setting their own standards which can result in no reporting at all, as was the case in 2013 when four countries failed to report. It remains to be seen whether tangible improvements will result from the RECOFI process.

(10) [Garibaldi et al. \(2014\)](#) state, “it is very probable that catches from weirs are included in the catch statistics reported to FAO.” This lack of confidence in the details of the FAO database by the very people who are in charge of it illustrates the lack of transparency and the need to improve the quality of the database through objective third-party estimates. Interestingly, the preliminary estimates presented by [Garibaldi et al. \(2014\)](#) of weirs contributing at most 10% of total catches in Kuwait, Bahrain, and Iran are consistent with our regional estimate of 6–8% ([Al-Abdulrazzak and Pauly, 2014](#)).

Proposed best practice for the use of Google Earth satellite images

Google Earth is emerging as a powerful and cost-effective tool for scientists in a wide variety of disciplines including archaeology, ecological theory, and public health ([Chang et al., 2009](#); [Pringle, 2010](#); [Madin et al., 2011](#); [Ploton et al., 2012](#)). Although Google Earth cannot be used everywhere—image resolution varies spatially and temporally—the potential to rapidly survey inaccessible or cost-prohibitive areas is tremendous. Here, we propose four “best practices” that we suggest should be considered when using Google Earth satellite images.

- (i) Develop a search image. Although predators may at first overlook potential prey, with experience, they “learn” to detect cryptic prey ([Tinbergen, 1960](#); [Dawkins, 1971](#)). The same concept applies to Google Earth, where with time, users can detect what they are looking for more quickly—and more accurately. For this reason, we scanned the coast of entire Gulf three times to ensure a complete count of weirs and to minimize the possibility that other structures were mistakenly included.

- (ii) When in doubt, err on the side of caution. If a structure is difficult to verify, do not include it in the survey. For example, for weirs, at least two out of the three components (wing, yard, pocket) should be visible.
- (iii) Ground-truth in the light of local knowledge. As explained above, ground-truthing exercises are only useful when they include an understanding of the local landscape and customs.
- (iv) Consider the dates of image availability. Different areas of the world have different years of image availability. Consider whether the dates are appropriate for the study and whether scanning several years can aid in verifying an object.
- (v) Accommodate for lack of images. We demonstrate two conservative and straightforward ways of accounting for common problems: image availability and poor resolution (Al-Abdulrazzak and Pauly, 2014). These methods can easily be modified to other studies that rely on object counts.

Conclusion

When a new approach is presented that leads to a scientific advance, it is very easy to point out its weaknesses and propose how it could be improved. Stating that reality is far more complicated than the new approach allows for, and using that argument to dismiss the results, does not move the science forward (Cheung *et al.*, 2013). Rather, critiques of this nature in effect discourage innovation and the exploration of new tools. We contend that a more constructive approach would be to propose how a new method could be improved and demonstrate that with studies that build upon the original work.

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