Conservation Letters
A journal of the Society for Conservation Biology
Open Access

CORRESPONDENCE

Research on Seafood Fraud Deserves Better

C. Josh Donlan[1,2], Gloria M. Luque[1], Chris Wilcox[3], Stefan Gelcich[1,4], George W. Koch[5,6], & Bruce A. Hungate[5,6]

[1] Advanced Conservation Strategies, Córdoba, Spain, 14011
[2] Department of Ecology and Evolutionary Biology, Cornell University, Ithaca, NY 14853, USA
[3] CSIRO Oceans and Atmosphere Business Unit, Hobart, TAS 7000, Australia
[4] Center of Applied Ecology and Sustainability & Centro de Conservacion Marina, Pontificia Universidad Catolica de Chile, Santiago, Chile, 8331150
[5] Department of Biological Sciences, Northern Arizona University, Flagstaff, AZ 86011, USA
[6] Center for Ecosystem, Science and Society, Northern Arizona University, Flagstaff, AZ 86011, USA

Keywords
Seafood fraud; seafood mislabeling; fisheries; salmon, seafood.

Correspondence
C. J. Donlan, Advanced Conservation Strategies, Córdoba, Spain, 14011
E-mail: jdonlan@advancedconservation.org

Received
2 December 2016
Revised
13 February 2017
Accepted
16 February 2017

doi: 10.1111/conl.12356

Stawitz *et al.* present an analysis of seafood mislabeling and make inferences about its financial and ecological implications. We applaud the authors for tackling this important topic. As presented, however, we have reservations about the research which call into question the main conclusions. First, based on the data and results that are presented, there appear to be errors and some of the conclusions are not supported. Second, there may be a bias in the analyses that favors the conclusions. Third, details are lacking regarding the analyses, challenging their verification. We briefly describe some of the issues.

At least, two main conclusions are not supported by the data and analyses presented. The authors claim that mislabeling results in the consumption of fish with less endangered conservation status, and thus "mislabeling may not mislead people into eating less sustainable seafood." First, the authors fail to mention that many substitute species come from aquaculture, where IUCN status is less relevant and environmental impacts are commonplace (e.g., *Salmo salar* and *Pangasius* spp.). In fact, it is perplexing that *S. salar* (Atlantic salmon) is included as a mislabeled species in the conservation status analysis, since it is commonly a substitute and rarely a mislabeled species (Cline 2012; Warner *et al.* 2015). Second, there are apparent errors. From our analysis of the data sources (Table S1 in Stawitz et al. 2016), 11 studies included salmon, and only two samples labeled as Atlantic salmon were mislabeled, substituted by *Oncorhynchus mykiss* in both cases (Filonzi *et al.* 2010). The former is listed as least concern and the latter has not been assessed (IUCN 2016). Yet, the authors' figure 2 (with no sample sizes reported) shows Atlantic salmon having an IUCN status of near threatened being substituted by a species with a status of least concern. It is unclear why Atlantic salmon (i.e., an aquaculture product) was included in the IUCN analysis, but several studies targeting wild Pacific salmon (*Oncorhynchus* spp.) were omitted, some of which revealed high levels of mislabeling (e.g., Cline 2012; Warner *et al.* 2015). Third, we suspect that outliers might be driving the authors' conclusion that true species

Table 1 Examples of issues with the dataset, presentation, and the use of statistical methodologies in Stawitz *et al.* 2016

Dataset is opaque and inconsistent.	The authors do not justify why they included a U.S. FDA report and a study from "an undergraduate genetics course" in their dataset but chose to exclude the many other mislabeling studies in the gray literature, which includes hundreds of samples barcoded by professional laboratories (e.g., Warner *et al.* 2015). The sample dataset is not presented by species or source.
Opaque data presentation with errors.	Many figures do not include standard information (or are presented opaquely), such as sample sizes and measures of variances (e.g., figures 2, 5, S2, and S3). Others appear to have errors (e.g., figure 4 reports sample sizes of log(6), i.e., 1,000,000; in figure 2, arrow thicknesses, which represent sample sizes, are the same).
Lack of justification and appropriateness of statistical methodologies.	Conclusions rely on bootstrapping; however, summary statistics of raw data nor its underlying distribution is presented. Regarding the multidimensional scaling, no information is reported on the potential complications with unequal sample sizes, which are likely to be significant, nor the appropriateness of its use (e.g., stress value or a Shepard plot to show the preservation of original dissimilarities in the reduced number of dimensions).

are of improved conservation status. In figures 2 and S7, there are more seafood pairs that are in the opposite direction (i.e., true species are of diminished conservation status), and there are a few pairs with large differences in the direction of the author's conclusion (i.e., grouper and toothfish). This may be influencing the overall conclusion; the authors state that the rest of the data (not included in figure 2) "had no difference in IUCN status between labeled and true items."

A bias may be present in the analyses favoring the conclusion that "mislabeling results in the sale of items of better conservation status and nearly equivalent price." In choosing substitutes to compare for cost and IUCN status, the authors exclude data-deficient species from their analysis. Thus, substitutes they consider may be drawn from a subset that is likely more valuable, better managed, and information rich. Similar biases have been documented in other systems, where research output was strongly biased toward well-funded settings and more common species (Roberts *et al.* 2016). Thus, the author's substitutes may overrepresent the value and conservation status of substitutes in general, in the direction of the authors' conclusions. It might be possible to avoid this potential bias by using life history-based indicators of sustainability. Given the data presented, we cannot quantify the bias (e.g., the authors fail to report the mean IUCN status of labeled and true fish species, and their table S3 reports the number of mislabeling cases, while it is the species that is of interest).

The second problematic conclusion is the claim that "distributors had the highest probability of serving mislabeled items (mean = 0.184)." The authors suggest that efforts to reduce mislabeling should be prioritized "at points in the chain-of-custody beyond ports, where the majority of mislabeling occurred." In figure 5 (with no sample sizes reported), however, the variability across purchase locations is substantial, and no pairwise tests are presented. Further, the statistical model is suspect. The authors first describe the model using a binomial distribution and response variable (i.e., mislabeled or not). They then present the model with mislabeled probability as the response variable (equation #1). The fact that the best performing model (i.e., source) has an AICw of 0.99 and that other models that include the same fixed effect have AICw of 0 suggests that all models in the set could be quite poor. Yet, there is no reporting on the goodness of fit or over dispersion in the final model—both standard practices, nor reporting on the deviance explained and the AIC of the null model which would allow evaluation of the explanatory power of the model.

As important, the above conclusion is based on an unbalanced dataset for five species, including the rarely mislabeled Atlantic salmon. This dataset also appears to contain errors. It includes a single study focused on distributors, which includes only 10 samples covering three of the five focal species, of which none were mislabeled (table 1 in Cawthorn *et al.* 2012). It is unclear where the 18% probability of mislabeling comes from: Cawthorn *et al.* report an approximately 9% mislabeling rate for all their 108 samples at the distributor level. Similarly, the port mislabeling rate is based on two studies with contradictory results: one from the United States reporting a mislabeling rate of 15% and one from Taiwan reporting a mislabeling rate of 70% from 34 samples for 17 seafood products (US Food and Drug Administration 2014; Chang *et al.* 2016). But the former study includes only two of the focal species and the latter study contains none.

While we commend the authors for their efforts to go beyond seafood mislabeling documentation, the above issues are not minor and are even more concerning given additional issues with the data, analyses, and reporting (Table 1). Combined with the potential bias, the

inferences of the manuscript are not supported, as currently presented. Seafood fraud is a nascent topic, one in which natural and human systems are interacting in complex ways that are likely resulting in place-based consequences. To characterize the system dynamics and provide insights into the financial and ecological implications of seafood fraud, a more careful and cautious approach is required. We urge the authors to formally address these issues and revisit the conclusions of their research.

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