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Abstract

Small-scale fisheries are recognised as making important contributions to nutrition and economic development despite a lack of accurate quantitative information on catches and consumption. While direct measurement remains the most appropriate way of collecting such data, it is impractical at large scales. Instead, household surveys based upon informant recall of fish caught and/or consumed are frequently used. However, the accuracy of weight recall by informants (even over short recall periods) has not been established.

Using data from household surveys, the accuracy and precision of catch and consumption estimates derived from 1) asking informants to recall weights of fish caught and; 2) asking respondents to recall lengths of fish caught and converting to weight, were tested. ~~The results suggest~~ L~~l~~ength-based methods, using visual aids to assist recall ~~are~~ were more accurate, precise and correctable. These methods could be useful for catch estimation, especially where fish are processed, sold or eaten shortly after capture.

Keywords

Household surveys; respondent recall; catch estimation; resource management; food security; nutrition

Introduction

Importance of small-scale fisheries and limitations to current assessment

It is now widely recognised that small scale fisheries are essential for food security in the developing world (Hall et al., 2013), both directly as a source of protein, micro-nutrients and long chain fatty acids (Kawarazuka and Bene, 2011; Tacon and Metian, 2013, Thilsted et al., 2016) and indirectly as a source of income for purchasing food, and access to health and education services (Bene and Friend, 2011; Kawarazuka and Bene, 2011). Fishing is a key livelihood strategy for millions of households (Kelleher et al., 2012) frequently being part of a wider livelihood diversification strategy that increases a household's resilience and creates a safety net in times of hardship (Bene et al., 2010; Arthur et al., 2016). As its' importance to household food security and poverty alleviation has been recognised, so, effective means of quantifying this importance have had to be devised.

Official national catch statistics (FAO Fishstat database) have been used for this in the past, (on their own or with import and export data to construct Food Balance sheets), but these cannot provide data on variability within country or between subpopulations and groups (FAO, 2008; Needham and Funge-Smith, 2015). In addition, underestimation of both catches and consumption has long been suspected, due to unmonitored subsistence fisheries (Coates, 2002; FAO, WorldFish and World Bank, 2008; Wellcome, 2011) and several recent studies in inland fisheries have confirmed this (Kelleher et al., 2012; Fluet-Chouinard et al., 2018). Instead of using catch statistics, Fluet-Chouinard et al. (2018) back-calculated national and global inland fishery harvests using estimates of consumption of freshwater fish from household consumption and expenditure surveys (548,000 households across 42 countries).

A similar approach, this time undertaking a meta-analysis of 20 different household surveys, was used to estimate fisheries production in the Lower Mekong Basin (Hortle et al., 2007). Fluet-Chouinard et al. (2018) concluded that freshwater catches were, on average, likely to be ~65% higher than those officially reported by national governments to the United Nations (UN) Food and Agriculture Organisation (FAO). An earlier large-scale research project (Kelleher et al., 2012) provided a similar result, estimating the global under-evaluation at around 70%. The estimation methods used in this project were different (but included the re-analysis of household survey data), as were results for individual countries, but they never-the-less called into question the reliability of national catch statistics for measuring catch and consumption, particularly in the inland fisheries sector. This underreporting of inland fisheries has "masked their critical role in feeding the world's poor and has confounded efforts to use catch statistics, with other biological information, to evaluate the impact of overharvest and ecosystem degradation" (Allison and Mills, 2018, p.7459). This has led many researchers to conclude that new procedures, in addition to traditional catch assessments, are required (So Youn et al., 2017; FAO, 2017)

Problems of underestimation arise because collecting data for the small-scale sector, with large numbers of fishers using a wide variety of seasonally shifting capture techniques, that target dynamic, multispecies fish communities, at decentralised and irregular landing sites is difficult, costly and time consuming (Coates, 2002; Welcomme et al., 2010; Mills et al., 2011; Kolding, 2017). It includes collecting data for the hundreds of millions of people not classified as 'fishers' but none-the-less routinely fishing (in marine areas, creeks, rivers, small lakes and reservoirs, seasonal and temporary ponds, wetlands and floodplains) for subsistence and sometimes local sale. Typical catches are small, and species small and varied (Halwart, 2008; Kelleher et al., 2012; Garaway et al., 2013; Allison and Mills, 2018).

To address this complexity So Youn et al. (2017) have suggested the need for, amongst other things, routine targeted surveys of household dynamics and food consumption studies, intensification of catch assessment methodologies, and using local communities to support data collection and reporting. Allison and Mills (2018) also highlight the value of employing a "tapestry" of methods for estimating inland fishery production, suggesting that the research of Fluet-Chouinard et al. (2018) "considerably strengthens the case for the central role of consumption studies in this tapestry" (Allison and Mills, 2018, p.7640). Meanwhile, Kolding (2017) advocates the use of fisher log books, filled in by fishers themselves, to estimate daily catches. Whilst recognising the potential accuracy and reliability issues that come with this approach, (and providing potentials solutions which will be discussed later in this paper), he sees this as the only realistic alternative to catch/effort surveys which are costly and heavily manpower dependent (Kolding, 2017).

It is clear from the above discussion that there is a move towards alternative and more localised data collection efforts to address the complexities of measuring catch and/or consumption of fish in the small-scale sector. Given that such data may then to be used to guide and inform policy (across a variety of sectors) at the highest of levels, it is critical to ensure that such methods for collecting fisheries data are robust.

Collecting fisheries data at household / individual level.

While direct measurement by a trained enumerator remains by far the most accurate and precise way of collecting household / individual data on fish catch and/or consumption, it is impractical, both in terms of time and resource, to carry out on a large scale. More routinely then, fishers, or households, are either asked to record the data themselves (in log books or food diaries) or asked to recall activities over a defined reference period. Respondent recall of catch /consumption has emerged as one of the most frequently used methodologies. For instance, in the meta review investigating household fish consumption in the Lower Mekong Basin,17 studies used recall, and only 3, direct measurement (Hortle, 2007). In addition, Fluet-Chouinard et al.'s (2018) household surveys relied on respondent recall in 42 countries to estimate consumption, with a recall reference period of 24 hours up to two weeks. Of all the available dietary assessment methods used by the nutritional research community in low-income countries, surveys relying on recall (24 hours) are also the most frequently used (Gibson, 2017). This is because they are "quick, culturally sensitive, do not require high cognitive ability, and provide quantitative data on both foods and nutrients" (Gibson, 2017 p. 980).

Within the nutrition community there has been significant research done to establish appropriate recall reference periods for different activities (Shim et al., 2014; Naska et al., 2017). For the type of fishing activities being considered here (frequent, routine activities), the 24-hour (24-h) reference period has emerged as the research standard, as it significantly reduces recall error (failing to accurately remember what was caught/consumed). However, even if the reference period is shortened to 24 hours, there are still many other potential sources of error that must be overcome. Globally, incorrect estimation of portion sizes, i.e. respondents failing to quantify accurately the amount of food consumed is one of the major sources of reporting error for foods in 24-h recalls (Rumpler et al., 2008) and probably the largest measurement error in 24-h recalls in low income countries (Gibson et al., 2017). In the latter case, this can be because of "poor memory, limited quantitative skills or the incorrect use of measurement aids by interviewers" (Gibson et al., 2017, p. 984). A body of research suggests that a variety of 'Portion Size Estimate Aids' (PSEA's), - such as local household utensils, drawings, photos graduated measuring jugs or cylinders, tape measures, and modelling clay or playdough moulded into the correct size and shape of the food (Gibson et al., 2017) - help participants more accurately estimate the amounts of foods consumed (Suba et al., 2010).

Recalling fish catch

Despite these well recognised sources of error with recall, there has been very little work carried out on whether respondents in small scale subsistence fisheries can accurately quantify the amount of fish they catch, even over a short time period. This is the case whether recalled data is subsequently recorded by an enumerator or self-recorded, by an individual, in a log book. There is also little research on whether, and how, the unit of measurement used to recall catch affects its accuracy; in particular, whether fishers are asked to estimate weights and/or lengths of the fish caught. This is despite it having been seen as a key area for research (Hortle et al., 2007; FAO, 2017) and despite the fact that in many countries' weights are not a common way of either describing fish size or of measuring quantities for sale, with people instead using ‘pieces’, ‘bunches’, ‘sticks’, ‘bowls’ or ‘sacks’ (e.g. Brugere, 2014; Moreau and Garaway, 2018).

This paper addresses this gap. It compares the accuracy and precision of two methods of collecting catch data over a short (<24-hr) recall period: 1) The most common method used; asking informants to recall the weight of fish caught in grams and; 2) using visual aids (VA’s) that have been called ‘fish sticks’ (sticks of different and known lengths) that assist respondents in recalling the *lengths* of fish caught, recording those lengths, and then subsequently converting the lengths to weights using established length/weight relationships (either estimated locally or obtained from databases such as FishBase). The ‘fish sticks’ methodology for estimating yields and/or fish consumption was developed for household fish catch and consumption studies in Lao PDR (Garaway 1999) and has been used in several studies since (Garaway et al., 2013; Moreau and Garaway, 2018). It is designed to take advantage of the fact that fish length is far easier to represent in the form of a visual aid than fish weight, and given the recognised role of VA’s/PSEA’s in improving recall accuracy (Suba, 2010), this may improve results. While earlier work relied on using length-weight data for a small set of commonly captured fish species, the present study provided an opportunity to compare the accuracy of weight and length recall methods and to provide more accurate conversion estimates for length-based catches.

A limited number of studies have attempted to study the accuracy and reliability of catch recall in the small-scale subsistence sector. Recalling fish length (and subsequently converting into weights using length/weight relationships) was the preferred methodology in a study investigating the accuracy of household reporting of subsistence catches in a village in Fiji (Kuster et al., 2006). Recalled household data were compared with data collected from contemporaneous creel surveys conducted by the research team. Results suggested that there were no significant overall differences in results between the two methods, leading researchers to conclude that households are “relatively accurate in their estimation of the number and size of fish from recalled catches” (Kuster et al., 2006 p. 177). This study demonstrates the potential of using length-based methods but falls short of describing whether recalling in other units (such as fish weight) would have produced a more accurate result. It is also limited by the fact that the catches being recalled were not subsequently measured by the research team and instead a separate survey was used for comparative purposes.

A direct comparison of recall versus measurement of the *same* fish was carried out in a survey in the Lower Mekong Basin by Garrison et al. (2006). In this study the researchers were interested in how well households could estimate the weights of their catches with the catches being weighed by the research team after they had been recalled by the household. Thirty-eight households across four countries (Cambodia, Vietnam, Lao PDR and Thailand) were monitored for four intensive two-week periods. Preliminary data analyses indicated that “people can accurately estimate weights of aquatic foods, within +/-10% on average" (Garrison et al., 2006 p. 761). Here then the accuracy of using weight estimates is described but again no direct comparison with length estimates is made and therefore no assertions can be made about the potential benefits or disbenefits of using one over the other.

Kolding (2017) believes length recall is a better unit of measurement than weight recall in the case of fishers self-recording catches in log books. He argues that the accuracy and reliability of using logbooks is often questioned primarily because of the inability to cross-check and validate the reported data (and usually only by total weight). However, if the lengths are recorded instead of weights (as he trailed in the Bangweulu fishery) the information collected by the fisher is still kept at a minimum but the higher-level data can be validated by simply plotting the catch distributions by gear/mesh size. This is because "it is practically impossible for a fisher to record a normal (or log-normal) distribution in random order, so this gives a direct visual tool to validate the data" (Kolding, 2017, p.15). Length-based methods have also been suggested as a more accurate alternative based on the fact that fishers frequently use length as a means of describing fish in any case, often using finger, hand or arms to describe various lengths. That said, it is possible that length-based methods might also suffer from biases, with fishers possibly overestimating lengths or categorising length in other ways. For example, it has been suggested that in some cases people measure the body length (excluding tail) rather than total length of the fish (K. Mam Pers. Comm.). As established length/weight relationships rely on total length (tip-tail), this could lead to systematic bias.

Taking all this into consideration, a Cambodian field trial was conducted to assess i) the accuracy and precision of weight versus length recall, ii) the accuracy and precision of weights estimated directly versus weights estimated via length and iii) the impact that measuring length excluding tail versus with tail has on results. To do this, fisher households were visited and asked about their recent catches and asked to estimate the parameters above. The fish were then subsequently weighed and measured by the research team.

Methods

Initial field testing in southern Lao PDR (Garaway, 2006) had shown that fishermen or fish buyers could estimate the length of fish to within 5cms in a 5–25cm range, a range that covered the majority of fish caught or sold locally. This suggested that local fishers' recollection of fish length (using different length sticks as a guide) could be used to estimate the size of fish caught and, from these, to estimate catch weights using length/weight relationships. However, it was also important to establish the accuracy of this method and how it might compare with using weight recall to establish catch estimates. This was then the focus of field trials in Cambodia.

The sampling in Cambodia was undertaken in four villages in Kampong Thom and Stung Treng provinces respectively. Sampling took place early in the morning to ensure that respondents had had time to catch fish but that they had not yet processed or consumed the fish. Each respondent was asked about the fish that they had caught and asked to give the estimated weight of each fish and then, following the methodology of Garaway (1999) to estimate the length of each fish (at this point respondents were asked to estimate length both with tail and without). Each fish was then measured and weighed and the information captured on a recording form. During the sampling a total of 34 people (18 households) were interviewed and 89 fish sampled.

Converting length to weights

For a given fish species, fish weight (*W*) can be estimated from fish length (*L*) using the following simple equation:

$$W = a.L^b$$

Where *a* and *b* are parameters of the equation with *a* representing form factor and *b* the allometric growth parameter. Many studies have been done to provide estimates of these parameters for a wide range of fish species and many of these are available in ecological databases such as FishBase and the MRC Mekong Fish Database. However, in order for a length-based methodology to be useful for small-scale fisheries in developing countries, it would not be possible or practicable to use individual length weight relationship for each species. Number of species commonly caught is large and there is a lack of available capacity to undertake species level identification in the field. Therefore, for the length-based fish sticks to be a useful field tool, a method for converting from length to weight, which minimises the number of different individual length-weight conversion calculations, is required.

Steps were therefore taken to calculate a single conversion factor. To get around the fact that two parameters are needed for each species, ~~estimates of~~ the form factors for many of the commonly caught species were estimated. The form factor ($a_{3.0}$), as described by Froese (2006) is the value parameter *a* would have if *b* had a value of three. This value is chosen as it is widely suggested that it represents a good approximation for weight at a given length (e.g. Hilborn and Walters, 2001) and allometric growth across species appears to be normally distributed around this value (Froese, 2006).

Following the practice of Froese (2006) the form factor was estimated for 93 commonly caught species reported from Southeast Asia, for which length weight relationships already existed (relationships were sourced from FishBase and the MRC Mekong Fish Database).

Firstly, a regression of *log a* against *b* was calculated using this data (see Figure 1). From this the form factor was estimated using the following equation:

$$a_{3.0} = 10^{\log a - S(b-3)}$$

Where *S* is the slope of the regression of *log a* vs. *b*.

Fish with low form factor are typically filiform and anguilliform (eel-like) while those with high form factor values tended to be compressiform, being shorter and deeper in shape. In-between were the typically fish-shaped or fusiform shapes. While this method provided a useful way to identify a single value for length weight conversions, analysis of the residuals suggested that estimates would be less accurate for long, thin anguilliform fish and introduce greater bias into a single conversion factor. It was therefore decided that to provide greater compensation for the differences in body shapes and the effect that this has on form factor, an alternative method, where the form factor was individually calculated and the mean taken, was used.

To do this, the form factor was determined by creating a 30-point length/-weight plot based on the available *a* and *b* parameters for each species and using lengths up to 30cm, unless the maximum reported size of the fish was less than this. In such cases, 30 points up to the maximum length of the fish was used. Thirty centimetres was used because in previous studies (Garaway, 1999) all fish caught in test fishing had been smaller than this and, in this study, over 95% of fish sampled were under 30 cm. Having constructed a series based on the existing relationship, a second series was created where *b* was set at a value of 3 and the Excel solver routine was used to determine the value of *a* for each species that would minimise the difference between the two series using least squares. This provided individual form factors for each species. The mean form function (0.0123) was then used together with the allometric growth rate value of 3 as a simple conversion factor from lengths to weight for all species.

Data analysis

The analysis used the data on the known lengths and weights and estimated lengths and weights for the same fish to explore the accuracy of participant recall of length and weight of fish catches. This was done by comparing estimated and actual lengths for all fish and estimated and actual weights of all fish. Given the interest in using lengths as a means to estimate consumption or yield, the accuracy of recalled length converted to weight and estimated weight to true weight was also compared.

Results

Weight vs length recall

In the first instance the accuracy with which respondents could recall weights and lengths (the latter using the fish sticks and asked to give total length including tail) was tested. The estimates of length and weight were divided by the actual length or weight to provide an indication of the degree of over and under estimation in each case (Figure 2). As can be seen respondents, on average, tended to overestimate when asked to recall weight (mean 1.47, SD 1.92). By comparison respondents were more accurate and more precise but tended to underestimate length when using the length-based ‘fish sticks’ (mean 0.81, SD 0.134). In addition, respondents were more consistent in their estimations using fish sticks, with 96.6% underestimating length. In the case of weight estimation, marginally more respondents overestimated weight (52.3%) but often to a high degree.

The results suggest that, using this method, respondents are able to more accurately describe fish in terms of their length than their weight and that length can potentially provide a good basis for catch/consumption estimates.

Given the suggestion that fishers may estimate the length of fish without the tail, data were also analysed to establish whether there was any difference in the accuracy and precision of estimates made on fish body length (no tail) compared to fork length (including tail). In fact, the results (based on a subset of 80 estimations) indicated that there was no significant difference between estimations using body length or fork length ($P>0.05$) and that the estimates in either case were very similar (body: mean = 0.82; fork: mean = 0.81).

Comparison of accuracy of weight and length methods

Applying the calculated length conversion factor ($W=0.0123L^3$~~L0.0123~~) to all ~~estimated~~ length estimates generated a series of estimated fish weights that were then used to estimate the aggregated catch across the 18 household catches (Figure 3). This again suggested that length-based estimates, using the fish sticks to aid in length recall, were closer than recalled weight estimates in 73% of cases. In addition, the average difference between estimated and actual weight (the error) is three times less for length-based estimates than for the weight-based estimates ($p<.05$).

Effects of body shape on recall and implications for the methodology

While the length-based recall method using fish sticks provides a fairly simple and robust method to estimate consumption and yields, it is acknowledged that reducing the diversity of fish body shapes and form factors to a single conversion factor is a potential limitation of the methodology. However, it is also important to note that increasing the number of conversion factors to account for the diversity of body shapes is also a limitation in terms of practicality and that these two aspects needs to be weighed carefully when making a decision. As a first step in examining this trade off and identifying directions for further refinement of the methodology we looked at the effect of fish body shape on length estimation and form factor.

For species where there were more than five data points and a form factor value, the estimated length was plotted against the form factor (Figure 4). Given that as form factor increases, fish are tending to become more compressed in shape, this suggested that respondents were tending to underestimate the length of the more compressed forms compared to longer, thinner shaped fish.

Because the conversion from length to weight is not linear, the effect on estimated weight is more pronounced (Figure 5). The results suggest that weight estimation could be made even more accurate if separate conversion factors could be calculated for different categories of fish based on their shape, as was done in the 1999 study, where local species were categorised into the three general categories (anguilliform, fusilliform, and compressiform) and this was noted at point of recall. Using separate conversion factors for anguilliform (0.0047), fusiform (0.0125) and compressiform (0.0255) to convert lengths to weight improved the accuracy over a uniform conversion factor for 66% of the aggregated household catches, with weight estimates on average 26.6% closer -to the actual weight. This results suggests a benefit to using shape-based conversion factors, although the results in this case were not significant (P=0.11)

Conclusion

Through the use of field trials, this study has tested and compared the precision and accuracy of two different methods for estimating household fish catches based on respondent recall of what has been caught and/or consumed. With growing interest in using household recall data to estimate fish catch/ consumption, driven by a recognition that current methods for doing this can lead to significant underestimation, ensuring that the methods used are simple yet accurate is critical. Simple, because they need to be able to capture the diverse fishing and consumption habits of households in the small scale fisheries sector, with all the challenges that this presents (large numbers of fishers, dispersed landing sites and fishing times, highly perishable goods quickly consumed or sold, limited fisheries personnel to carry out data collection etc.). Accurate, because even small inaccuracies can produce large sources of error when data are aggregated.

The study demonstrates that respondents in small scale subsistence fisheries are able to fairly accurately quantify the amount of fish they catch. They are able to more accurately and precisely describe fish in terms of their length, using VA's as a guide, than their weight. This may be because using length and shape is a more common method for describing size and it is also more amenable to visual aids than weight, with visual aids known to be helpful in aiding respondents in consumption studies. Given that recalling weight directly is by far the most common method used in household catch surveys at present, this is an important finding. Whilst respondents, on average, tended to overestimate when asked to recall weight (mean 1.47, SD 1.92), they consistently (96.6% responses), and more precisely, *underestimated* length when using 'fish sticks' (mean 0.81, SD 0.134). The consistency of this underestimation suggests that correction factors could be applied to improve results further.

However, without a simple but effective means of converting these lengths to weights, the method would be of little practicable value. The study also demonstrated that, even using just a single averaged length conversion factor, weight estimates based on length were more accurate than those based directly on weight, with the average difference between estimated and actual weight (the error) being three times less for length-based estimates than for the weight-based estimates. Further accuracy gains could be made by increasing the number of length conversion factors to reflect the form of the fish. Whilst there is always a trade-off between ease of use and results, categorisation of fish, based on three fish shapes, provided more accurate results and has previously been found to be practicable in the field and may be beneficial in multi-species fisheries.

Given that respondents in small scale subsistence fisheries are able to fairly accurately quantify the amount of fish they catch through recall, household surveys (or log books) represent a promising way to collect data on catches and consumption at the local level. The study illustrates that precision and accuracy of results will be improved by using fish length as opposed to weight ~~suggests that results may well be improved by using fish length as opposed to weight~~ as the standard measurement recalled. The length-based recall method using fish sticks, as described in this paper, provides a simple, low cost and robust method to do this.

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List of Figures

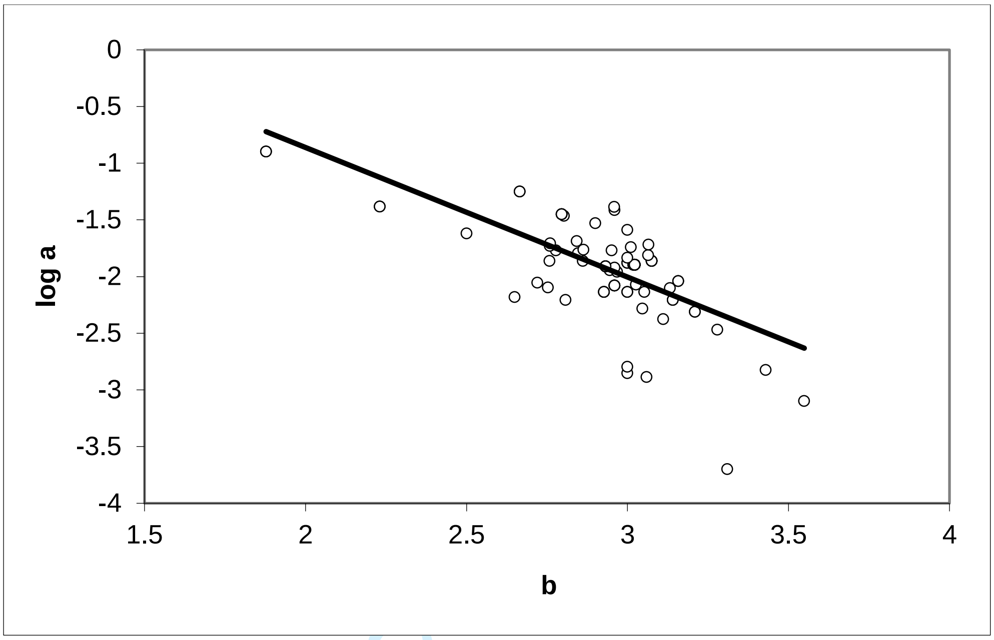
Figure 1. Scatter plot of *log a* against *b* for 93 commonly caught species in the Mekong region with linear regression line fitted. The relationship is described by the equation *log a* = 1.4246 – 1.1429 *b*.

Figure 2. Accuracy and precision of length and weight estimates of each fish as a proportion of the actual length or weight.

Figure 3. Actual total household fish catch and estimated catches based on weight and converted length recall methods.

Figure 4. Variation in average reported length as a proportion of actual length with increasing form factor.

Figure 5. Variation in average estimated weight as a proportion of actual weight with increasing form factor.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-1
-1.5
-2
-2.5
-3
-3.5
-4
log a
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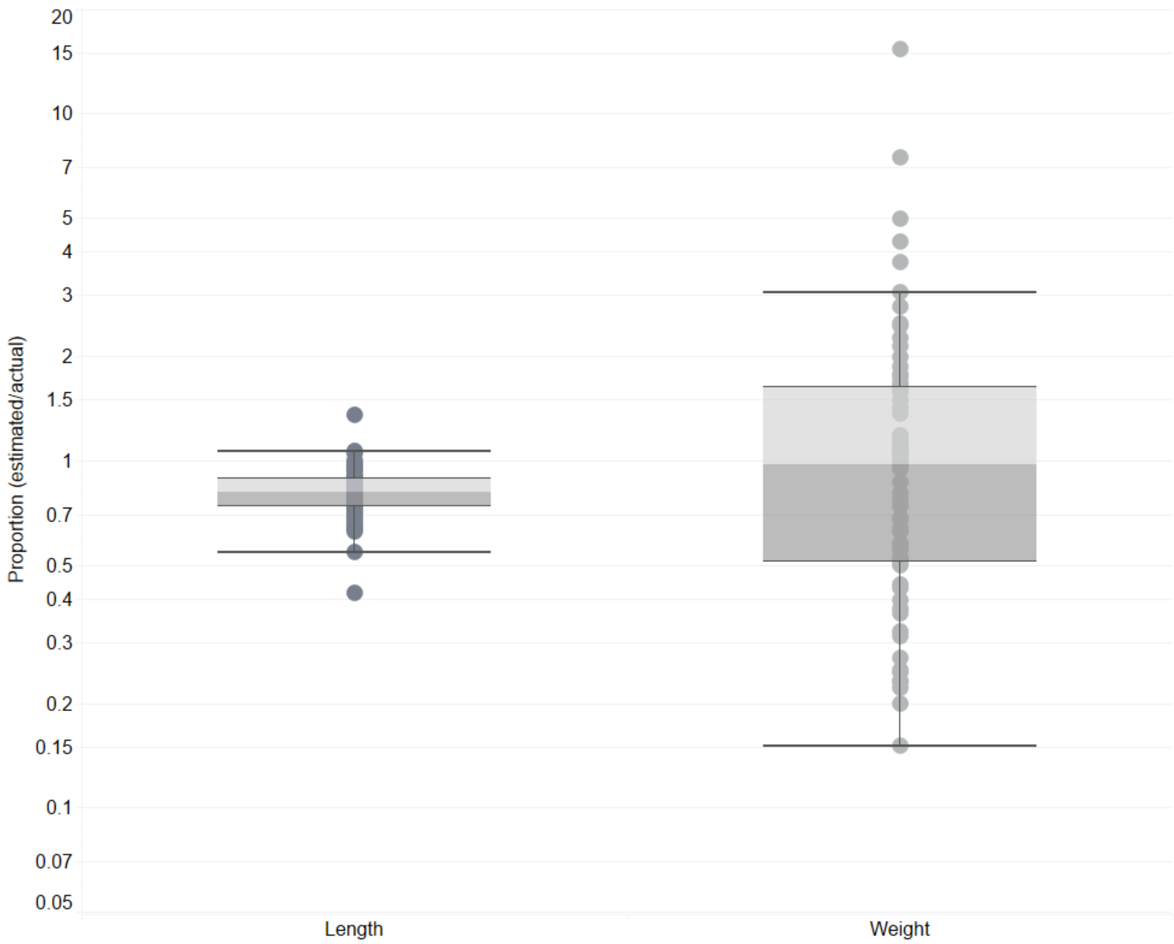
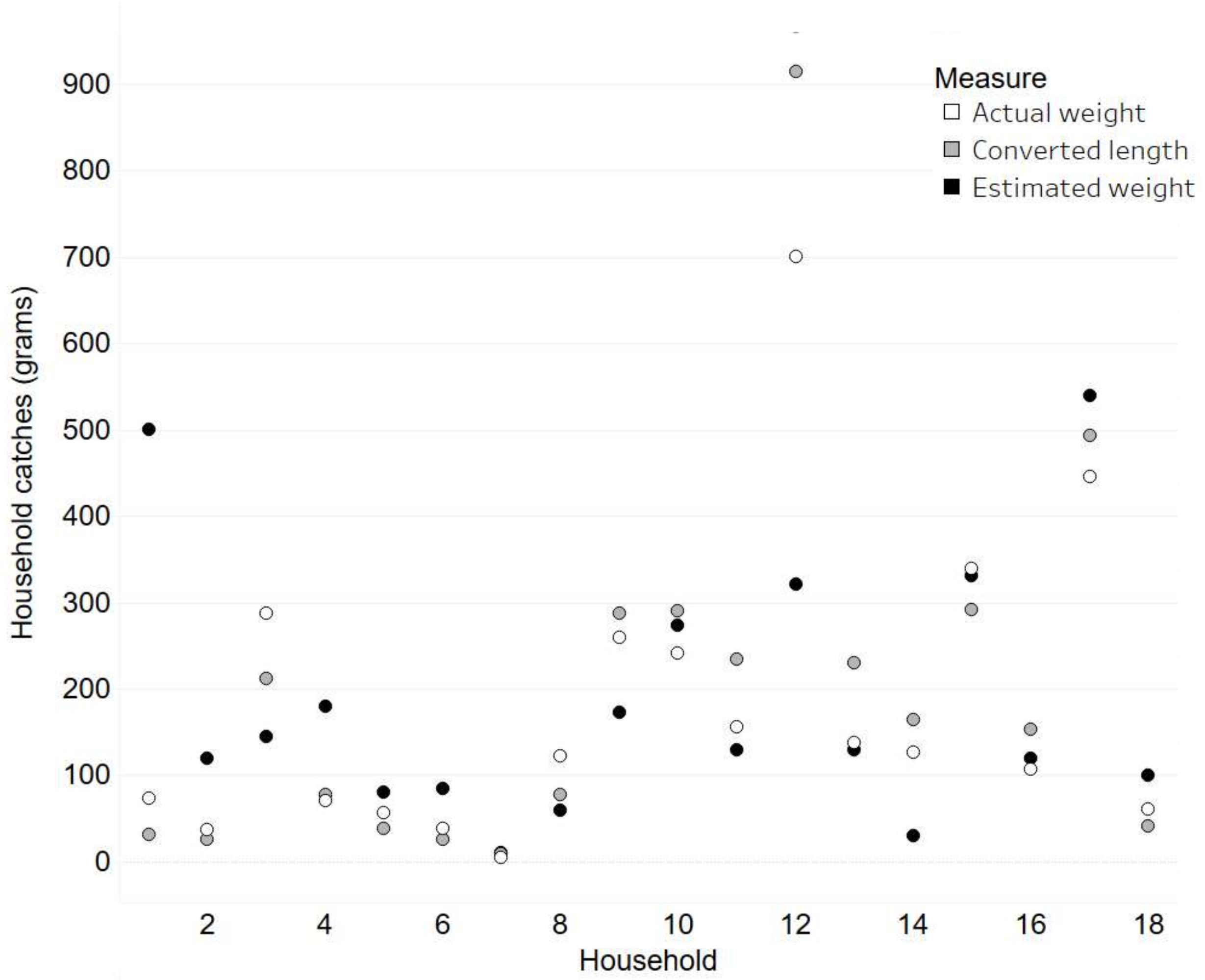
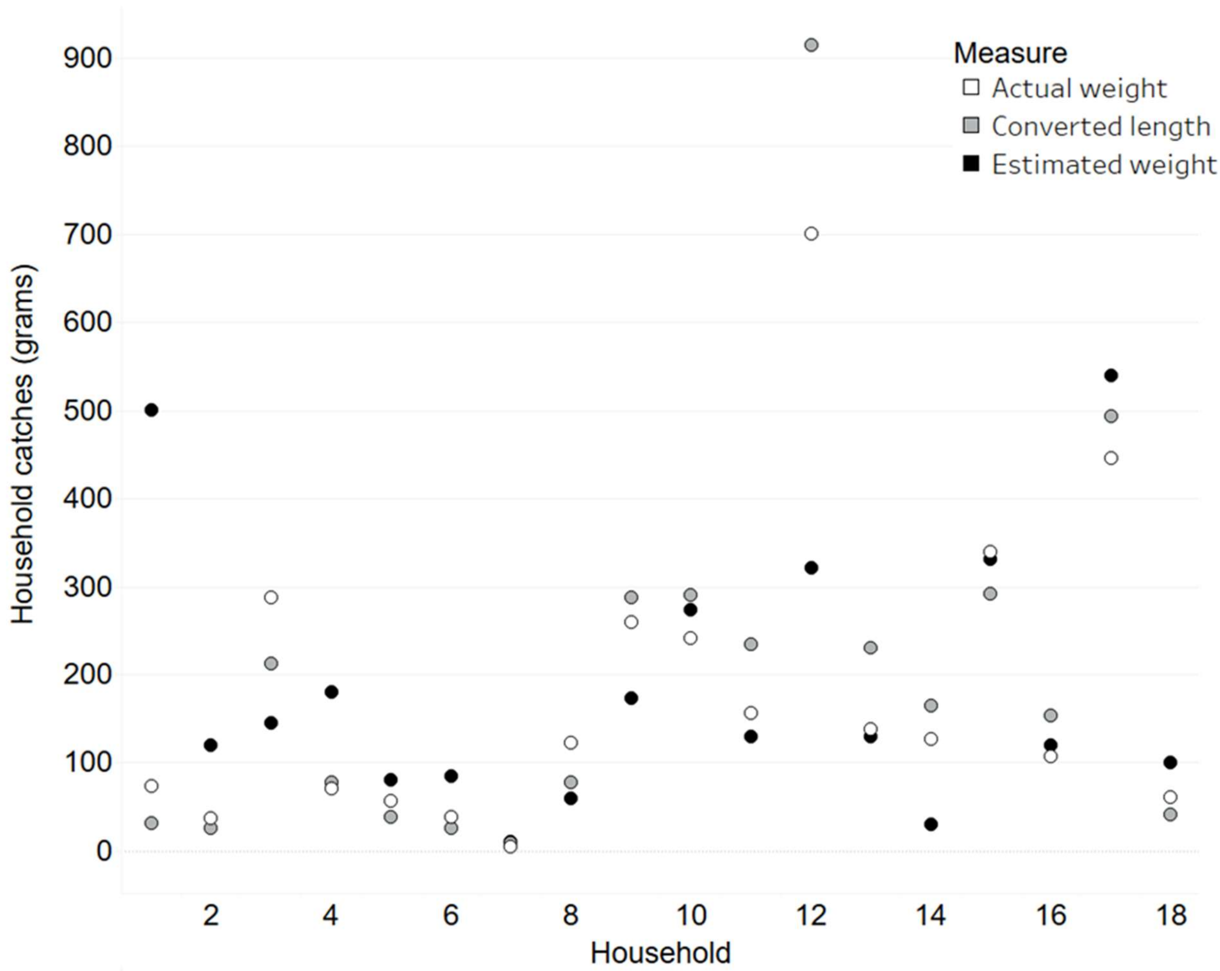
2
2.5
3
3.5
4
b


20
15
10
7
5
4
3
2
1.5
1
0.7
0.5
0.4
0.3
0.2
0.15
0.1
0.07
0.05
Proportion (estimated/actual)
Length
Weight


Measure
Actual weight
Converted length
Estimated weight
Household catches (grams)
900
800
700
600
500
400
300
200
100
0
2
4
6
8
10
12
14
16
18
Household


Measure
Actual weight
Converted length
Estimated weight
900
800
700
600
500
400
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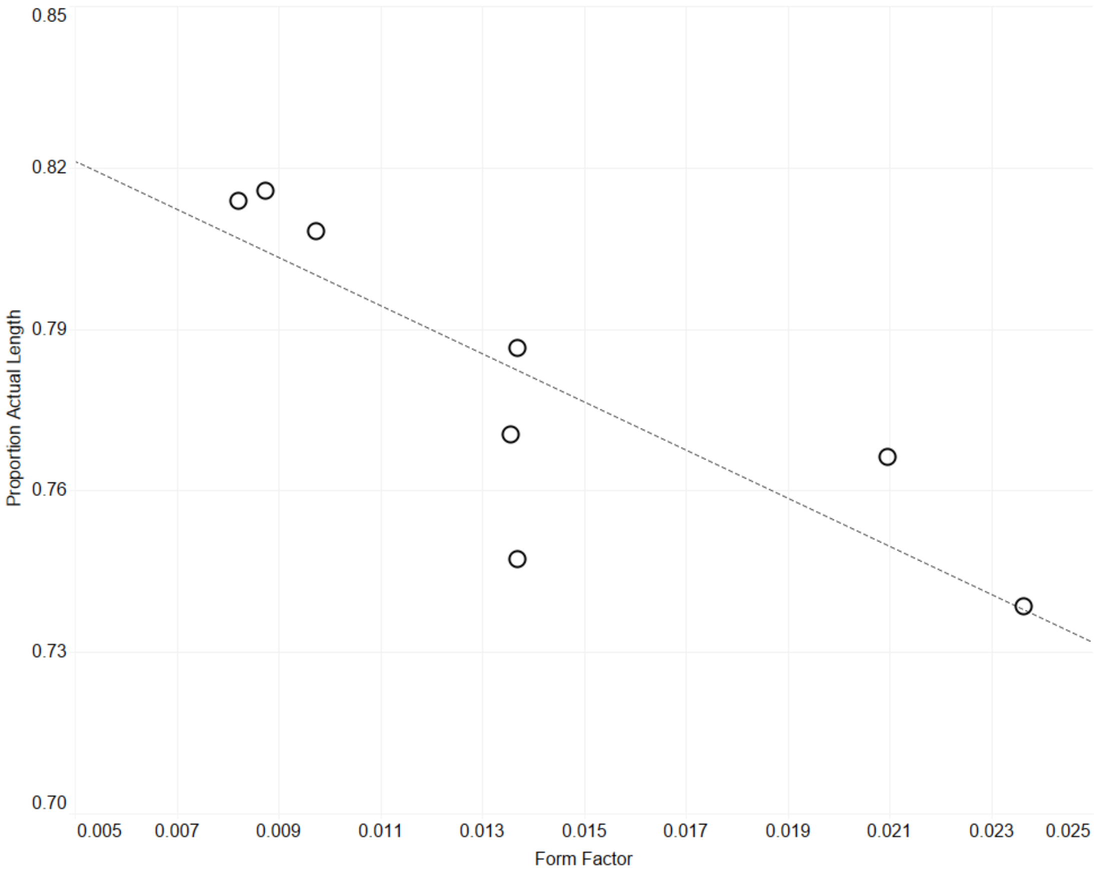
200
100
0
Household catches (grams)
2
4
6
8
10
12
14
16
18
Household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0.82
0.79
0.76
0.73
0.70
Proportion Actual Length
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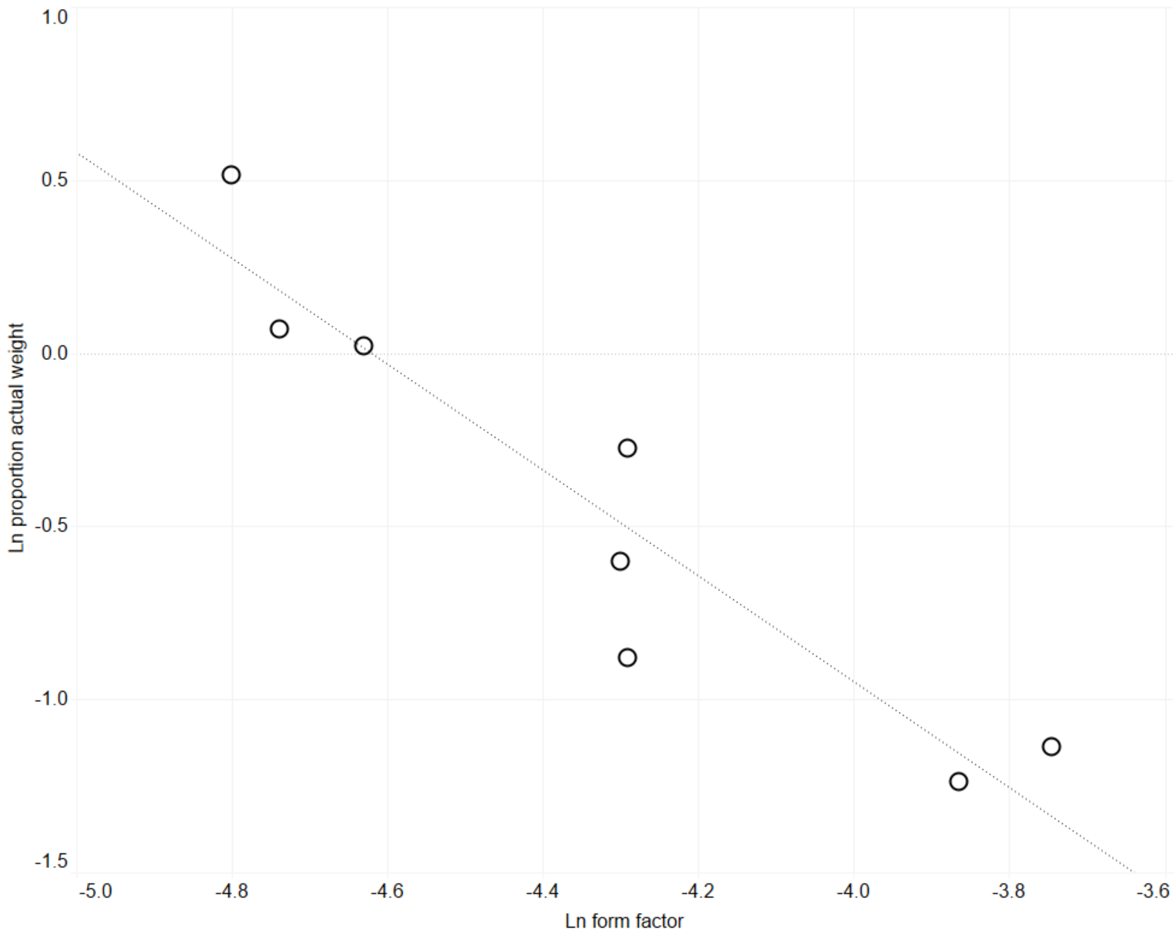
0.007
0.009
0.011
0.013
0.015
0.017
0.019
0.021
0.023
0.025
Form Factor


Ln proportion actual weight
1.0
0.5
0.0
-0.5
-1.0
-1.5
-5.0
-4.8
-4.6
-4.4
-4.2
-4.0
-3.8
-3.6
Ln form factor