Agreement on the Conservation of Albatrosses and Petrels

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Statistical Characteristics of BPUE (Birds per Unit Effort) of longline fisheries

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1. INTRODUCTION

The Birds per Unit Effort (BPUE), in the context of number of seabirds captured by 1,000 hooks of longlines, seems to have been accepted as a) standard indicator to measure the effectiveness of seabird bycatch mitigation measures, as well as b) an indicator representing the "average" status, or central tendency, of the seabird bycatch occurred in the longline operations.

This document, first, briefly describes an implication of general concept of catch per unit effort (CPUE) and the nature of BPUE data as it stands, and then examines the reliability of two indicators (a and b above) based on BPUE. In this document, the "BPUE" is referred only to the seabird capture rates standardized with 1,000 hooks of pelagic longline effort, collected through the Japanese Observer Program, while the "CPUE" is referred to a general concept of catch per unit effort, broadly utilized in fisheries assessment and estimation procedures.

2. CONCEPTUAL CONSIDERATION

2.1. General implication of CPUE

The catch per unit effort (CPUE) is mainly utilized in two ways in the fisheries data analysis. One is as an indicator of central tendency (average) of catch/ landing for estimating total catch/ landings for at certain landing areas, with a formula of:

[Total Catch] = [CPUE] * [Total Effort]   (1)

where most commonly used effort is catch/ landing by boat by fishing day. This is called 'sample-based fishery survey' of FAO, a standard procedure to estimate total catch/ landings based on data samplings at landing sites as an alternative to census approach, and various guidelines and handbooks have been disseminated[1].

[1] e.g. Stamatopoulos (2002), Sample-Based Fishery Surveys - A Technical Handbook, FAO Fisheries Technical Paper 425; De Graaf *et al.* (2015), International Training Course in Fisheries Statistics and Data Collection, FAO Fisheries and Aquaculture Circular 1091

The procedure follows the Central Limit Theorem in determining the appropriate sample size required to achieve target level of accuracy of estimates, which implicitly presume that target events follow a normal distribution. Therefore, the survey design focuses its efforts in defining proper stratifications to ensure homogeneity in terms of CPUE within each stratum.

The second main use, and original implication of CPUE is as a measure of fish stock status. Rather, the concept of unit effort is defined as a quantity to produce catch amount in proportion to the stock abundance. Accordingly, a measure of efforts is selected to reflect a component controlling harvest success, e.g. search time, number of gears (hooks, traps, poles, etc.), length or extent of area covered by gears, etc.

A basic formula becomes:

$$[\text{CPUE}] = [\text{Fish Abundance}] * [\text{Catchability}]. \qquad (2)$$

Here, both terms of “fish abundance” and “catchability” are used in a quite generic way. When main interest is to obtain an indicator of stock as a whole, all factors affecting a relation between stock abundance and resulted harvest can be assigned to the “catchability” term, which includes distribution pattern of fish stock, gear selectivity and effectiveness, and environmental impacts. On the other hand, it is also possible to define “fish abundance” to be a local abundance available to harvest effort to evaluate specific gear selectivity such as utilization of certain mitigation measures.

The CPUE standardization in general is an effort to remove the impacts of “catchability” component as much as possible to extract the best signal on “fish abundance”, which may involve heavy modelling and then allow flexibility in its distribution pattern as long as properly modelled.

2.2. Statistical nature of BPUEs available for offshore pelagic longlines

This section briefly summarizes key issues regarding the seabird bycatch data currently available for the offshore pelagic longline fisheries. Most of the issues are originate from the fact that the data collection on seabird bycatch almost exclusively relies on the scientific observer programs. The section mainly focuses on general statistical nature of data obtained and will not cover the issues relating to data quality reported and other potential biases and uncertainties relating with selection of observers and observed vessels.

First, most of observer programs have been designed and implemented to enhance the understandings on actual fishing operations and to collect materials for evaluating biological characteristics of targeted species. Observer programs are expected to provide supplementary information while other mechanisms such as logbooks and daily reporting system covering full fleets provide the information necessary for stock assessment and fisheries management. In the other words, none of scientific observer program have been designed for collecting statistically representative information on catch or CPUE of any species, which would introduce significant complication if extrapolating the results obtained from observer programs to a whole fleet.

Second, due to long trip duration and practical difficulty of transferring observers among vessels, there has been strong tendency that an observer remains on board a certain vessel throughout its relevant fishing season, in the case of offshore pelagic longline fisheries. While this would be perfectly fine for the original purpose of the observer programs, from statistical view point, it would substantially reduce the detection power on inter-vessel variability, when comparing with true random scheme.

Third, even though the observer protocols of recording all captures including non-targeted species such as seabirds during its observation remain the same, the enhanced regulations relating with seabird bycatch would result in an increased attention to seabird related items both in training, actual observations, and at the time of debriefing and evaluation, and then an improvement of data quality. Such an improvement could often cause an apparent increase of observed statistics, i.e. BPUEs, though it would be a huge challenge to separate actual change of observed events, out of impacts caused by improvement of data and reporting quality.

3. RELIABILITY AND DETECTION POWER OF BPUE AS INDICATORS

3.1. Central tendency of seabird catch

The fisheries management target relating to seabird bycatch is to minimize the seabird bycatch mortality as extent as practical. Then, the total seabird bycatch would be the indicator of the primary importance.

Current protocol to achieve this indicator seems:

$$[\text{Total seabird bycatch}] = \sum ([\text{BPUE}_{i,j,k,\ldots}] * [\text{Effort}_{i,j,k,..}]) \qquad (3)$$

where i, j, k, … corresponding to appropriate stratifications. This is the same approach as the FAO sample-based survey if the prerequisite assumptions were satisfied, i.e. quasi normal distribution of events within a stratum.

The BPUE typically showed a distribution with large proportion of zero events together with a long tail, as shown in Figure 1, which is typical to a probability distribution of rare species bycatch events. In this specific case, over 70% of operations did not have seabird bycatch reported and a maximum value reported as 13.7. An arithmetic mean of all BPUEs was 0.26, which has no statistical meaning nor stability to represent the “central tendency”. Assuming this as a mother population, the value of arithmetic mean varies significantly according to how many points would be sampled from high-end tail. In the other words, it is hard to distinguish whether changes in mean BPUE being caused by sampling variability or reflecting real changes. It should be noted that the figure was prepared after filtering the data from the high risk area of seabird bycatch, the area south of 35S, and the zero-inflated nature of bycatch events was already mitigated to some extent.

More fundamental problem is that the information contained in the high-end tail of low frequency has major significance in estimating total seabird bycatch. Accumulated seabird bycatch based on the same data (Figure 2) indicated that only 5% and 10% of total fishing operations (efforts) accounted for 45% and 64% of total seabird bycatch, and similarly 10% of observed trips responsible for close to half of seabird bycatch. It is critical to capture those low occurrence high BPUE event in order to provide a reasonably reliable estimation on total seabird bycatch. Apparently, random sampling scheme would not suit for this purpose due to its in efficiency where majority of survey efforts will turn into vain, and alternative innovative approach need to be developed.

In conclusion, the current protocol of estimating total seabird mortality by multiplying the mean BPUE with total effort would result in fragile values with large uncertainties. At least, the use of arithmetic mean of BPUE should be replaced with more appropriate procedures, e.g. separation of the estimation of seabird bycatch occurrence and its magnitude, use of zero-inflated model, non-parametric model, or Baysian approach. It is strongly recommended to consider an innovative monitoring approach focused on capturing the low occurrence high BPUE events.

3.2. Effectiveness of seabird bycatch mitigation measures

Corresponding to the recent effort of enhancing the seabird bycatch mitigation measures among various Regional Fishery Management Organization relating with tunas, there seems to be an agreement to accept mean BPUE as a standard indicator of evaluating the effectiveness of mitigation measures. This section examines this concept. It should be noted that the arguments relating with the arithmetic mean BPUE still remain.

Since our main interest is to detect differences in seabird catchability, the [fish abundance] component of the Equation (2) in the section 2.1 is considered as local bird abundance that incorporates temporal and spatial bird distribution pattern as well as local and dynamic micro-scale aggregations. Then, the remaining term of [catchability] is expected to largely reflect the difference induced by utilization of bycatch mitigation measures and other corresponding efforts. It is important to note that the seabird local occurrence is essential for evaluating the effectiveness of mitigation measures from the BPUE.

Although certain measures, e.g. night setting and weighted branch line, were proven to be effective in reducing seabird bycatch rate significantly, the actual effectiveness of avoiding seabird bycatch seems to depend on a combination of many factors, including way of operations, detailed gear configurations, whether and ocean current condition, in addition to mitigation measures deployed according to the regulations. In that sense, it is considered to be most appropriate to attribute all components relating to fishing operations to [catchability] component for the purpose of evaluating mitigation measure effectiveness.

Taking account the role of fishing master in managing fishing operations as a whole, it is natural to assume that bycatch mitigation efforts and their effectiveness are largely dependent on vessel, not on individual operation. Comparison of mean-BPUE of observed trips against random bootstrap extraction of operation data, mimicking fishing trip, indicated that there were strong vessel/ trip effects (Figure 3) splitting into two groups, one with lower seabird bycatch and the other, though the proportion is low, capturing more seabird than randomly expected.

Quick examination of mean-BPUE of observed trip within a time-area stratum, small enough to be able to assume relatively consistent risk of exposing to seabird flocks almost consistently indicated the similar pattern observed in global situation, i.e. large proportion of vessels/ trips with relatively low seabird bycatch and the rest indicating higher bycatch, including some with very high bycatch. One example is shown in Figure 4.

As a result, it was considered that the major part of differences in observed BPUE among vessels/ trips in the same time-area stratum could be attributed to the s variation in effectiveness of mitigation measures among vessels.

In conclusion, the mean-BPUE of observed trip could provide a good measure of effectiveness of seabird bycatch mitigation measures, though it is essential to integrate local seabird abundance information in the assessment. The preliminary analytical exercise suggested a wide variety among vessel capacities in suppressing seabird bycatch and their distribution pattern does not suit for treatment with arithmetic mean. While it is apparently needed to focus the improvement of mitigation capacity of those vessels indicating significantly low mitigation effectiveness, as a potential indicator representing the status of fleet, alternative types of indicators, such as a proportion of vessels who achieved a given threshold of mitigation effectiveness target, might be more valuable for management than an indicator seeking for central tendency.

ANNEX 1

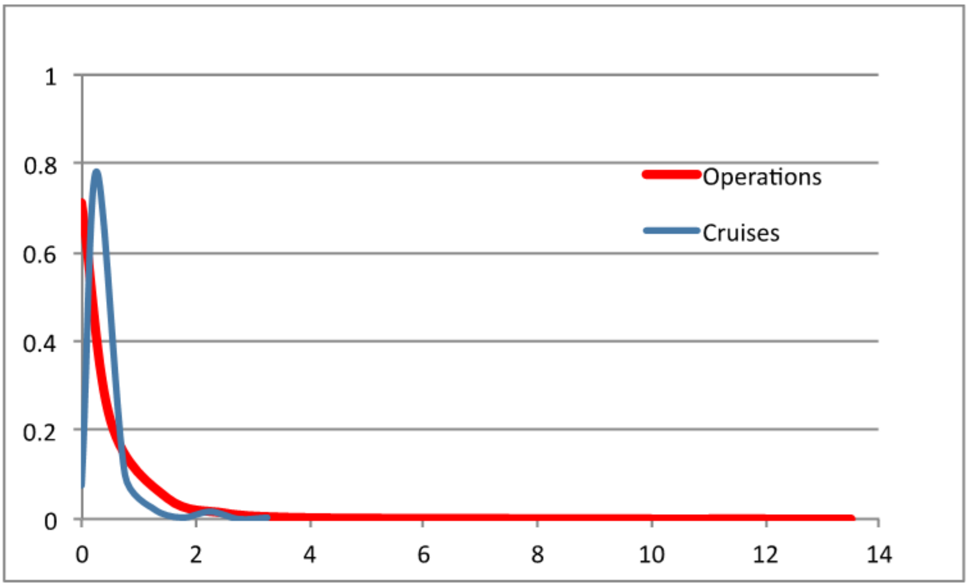

Figure 1 BPUE distribution of individual operations (red) and mean BPUE of observed trips obtained from Japanese longline vessels operating in the south of 35S during 1997 and 2015.

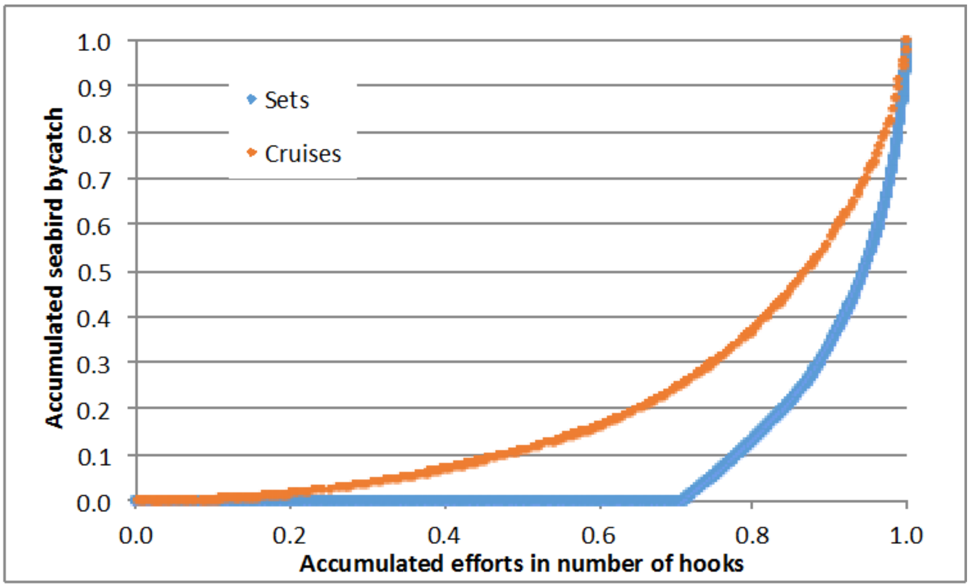

Figure 2 Accumulated seabird bycatch in accordance with the accumulated fishing efforts defined with the number of hooks. Blue indicated the results based on individual operations, while orange based on the observed trips.

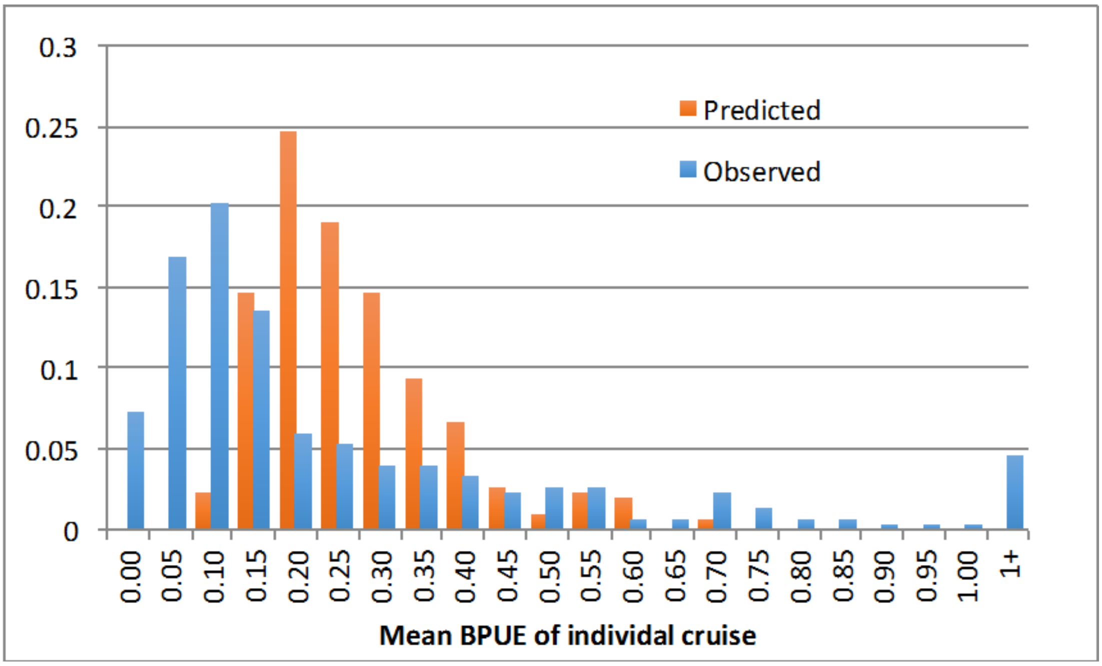

Figure 3 Comparison of between distribution of mean-BPUE of observed trips and result of bootstrap random extraction mimicking observed trips.

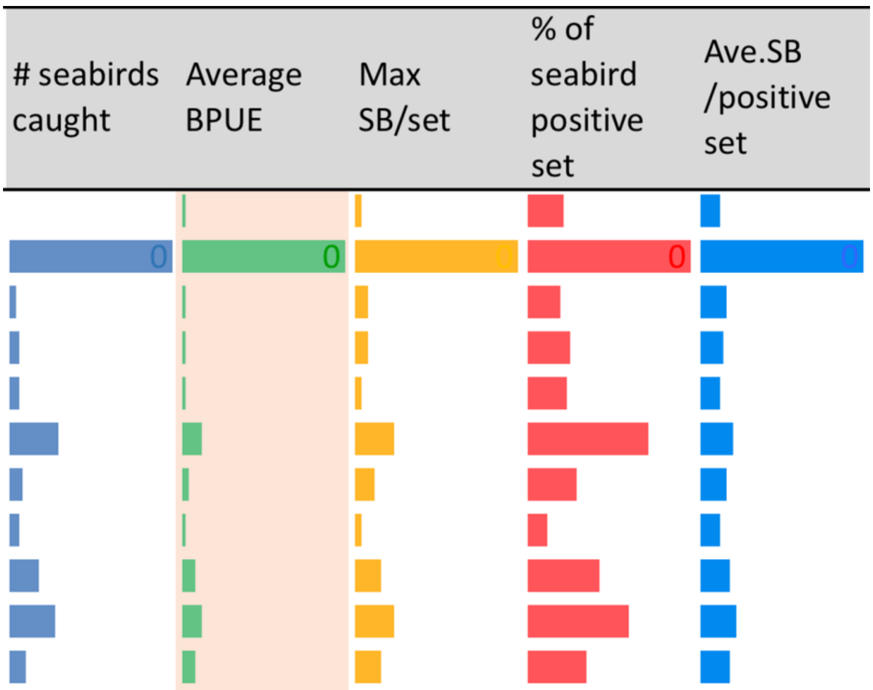

Figure 4 Seabird bycatch related statistics of observed trips/ vessels operating within the same time-area stratum where relative consistent seabird exposure risk can be assumed.