METHODOLOGY TO ESTIMATE BYCATCH AND DISCARDS

by

Tatsuro Matsuoka
Kagoshima University, Japan

Abstract

FAO Fisheries Technical Paper 339 (1994) provided the first estimation of global bycatch and discards, however, the estimated discards of 27 million tons have been abolished at FAO Consultation Meeting in Tokyo (1996). This was attributed to application of its discard ratios, total discard/landing of target species, to total landing with little respect to multi-species fisheries, which resulted in over-estimates of fishing effort and, consequently, discards. In order to determine the methodology for estimation of discards in multi-species fisheries in Asia, it is important to take into account; (1) it is difficult to segregate target and bycatch species, and (2) discards of species are not necessarily correlated to landing of single species positively. Therefore, the realistic approach is to define discard ratios as total discard/total landing and species discard ratios, if necessary, also against total landing in each fishing sector. Several methods to estimate bycatch and discards have been proposed recently with increasing concern to by-catch and discard issues, while information of by-catch in multi-species fisheries is scarce. Researches on characteristic discards in multi-species fisheries in the Region must be promoted for the regional fisheries to contribute in the international fisheries management

1. INTRODUCTION

Discards of bycatch in capture fisheries is one of the most serious concern in fisheries management over the world. This is reflected in that the issue has occurred in many international agreements and documentation in the recent years, *e.g.* FAO Fisheries Technical Paper 339 on Global Assessment of Fisheries Bycatch and Discards (1994), Agreement Relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks (1995), FAO Code of Conduct for Responsible Fisheries (1995), and Kyoto Declaration and Plan of Action (1995). The FAO Consultation on Reduction of Waste in Tokyo in 1996, which involved experts in this field and attempted to review global discards was also an epoch-making action.

It is a world-wide need to establish the methodology for estimation of discards for the purpose of both assessment of their impacts to stocks and environment and clarification of fishing sectors which induce discards. As it is nearly impossible to observe all the discard practices over the diverse fishing activities, discards are usually estimated on the basis of observed discard ratios and industrial statistics of landing. However, there seems to be a confusion in methodology for discard assessment.

This presentation overviews the recent trend in bycatch and discard issues in international fisheries management at first. It, then, summarises the methodological problem in discard estimation of FAO Technical Paper 339 and abolition of its estimation of 27 million tons of discards. The presentation also reviews the methods recently proposed for discard estimation and assesses their applicability for fisheries and landing statistics of different characters, with particular emphasis on the methodology for multi-species and multi-gear fisheries which are prevailing in Asia.

Bycatch focused here is incidental catch which is discarded at sea and the portion of bycatch which is utilised is dealt little. This is because, as widely stated, bycatch is not necessarily a negative practice as there are many fisheries which are feasible with by-products in addition to the principal species. It is more fundamental that a majority of fisheries in the Region have been established on utilisation of multiple species. The principle of this presentation is that bycatch is not a problem as long as organisms are harvested and utilised within the range of stock sustainability. The methodology here considers mainly fisheries resource organisms and bycatch of protected animals are little considered.

2.   OVER-ESTIMATES IN FAO FISHERIES TECHNICAL PAPER 339

2.1   Abolition of estimated discards of 27 million tons:

FAO Fisheries Technical Paper 339 (referred to as the Paper 339 in the following sections) provided the first estimation of global bycatch and discards, where the estimated discards of 27 million tons were sensationally presented. The estimates were reviewed at the FAO Consultation on Reduction of Waste in Tokyo in 1996, where Matsuoka criticised the method which was used in the Paper 339 because of its over-estimate of discards. For example, Matsuoka's estimation on his method was that the discard by the Japanese fisheries in Region-61 during 1988-1990 was some 839 thousand tons, which was quite small in comparison to the regional discard of 9,132 thousand tons estimated in the Paper 339. The portion to which Japanese fisheries were responsible in the Region was not clarified in the Paper 339, however, inconsistency between the two figures is apparent, even if taking other countries in the region into account.

The flawed estimation in the Paper 339 was attributed to application of its species-based discard ratios, or total discard divided by retention of target species, to the total landing of the species with little respect to multi-species fisheries, which resulted in over-estimates of fishing effort to induce discards.

The FAO Fisheries Report 547 (referred to as the Report 547 in the following sections) which summarised the Consultation on Reduction of Waste noted as 'the (consultation) Group recognised that there were several factors which had contributed to an over estimate of discards in several FAO statistical areas. These included: .....application of questionable discard rates to fisheries for which discard information was missing - particularly between regions, and application of discard rates to some marine fish landings that have catch components taken in other fisheries ....'

The estimated discard of 27 million tons has been abolished and revised to some 20 million tons recently, although the scientific basis of the revised estimate is not clear.

2.2   Method of discard estimation in FAO Paper 339:

The over-estimates by the Paper 339 was attributed to its methodology to induce multiple-count of fishing effort to induce discards.   Its estimation was based on the discard ratio, r_j to a target species which was defined as;

$$r_j = d_{(j)} / c_j   ----- (1)$$

where c_j is the observed retention of target species-j and $d_{(j)}$ is the summed discard which is associated with the targeted capture of species-j.   The estimated summed-discard, $D_{(j)}$ when targeting species-j was assessed on the basis of landing statistics, C_j of species-j and r_j or an average of r_js among the sectors which target species-j as;

$$D_{(j)} = r_j \cdot C_j   ----- (2)$$

This could be correct when a sector lands only single target species and the species is caught exclusively by the sector, however, a different consideration is required, if otherwise.

If a discard ratio, $r_{i(j)}$ in sector-i is defined on the basis of the summed discard, d_i and the retention, c_{ij} of species-j in the sector, the summed discard, D_i in sector-i is represented as;

$$r_{i(j)} = d_i / c_{ij}   ----- (3)$$

$$D_i = r_{i(j)} \cdot C_{ij}   ----- (4)$$

where C_{ij} is landing of species-j in sector-i.   When there are by-products of species-j in other sectors, summed discard, D_j' which is associated with species-j becomes;

$$D_j' = r_{i(j)} \cdot C_j'$$
$$= r_{i(j)} \cdot (C_{1j} + C_{2j} + C_{3j} + \ .... \ + C_{ij} + ... + C_{Ij})$$
$$= D_i + r_{i(j)} \cdot (C_{1j} + C_{2j} + ... + C_{(i-1)j} + C_{(i+1)j} + ... + C_{Ij})   ----- (5)$$
$$> D_i$$

where C_j' is the total landing of species-j, including by-products, $C_{1j}, C_{2j}, ... C_{(i-1)j}$, $C_{(i+1)j} ....$, C_{Ij}, by sectors-1, 2, ... (i-1), (i+1) .... I, and I is the number of sectors which land species-j.   As apparent in the above, the approximated discard, D_j' falls in exceeding the discard to be estimated for sector-i, or D_i.   This falls in an odd result as;

$$D_t = \sum_{j=1}^{J} D_j' > \sum_{I=1}^{I} D_i = D_t \quad \text{----- (6)}$$

where D_t is the estimated total discard and J is the number of species. Apparently this is wrong.

The magnitude of over estimate in the sector-i is evaluated as;

$$\frac{D_j'}{D_i} = \frac{r_{i(j)} \cdot (C_{1j} + C_{2j} + C_{3j} + \dots C_{ij} \dots + C_{Ij})}{r_{i(j)} \cdot C_{ij}}$$

$$= 1.0 + \frac{C_{1j} + C_{2j} + \dots C_{(i-1)j} + C_{(i+1)j} \dots + C_{ij}}{C_{ij}} \quad \text{----- (7)}$$

Equation (7) indicates that over estimate is exaggerated where the portion of target species in a concerned sector is smaller and by-product of the concerned species in other sectors is greater. Over estimate as such is unavoidable in multi-species fisheries as far as an estimate for a sector is substituted with that for a target species. Such over estimates appear in all the sectors, therefore, bycatch in a sector affects estimates in other sectors each other and, consequently, this results in an over estimate of the total discard.

The factors in Equation (7) for the species which are assumed to be 'targets' in fishing sectors in Japan were reviewed. For example, tunas which are the major or target species in the tuna longline fisheries comprise 64.6% to 84.5% of their landing, however, landing of tunas as by-product in other sectors is equivalent to 49.5% of the landing by the tuna longline sectors. Roughly, Equation (7) yields some 2.6 in average over major species in Japan. This suggests that the Paper 339 may have estimated discards by the Japanese fisheries in Region-61 as some 2.1 million tons over the 1988-90 period. The reason to have estimated 9.1 million tons of discards for the Region in the Paper 339 could be conceivable, if taking over estimates as above and landing by the other nations around the Region-61.

In tropical countries in Asia where multi-species and multi-gear fisheries are common, the factors mentioned in the above to enlarge the over-estimate ratio in Equation (7) must be more prevailing.

3.   VARIOUS METHODS RECENTLY PROPOSED

3.1   Alverson and Hughes 1994:

In 1994, Alverson and Hughes revised their method for discard estimation. The method seems to aim at evaluation of discards of individual species in individual sectors, therefore, discard ratios, r_{ij} are defined for species-j which are retained and discarded by fishing gear-i, c_{ij} and d_{ij}. Estimated discards, D_{ij} of species-j by gear-i are

calculated with r_{ij} and landing, C_{ij} of species-j by fishing gear-i as;

$$r_{ij} = d_{ij} / c_{ij} \quad \text{----- (8)}$$

$$D_{ij} = r_{ij} \cdot C_{ij} \quad \text{----- (9)}$$

Accordingly, the summed discard, D_i by gear-i and the discard of species-j, D_j by multiple gears are assessed individually and the total discard, D_t in all the fisheries are assessed as a sum of the above as;

$$D_i = \sum_{I=1}^{J} D_{ij} \quad or \quad D_j = \sum_{j=1}^{I} D_{ij} \quad \text{----- (10)}$$

$$D_t = \sum_{I=1}^{I} D_i = \sum_{j=1}^{J} D_j \quad \text{----- (11)}$$

This method seems to be designed for the purpose to assess 'ecological use efficiency' and 'stock use'. The ecological use efficiency indicates how a gear or a fishing sector utilises an assemblage of species in an ecological unit rationally and stock use, how a species is utilised rationally in the capture fishery as a whole.

This theory seems ideal to evaluate discards in detail, however, it is hardly applicable particularly to multi-species fisheries theoretically and practically as explained later.

3.2   FAO Fisheries Report 547:

FAO proposed a new method in the appendix of the Report 547 as to be the international standard method as stated in the Report.

The method is said to aim at adaptation to the realistic condition where the only data that are readily available on a global basis are reports of country landings by species. On the other hand, according to revision of inapplicability of the method in the Paper 339 to multi-species fisheries, the discard ratio, r_i is defined on the basis of observed summed-discard, d_i and summed landing, c_i by a fishing gear-i or sector-i as;

$$r_i = d_i / c_i \quad \text{----- (12)}$$

However, as the raw data which are utilised to calculate the estimated discards are the landing, C_j by species-j with no data about the sector-i, C_j is allocated among the various fisheries in the form of C_{ij}. Applying r_i to all the C_{ij}, D_{ij} is obtained as the discard of all species allocated proportionally to the retained catch;

$$D_{ij} = r_i \cdot C_{ij} \quad \text{------ (13)}$$

The sub-total discards, D_i by sector-i and the total discard, D_t are, then;

$$D_i = \sum_{j=1}^{J} D_{ij} \quad ----- (14)$$

$$D_t = \sum_{i=1}^{I} D_i = \sum_{i=1}^{I} \sum_{j=1}^{J} D_{ij} \quad ----- (15)$$

As it is stated that there is no attempt to define the discard of species, D_{ij} is simply a figure which appears in the process of calculation. Therefore, Equation (15) is rewritten as;

$$D_i = \sum_{j=1}^{J} D_{ij} = r_i \sum_{j=1}^{J} C_{ij} = r_i \cdot C_i \quad ----- (16)$$

Since there is a step to allocate C_j to C_{ij} in the procedure, the method is equivalent to estimation for gears. Even each gear is divided into several groups of different discard characters, therefore, it is also equivalent to estimation for sectors and similar to the method which was proposed by Matsuoka at the Consultation in Tokyo in 1996, which will be summarised later.

4.   CHARACTERS OF DISCARDS IN MULTI-SPECIES FISHERIES

In order to review applicability of the differently-defined discard ratios and to consider appropriate methodology for quantitative estimation of discards, a case-study analysis on a small coastal boat-seine fishery in Southern Kyushu, Japan is presented. Occurrences of species in retention and discards were analysed to clarify the nature of multi-species and multi-gear fisheries. For the purpose of revision of discard estimation on the basis of summed landing and specific landing, the correlation between retention and discards was also examined.

4.1   Multi-species nature of sectors:

Over the 37 times of on-board observation, ten major species in retention comprised of only 75.4% of the summed retention in weight. In the four sub-sectors which target different fishes, as red sea-bream, cuttlefish, pike conger and mixed-fish respectively, each target species comprised of only 28.4% to 47.5% of the summed retention. The total of respective five major species in retention in the four sub-sectors involved as many as 14 species.

In the cuttlefish sub-sector, during the 14 times of on-board observation, 29 species occurred in the retention and 79, in discards. There were only 17 species which commonly occurred both in retention and discards and remaining 72 species occurred only either in retention or discards. The 17 species comprised of 78.5% (in weight) of

the retention, while, only 24.2% of discards. For the purpose of discard estimation on the basis of specific discard ratios, discarded species must occur in the list of retention, however, a total of 62 discard species did not occur in the retention list. This portion comprised of 75.8% of discards.

These indicate that there are such a variety of species retained that target species in each sub-sector is just a quarter to half of landing, therefore, summed landing is hardly substituted with landing of target or major species. Species correspondence between retention and discards is very poor. The species to which discard ratios, r_{ij} can be calculated comprised of only a quarter of discards. It implies that specific discards, D_{ij} equivalent to three quarters of summed discards cannot be evaluated, if based on r_{ij}.

4.2   Correlation between retention and discard:

The correlation between the retention and discards in the cuttlefish sub-sector was analysed. The correlation coefficient between the summed-retention and summed-discard was 0.661. In the analysis between the specific retention of cuttlefish and summed discard, the correlation was 0.617, which was lower than that between summed retention and summed discard.

The correlation coefficients between summed retention and specific discards for the 17 species ranged from -0.479 to 0.593 with an average of 0.106. It is noted that discard amount of a species is even negatively correlated with the summed retention. This suggests that Equation (13) for the method proposed in the Report 547 is not applicable for the purpose of specific discard estimation.

In the comparison between specific retention and specific discards, the correlation coefficients varied from -0.252 to 0.649 with an average of 0.114.   This also suggests that estimation of specific discards and the sub-total discard in a sector on Equation (8), (9) and (10) for the method of Alverson and Hughes is not applicable.

As a result of this analysis, the correlation coefficient was highest between both summed discard and summed retention.   In comparison, correlation both between summed retention and specific discard and specific retention and specific discard was poorer.

Low correlation between retention of target species and summed discards reflects that when the expected fishing for more preferable and profitable species is successful, *i.e.* catching cuttlefish in this case, there are relatively less discards, on the other hand, if unsuccessful, greater discards.   Negative correlation between summed retention and discards of some species indicates the typical discard practices as above.

A wide range of specific retention and specific discards, from positive to negative, has especial implication in multi-species fisheries.   Positive correlation is conjectured to indicate that the species are mainly selected in size by human.   On the other hand, negative correlation between specific retention and specific discards

indicates that some species are determined to be either retained or discarded occasionally. Determination of either retention or discard is flexible for some species. It reflects a complex nature of discards in multi-species fisheries.

5. PROPOSED METHOD OF DISCARD ESTIMATION

In order to determine the methodology for estimation of discards in multi-species fisheries in Asia, it is important to take the following facts into account;

1) it is difficult to segregate target species and bycatch species,

2) preferred species comprises a small part of landing and summed landing is not approximated with target species,

3) there are a large variety of species in both retained and discarded catches, therefore, precise record of all the species is not expectable,

4) correspondence between species in retention and discards is poor, therefore, specific discard ratios are hardly available for some of discarded species, and

5) discards of species are not necessarily correlated to landing of single species positively.

Therefore, the realistic approach is to define discard ratios as summed discard/summed retention. It is proposed that a discard ratio, r_i for the i-th sector is defined as a ratio between weights of summed discard, d_i and summed retention, c_i in the observed operation as;

$$r_i = d_i / c_i \quad ----- (17)$$

A sector is defined as a certain unit of capture fishery which is identified with a unique fishing gear and method and a unique composition of harvested species. The summed discard amount, D_i in a sector is assessed on the discard ratio, r_i and the summed landing, C_i as;

$$D_i = r_i \cdot C_i \quad ----- (18)$$

The total discard, D_t in a region such as a country is estimated as;

$$D_t = \sum_{i=1}^{I} D_i \quad ----- (19)$$

where I is the number of identified sectors operated in a region.

Discard of a species can be estimated, if required, also based on summed landing. When a specific discard ratio, r_{ij} is available, a specific discard amount, D_{ij} of the j-th species in the i-th fishery is assessed as;

$$r_{ij} = d_{ij} / c_i \quad \text{----- (20)}$$

$$D_{ij} = r_{ij} \cdot C_i \quad \text{----- (21)}$$

where d_{ij} is the observed discard of species-j within a range of sector-i.

Discard ratios were defined against whole landing in respective sectors in this method. This reflects that a discard ratio is not simply a ratio between discard and retention of a species. It is important to recognise that a discard ratio must be evaluated on the factor which is best correlated to a discard amount in a sector and it is emphasised that a discard ratio is a representation of fishing effort to induce discards in each sector.

6. DISCUSSION

Several methods to estimate bycatch and discards have been proposed recently as reviewed in this presentation, however, some of them have not considered sufficiently if they are applicable to multi-species fisheries or not.

6.1 FAO Paper 339:

It is proved that the fundamentals for the method in the Paper 339, or the assumption that a sector is represented with landing of the target species, is not satisfied. It is generalised from the present analysis that;

1) discard estimation on target-species is appropriate only where bycatch of targeted species are peripheral in other sectors, and

2) the target-species concept may be effective in single-species fisheries, but the principle and subsequent estimation are not applicable for multi-species fisheries.

These have special consequences in tropical/subtropical fisheries in Asia, where fisheries are conducted with a variety of fishing gears for a variety of species and, therefore, this method is inapplicable.

6.2 Alberson and Hughes:

Estimation of discards for species over sectors, such as Alverson and Hughes, may seem rational. However, the present analysis does not support the method as;

1) if the new method of Alverson and Hughes is tried for multi-species waters, their calculation table becomes impracticably large,

2)	definition of the discard ratio, r_{ij} is impossible from species to species, and

3)	correlation between specific retention and specific discard is poor for many species.

Consequently, estimation of discards of each species in each sector is inapplicable.

## 6.3	FAO Report 547:

As indicated by Equation (16), the method is, in fact, an estimation for sectors, although, the method is stated to be for utilisation of landing statistics of species. The table in the Report 547 does not specify sectors and its calculation is applied for gears, however, different discard ratios are applied even among the same gears. This implies that the method is applied for individual sectors and it is the same to that proposed by Matsuoka at the Consultation in Tokyo in 1996 and summarised here. In application of the method in the Report 547, it is strongly emphasised that its estimation of specific discards has totally no meaning and they appear simply in a process of calculation.

## 6.4	Proposed Method and Multi-species fisheries in Asia:

It is concluded that discards in multi-species fisheries must be estimated for individual sectors which are defined according to fishing gear and methods on the basis of discard ratios from summed dretention and summed discards (the methodology for multi-species can be generalised for single species inclusive).

Despite the proposed method, the author does not reject estimation of specific discards. Partial estimate of specific discards in a sector or across sectors is possible as Equation(21). However, estimation of total discards in individual sectors based on summation of specific discards is beyond reality in multi-species fisheries due to a range of species and a range of correlation between retention and discard as proved in the analysis. Specific discard estimation may be confined to only when specifically required, *e.g.* for assessment of the impact of discards to an important resource species or assessment of a fishing gear. It is important that correlation between retention and discard and the nature of discard practices must be examined in prior to specific discard estimation.

Methodology for discard survey and estimation differs according to purposes, available information and situations of fishing industries in different areas over the world. It is strongly recommended that the strategy and methodology against discards must give due consideration to multi-species fisheries which prevail in a large number of Asian countries. On the other hand, researches on characteristics of discard practices in multi-species fisheries in the Region must be promoted for the regional fisheries to contribute to the international fisheries management.

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7. REFERENCES

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