Choice, use and reliability of historic CPUE

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Abstract

Fisheries dependent catch and effort data from long line operations have provided the foundation of previous stock assessments and management advice for SBT. Two reviews of fisheries dependent data, in particular uncertainties in the size sampling protocols for the surface fishery and uncertainties in magnitude of the total longline catch, were conducted in 2006. Revelations of large market anomalies substantially undermined the confidence of the Scientific Committee and Commission in the use of long line CPUE as: i) the primary index of stock abundance for conditioning the operating model and ii) a data input into the management procedure adopted by the Commission. Subsequently, the Scientific Committee identified a number of types of data that would be required to characterise the nature of the unreported catches in order for improved evaluations of their implications to be completed, and agreed on a work-program to address this. In this paper we summarise the progress achieved to date and the implications for addressing the impacts of the unreported catches on CPUE, stock status and management advice. We also comment on the future development and evaluations of management procedures for SBT. We conclude that while considerable resources and effort have been expended in the intervening period, the Scientific Committee has little substantive data, or information, on which it can provide improved evidence-based advice on the impacts of the unreported catches on CPUE and stock status, beyond that provided in 2006. In light of this we recommend: i) that alternative approaches to the provision of management advice, in the short term, and development and evaluation of management procedures, in the medium-term, based on fisheries independent data be pursued, and: ii) that this be done in conjunction with the development and implementation of systems which would lead to reliable and verifiable CPUE data in future. The rationale and potential approaches to point i) are provided in ESC/09/08/30.

1. Introduction

Fishery-based catch per unit effort data (CPUE) are widely used to construct an index of abundance for use in stock assessments of pelagic and demersal fisheries. Two common reasons for the use of fishery dependent CPUE data are that they are relatively easy and economic to collect and, in the majority of cases, they are the only long time series of data available; at least from the earlier stages of fisheries development.

There are a number of assumptions underpinning the use of commercial CPUE data as an index of abundance. Foremost among them are: i) that the data can be standardised to obtain a reliable and representative index of total stock abundance, and ii) that there is a known (linear or non-linear) and constant relationship between the index and stock abundance. In our experience these assumptions are commonly taken 'in good faith' and are rarely tested.

The CPUE standardisation process in itself can be fraught with difficulties. These include:

- Lack of, or inconsistent collection of, the necessary data at a spatial and temporal resolution consistent with the scale at which the operational and behaviour processes that influence the relationship between catch rates and stock abundance operate;
- Confounding or lack of replication of important determinants of CPUE (e.g. fishing master, vessel, season, location and years), and;
- Provision of these data at the appropriate scale for the purposes of exploratory analyses and standardisation.

The extent to which these issues are problematic in the use of CPUE for stock assessment and provision of management advice depends on the particular way in which they are used and the nature and quality of other data available for assessment purposes (e.g. size at age, tagging , survey etc). Unfortunately, for many pelagic longline fisheries, fisheries dependent catch and effort data is the only substantial time-series available, or, in the case where other data is available, the CPUE series is often still the dominant signal that drives the abundance trends in an assessment. This has been the case for SBT. Even though, in relative terms, there is a substantial amount of ancillary data incorporated into the assessment and MP evaluation processes, the catch and CPUE series are the primary determinants of the outcomes of the assessment and performance of MPs. Given this, the SAG and SC have dedicated considerable attention in the past to addressing the potential sources of uncertainty in the LL CPUE series (e.g. Anon., 2002 and references therein). Of particular relevance is the substantial change (reduction) in spatial coverage of the fleet over time, and the uncertainty this implies for CPUE as an index of overall abundance. This is reflected in the past use of five CPUE series, which are derived from standardisation processes with different underlying assumptions about density of SBT in unfished 5x5^{o} squares, in the conditioning of the operating model for MP evaluations.

In 2005 revelations of large market anomalies substantially undermined the confidence of the SAG and SC in the use of long line CPUE as the primary index of stock abundance for conditioning the operating model and as a data input into the management procedure subsequently adopted by the Commission. The scale of the uncertainty induced by these unreported catches was substantially greater than what had historically been considered important differences among CPUE standardisation approaches. In particular, the proportion of the unreported catches that may have arisen from the reported longline effort and the nature of the unreported catches (i.e. size structure, source, time trend in catches and marketing etc) became the dominant factors in the scenario analyses and management advice from the SC (Anon., 2006b). As a result, at the conclusion of the 2006 meeting the SC identified a number of types of data that would be required to characterise the nature of the unreported catches in order for improved evaluations of their implications to be completed, and agreed on a work-program to address this. In this paper we summarise the progress achieved to date and the implications for addressing the impacts of the unreported catches on CPUE, stock status and management advice.

The remainder of the paper consists of four sections. The first outlines the work program to address the impacts of the unreported catches agreed by the SC and summarises progress to date. The latter sections briefly consider the issues and implications of this for how the SC uses longline CPUE in the short-term as part of the indicators analysis, reconditioning the operating model and development and evaluations of future MPs. Section four reflects on the different contexts in which catch and CPUE data have been used by the SAG and SC to assess the status of the SBT stock and provide management advice. The final section concludes with some suggestions on ways to proceed in the short-term and should be considered in conjunction with Basson and Davies (2008).

2. Inter-sessional progress on the impacts of unreported catches

At their 2006 meetings the SAG and SC considered the outcomes of the Independent Panel reviews and provided the Commission with advice on the implications for stock status and management advice in light of the market and farm anomalies. As part of this advice, the SC noted that the SAG had not been able to conduct a stock assessment, in the usual sense, due to the fact that there were only the catch scenarios, and not catch and effort data, available for the unreported catches (Anon 2006a, paragraphs 40, 55). In this regard, the SC agreed it was essential to obtain verified catch data for all components of the fishery and reliable future indices of abundance (Anon 2006 a, paragraph 48) and that the absence of such data, and appropriate feedback management systems, would reduce the probability of rebuilding under future constant catch scenarios.

A summary of the information necessary to improve the evaluation of the impacts of the unreported catches identified by the SAG and SC is provided in Table 1. It is apparent from this summary that while some progress has been made on improving the continuity, reliability and verification of future data series for monitoring and assessment (e.g. recruitment index, monitoring of Indonesian catches from the spawning grounds, and improved monitoring and verification of catch and effort data from longline operations), very little progress has been made in terms of the estimates of the magnitude and trend in the unreported catches relative to the market anomalies nor our understanding of their impact on longline CPUE since the 2006 meetings of the SAG and SC. Further, it appears that there is little scope that the necessary information will be available for the SAG and SG to consider in the near future (Anon 2007, paragraph 16).

The CPUE WG has attempted to address the potential impact of the unreported catches on CPUE by focussing on identifying a “core fleet”, which is assumed to be less likely to have contributed to the unreported catches (Itoh et al., 2008). This assumption is largely base on the concept that vessels that: i) appear to be targeting SBT, ii) have high reported catches of SBT and iii) met these criteria for 3 or more years between 1986 and 2006, are less likely to have contributed to the unreported catches. As these vessels have reported high catches of SBT it is considered less likely that either: i) they would have had the opportunity to catch more SBT than reported and, if they did, they were more likely to report it than not. Four significant issues with this approach are: a) to meet the criteria, it is only necessary to be in the top catching vessels in 3 of the 20 years in the series, b) Core vessels, on average, constitute 35-50% of the fleet reporting catches of SBT. This assumption implies that in any year there would be 50-65% of the fleet that would need to account for the TAC not taken by the "core fleet, plus the unreported catches in that year. On the basis of earlier analyses considered by the SAG and SC (Polacheck et al 2006), this seems unlikely to hold over the period of the unreported catches: c) This approach resulted in 12 vessels with "anomalously" high CPUE being included in the "core" set, which were subsequently excluded: d) it considered vessels, rather than fishing masters. In our view, these issues mean it is unlikely that the "core vessel" concept is likely to provide a substantive basis for inferring the degree to which the standardised CPUE series is impacted by the unreported catches.

From this brief summary of the outcomes of the inter-sessional work, it is evident that the SAG and SC have very little in the way of new data, or information, to make substantive new conclusions on how the market anomalies relate to unreported longline catches and, in turn, have impacted on CPUE beyond that considered at the 2006 meetings. In light of this, and consistent with the 2006 conclusions of the SC we consider the most appropriate way to proceed with the provision of management advice and development of a new Management Procedure is to focus on fisheries independent indicators of stock status and fishing mortality (Anon 2006b, see Basson and Davies 2008 for elaboration of these approaches).

This conclusion, however, does not mean that we do not see a role for the use of historical and future CPUE in the assessment and MP of SBT. We do consider that there is useful information in the historical series. It is the context and way in which these data are used that is important. The following sections of this paper provide some initial thoughts on how these data and or CPUE series may be used appropriately in the future.

Requirement	**Information**	**Progress to date**
Reduce uncertainty in historical LL catch and effort series	Refine estimates of catch from market anomalies Source and location of catches, Characteristics (size/age) of unreported catches	Very limited [3]
Restore confidence in reliability of future LL CPUE	Improved monitoring and verification of catch and effort (CDS, VMS, Observers etc)	In progress[4]
Improve monitoring of size structure of catches from surface fishery	Unbiased estimate of size structure of catches from surface fishery	In progress[5]
Continued monitoring of recruitment	Continuation of aerial survey to provide index of recruits in GAB	Achieved 2006/7-2007/8[6]
Continued monitoring of Indonesian catches	Continuation of Indonesian catch monitoring	Achieved[7]

Table 1: Summary of agreed data and information requirements to improve evaluation of implications of unreported catches for advice on stock status and management advice.

[3] see 2007a and b, Itoh et al., 2008
[4] Ref to compliance committee reports
[5] Ref to 2007 and 2008 papers
[6] Note: Future funding not secure

3. Summary of relevant historical issues associated with standardisation and use of CPUE

The issue of unreported catches and the potential effect of this on CPUE has changed the SAG and SC's level of confidence in CPUE as an index of abundance. It is, however, relevant to recall some of the longer-standing issues which were of some concern before the revelation of unreported catches. It is also worth noting some of the standardisation problems and difficulties that remain and ways in thes may be addressed using alternative approaches.

3.1 Range contraction of the fishing fleet

Substantial changes have occurred in the extent and patterns of spatial coverage of the longline fishing fleets over time. It is also very likely that there have been changes in the spatial distribution of the stock over time. If areas of different abundance have been fished in different years, and some areas received no effort in some years, how can we compare CPUE across years?

Changes in the areas fished by the fleet, and potential changes in stock distribution, were recognised as important factors when CPUE was first used to develop an abundance index for use in a "tuned" VPA (Virtual Population analysis). For example, the Report of the Third Scientific Committee meeting (1997) notes that: "A number of CPUE analyses were conducted to develop a range of abundance indices. These indices reflect a range of hypotheses relating to changes in area fished and stock distribution of SBT". The report lists seven different models and concludes that "problems were identified with respect to all models and no single model was favoured."

There is still no external information to help distinguish between the different hypotheses, though since then there have been important developments in statistical software (e.g. Splus, R) that allow for more flexible modelling approaches i.e. general additive models (GAMs). GAMs applied to the disaggregated data may allow a more rigorous examination of the uncertainty associated with unsampled areas; they are already used in this way for CVs in the GAB Aerial survey where some combinations of month and spatial block end up being unsampled due to bad weather (Eveson et al. 2008). This might have the benefit of moving some of the uncertainty out of 'scenario modelling' and into quantifiable parametric terms.

Given the growing set of archival tag data for SBT, it would also be interesting to examine the proportion of time SBT spend in currently unfished areas.

3.2 Targeting and Bycatch information

Targeting of species other than SBT is another issue which can affect the interpretation of CPUE. This was recognised by the CPUE working group and listed as an important source of potential bias (Table 2, Anon.,2002). Catches of other species, such as yellowfin or bigeye tuna taken on sets which also captured SBT, could contain implicit information on targeting, and could potentially be used in the standardisation process. The CPUE WG has, in its recent work program (2007/08), started to address this issue, but it is clearly not straightforward. There are issues of data availability, transparency and important questions about how to conduct appropriate statistical analyses which take the notion of targeting into account by incorporating information on bycatch.

3.3 Standardisation Methods

The CPUE WG, through the commendable efforts of a few, has conducted a substantial amount of analyses over the past year. This work has highlighted many of the difficulties associated with CPUE standardisation. Unfortunately, the time-frame and the nature of the meetings (by webinar) have not been ideal for reflecting on, and effective discussion of, alternative approaches that could resolve some of the issues and improve the statistical standard and rigour of the analysis. There is, of course, the difficult question of whether the data, particularly from some years, warrant extensive additional analyses given doubts about reliability and information content for use as an index of relative abundance. How best to progress further analyses would benefit from consideration by the wider SAG and SC and agreement on protocols for joint analyses.

Difficulties arise when using log(CPUE) as the response variable in a model when there are zero CPUE values in the data. There are statistical techniques which deal elegantly with zeros and which do not require the addition of an arbitrary amount to CPUE to ensure taking logarithms of positive numbers. The delta method is one such approach, but there is the much simpler approach of using the Tweedie distribution. This is, for example, used in the standardisation of the SAPUE data (Farley and Basson, 2008), and in the standardisation of CPUE for Patagonian toothfish (Candy, 2004).

Although it has been customary to treat the ratio of catch over effort (CPUE=Catch/Effort) as the response variable there are statistical advantages in treating the catch as the response variable and treating effort as an offset in the model. One advantage is easily illustrated. In the case of aggregated data a value of 0.5 for CPUE, for example, could come from a catch of 5 'units' with 10 effort 'units', or a catch of 500 'units' with 1000 effort 'units'. If used as 'CPUE' they would effectively get the same weight in the analysis whereas they would be more appropriately weighted if effort is used as an offset. The issue of implicit weighting invalidates variance estimates from a model which uses aggregated data and CPUE as the response.

In the past, estimates of variance associated with CPUE series have not been used in assessments or in the operating model. It is difficult to see how one can continue to justify using something as a quantitative input into an assessment (or conditioning of an operating model) in the absence of a realistic variance estimate.

One main reason for doing a disaggregated CPUE analysis is to see whether there are signals in the finer scale (raw, shot by shot) data which are not reflected in the aggregated data, and which would lead to different CPUE series. This cannot be investigated by fitting the same coarse spatial scale model to the two types of data (disaggregated and aggregated). Given that the analysis is at a coarse spatial scale, any spatial patterns at a finer scale would not be apparent in results from the model fitted to the disaggregated data. The conclusion that the two versions of the index are similar is therefore inevitable given the restricted way in which the analysis has been done. It would be wrong to suggest that the comparisons done so far have 'proved' that there is no additional information in the shot by shot data.

Another reason for doing a disaggregated analysis is to include relevant covariates which can't be aggregated (such as gear sor vessel specific characteristics). Further exploration of the disaggregated (i.e. shot by shot) data is, in our view, still worth doing. In particular, analyses which uses general additive, or general additive mixed, models with spatial and temporal smooths should lead to much superior estimates of variance. For example, the variances for squares that have not been fished in a particular year should be large and this should then also be reflected in the variance of the overall CPUE index. Nowadays these models are simple to fit and are becoming commonplace in fisheries[8] (Maunder and Punt, 2004; Venables and Dichmont, 2004).

Unfortunately the issue of data confidentiality still hampers this exercise within the CCSBT. We note that there are mechanisms for dealing with some of the issues (e.g. replacing the vessel name by a code which is unknown to the analyst).

3.4 Focus on developing a single CPUE series

At the commencement of the MP development process, it was recognised that it would be ideal to have a single CPUE series as input to the decision rule. It was also recognised that the conditioning of the operating model and the testing of the decision rule ("MP") could be done with several or all five CPUE series[9]. As long as the decision rule is robust to the five series used in the testing phase, the use of a single series in the decision rule should not be a problem.

The use of five series in the conditioning and testing phase obviously increased the workload and number of test-scenarios that needed to be conducted. At one stage the MP process only used the median of the five series to try to reduce the workload. This was justified on the basis that the overall, long term, patterns in all five series were very similar and conditioning results were also very similar for each of the series. However, when the implications of the different series for stock abundance in the most recent years and for projections were considered, they revealed quite different behaviour (Kolody et al., 2004). The MP process therefore reinstated the five series to ensure that the underlying uncertainties were appropriately reflected, and to test whether the decision rule would be robust to this.

It is worth recalling that the main difference between the five series, which were used in the MP development and testing, lies in the assumptions they make about the density of SBT in the unfished squares (though note that one of the 5 series was nominal CPUE). Our ability to distinguish between the series, in other words, between the alternative hypotheses, is no better now than it was at the start of MP development. What has, however, changed is our perception of the magnitude of this uncertainty; the uncertainty implied by the unreported catches is substantially larger than that between the 5 different series.

The two proposed series developed by the CPUE WG (based on the hypotheses underlying the old W0.8 and W0.5 series) will carry some of the uncertainty about SBT density in unfished squares forward. We consider this to be appropriate since it is, at least conceptually, an important uncertainty. Although it (the assumption about SBT density in unfished squares) may prove to be a minor source of uncertainty compared to others (e.g. unreported catch) in the current context, it may in future become an important source again. It is for this reason that we caution against the persuit of a single CPUE series.

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[8] A Google search on {GAM model fisheries CPUE} revealed about 99 thousand entries; even excluding a half to two thirds for irrelevant or duplicate occurrences as suggested by the first 10 pages, implies a substantial number of results.

[9] The five series were: Nominal CPUE, Proxy B-ratio (W0.8), proxy Geostatistical (W0.5), Space-Time window and Laslett Core area (see e.g. Table 2 of CPUE WG Report, 2002).

3.5 Changes in management

Changes in the Japanese domestic management arrangements in the recent past, as well as the change in total quota are highly likely to have affected the fleet behaviour of Japanese longline vessels (Anon., 2007b, paragraph 16). Other external factors, such as fuel price increases, can also affect fleet behaviour. These factors therefore also have implications for the interpretation and usefulness of CPUE. This is commented on further under section 4.2 and 4.3 below.

4. Uses of CPUE

It is important to note here that although we, and in fact the SAG and SC, currently have serious concerns about the reliability of historic CPUE as an indicator of abundance, we also recognise that CPUE and the underlying catch and effort data should not be discarded out of hand. First, it is the only long term indicator (at least since 1969) we have to inform our understanding of current stock status relative to the unexploited level. Recall that estimates of relative depletion (current biomass relative to unexploited) were remarkably consistent between the different scenarios for unreported catch (SAG Report, 2006). Also note that on the basis of current information it seems less likely that CPUE prior to the mid or late 1980s would be affected by unreported catches. Second, catch and effort data (if reliable) contain information on the dynamics and performance of the fishing fleet. Third, these data (if reliable) also contain information on relative SBT density in those areas and times where the fleet is operating. The more serious difficulties arise when trying to interpret these data as a consistent index of the total (fishable by longline) abundance.

In the next several sections we discuss the different uses of CPUE and consider the relative appropriateness of historic/current CPUE in each situation.

4.1 Indicators analysis

Overall CPUE and age-specific CPUE have been used as indicators and as inputs to stock assessments. If overall or age-specific CPUE is used as an indicator to identify trends, it is of limited use if there is no associated estimate of variance. If the CPUE series is biased, for example, by under-reporting of catches, then its use as an indicator will most likely be misleading.

It is also worth noting that apparently small differences between alternative standardisations (particularly, different assumptions about densities in unfished squares) could become important when such series are used as indicators of recent trends. The problem would be worse if they are used without any estimates of associated variance.

Even if the catch-effort data are reliable, care needs to be taken with both the standardisation of CPUE and the interpretation given the issues highlighted in Section 3. Depending on where and when the fleet fishes currently and into the future, it may be necessary to reconsider whether CPUE can be used as an indicator of the total stock, or whether it should rather be considered as an area/time specific indicator if spatial coverage is low and inconsistent. Any changes in operational or management conditions that cannot/are not standardised for would also affect the reliability of the CPUE series as an indicator of abundance.

4.2 Conditioning of Operating Model

In conditioning of the existing operating model, it is both the uncertainty in catches and in CPUE that are of relevance. As noted in Basson and Davies (2008), one important concern lies in the fact that the catch scenarios, and hence CPUE scenarios, have not been arrived at through a scientific process. It is therefore unknown to what extent the uncertainties reflected in the scenarios reflect the true uncertainties and even whether the true catch and CPUE series lie within that range. As noted in section 2, we have no new data or information available to better inform the characteristics of the scenarios. This implies, in our view, some doubt over the true robustness of a decision rule tested within the operating model and using the scenario inputs (catch and CPUE)

A further concern about using one CPUE series over the whole time period (1969-2007) in the conditioning of the MP is the question of compatibility of the series over time. The CPUE WG noted that its most recent analysis (based on a set of core vessels) cannot be extended back in time due to a lack of necessary data. An ad hoc solution had to be found to calibrate the two series in order to have a series that extend back to 1969. There are also issues of compatability in recent times following changes in management and the total quota (also see Basson and Davies, 2008). Given the importance recent CPUE seemed to play in the scenario modelling and in the projections for MP testing (including assumptions made about future uncertainty in CPUE), the issue of ensuring compatibility of a CPUE series over time is relevant. It may be useful to consider whether several shorter time series of CPUE could be used instead, and whether CPUE for some time periods could be omitted (noting the problem with catch uncertainty over that period will still be there).

4.3 Data input to MP

As noted in Basson and Davies (2008) we consider it risky to base a decision rule (or MP) only on CPUE information given the issues raised above. We note that many of the difficulties exist irrespective of whether the data are reliably recorded and reported, or not. It would be less risky and more ideal to base an MP on fishery independent data, or at least on a group of indicators, some of which are based on fishery independent data.

An MP is likely to be based on recent values or recent trends in an indicator. Therefore, spurious changes, or changes due to external factors that have nothing to do with SBT abundance (e.g. changes in fleet behaviour following a change in management, or operational conditions) could lead to poor behaviour of such an MP. The risk is greater when the indicator (e.g. CPUE) is used without any estimate of variance.

In our view, this is an opportune time to consider the potential of other indicators, for example, the aerial survey index and tag-based estimates of harvest rates, for use in a new MP. We recognise that all indicators will have some strengths and some weaknesses. The use of alternative indices in an MP is discussed further in Basson and Davies (2008).

4.4. Scenario modelling

Although the operating model used for MP testing has also been used for scenario modelling, it is worth distinguishing between the two uses. In the context of the scenarios defined for unreported catches and for CPUE, it is appropriate to use CPUE as an input to explore "given these inputs, what are the implications for estimated stock dynamics?". The danger lies in forgetting the underlying caveats, possible biases and uncertainties associated with the inputs, or forgetting that there may be other plausible scenarios not in the defined set. It is this issue that becomes highly relevant in the process of MP testing to evaluate the robustness of decision rules.

4.5. Use of future CPUE data

CPUE data are still important and relevant for monitoring the fishery dynamics, and could provide insights into local density of SBT. Also, information on total catch is obviously critical for stock assessments, MP testing and the proper functioning of an MP. It is therefore still important to strive for good monitoring of catch and effort data.

The difficulties associated with CPUE standardisation and interpretation implies that future CPUE should be used with great caution. Even if reliable catch and effort data are collected in future, we consider that it should not be relied on as the only driver of trends in a stock assessment, or conditioning of an operating model. It would be preferable to develop alternative approaches (such as tag-based approaches, e.g. Basson and Davies 2008), which do not rely on CPUE at all. We also consider that CPUE should ideally not be used as an input to an MP (decision rule); if it is to be used, it should be used together with other indicators and with careful consideration of exactly what the CPUE means (i.e. what aspect of the stock it is likely to reflect).

5. Conclusions regarding the use of historic and future CPUE

The only long and continuous time-series of a potential abundance index for SBT is historic CPUE. There are many difficulties in interpreting these data, and the reliability of the data has probably varied over time. There was substantial consistency between estimates of relative biomass obtained from the scenario modelling (conducted in 2006). In the absence of alternatives, the use of long term CPUE to inform our view of current stock status in relative terms (i.e. current biomass relative to unexploited biomass) is acceptable in our view.

More serious difficulties arise when trying to use CPUE, particularly recent CPUE, as an indicator of SBT abundance over its full geographic range, as a reliable indicator of recent trends and as the driver of a decision rule in a management procedure.

We recommend that, in the short term, instead of using CPUE and the operating model as the basis for management advice, alternative approaches based on other indicators be developed as outlined in Basson and Davies (2008). We recommend that, in the medium term, evaluation of management procedures based on fisheries independent data, and an operating model which is less critically reliant on the historic CPUE data be pursued. In spite of cautions about the future use of CPUE as an index of abundance, it is still critical to collect reliable catch data and effort data, particularly information on total catch. It is therefore still relevant and important to develope and implement systems which would lead to reliable and verifiable catch and effort data in future.

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