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Initial considerations on forms of candidate management procedures for SBT

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Abstract

At its 2015 meeting the Extended Commission agreed to implement a new recruitment-monitoring program, using gene-tagging, to estimate absolute abundance of 2 year olds. The impetus for this decision revolved around the cost and logistic frailty of the existing recruitment monitoring based the scientific aerial survey. The scientific aerial survey provides a relative abundance index for 2-4 year olds, which is used in combination with the standardised longline CPUE in the CCSBT "Bali Procedure". The change in the recruitment monitoring method means it will be necessary to develop a revised/new MP for implementing the Commission's stock rebuilding plan. The work program for the development, testing, selection and implementation of a new MP is ambitious: commencing at the 2016 OMMP Technical Meeting with the aim of completion in time to recommend the 2021-2023 TAC block with a new MP in 2019. In this paper, we summarise the process for developing and testing candidate MPs and selecting and implementing a final MP. We recap on the objectives for the Commission's rebuilding plan, their technical specification in the current Bali Procedure and the operational constraints included in the decision rule to achieve the desired behavioural characteristics from the MP. An important aspect of the last MP development exercise was the development of a wide range of candidate MPs for initial testing, followed by an iterative selection process. This had many positive benefits and we consider this an important aspect of the process for the ESC. We provide an overview of the characteristics of the available monitoring series for each component of the SBT population (i.e. recruits, sub-adults and spawning adults) that are considered appropriate for use in candidate MPs and the rationale behind the use of model and empirical decision rules in MPs. Finally, we offer some thoughts on the "process", both technical and engagement with the ESC and Commission, with a view of increasing engagement, understanding and collaboration.

1 The MP development process

At its 2015 meeting the Extended Commission agreed to implement a new recruitment-monitoring program, using gene-tagging, to estimate absolute abundance of 2 year olds. The impetus for this decision revolved around the cost and logistic frailty of the existing recruitment monitoring series, derived from the scientific aerial survey. The aerial survey provides the current recruitment index of relative abundance of 2-4 year olds, which is used in combination with the standardised longline CPUE in the CCSBT "Bali Procedure". The change in the method used to estimate recruitment means it will be necessary to develop a revised, or new, candidate Management Procedures (MP).

A management procedure is the combination of monitoring data, method for analyses of those data, the decision rule (Also known as Harvest Control Rule (HCR)) and its implementation (Figure 1).

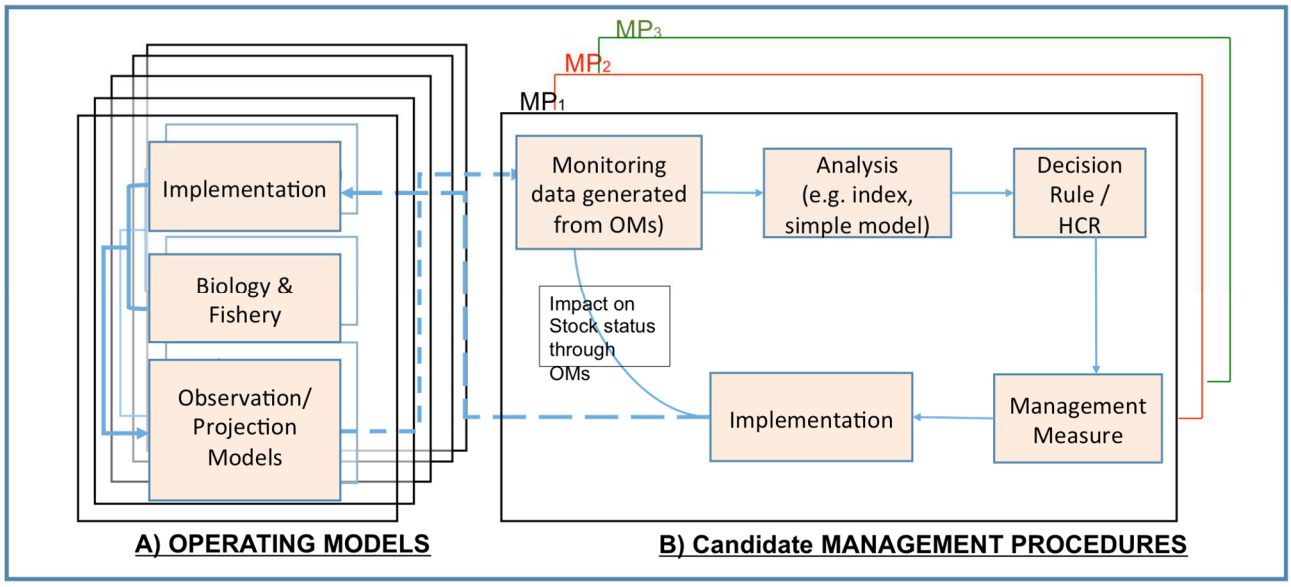

Figure 1: Schematic representation of the components of a) the Operating Models and b) Management Procedure used as part of Management Strategy Evaluation (MSE). The MSE process starts with development of multiple Operating Models, which define the status and dynamics of the stock, fisheries and monitoring data, including the plausible uncertainty in them. Multiple candidate MPs are developed, and their relative performance compared across a range of criteria, given that each candidate MP has been "tuned" to meet the CCSBT rebuilding objective.

Importantly, the development and implementation of effective MPs is generally very context specific and guided by decisions on the objectives for the rebuilding the stock agreed by the Extended Commission (EC). Implementation of the selected MP includes performance measures for review at a an appropriate time following implementation (e.g. for the Bali Procedure this was 6 years); the schedule of activities for TAC recommendations (every 3 years), assessment of stock status (every 3 years) and evaluation of meta-rules (annual); and examination of evidence of exceptional circumstances (annual). This implementation framework serves to ensure, to the

extent possible, that operation of the MP is consistent with the conditions and manner in which it was tested.

The timetable for testing and selection of a new MP was developed by the OMMP Technical meeting in 2015, and subsequently recommended by the ESC to the EC (Anon. 2015a, Anon 2015b). The process of testing and selecting candidate MPs (known as Management Strategy Evaluation, MSE) involves reconditioning the CCSBT Operating Models with updated and/or new data, defining data generation methods for monitoring series for use in projections, defining performance measures for testing of the candidate MPs and tuning the individual MPs to the rebuilding objective of the Commission (Table 1) (see Anon 2009, 2010 and 2011 for most recent round of MP development, testing and selection).

Table 1. The schedule for development of a new MP. Note shaded events (numbered with suffix "i") represent an inter-sessional activity. Source: 2015 OMMP report, Anon (2015a).

No.	Activity/Meeting	Purpose	Timing
1i	Evaluation of potential recruitment indices	Provide detailed evaluation of the statistical properties of potential recruitment indices	Nov 2015-May 2016
2	OMMP7	Evaluate and select candidate indices	June-July 2016
2i	Initial conditioning	Initial conditioning, data generation etc.	
3	OMMP-ESC21	Review of initial conditioning, data generation for projection models and form of potential MPs. These MPs may need to be quite different from the existing MP.	Sept 2016
3i	Finalise conditioning	Update OM with most recent data. Complete data-generation and specification of candidate MPs.	
4	OMMP8	Finalise conditioning (coinciding with scheduled OM reconditioning), data generation and initial MP runs	June-July 2017
4i	Refine MP performance	Refine MP performance and robustness tests	
5	OMMP-ESC22	MP selection	Sept 2017
5*i*	MP TAC recommendation	Any refinements required from ESC	
6	Sp. Commission	MP adoption	
7	OMMP9	Refinement and final tuning, if required	June-July 2018
8	ESC23	Final review	Sept 2018
9	Commission	Final Adoption/Implementation	Oct 2018

The initial steps in the MP development process are considered here. We provide an overview the potential monitoring series (Table 2), and alternatives for analysis and decision rules that could be combined with these monitoring series to form alternative candidate MPs.

Relative to the last round of MP development that resulted in the Bali Procedure, there are three new potential data series to consider for inclusion in candidate MPs: i) gene-tagging as an absolute index of 2 year old recruits, ii) Parent-Offspring-Pairs, and ii) Half-Sibling Pairs from the Close-Kin Mark Recapture method. The potential information content of each of these new series has been examined in Hillary et al (2016a), and proposed methods for data generation are provided in Hillary et al (2016b).

Consideration will also need to be given to how to include implementation uncertainty (in this case, total catches being greater or less than the TAC recommended by the MP. The EC has requested advice on this issue in the context of the Bali Procedure and initial considerations on this are provided in CCSBT-OMMP/1609/05.

Finally, and very importantly, further consideration needs to be given to the consultation and engagement process at both the ESC and EC level for this round of MP development. We identify a number of issues that the ESC may wish to consider in further detail.

2 Monitoring series for Candidate MPs

The CCSBT and members have a history of strategic investment in collection of data to be used as monitoring series within an MP and address major uncertainties in the understanding of the stock and fishery. Current monitoring series include information on different life-history stages (recent recruits, sub-adults and adults), in relative and/or absolute abundance as well as information on fishing and natural mortality, from both fishery-dependent and fishery-independent sources. This provides a wide variety of combinations to consider in the development of candidate MPs. Selection of the data sources should consider their information content, reliability, biases (known and potential), cost-effectiveness, logistical frailty and how best to combine these with appropriate analyses/models and harvest control rules to form candidate MPs.

The first formal round of CCSBT MP development (2000-2005) used catch, effort, CPUE and size data as the monitoring series to construct candidate MPs. In the second round of MP development (2009-2011), this was extended to include the scientific aerial survey and a requirement for candidate MPs to include an index of recruitment, given the low status of the stock and the historically low recruitments at the turn of the century (Anon. 2009). While there have been positive indications in recruitment and the status of the spawning stock in recent years (Anon 2014), the ESC continues to consider a fishery independent index of recruitment an important component of the monitoring programs that provide data for the OM and of the MP (Anon 2015). This is a function of the late maturity of SBT and the current selectivity of the majority of the fleets being focussed predominantly on juvenile and sub-adult fish, which results in a substantial delay between catches being taken and the impacts propagating through to the spawning stock. Until recently, there was no direct monitoring of the abundance of the spawning stock. The advent of the Close-kin Mark –Recapture methods has filled this gap to some extent, providing the biological sampling programs that underpin the approach can be maintained and the quality control remain high.

2.1 Candidate recruitment monitoring series

2.1.1 Scientific Aerial Survey

In 2015, the OMMP meeting evaluated the importance of recruitment data in the adopted MP. A quantitative analysis of Aerial Survey data in the current MP demonstrated the value of a fishery independent recruitment index in the MP. Under plausible robustness tests for future poor recruitment and future CPUE catchability changes, a performance benefit was noted from including a recruitment index in the MP, particularly with respect to risk of further stock declines (Anon 2015 OMMP rep).The meeting considered, in detail, alternative indices of recruitment (Anon 2015 OMMP rep), that could be used in a new MP and summarised their qualitative attributes (see Table 5 OMMP rep Anon 2015).

The summary indicated that the aerial survey and gene-tagging indices may be the most useful for use in candidate MPs. The grid-type troll index was considered potentially useful, but the method

required additional research and a design study. The SAPUE and Longline CPUE (age specific CPUE for 2, 3, 4 year olds) indices were not considered to be useful as recruitment indices in an MP (see Anon 2015 OMMP rep). The SAPUE index is from targeted commercial fishing operations, has shifted markedly in its area of operation over the past 4-5 seasons and CPUE standardisation cannot account for the potential biases (Basson and Farley 2015).The longline CPUE data is incomplete for these ages because age 4 or younger SBT are not consistently targeted or retained, if caught.

The ESC reiterated the need for a fishery independent index of recruitment given, the low status of the stock, historically low recruitments at the turn of the century, and the historical problems with the CPUE data. The scientific aerial survey data has been collected by a consistent scientifically designed line transect method over the years 1993-2000, 2005-2014 and in 2016 (Eveson and Farley 2011, 2016). Results of models of biomass per sighting and sightings per nautical mile are combined to provide a standardised relative abundance index of 2-4 year old SBT in the Great Australian Bight. The EC has agreed to fund the aerial survey in 2017. There is currently no commitment to fund the survey beyond 2017.These data are used in the SBT operating model as a relative abundance estimate of juveniles, and in the Bali Procedure as an index of recruitment.

Table 2: Candidate monitoring series for recruits, sub-adult and spawning adult life-history stages of SBT for potential inclusion in MPs.

Life-history stage	Candidate monitoring series	Measure	Age classes	Times series available by 2019	
Recruits	Aerial survey	Relative abundance juveniles	Recruitment 2,3,4 year olds	1993-2000, 2005-2014, 2016-2017	Fishery independent
	Gene-tagging	Absolute abundance Juveniles	Age 2 cohort	2016, 2017	Fishery independent
Sub-adults	CPUE LL	Relative abundance sub-adults	Sub-adults ages 4-8 or 4-11		Fishery dependent
Spawning Adults	POPs	Absolute/relative abundance adults	Adults	2002-2013	Independent
	HSP	Absolute abundance adults and adult mortality	Adults		Independent

2.1.2 Gene-tagging

Gene-tagging is a new method being trialled following a comprehensive design study in 2015 that indicated its potential to provide a more cost-effective recruitment monitoring series. It will provide an absolute abundance estimate for age 2 SBT in the year of release. It is a mark-recapture method that uses tissue samples from biopsy's at tagging and catch sampling to identify individuals caught in both samples. The genetics associated with the individual ID is well established, in that it is considerably easier to match an individual with itself than determine parentage as is required the close-kin methods. The ESC recommended the gene-tagging program was the best recruitment index in the near term, suitable for an on-going monitoring program to provide annual estimates of the abundance of recent recruits (i.e. the age 2 cohort) for use in monitoring the rebuilding of plan and use in future MPs.

2.2 Sub-Adults

2.2.1 LL1 CPUE

Longline CPUE data are used in the current MP as an index of the sub-adult, or "harvested" component of the population. The actual CPUE input data series used in the current MP is the average of two standardised CPUE indices that have been adjusted for an agreed unreported catch scenario (for the historical period where that applies). The CPUE combines data across age classes from age 4 upwards and is assumed to represent the relative abundance of sub-adult fish, as these have been the dominant age classes in this component of the fishery over the past few decades. CPUE indices are reliant on the collection of good quality data from the fishing industry. The relationship between CPUE and underlying abundance can potentially be biased through range contraction and changes in fishing behaviours that, generally, cannot be captured in the standardisation. Hillary et al., 2016b, examine the relationship between spawning stock biomass and CPUE and this analysis indicated weak information content between CPUE and spawner abundance over the last two decades of the SBT series.

2.3 Spawning Adults

The ESC agreed and included the close-kin parent-offspring (POP) data in the SBT operating models in 2013. The spawning abundance information currently included in the OMs is for the years 2002-2007, which were part of the original close-kin project. These data provide information on the adult abundance in the operating models (see Bravington et al 2014, Hillary et al 2012). In 2015, the CCSBT commissioned a design study on close-kin that investigated the use of next generation DNA sequencing techniques that could provide additional data from close-kin tissue samples collection (Bravington 2015). The design study described the information that could be gained on parent-offspring pairs and from half-sibling pairs and their potential use in future models and included a review by two prominent international referees.

The EC agreed to fund the 2016 collection of tissue samples (this has been on-going since the original project was completed), and to use the new genotyping method on the most recently collected tissue samples. CSIRO has proposed a parallel research project with the Australian

Fisheries Research and Development Corporation that will use the same genotyping method to process the historical (2006-2014/15) SBT tissues samples to provide a continuous time series on spawner abundance and mortality from 2002 to the present. The raw HSP and POP observations provide 2 separate and independent data sources on spawner abundance and/or total mortality that could be considered for use in candidate MPs.

3 Analyses, Models and Decision-rules

The current MP (the Bali Procedure) is a model-based rule. It uses 2 monitoring series as inputs (the AS and CPUE series) and generates recruitment and population growth estimates in a two-stage biomass random effects model. The decision rule takes the trends in these and compares the recruitment levels to historical lows and combines this information to recommend changes (up or down) to the TAC.

Empirical based MPs can use monitoring data and analyses to detect trends, or proximity to target or limit reference points, or indicators relative to threshold levels- directly from the input data and recommend changes in TAC (e.g. Anon 2013, Prince et al 2012, Kolody et al 2012).

Focussing on the CCSBT experience, both the 2005 (non-implemented) MP and the current MP were model-based. In the 2005 MP, which was set in a biomass dynamic model framework, there were problems with cases of model non-convergence, which required ad hoc solutions. The current MP solved this issue by having a simpler, relative abundance model that made non-convergence effectively disappear. However, as we have seen for the current MP we must update input parameters every time the MP is to be run, and check the estimation performance of the underlying model (see CCSBT-ESC/1609/18). This both increases workload and adds an additional requirement for members to understand when running the MP. There were performance advantages to using a model-based MP previously, but we suggest that in developing a new MP that the ESC consider the merits of both empirical and model-based MPs, as was the case in the most recent development exercise (2009-2011).

There will need to be a defined transition from the Bali Procedure to a new MP as the aerial survey ceases and gene tagging estimates of 2 year old recruitment become available. The gene-tagging data cannot simply replace the aerial survey data in the current biomass random effects model as they are fundamentally different forms of data (e.g. relative abundance of 2-4 year olds with a covariance matrix and absolute abundance of a single year class derived from mark-recapture data).

In addition to new sources of recruitment information from gene-tagging and the existing LL1 CPUE, there will potentially, be additional data sources on the spawning component of the stock from close-kin. A model-based MP that can incorporate all of these data sources and temporal shifts in their availability will be significantly more complex than the current model-based MP. So carefully consideration will need to be given to the both the combination of monitoring series and Analysis-Decision-rule used in candidate MPs. It may be better, for example to design an empirical–based MP that incorporates a combination of these potential data sources in a manner that delivers comparable performance to model based candidates and has the additional benefit of being easier for the ESC, EC and stakeholders to understand.

3.1 Recruitment index

Be it an aerial survey or gene tagging index, some kind of moving average makes sense in terms of the actual index that is used in the candidate HCRs. This is precisely how the aerial survey is

currently used in the MP, where a 5-year moving average in future relative juvenile biomass is compared to the historical lows. In paper CCSBT-OMMP/1609/7 it was demonstrated that a similar 5 year moving average of the estimate of 2 year old absolute abundance from gene tagging was able to achieve very good correlation (always above 0.75) with the "true" simulated value across a wide range of future dynamics. Using the gene tagging index in this kind of relative fashion also has the benefit of providing a solution to the one potentially problematic "non-mixing scenario" in the gene-tagging design study.

3.2 CPUE index

In the current MP both trend and target approaches are used for the CPUE data series. The trend approach was better at dealing with catchability changes, whereas target approaches helped to avoid the MP getting "lost" in low abundance regimes (Hillary et al 2016c). On the basis of this experience with testing CPUE-based rules in the previous round of development it makes sense to explore both trend and target uses of the CPUE in future candidate MPs.

3.3 POP an HSP

Paper CCSBT-OMMP/1609/7 demonstrated (using data generated in a simulation model) that one can develop relatively simple indices (compared to the standalone CKMR estimation model) directly from the simulated POP and HSP close-kin data that correlate well with spawning abundance and, in certain instances, total adult mortality. For both the POPs and HSP abundance indices, and indeed even a hypothetical spawner survey, it appears that trends (such as log-linear trends) were not nearly as informative as moving averages for the underlying indices. This suggests that the two forms of close-kin indices would be best used as moving average if used in candidate MPs.

Target-driven approaches are also worth considering in the SBT context, given the aim of the rebuilding strategy is to rebuild the spawning stock to a target level of depletion (i.e. 20% of SSB). The CKMR half sibling pair data also potentially allows a situation of falling recruitment to be distinguished from high adult mortality in scenarios where the spawning population is declining (CCSBT-OMMP/1609/7). As an example, this could potentially be used via the "decision tree" form of MP used elsewhere (Davies et al 2008, Prince et al 2012; Kolody et al 2012) where the intent is to identify hyper-stability in the CPUE index in the used in the first step of the HCR.

3.4 General form of the HCRs

It makes sense to have a Markov approach to how we change the TAC via the MP. That is, the future TAC is the current TAC with some alteration based on the MP input data and analysis:

*TACy+1 = TACy * (Recruitment + CPUE + CK alterations)*

We currently specify a minimum change of 100t and a maximum change of 3,000t. These "hard wired" constraints on minimum and maximum TAC changes were based on feedback from the EC and SFM-WG following considerations of likely behaviour of candidate MPs. Given the potential rebuilding trajectories of the stock it might be more appropriate to translate these constraints

from absolute quantities to agreed fractions of a change. For example, in 2011 the minimum and maximum changes were 1% and 30% of the then TAC of 9,449t; for the 2016 TAC decision for the 2018-2020 quota block they are 0.7% and 20%, respectively. The intent of these limits, especially the maximum change limit, is to entrain stability into the TAC for industry and to avoid large and potentially erroneous changes in the TAC driven by spurious short-term variation in the data. Percentage limits would be worth considering in more detail if a move to this type of control approach in the new candidate MPs is considered appropriate.

4 Engagement Process

Iterative consultation between Scientists, Managers, Industry and conservation advocates is an important component of MP development. The EC and ESC have changed since the Bali Procedure was adopted, with new members and new Commissioners, and with new staff within member's governance and science agencies. The MP implementation framework (schedule of TAC setting, stock assessments and meta-rule reviews, Anon 2013, Attachment 10), will need to be reviewed by decision makers, and some aspects of the existing framework may need revision. Commissioners will ultimately select the final MP for implementation based on technical advice provided by the ESC and member scientists.

The objective of the current MP is to rebuild the spawning stock to 20% of the initial spawning stock size by 2035. Given the uncertainties in the models and future projections, the management procedure has been tuned to meet this objective with a 70% probability. The reconditioned operating models and performance of new MPs may change our understanding of the potential speed and probability of rebuilding. Hence, the ESC and EC will need to consider the implications of this for the overall rebuilding plan.

The implementation framework for the Bali Procedure includes annual review of fishery and stock indicators and examination of evidence of exceptional circumstances and processes for action via the meta-rules. The MP TAC recommendations are used to set 3 year TAC blocks with a 1 year lag between calculation and implementation. A stock assessment is scheduled to be conducted every 3 years to provide updated advice on current stock status, and this is off-set from the TAC recommendation year. A review of the MP is scheduled to occur every 6 years to review performance of the MP. The rationale for the above decisions and any recommendations to change these in developing a new MP will need to be considered and revised to reflect the current circumstances and those that can be reasonably expected to arise in the near-medium term.

Managers will need to provide advice on their preferred objectives, Industry advice is required on operational feasibility of management actions, and Scientists will need to communicate the underlying concepts of management strategy evaluation and management procedures in science-based management, and the subtleties in performance and implications between final candidate MPs that will be presented to the EC.

With this context we identify three elements for discussion at the ESC:

i) **Schedule:** As noted above, the work program and time-table proposed by the ESC and agreed by the EC is very ambitious and provides very limited opportunity for iteration between highly technical tasks; review by the ESC and consideration/decision by the EC. The schedule reflects both the previously agreed schedule for MP implementation and constraints on resources. The ESC may wish to reconsider the current schedule in light of the information gained since it was proposed.

ii) **Policy-Science engagement:** In both previous MP development processes, there were resources allocated to consultation between the EC and ESC re: a) important aspects of MP design and performance and capacity building and b) capacity building in the

fundamental concepts and their application. There has been considerable "renewal" at both the EC and ESC since the previous MP development exercises, so how to most effectively and efficiently achieve this should be given some specific attention by both the ESC and EC. In this regard, engagement or coordination with other MP/HS and MSE initiatives should be considered.

iii) **Technical Cooperation and capacity building:** The development, testing, selection and implementation of MPs is a conceptually and technically challenging process. The success of any process relies on harnessing the collective understanding of the monitoring, stock, fishery and management and the important uncertainties in each component. Aspects of the process are highly technical, but this should not be a barrier to effective participation by those interested in contributing and learning. The key to this is appropriate fora and time/opportunity for communication. In the decade since the first round of MP development, the time and resources available for the technical work and ESC engagement and review have decreased. The ESC and EC will need to consider how best to balance the need for engagement and understanding at the ESC level, which impacts on the ability of members to advise their Commissioner. In this context, thought should also be given to the technical process for developing alternative MPs. In the past rounds a "competitive" model has been employed. This has the advantage of generating a creative environment in which "MP developers" develop alternative MPs that can out-perform others and also, increases the level of rigour of technical review. Composition of MP teams do, however, tend to fall out along delegation lines, which is not always conducive to cooperative outcomes; nor does it promote conceptual or technical capacity building across delegations. We suggest the ESC may want to consider alternative processes, which take the positive elements of the competitive MP development team model and combine it with more collaborative elements that lend themselves to more cross-delegation technical engagement and capacity building.

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