What is going on with bigeye tuna?

John Hampton[1]

*The 13th Regular Session of the Scientific Committee (SC13) of the Western and Central Pacific Fisheries Commission (WCPFC) was held in Rarotonga, Cook Islands from 9 to 17 August 2017. A major topic of debate at SC13 was the new bigeye tuna (*Thunnus obesus*) stock assessment, which was conducted by the Oceanic Fisheries Programme (OFP) of the Pacific Community. This new assessment indicates that the bigeye tuna stock is in a healthier condition than suggested by previous assessments that were carried out in 2011 and 2014. In this article, we outline the changes that were made to the 2017 assessment, why they were done and what they mean for management.*

Previous bigeye tuna assessments

To recap, previous assessments of bigeye tuna conducted by the OFP in 2011 and 2014 had relied on size data – i.e. length frequency and weight frequency samples of catches – to provide information on the rate of growth of bigeye tuna. In those assessments, the mean size of the oldest fish in the population (10 years of age and older) was estimated or assumed to be around 180 cm, which is equivalent to a weight of around 140 kg. This was consistent with available information on growth from the eastern Pacific Ocean, where the Inter-American Tropical Tuna Commission had conducted detailed studies on the age and growth of bigeye tuna. However, while these large bigeye tuna are fairly common in the eastern Pacific, they are relatively rare in the western and central Pacific Ocean (WCPO, west of 150°W). This is shown in Figure 1. For the history of all longline catches of bigeye tuna in the WCPO, <0.1% of the historical catch has been larger than 184 cm or 140 kg, even in the very early days of the fishery, when the presence of larger fish would be expected.

The rarity of large fish in the catch relative to the biological assumptions about the mean size of the oldest fish was attributed to fishery-induced depletion in the stock assessment model. To reconcile the paucity of large bigeye tuna in the catch, the model estimated that few survived to 10 years of age or more. The model did this by estimating high levels of fishing mortality, which greatly reduced the number of bigeye tuna that lived to older ages; thereby, they

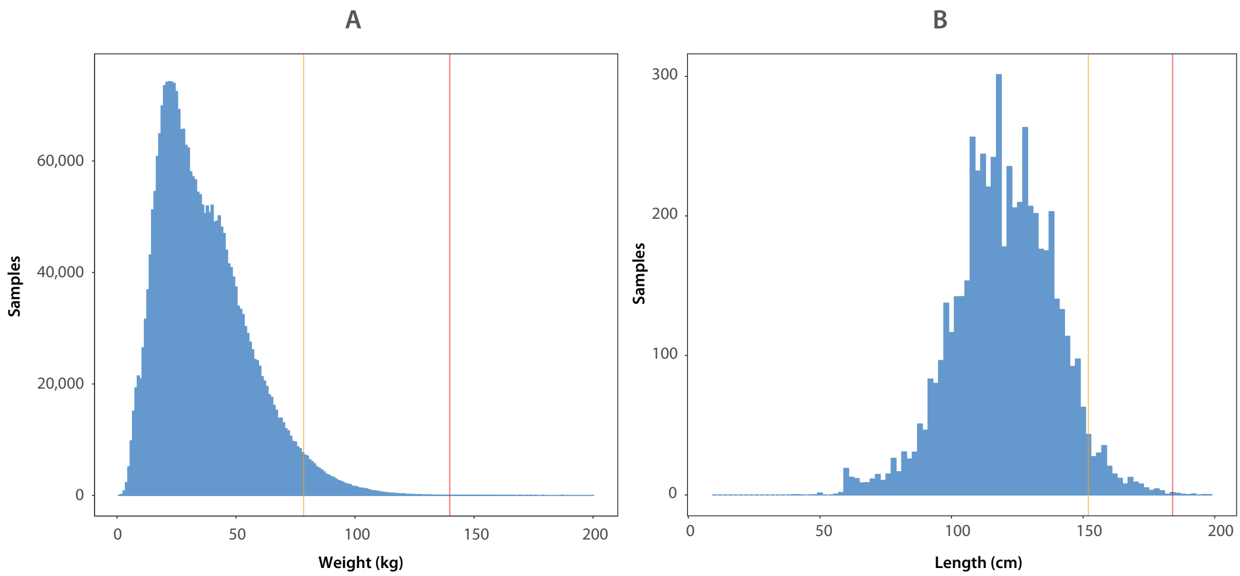

Figure 1. Weight frequency (A) and length frequency (B) distributions of the longline catch of bigeye tuna, 1952–2015, in the western and central Pacific Ocean. The red vertical lines represent the mean size of the oldest fish in the longline catch assumed for the 2014 assessment. The yellow vertical lines represent the mean size of the oldest fish as indicated by the new growth data.

[1] Chief Scientist – Deputy Director, FAME (Oceanic Fisheries), Pacific Community. Email: JohnH@spc.int

were not able to grow to these larger sizes. This implied a large fishery depletion effect, and gave rise to the estimate from the 2014 assessment that the ratio of the spawning (adult) biomass in 2012 (the final year of the 2014 assessment time period) to the spawning biomass estimated to occur in the absence of fishing, was 0.16 – i.e. the model determined that the stock was 84% lower than it would have been if no fishing had occurred. As this was below the agreed 'limit reference point' of 0.2 times the unfished spawning biomass, the stock assessment indicated that the stock was in an overfished state.

The 2017 bigeye tuna assessment

The new bigeye tuna assessment presents a considerably more optimistic outlook for the current status of the stock and the impacts of fishing (Figure 2). The assessment updated the data for the past three years and explored a wide range of uncertainty across 72 separate models that made different assumptions about biological characteristics (e.g. whether the new growth information was used, or that used in the 2014 assessment) and assessment model settings. This exploration of uncertainty was the most comprehensive of any WCPFC tuna stock assessment to date. SC13 weighted some of these models higher than others (more on this later), and the overall weighted median ratio of recent spawning biomass to the unfished level was 0.32, with 16% of the model runs falling below the limit reference point of 0.2 times the unfished spawning biomass. The median ratio of recent fishing mortality to the fishing mortality at maximum sustainable yield (MSY) was 0.78, with 23% of the model runs exceeding the MSY level. For this new assessment, it therefore appears that the stock is not in an overfished state nor is it experiencing overfishing. SC13 noted that while this assessment is more positive than previous assessments, it is recommended that fishing mortality should not be increased from the current level.

So what changed in the 2017 assessment?

Four main things changed in the 2017 assessment, and we discuss each of these in the following section.

Change 1: Inclusion of new growth data

As early as 2008, the WCPFC Scientific Committee (SC) recognised that the absence of scientific data on age-at-length represented a key uncertainty in bigeye tuna assessments. The SC also recognised that better biological information was required on bigeye tuna size-at-maturity, so that an accurate definition of 'spawning biomass' could be used in the assessments. This was important, as WCPFC was in the process of

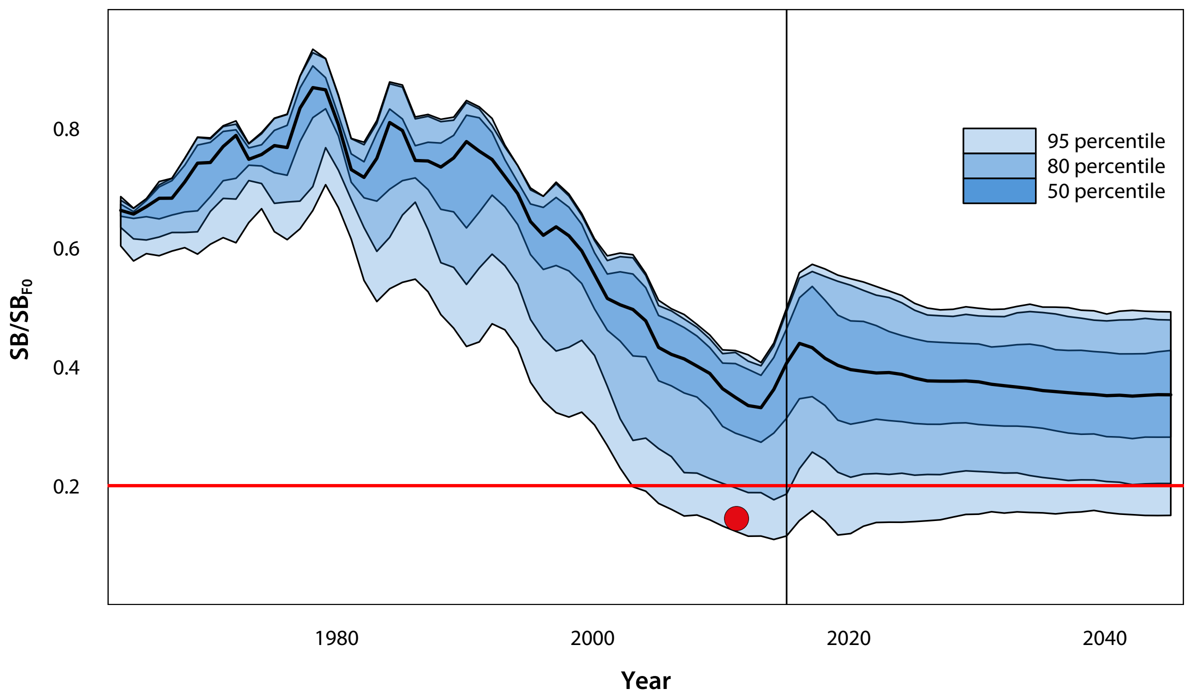

Figure 2. Estimates of historical (to the left of the vertical black line) and projected future bigeye tuna spawning biomass depletion (SB/SB_{F0}) assuming the continuation of recent levels of fishing.[2] The different shading of the trajectory represents the uncertainty in the estimates across 72 model runs that were weighted according to SC13 advice. The horizontal red line represents the limit reference point of 20% of the recent unfished spawning biomass. The solid red circle indicates the estimate of spawning biomass depletion in 2012 from the 2014 bigeye tuna assessment.

[2] SB/SB_{F0}: The ratio of spawning biomass – usually measured as the total weight (in tonnes) of spawners – to the estimated spawning biomass if the stock had never been fished.

moving to the use of spawning biomass depletion as the indicator for reference points. Thereby, the SC proposed and the Commission agreed to fund a major project on bigeye tuna age and growth, and reproductive biology.

During 2009 and 2010, the OFP, with the assistance of national observer programmes around the region, mounted a pilot study aimed at providing initial information to help design a comprehensive sampling programme. The pilot study was completed and reported to SC7 in 2011. The 313 otoliths collected gave the first indications that the size of the oldest bigeye tuna in the WCPO may be smaller than previously thought; however, the samples had been taken from a fairly restricted area of the WCPO, and the SC concluded that a full project, which aimed to collect 2,500 bigeye tuna otoliths and 300 gonad samples from throughout the WCPO and distributed across the size range of the fish, was required before the information could be incorporated into the stock assessment. Thereby, otolith and gonad sampling continued through mid-2016, and the necessary samples were eventually accumulated. WCPFC then committed to funding the processing and analysis of 1,100 otoliths and 300 gonads, which were sent to CSIRO in Hobart, Australia. This work took place in 2016 and early 2017 and the results were presented to SC13 in 2017. The main conclusion was that bigeye tuna grew to a smaller size than had been assumed in previous assessments (Figure 3), which confirmed the preliminary findings of the pilot study. The mean size of the oldest fish in the population, around 150 cm, estimated from these new data is considerably smaller than the size of 184 cm assumed in the 2014 assessment. As evident from Figure 1, there are significant numbers of fish in the longline catch at this smaller size – around 4% of the longline catch.

In the 2017 assessment, half of the 72 models that were considered used the new growth curve that is based on the otolith data, while half used the old growth curve, which had been used in the 2014 assessment. The incorporation of the new growth model had a profound effect on the stock assessment results. These models no longer had to attribute a lack of older fish to high fishing mortality, because greater numbers of older fish in the population could now be predicted by the models. The impact of the change in growth is easily seen in the 'Majuro Plot' of spawning biomass depletion and fishing mortality in relation to MSY conditions (Figure 4). Models that incorporate the new growth generally have moderate spawning biomass depletion and fishing mortality less than MSY; however, those that incorporate the growth assumption that was used in the 2014 assessment mostly have spawning biomass depletion to less than the limit reference point, and fishing mortality above the MSY level. These latter results – that used the old growth – are fairly consistent with the 2014 assessment.

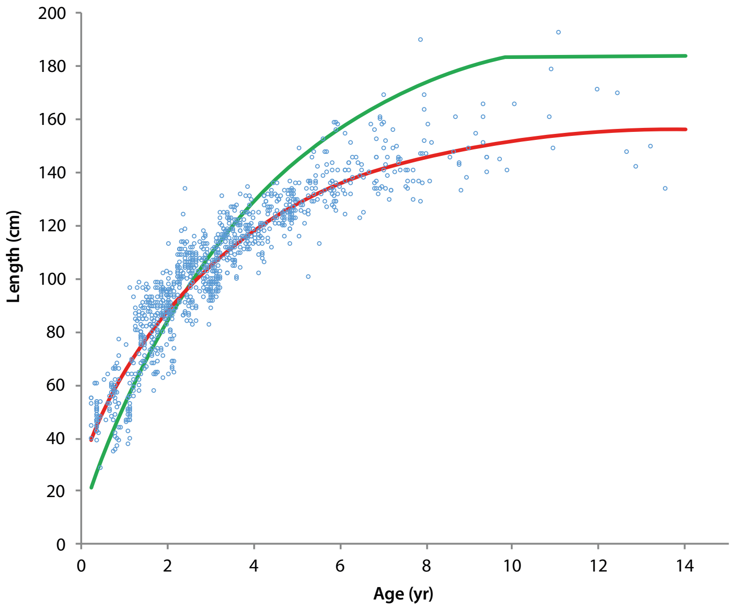

Figure 3. Estimated bigeye tuna growth. The green line represents the growth curve used in the 2014 assessment; the blue circles are the lengths and estimated ages from the otolith samples; and the red line is a von Bertalanffy growth curve fitted to the otolith data.

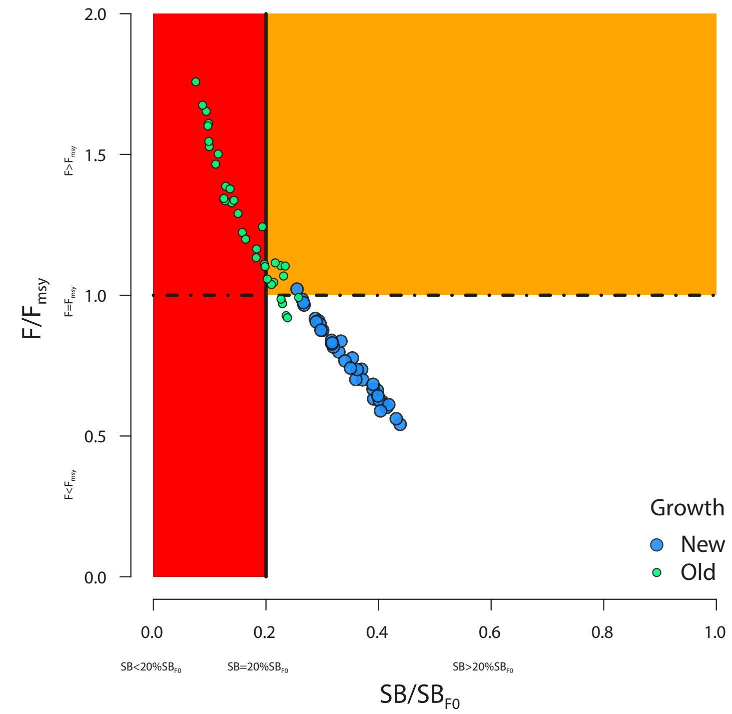

Figure 4. Estimates of recent average spawning biomass depletion (SB/SB_{F0}) and fishing mortality in relation to MSY conditions (F/F_{msy}).[3] The red area of the plot indicates spawning biomass less than the limit reference point of 20% of the unfished level. The red and orange areas above the dashed horizontal line indicate levels of fishing mortality higher than MSY. The blue and green points represent 2012–2015 average spawning biomass depletion from models incorporating the new growth information and old growth assumption, respectively.

[3] F/F_{msy}: Current fishing mortality relative to the fishing mortality that would result in the maximum sustainable yield.

To construct its final scientific advice, SC13 decided to use all 72 models, but gave three times the weight to the new growth models compared with the old growth models. This gave the weighted distribution of outcomes shown in Figure 2.

Change 2: Inclusion of new reproductive maturity data

The same project that SC initiated to acquire new information on bigeye tuna age and growth also obtained new information on size- and age-at maturity. As noted above, this information is important for the definition of spawning biomass in the assessment.

The new data on reproductive maturity resulted in new estimates of reproductive output by age-class that were quite different to those used in the 2014 assessment (Figure 5). In particular, bigeye tuna were found to reach reproductive maturity at a younger age (50% mature at about 3 years of age) than previously assumed (50% mature at 4 years of age). This means that a full additional year-class was added to the spawning biomass as a result of the new information. As younger age-classes are less depleted by fishing than older age-classes, the addition of these younger fish to the spawning biomass means that it is somewhat less depleted overall. So the incorporation of this new information to the assessment also had a positive impact on the estimated stock status.

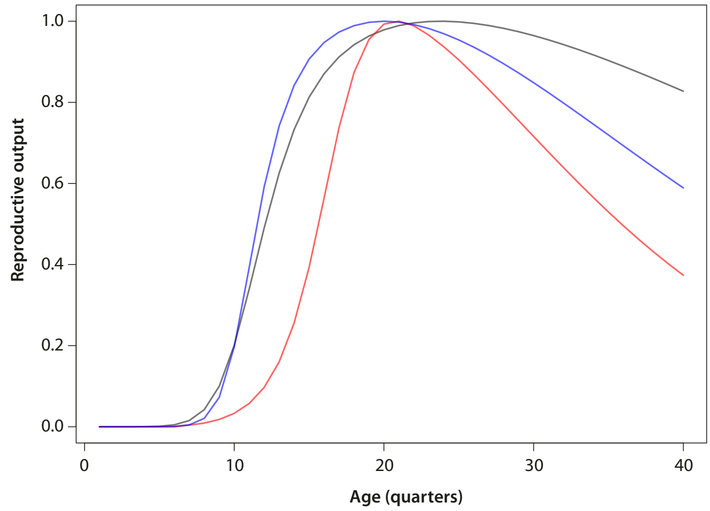

Figure 5. Bigeye tuna maturity-at-age. The red curve is that used in the 2014 stock assessment. The blue curve is based on new maturity-at-length information from the reproductive biology project and converted to maturity-at-age using the growth assumptions used in the 2014 assessment. The black curve is based on the new maturity-at-length information and converted to maturity-at-age using the new growth curve based on otolith data.

Change 3: Spatial structure of the assessment

A considerable amount of bigeye tuna tagging has been undertaken by the Pacific Community and the Inter-American Tropical Tuna Commission in recent years. This work has provided new insights into the extent of mixing of bigeye tuna across the tropical Pacific, both in the E-W and N-S directions (Figure 6). The key observation from these data is that bigeye tuna, at least during their juvenile stage, appear to be tightly constrained within the region from 10°N to 10°S. In previous bigeye tuna assessments, the boundary between the tropical and subtropical regions of the WCPO had been set at 20°N in the North Pacific and at 10°S in the South Pacific. This new information suggested that a boundary of 10°N in the North Pacific would be more appropriate. This boundary would also better demarcate the distribution of the purse seine fishery and better represent oceanographic

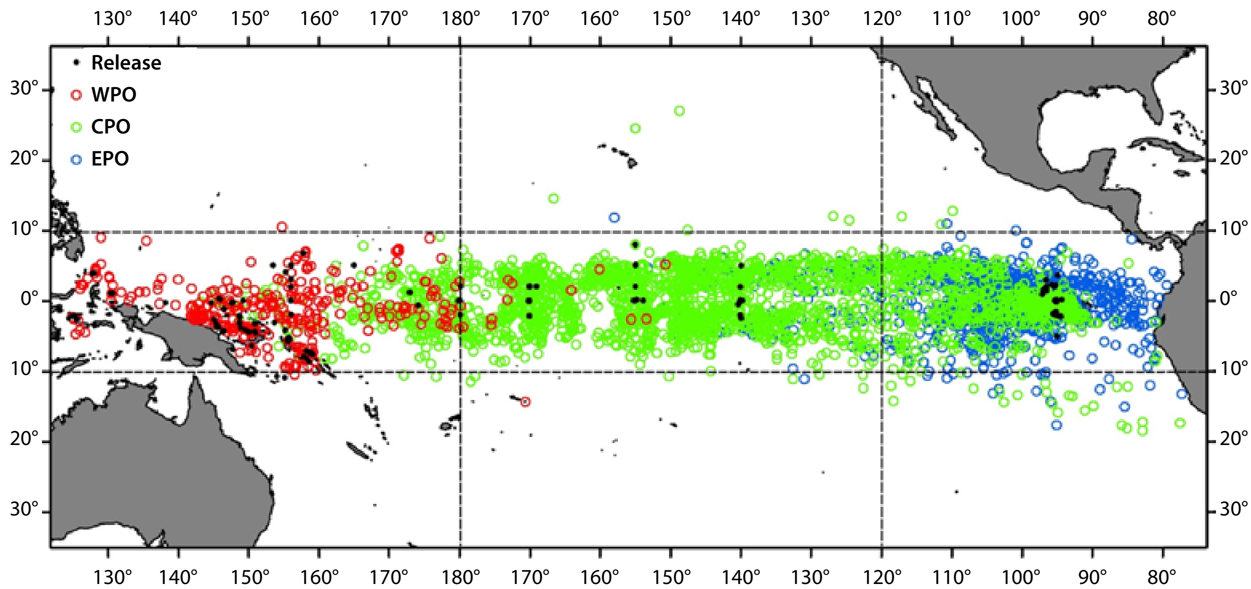

Figure 6. Tag recovery locations of bigeye tuna tagged in the western Pacific (red circles), central Pacific (green circles) and eastern Pacific (blue circles). The small black circles represent the release locations within these areas.

provinces in the Pacific Ocean. Therefore, half of the 72 models used for the 2017 assessment adopted a tropical-temperate boundary in the North Pacific of 10°N, while the other half retained the original 20°N boundary (Figure 7).

The change in regional structure had some effect on the stock assessment estimates by constraining the high exploitation component of the fishery in the equatorial region into a smaller spatial area. Conversely, larger areas were then associated with regions 1 and 2, in which fishing mortality rates of bigeye tuna are lower. This had the overall effect of reducing stock-wide impacts of fishing on the stock. This effect is shown in a 'Majuro Plot' whereby models using the changed (2017) regional structure produce more moderate spawning biomass depletion and fishing mortality in comparison with the previous (2014) structure (Figure 8).

Change 4: Estimated recent increase in spawning biomass

One of the features of the new assessment is an estimated increase in spawning biomass in the final year of the assessment. This increase occurs, albeit with slightly different timing in some cases, for all of the models considered in the assessment. It is consistent with increases in catch-per-unit-effort (CPUE) in many longline fleets and is projected to persist for at least several years in the future (Figure 2). There are several possible reasons for the increase, including: 1) a series of strong recruitments into the population, which is suggested by the recent recruitment estimates in the models; 2) reduced fishing mortality primarily of juvenile bigeye tuna due to management measures implemented by WCPFC and its members; and 3) higher bigeye tuna catchability by longline fleets that was not removed by CPUE standardisation and hence interpreted by the models as an abundance effect. At this point, the first and second reasons appear to be the strongest candidates, and there is some internal consistency for both in the model results. In the case of recruitment, the terminal estimates are consistently high over the period from 2011 to 2013, with these fish now entering the spawning population. Also, there is some evidence of fishing mortality of both adults and juveniles being at least constrained, and possibly slightly decreased, since the introduction of measures such as seasonal closures of purse seine fishing on fish aggregation devices (FADs). In the case of the FAD closures, there is a clear signal of reduced juvenile bigeye tuna fishing mortality in the third quarter since 2010, which coincided with the FAD closure periods, and bigeye tuna catches by purse seine have been estimated to have been reduced by around 35% compared with what they would have been without the closures.

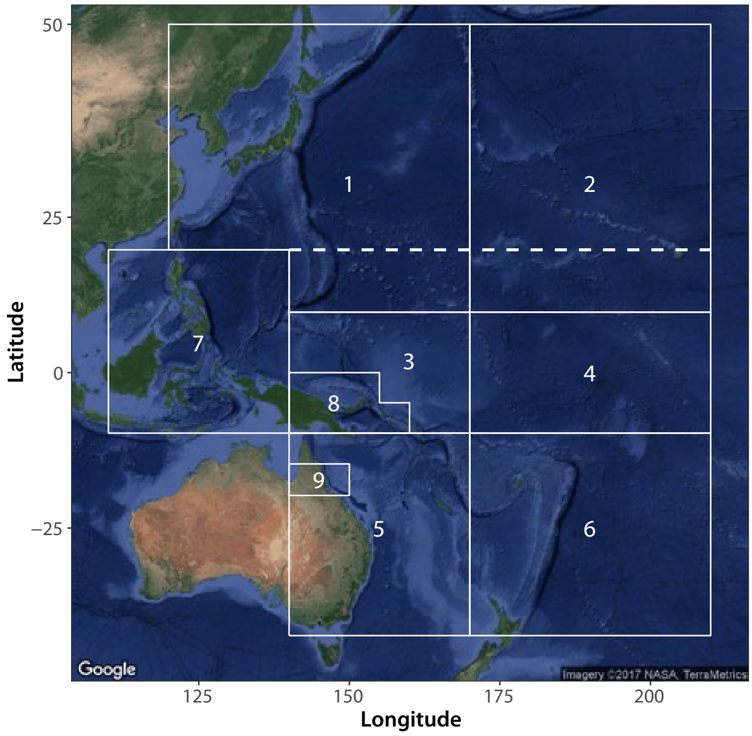

Figure 7. The definitions of spatial structure used in the 2017 bigeye tuna assessment. The dashed white line at 20°N separating regions 1 and 3 and regions 2 and 4 was used in the 2014 assessment. The white line at 10°N is the alternative definition adopted in the 2017 assessment.

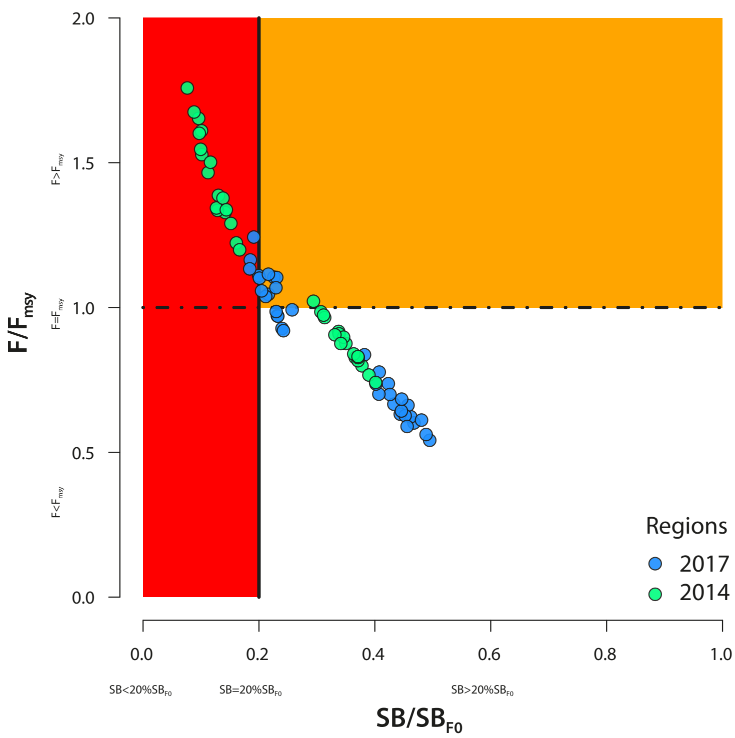

Figure 8. Estimates of recent average spawning biomass depletion (SB/SB_{F0}) and fishing mortality in relation to MSY conditions (F/F_{msy}). The red area of the plot indicates spawning biomass less than the limit reference point of 20% of the unfished level. The red and orange areas above the dashed horizontal line indicate levels of fishing mortality higher than MSY. The blue and green points represent 2012–2015 average spawning biomass depletion from models incorporating the changed (2017) and previous (2014) regional structure, respectively.

Where to from here for the bigeye tuna assessment?

As noted above, SC13 accepted the results of the assessment and made several important recommendations, which are listed below.

1. Use all 72 models that are presented as part of the assessment to characterise the uncertainty in the assessment, with the models that included the new growth curve being accorded three times the weight of the old growth models.
2. Conduct further work to improve the growth data set through the inclusion of additional otolith samples for larger-sized bigeye tuna.
3. Undertake work to indicate which regional stratification is most appropriate for the assessment.

The SC was of the view that the additional work proposed under recommendations 2 and 3, above, should allow the uncertainty in the assessment results to be reduced, ultimately through the use of a reduced suite of models that use the best scientific information on growth and regional structure in particular. It is likely that this question will be re-visited next year at SC14. In the meantime, the OFP will use the weighted model ensemble to conduct evaluations of management alternatives for bigeye tuna, and the other tropical tunas using the latest assessments, for the 14th Annual Regular Session of the WCPFC to be held in Manila, Philippines in December 2017.

Concluding remarks

Rapid and substantial change is rarely comfortable. The changes resulting from the 2017 bigeye tuna assessment have certainly tested the scientists involved in the work. We were acutely aware of the impact that the new assessment would have, and there was pressure on everyone involved to 'get it right' within the limits of the information at our disposal. There was a feeling that our credibility, and that of the science process generally, would be under intense scrutiny. The representatives of WCPFC members participating in SC13 were also tested in interpreting the results and reacting with appropriate recommendations. Many of those representatives will also have to explain to their fisheries managers and industries in their home countries why the assessment has changed and why the outlook now seems to be considerably better. In some cases, this is bound to be a difficult conversation, particularly where difficult decisions were made in the past.

But on the positive side, it does seem as though the science process has worked as it should. Uncertainties in earlier assessments were identified, research to address those uncertainties was designed, funded and implemented, the results of the research were incorporated into a new assessment and appropriate follow-up research and management responses are being formulated – continuing the process of improving assessments and the management decisions that flow from them.