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# Torres Strait Tropical Rock Lobster Fishery

Working Draft

Harvest Strategy

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GLOSSARY

**Types of reference points:**

|  |  |
| --- | --- |
| **Reference Point** | **Description** |
| Metarule | A rule that describes how the RBCs obtained from an assessment should be adjusted in calculating a recommended TAC |
| Target | Relates to a target reference point as per the HSP. Expressed in terms of biomass |
| Limit | Relates to a limit reference point as per the HSP. Fishing stops if this reference point is exceeded a specified number of times. Expressed in terms of biomass |
| Threshold | The reference point below which the TAC is adjusted to allow the stock to rebuild to the target reference point |
| MEY | Maximum economic yield occurs when the total profit from the Fishery is maximised |
| MSY | Maximum sustainable yield is the maximum that can be taken from a stock in perpetuity |

**Notation:**

|  |  |
| --- | --- |
| **Notation** | **Description** |
| B | Spawning biomass level |
| B0 | The unfished spawning biomass (determined from an appropriate reference point) |
| F | Fishing mortality rate |

**Other acronyms:**

|  |  |
| --- | --- |
| **Acronym** | **Description** |
| CPUE | Catch per unit effort |
| HSP | Commonwealth Harvest Strategy Policy and Guidelines 2007 |
| HS | Harvest Strategy |
| HSF | Harvest Strategy Framework |
| HCR | Harvest Control Rule |
| RBC | Recommended Biological Catch |
| TRLRAG | Tropical Rock Lobster Resource Assessment Group |
| TRLWG | Tropical Rock Lobster Working Group |
| TAC | Total Allowable Catch |
| Tiered approach | A framework that uses different control rules to cater for different levels of uncertainty about a stock |
| TIB | Traditional inhabitant boat |
| TVH | Transferrable vessel holder |

OVERVIEW

The Torres Strait Tropical Rock Lobster Fishery (the Fishery) Harvest Strategy (HS) sets out the management actions needed to achieve the agreed Fishery objectives. The Fishery HS describes the performance indicators used for monitoring the condition of the stock, the fishery‑independent survey and stock assessment procedures and the rules applied to determine the recommended biological catch and total allowable catch each fishing season.

The HS uses a single tier approach with an empirical harvest control rule (eHCR) that is used to determine a recommended biological catch (RBC). The eHCR uses the pre‑season survey to estimate an index of abundance of juvenile (1+) and newly recruited (0+) TRL and the catch per unit effort (CPUE) indices for the traditional inhabitant boat (TIB) and transferrable vessel holder (TVH) fishing sectors. The RBC is the best available scientific advice on what the total fishing mortality (landings from all sectors and discards) should be for the stock. The RBC is currently used to monitor the performance of the fishery, in future years it will be used to recommend Total Allowable Catches (an enforced limit on total catches).

The HS meets the requirements of the *Commonwealth Fisheries Harvest Strategy Policy and Guidelines 2007 (*HSP) by applying a precautionary approach to applying the reference points and measures to be implemented in accordance with the reference points. This is reflected in the use of proxy reference points that are more precautionary than those specified in the HSP. The eHCR is designed to decrease exploitation rate as the stock size decreases below the target reference point. The HSF uses maximum economic yield as a target and a biomass limit reference point to trigger no further targeted fishing. The HS proxies are BLIM is 32% of B0, BTARG is 65% of B0.

Further work includes the development of a tiered approach for the HS. The tiered approach applies different types of control rules to cater for different amounts of data available and to account for changes to uncertainty on stock status. A tiered approach adopts increased levels of precaution that correspond to increasing levels of uncertainty about the stock status, in order to maintain the same level of risk across the different tiers.

The status of the stock and how it is tracking against the HS, is reported to the RAG, Torres Strait Tropical Rock Lobster Working Group (the Working Group) and the Protected Zone Joint Authority (PZJA). The stock assessment includes considerations of the catch rates in current and previous fishing seasons, how the catches compare to the RBCs, stock status indicators in relation to the reference points and an RBC for the upcoming fishing season.

* 1. BACKGROUND

This Torres Strait Tropical Rock Lobster Fishery (the Fishery) Harvest Strategy (HS) has been developed in accordance with the *Commonwealth Fisheries Harvest Strategy Policy and Guidelines 2007* (HSP) and consistent with objectives of the *Torres Strait Fisheries Act 1984* (the Act).

The Fishery HS takes into account key fishery specific attributes including:

1. there is potential for large, unpredictable inter‑annual variations in availability and abundance of tropical rock lobster (TRL);
2. TRL is a shared resource important for commercial, traditional and recreational sectors; and
3. advice from the Tropical Rock Lobster Resource Assessment Group (the RAG) industry members to maintain stock abundance at current levels (RAG, 31 March 2016). (NOTE: Working Group advice to be added)
   1. COMMONWEALTH FISHERIES HARVEST STRATEGY POLICY

The objective of the HSP is the sustainable and profitable use of Australia’s Commonwealth fisheries in perpetuity through the implementation of harvest strategies that maintain key commercial stocks at ecologically sustainable levels, and within this context, maximise the economic returns to the Australian community.

To meet the HSP objective, harvest strategies are designed to pursue an exploitation rate that keeps fish stocks at a level required to produce maximum economic yield (MEY) and ensure stocks remain above a limit biomass level (BLIM) at least 90 per cent of the time. Alternative reference points may be adopted for some stocks to better pursue the objective of maximising economic returns across the Fishery as a whole or other fishery specific objectives.

The HSP provides for the use of proxy settings for reference points to cater for different levels of information available and unique fishery circumstances. This balance between prescription and flexibility encourages the development of innovative and cost effective strategies to meet key policy objectives. Proxies must ensure stock conservation and economic performance as envisaged by the HSP. Such proxies, including those that exceed these minimum standards, must be clearly justified.

With a harvest strategy in place, fishery managers and stakeholders are able to operate with pre-defined rules, management decisions are more transparent, and there are likely fewer unanticipated outcomes necessitating hasty management responses. However, due to the inherently natural variability of TRL abundance there may be a need for significant changes in recommended catch on an annual basis.

* 1. DEVELOPMENT OF THE TRL HARVEST STRATEGY

The HS has been developed in consultation with the RAG and Working Group. It replaces the interim HS developed for the Fishery in 2008 **(Section 2.2)**.

NOTE: TRLWG advice to be provided once TRLRAG advice finalised – this statement is to be updated as required.

* 1. TRL FISHERY HARVEST STRATEGY
     1. SCOPE

This HS applies to the whole fishery and it takes into account catch sharing arrangements between Australia and Papua New Guinea (PNG).

The HS outlines the control rules used to develop advice on the recommended biological catch (RBC) and in future years it will be used to recommend Total Allowable Catches (an enforced limit on total catches)[[1]](#footnote-1). The HS sets the criteria that pre-agreed management decisions will be based in order to achieve the Fishery objectives.

Overtime the HS may be amended to use a tiered approach to cater for different amounts of data available and different types of assessments (for example mid-year surveys and annual assessments). Underpinning a tiered HS is increased levels of precaution with increasing levels of uncertainty about the stock status. Each tier has its own harvest control rule (HCR) and associated rules that are used to determine a RBC.

* + 1. OBJECTIVES

The operational objectives of the Harvest Strategy are to:

1. maintain the stock at (on average), or return to, a target biomass point BTARG equal to the stock size that aims to maximise net economic returns for the Fishery by maintaining the stock abundance around recent levels while having regard for the fact that the resource is shared and important for the traditional way of life and livelihood of traditional inhabitants;
2. maintain stocks above the limit biomass level (BLIM), or an appropriate proxy, at least 90 per cent of the time; and
3. implement rebuilding strategies, if the stock moves below BLIM in successive years.
   * 1. RECOMMENDING TACs FROM RBCs

The RBC is the recommended total catch of TRL (both retained and discarded) that should be taken by all sectors of the Fishery. The HSP states that when setting the TAC for the next fishing season the HS should take into account all sources of fishing mortality.

The HS does not include catches taken by non-commercial fishing sectors, for example traditional, recreational or research catches. The RAG recommended at Meeting No.18 on 2‑3 August 2016 that non‑commercial catches should not be accounted for, because the overall catches are likely to be relatively low and there would be limited impact on the stock assessment. The HS may be updated in the future to account for changing circumstances in the Fishery, the review provisions are described in Section 2.12.

NOTE: The total allowable catch (TAC) for the Fishery is currently notional (not enforced) and is not used to control harvest. It is used to inform catch sharing arrangements with Papua New Guinea and to inform the status of the stock.

* + 1. MONITORING

Biological data for the Fishery are monitored by a range of methods listed below. Currently there is no ongoing monitoring strategy in place to collect economic information.

**Fishery independent surveys**

A key component of the monitoring program is the fishery‑independent survey which provides a time‑series of relative abundance indices for TRL. Fishery‑independent surveys have been conducted in the Fishery since 1989. Historically (1989-2014), mid‑season (July) surveys focused on providing an index of abundance of the spawning (age 2+) and juvenile (age 1+) lobsters. Mid-season surveys have been replaced with pre‑season (November) surveys (2005-2008; 2014 to current) which focus on providing an index of recruiting (age 1+) lobsters as close as possible to the start of the fishing season to support the transition to quota management and setting of a TAC. Pre-seasons surveys also provide indices of recently-settled (age 0+) lobsters, which may become useful under quota management as they allow forecasting of stock one year in advance.

**Catch and effort information**

Fishers in the transferrable vessel holder (TVH) sector are required to record catch and effort information in the Torres Strait Tropical Rock Lobster Daily Fishing Log (TRL04). The following data is recorded for each TVH fishing operation: the port and date of departure and return, fishing area, fishing method, hours fished and the weight (whole or tails) of TRL retained. Fishers in the traditional inhabitant boat (TIB) sector voluntarily report catch and effort information to buyers and processors who record the information in the Torres Strait Seafood Buyers and Processors Docket Book (TDB01). Some processors previously (2014‑2016) reported aggregate TIB catch information directly to AFMA, these processors are currently reporting with the TDB01 docket book.

* + 1. INTEGRATED STOCK ASSESSMENT MODEL

The stock assessment model (termed the ‘Integrated Model’) (Plagányi *et al.* 2009) was developed in 2009 and is an Age-Structured Production Model, or Statistical Catch-at-Age Analysis (SCAA) (e.g. Fournier and Archibald 1982). It is a widely used approach for providing RBC advice and the associated uncertainties.

The model integrates all available information into a single framework to assess resource status and estimate a RBC. The model addresses all of the concerns highlighted in a review of the previous stock assessment approach (Bentley 2006, Ye *et al*. 2006, 2007). The model is fitted to the mid‑season and pre‑season survey data and TIB and TVH CPUE data. The growth relationships used in the model were revised from the previous stock assessment model (Ye *et al*. 2006), and average mass compared with observations. The model is compatible as an Operating Model in a Management Strategy Evaluation (MSE) framework to support the management of the Fishery.

The stock assessment model is non-spatial and assumes that the Torres Strait Tropical Rock lobster Fishery stock is independent of the Queensland East Coast Tropical Rock Lobster Fishery stock. A spatial version of the model has been developed as part of an earlier MSE project, and can be used to investigate plausible linkages between these stocks (Plagányi *et al*. 2012, 2013).

The model includes three age-classes only (0+, 1+ and 2+ age lobsters) as it is assumed that lobsters migrate out of Torres Straits in October each year. Torres Strait TRL emigrate in spring (September‑November) and breed during the subsequent summer (November-February) (MacFarlane and Moore 1986; Moore and Macfarlane 1984). A Beverton-Holt stock-recruitment relationship is used (Beverton and Holt 1957), allowing for annual fluctuation about the deterministic relationship. The model is fitted to the available abundance indices by maximising the likelihood function. Quasi-Newton minimisation is used to minimise the total negative log-likelihood function (using the package AD Model BuilderTM) (Fournier *et al*. 2012).

* + 1. EMPIRICAL HARVEST CONTROL RULE (to be finalised by CSIRO)

The empirical harvest control rule (eHCR) recommended by the TRLRAG uses the pre‑season survey 1+ and 0+ indices, both CPUE indices (TVH and TIB), applies the natural logarithms of the slopes of the five most recent years’ data and includes an upper catch limit of 1,000 t. The relative weightings of the eHCR indices are 70 per cent pre-season survey 1+ index, 10 per cent pre-season survey 0+ index, 10 per cent TIB sector CPUE and 10 per cent TVH sector CPUE.

The basic formula is:



or if  > 1000t, = 1000.

where

 is the average achieved catch during the past 5 years, including the current year i.e. from year *y*-4 to year *y*,

 is the slope of the logarithms of the preseason survey 1+ abundance index, based on the 5 most recent values;

 is the slope of the logarithms of the preseason survey 0+ abundance index, based on the 5 most recent values;

 is the slope of the logarithms of the TVH and TIB CPUE abundance index, based on the 5 most recent values;

wt\_s1, wt\_s2, wt\_c1, wt\_c2 are tuning parameters that assign relative weight to the preseason 1+ (wt\_s1) and 0+ (wt\_s2) survey trends compared with the CPUE TVH (wt\_c1) and TIB (wt\_c2) trends.

* + 1. REFERENCE POINTS

The HS reference points are:

1. The unfished biomass B0 is the model-estimate of spawning stock biomass in 1973 (start of the Fishery). B0 = B1973.
2. The target biomass BTARG is the spawning biomass level which would result in a maximum economic yield (MEY), which is the point at which the sustainable catch for the Fishery maximises profits. BTARG is the proxy for BMEY, BTARG = 0.65 B0.
   * The RAG noted a higher target biomass was considered important for the Fishery because: 1) the stock: is a shared resource that is particularly important for traditional fishing; 2) the stock has high variability; and, 3) all industry members recommended the HS maintain the stock around the relatively high current levels (RAG meeting no. 17, 31 March 2016 and meeting no. 18, 2‑3 August 2016).
3. The limit biomass BLIM is the spawning biomass level below which the risk to the stock is unacceptably high and the stock is defined as ‘overfished’. BLIM is agreed to be half of BTARG, BLIM = 0.32 B0.
4. If the limit reference point (BLIM) is triggered two years out of the most recent three year period, then the Fishery is closed.
5. The target fishing mortality rate FTARG is the estimated level of fishing mortality rate that maintains the spawning biomass around BTARG. FTARG = 0.15.
   * FTARG = 0.15 is assumed to be a proxy for BMEY because stakeholders agreed that this target level corresponded to an optimal level in terms of economic, biological and social considerations (RAG meeting no. 18, 2‑3 August 2016)

***Rational for reference points***

The HSP recognises that each stock/species/fishery will require an approach tailored to the fishery circumstances, including species characteristics. The HSP identifies that for highly variable stocks that may naturally (in the absence of fishing) breach BLIM, the default reference point proxies may not be appropriate. The HSP states ‘with highly variable species it is important to develop a harvest strategy that meets the intent of the HSP.’ Further, ‘stocks that fall below BLIM due to natural variability will still be subject to the recovery measures stipulated in the HSP.’ A number of adaptive management approaches may be used to deal with this, such as pre-season surveys to provide estimates of abundance to which the eHCR is applied.

The Fishery is characterised by a highly variable stock where majority of the catch (since 2001 due to the introduction of a minimum size limit) is from a single cohort. The stock assessment model and MSE testing have identified the target biomass should be set between 65 and 80 per cent of the unfished biomass. The HS higher average target biomass level, compared to the default HSP target of 0.48 per cent of unfished biomass, reduces the risk of recruitment being compromised.

The unfished biomass (B0) is calculated within the stock assessment model, the value of unfished biomass and target biomass have therefore varied over time in response to annual data updates and model parameter settings and estimates. Estimates of unfished biomass and target biomass are particularly sensitive to changes to parameter *h*, which determines the steepness of the stock-recruit relationship, and the input parameter that controls the level of stock-recruit variability.

Independent of variability to the unfished biomass value, the target fishing mortality rate FTARG =0.15 is applied to maintain the spawning biomass around the biomass target reference point (BTARG), which is the average level over the past two decades. This is assumed to be a proxy for BMEY because stakeholders agreed that this target level corresponded to an optimal level in terms of economic, biological and social considerations (TRLRAG meeting no. 18, 2‑3 August 2016).

The biomass limit reference point (BLIM) is 32 per cent of unfished biomass. The higher limit reference point, compared to the HSP proxy of 20 per cent of unfished biomass, is supported by recommendations of similar limit reference points for other highly variable species such as forage fish. Due to the changing values of unfished biomass and target biomass the value of the limit reference point has previously varied between 32 and 40 per cent of unfished biomass.

Recent MSE testing identified that a limit reference point of 40 per cent unfished biomass may be too conservative and unnecessarily breach the limit reference point. The RAG agreed to set the limit reference point at 32 per cent of unfished biomass with the condition that if the stock falls below the limit reference point in successive years (years two and three only) during the three year stock assessment cycle it triggers a Fishery closure. The eHCR is consistent with the HSP criterion to ‘ensure that the stock stays above the limit biomass level at least 90 per cent of the time.’ The HSP states that for highly variable species the risk criterion can be amended to increase the frequency the limit reference point may be breached or by altering the reference point value.

* + 1. ASSESSMENT CYCLE

The integrated stock assessment occurs on a three year cycle. In the intervening years the eHCR will be applied.

If the Fishery is assessed to be at or below the biomass limit reference point (BLIM) in successive years (years two and three) during the cycle, the stock assessment must be repeated the following year in order to monitor the condition of the stock (RAG meeting no. xxxx).

If the integrated stock assessment determines the stock to be below the biomass limit reference point in successive years the Fishery is closed to commercial fishing. The Fishery can only open when the integrated stock assessment determines the Fishery to be above the biomass limit reference point.

* + 1. DATA SUMMARY

The annual data summary reviews the catch per unit effort (CPUE) from the TIB and TVH sectors, as well as total catch from all sectors, and size‑frequency information provided from a sub-sample of commercially caught TRL. The data summary is used as an indicator to identify if catches correspond to the TAC, and to monitor CPUE.

Information to be included in the annual data summary to be inserted by CSIRO.

* + 1. DECISION RULES

Maximum catch limit:

* The eHCR includes a maximum catch limit of 1000 t. Once the HS is implemented the cap will be reviewed after three years using the integrated stock assessment model.

Stock assessment trigger

* A pre season (age +1 lobster) survey trigger point of 1.25 average lobsters per survey transect, if in any year the index is lower than 1.25 it triggers a stock assessment.

Limit reference point decision rules (**Figure 1**):

* If after the first year the stock is assessed below the biomass limit reference point it is optional to conduct a mid‑season survey, the pre‑season survey must continue annually.
* If the biomass limit reference point is triggered in successive years, the Fishery closes. It is optional to conduct a mid-season survey, the pre-season survey must continue annually.
* The Fishery must remain closed until a fishery independent survey has been completed and the stock assessment model shows the stock has recovered to be above the limit reference point.



**Figure 1.** Decision rules to apply if the limit reference point is triggered.

* + 1. GOVERNANCE

The status of the Fishery and how it is tracking against the HS is reported to the RAG, Working Group and the PZJA as part of the yearly RBC and TAC setting process.

* + 1. REVIEW

Under certain circumstances, it may be necessary to amend the harvest strategy. For example if:

* there is new information that substantially changes the status of a fishery, leading to improved estimates of indicators relative to reference points; or
* drivers external to management of the fishery increase the risk to fish stock/s; or
* it is clear the strategy is not working effectively and the intent of the HSP is not being met; or
* alternative techniques are developed (or a more expensive but potentially more cost-effective harvest strategy that includes mid-year surveys and annual assessments is agreed) for assessing the Fishery. The HSF may be amended to incorporate decision rules appropriate for those assessments.
  1. REFERENCES

Bentley, N. 2006. Review of chapter 5 of Ye et al (2006) “Sustainability Assessment of the Torres Strait Rock Lobster Fishery”. Report submitted to AFMA.

Beverton, R.; Holt, S. On the dynamics of exploited fish populations. UK Ministry of Agriculture and Fisheries Investigations (Ser 2). 19; 1957

Fournier, D.A.; Skaug, H.J.; Ancheta, J.; Ianelli, J.; Magnusson, A.; Maunder, M.N.; Nielsen, A.; Sibert, J. AD Model Builder: using automatic differentiation for statistical inference of highly parameterized complex nonlinear models. Optimization Methods and Software. 27:233-249; 2012

MacFarlane, J.; Moore, R. Reproduction of the ornate rock lobster, Panulirus ornatus (Fabricius), in Papua New Guinea. Mar Freshwater Res. 37:55-65; 1986

Moore, R.; Macfarlane, J.W. Migration of the Ornate Rock Lobster, Panulirus-Ornatus (Fabricius), in Papua-New-Guinea. Aust J Mar Fresh Res. 35:197-212; 1984

Plagányi, É.E., Darren Dennis, Marco Kienzle, Yimin Ye, Michael Haywood, Ian Mcleod, Ted Wassenberg, Richard Pillans, Quinton Dell, Greg Coman, Mark Tonks, Nicole Murphy (2009). TAC estimation & relative lobster abundance surveys 2008/09. AFMA Project Number: 2008/837. CSIRO Final Report, October 2009. 80 pp.

Plagányi, É.E., Kienzle, M., Dennis, D., Venables, W. Tonks, M., Murphy, N. and T. Wassenberg, 2010. Refined stock assessment and TAC estimation for the Torres Strait rock lobster (TRL) fishery. Australian Fisheries Management Authority Torres Strait Research program Final Report. AFMA Project number: 2009/845. 84 pp.

Plagányi, É.; Deng, R.; Dennis, D.; Hutton, T.; Pascoe, S.; van Putten, I.; Skewes, T. An integrated Management Strategy Evaluation (MSE) for the Torres Strait Tropical Rock Lobster Panulirus ornatus fishery. CSIRO/AFMA Final Project Report; 2012

Plaganyi, E.E.; van Putten, I.; Hutton, T.; Deng, R.A.; Dennis, D.; Pascoe, S.; Skewes, T.; Campbell, R.A. Integrating indigenous livelihood and lifestyle objectives in managing a natural resource. P Natl Acad Sci USA. 110:3639-3644; 2013

Ye, Y., Dennis, D., Skewes, T. (2008). Estimating the sustainable lobster (*Panulirus ornatus*) catch in Torres Strait, Australia, using an age-structured stock assessment model. *Continental Shelf Research.* **28:** 2160-67

**ATTACHMENT A**

INTERIM HARVEST STRATEGY

In 2008 an interim harvest control rule (HCR) was developed to support the planned transition to quota management for the Fishery. The RAG agreed to the interim HCR reference points:

1. BTARG = SMSY
2. BLIM = 0.2 S0
3. FTARG = 0.35 Year-1
4. FLIM = FMSY

In 2009 the RAG agreed to update the fishery assessment to an integrated stock assessment model (Plagányi *et al.* 2009) **(Section 2.6)**. The RAG agreed to amend the interim HCR to be consistent with the integrated model. The RAG agreed to a target biomass reference point of 65 per cent of the unfished biomass to be the proxy for BMEY. The target biomass was set as the average biomass level over the past 20 years, this corresponded to an FTARG = 0.15year-1.

1. BTARG = 0.65 B0
2. BLIM = 0.4 B0
3. FTARG = 0.15 year-1
4. FLIM = FTARG

The RBC for the years 2009 to 2015 was computed using the target fishing mortality rate of 0.15. The assessment has been updated since 2009 due to changes in catch data, estimation of model parameters such as stock-recruitment steepness *h* and setting for the parameter (sigma) that determines the level of variability about the stock-recruit relationship. As a result, the estimation of unfished biomass (B0) has varied and the estimated target spawning biomass level (BTARG) has also varied between 65 and 80 per cent of unfished biomass. The biomass limit reference point was set at half of the upper limit of the target reference point (80 per cent of unfished biomass) therefore BLIM = 0.4.

*Target reference point – further explained*

Target reference points specify preferred targets for management to aim at. However it was noted that these are estimated quantities only and hence have associated errors and uncertainties. Moreover, they correspond to deterministic assumptions regarding the stock-recruit relationship, yet for variable recruit-driven fisheries such as this, yield is determined predominantly by the strength of recruitment, and hence annual sustainable yields can be expected to fluctuate widely about the deterministically predicted estimates.

Hence the RAG agreed that a sensible target reference point to specify where management should aim was to keep the stock on average at the target biomass level, as a proxy for BMEY, which was set as the average biomass level over the past two decades and corresponded to Ftarg=0.15 year-1 as the average fishing mortality over the past two decades was 0.15 year-1. The RBC for years 2009-2015 was computed using this target fishing mortality rate. However, there have been a number of changes to the assessment over time due to changes in data, as well as estimation of key parameters such as stock-recruitment steepness *h*, as well as the setting for parameter (sigma) that determines the extent of variability about the stock-recruit relationship.

As a result, estimation of B0, which is assumed to be the model-estimated start biomass in 1973, has varied from lower to higher values without substantially affecting model predictions of productivity or replacement yield (RY) – the latter is generally considered more robustly determined than B0 in isolation. As a result, the estimated target spawning biomass level as a proportion of B0 has varied from 0.65B0 to 0.8B0 as it is dependent on model-estimation. For this reason, when Btarg=0.8B0, Blim was set at half this level, i.e. Blim=0.4B0. It has been queried whether these target levels are too high, but it is important to bear in mind that this is a single cohort recruit fishery (rather than a long-lived multiple cohort fishery) that displays very large inter-annual fluctuations in recruitment (e.g. recruitment of the fished age class can double or halve from one year to the next) and hence the stock fluctuates about the target level, which needs to be high enough so that during poor recruitment years the stock abundance does not drop unacceptably low. A lower biomass limit and threshold level (defined as the biomass level below which more stringent rules for calculating a TAC are applied) were selected based on comparison with past stock fluctuations and preliminary simulation testing.

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1. The total allowable catch (TAC) for the Fishery is currently notional and is not used to control harvest. It is used to inform catch sharing arrangements with Papua New Guinea and to inform the status of the stock. [↑](#footnote-ref-1)