# Review of New Zealand
# Paua Stock Assessment Models, March 2015

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# Introduction

An independent, external, expert panel was convened to review the efficacy of New Zealand's paua stock assessment models and associated data collection programmes. Most of the work was conducted during the period 9-13 March 2015.

Panel members were:

Dr Doug Butterworth (University of Cape Town, South Africa)
Dr Malcolm Haddon (Commonwealth Scientific and Industrial Research Organisation, Tasmania, Australia)
Vivian Haist (Fisheries Science Consultant, Nanaimo, British Columbia, Canada)
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Collectively, the panel has scientific expertise in Bayesian stock assessment models, length-based models, paua biology, and the utility of real-time data loggers.

The primary objectives for the expert panel were to:

1. Provide advice to the Ministry for Primary Industries on the quality and reliability of the current length-based Bayesian paua stock assessment models used to determine stock status for key paua stocks.
2. Provide advice to the Ministry for Primary Industries on how, from the data-logger data, to develop reliable abundance indices or other information that can be used in the assessment and/or management of paua stocks.

Further details are provided in the Terms of Reference in the Appendices.

# Recommendations

While the Panel was requested to comment on the current assessments of certain QMAs, after consideration the Panel reached the view that any comments they might wish to make had been included in the generic comments and recommendations provided below.

The report structure is as follows: recommendations are assigned an individual number (e.g. R-1); this is followed by an assigned ranking according to the following table, accompanied by a rationale for each recommendation provided in *italics*.

| Symbol | Description |
|---|---|
| H – High | Short term; complete in time for next assessment |
| M – Medium | Medium term; complete after next assessment |
| L – Low | Medium term with lower priority |

# 1. Priors

**R- 1**. **[H]** Priors for Bayesian assessments should generally be uninformative.

**Rationale:** *In the absence of external information there is no reliable basis to set priors, so these should be chosen to be uninformative, generally by being set to be uniform for a suitable transformation of the parameter concerned and over a range that covers all plausible values. One exception, however, is natural mortality, M, where to aid assessment precision, if in some QMAs the data do meaningfully update the priors for M, the resultant posteriors may be used to inform priors for M in other QMAs as detailed in [2 Natural Mortality]. Other parameters covered by this advice are those associated with growth [13 Growth], selectivity [14 Selectivity], and with catchability and recruitment [0 Recruitment]. At this stage, understanding of spatial growth variability is not considered to be sufficient to use estimates from some QMAs to inform priors for others, though that position might be reviewed at a future date as data availability and understanding increase.*

# 2. Natural Mortality (*M*)

**R- 2**. **[H]** The following procedure should be used to estimate natural mortality (*M*) for each area assessed.

i) Conduct assessments for each QMA for which there are sufficient data to do so, using an uninformative prior U[0.05; 0.25] for *M*.
ii) Review the posteriors for *M* for each assessment. If none have been meaningfully updated, then conduct assessments for each QMA for three fixed values of *M*: 0.1, 0.15 and 0.2.
iii) If there is only one QMA for which the prior for *M* is meaningfully updated, the associated posterior should be considered to provide the best estimate of *M* for that QMA. For the other QMAs, that posterior after some broadening (e.g. approximate the posterior by a normal distribution and increase its standard deviation by 50%) should be used as the prior.
iv) If the prior is meaningfully updated for more than one QMA, those posteriors should be considered to provide the best estimates for *M* in those QMAs, and discussions should be held about how best to combine them to provide priors for the other QMAs.

**Rationale:** *The current basis to fix or estimate M is somewhat ad hoc, with the priors used generally being unduly informative, so that a revised approach is considered preferable. The starting point for the suggested new approach is Sainsbury (1982), who estimated M to lie in a broad range of [0.02; 0.25]. In transforming this to an intentionally uninformative (and hence uniform) prior, the lower end of Sainsbury's range was considered unrealistic, given that it implies an average age for a pristine paua stock of 50 years, so the 0.02 was increased to 0.05. The balance of the recommendation intends a structured approach across the various QMAs, driven by the bases:*

*a) that M estimates be derived where possible only from the data available for the QMA concerned, and*

b) *for QMAs where those data alone are inadequate to provide a reliable estimate, use be made of estimates from QMAs for which reliable estimation is possible.*

## 3. Growth

**R- 3**. **[H]** Use a more flexible growth model, such as the inverse logistic model, that results in an improved fit to the growth increments.

**Rationale:** *According to models 2.2 and 2.4 in the PAU 5D stock assessment presentation (and in the PAU 5B assessment), the inverse logistic fitted the growth increments in the higher size classes better than the exponential growth model (**Figure 1** and **Figure 2**). In addition, if the size distribution covered by the model is extended down below the current 70 mm size class, then, unlike the inverse logistic model, the exponential growth model is incapable of predicting plausible growth increments. To reduce issues of correlation between growth curve parameters, a re-parameterisation of the inverse logistic into a form that eliminates the L95 should improve the fitting procedure (e.g.):*

$\Delta L = Max\Delta L/(1+exp[Ln(19)((L_t - L_{50})/\delta L)]$ where $\delta L = (L_{95} - L_{50})$

**R- 4. [H]** The growth curves should be fitted only to the areas that dominate the catch.

**Rationale:** *Within the stock assessment model growth for a region is estimated using data from tagging experiments designed to estimate growth and, in addition, the fitted growth curve must be consistent with the length frequency data taken from the commercial catches. In PAU 7 for example, the most sampled region is that which yields the most catch (Cook Strait) and this has the effect of reinforcing the location of the mean growth curve such that it runs approximately through the centre of the data from the Northern Faces; considered to be approximately typical of both the Northern Faces and Cook Strait. However, currently equal weight is given to all tagging data, including those from Perano and Rununder, and while this does not affect the mean growth curve it greatly expands the variation considered as typical about the mean curve. Currently the spread of predicted values about the mean growth increments appears implausibly wide, particularly for the smaller paua. Thus, by giving equal weight to all sources of tagging data, the proportion of relatively slow and relatively fast growing individuals in the population will be biased high.*

*An alternative to using the tagging data from only the area with the greatest catch would be to weight the different tagging data by the relative weight of average yield from the different areas so that the influence of the faster and slower areas should be reduced but would not be totally absent. The option that would provide the most realistic approximation to a real situation is most easily determined using simulation (see recommendation R- 17 for further details).*

**R- 5**. **[H]** Include a sensitivity that fits the model's predicted unfished length frequency distribution in PAU 7 to the Fighting Bay survey (pre-depletion experiment) length frequency data. Explore the use of different weightings applied to this fit.

**Rationale:** *The current estimate of the unfished equilibrium size distribution using the 70 – 170 mm exponential growth increment model is very different from the length frequency distribution seen in the Fighting Bay survey length frequencies (which, following a 17-year recovery period, may approximate the pre-fishing distribution,* ***Figure 3****). The larger size classes are poorly represented in the commercial and survey length frequency data and in the tagging data; hence the size distribution for larger paua is not well determined from the data. Including the pre-depletion experiment Fighting Bay LF data will give some indication of whether the growth curve fitted to the smaller sized observations is greatly altered by the advent of data from the larger size classes. Fitting the model to the Fighting Bay data should be limited to the fully emerged size classes (> 125 mm) to avoid confounding with the emergence curve. The base case should not include these additional data because there is uncertainty as to whether the Fighting Bay animals had achieved or come close to an equilibrium size distribution and whether Fighting Bay paua growth is representative of the QMA. Alternative weightings should be explored for the Fighting Bay size-frequency data, because it is uncertain whether these data are representative of the PAU 7 unfished size distribution.*

**R- 6**. **[H]** Start the size distribution of the population dynamics from a smaller size class closer to the size at larval settlement.

**Rationale:** *Currently, new recruits into the population are spread evenly across the first five size classes (70 – 80 mm) and there are no time lags in the stock-recruitment relationship. As it would take between two and four years for paua to grow from settlement to the 70 – 80 mm size classes, time lags in productivity are neglected despite them potentially having important implications for the stock's dynamics (especially the speed of response to, for example, a change imposed in the total catch). To take account of the effects of these time lags the new recruits would need to enter the stock at much smaller sizes; perhaps down to 1 or 2 mm. Whether these smaller recruits would still need to be spread over so many of the early size classes should be examined to determine how sensitive the model is to such structural assumptions. The number of such smaller recruits would also be expected to increase ($R_0$ would likely increase) as the smaller animals from 2 mm will be exposed to natural mortality for at least two to three years prior to achieving the previous size of 70-80 mm assumed for recruitment.*

*In addition to the effects on the unfished size distribution and the population dynamics, the placement of new recruits down into the smallest size classes leads to a smoother and more plausible size distribution and a very different distribution of sizes across the population. The* *patterns of recruitment predicted by the model differ greatly between using the inverse logistic and exponential and between using 70 – 170 mm or 2 – 170 mm (**Figure 4**).*

**R- 7**. **[M]** The equation for the standard deviation describing the variation about the mean growth curve provides a parameter that allows for non-linearity. Rather than fixing this parameter to 1.0, as at present, sensitivities should be conducted to explore the non-linearity that controls the expansion of variation about the mean growth as the initial length decreases.

**Rationale:** *The spread of the variation around the mean growth curve appears implausibly wide at small sizes (exceeds the range of the increment values), especially in PAU 7. This is clear in the lower size classes (approximately 70 – 90 mm) where the exponential growth model results in high CVs (**Figure 2**). The confidence bounds also follow exponential trajectories. Attempts need to be made to reduce this spread to more plausible levels and results indicate that the inverse logistic provides a less exaggerated and closer model fit (**Figure 1** and **Figure 2**). The variation around the mean growth curve currently increases linearly with the length increment, i.e std.dev = CV × increment, resulting in large standard deviations at small sizes. To reduce the standard deviation consider changing the* □ value *e.g. std.dev = CV × L*$^{□}$ *(e.g.* □ = 0.85, CV = 0.42)(**Figure 5**).

**R- 8**. **[M]** It is important to obtain growth data from tagging animals with initial lengths from above 125 mm (at least between 125 – 145 mm), so as to better inform the shape of the growth curve for the larger sizes.

**Rationale:** *There is increased uncertainty concerning the growth dynamics of the larger paua and this can be resolved by increasing the amount of data from the relatively unknown region of the growth curve. It may be possible to increase the amount of data in the commercially vulnerable size classes by tagging within formally closed areas. However, care may be required if there are possible density dependent effects due to high population densities within closed areas.*

**R- 9**. **[M]** The model structure should include size classes greater than 170 mm; however, when fitting the model to length frequency data it would be most effective to use a plus group at 170 mm to avoid empty or sparse size classes.

**Rationale:** *To obtain a full expression of the biological properties of the modelled population, the wider range of size classes up at least to 200 mm will allow a more accurate representation of properties such as the value of* $B_0$ *in the original unfished state (by allowing for a more correct representation of weight at length than allowed for in a plus group). However, when fitting the model to available data, because the upper size classes would be expected to be empty or sparsely populated, especially in a depleted population, then the use of a plus group will avoid the inclusion of uninformative data sets.*

## 4. Selectivity

**R- 10**. **[M]** The implications of slight doming of the commercial selectivity curves should be explored through sensitivity tests.

**Rationale:** *For current assessment model fits assuming logistic selectivity functions, there are indications of systematic over-prediction of proportions at the largest lengths by the model. This could be a reflection of larger paua moving to deeper waters where fishing effort is less. Though such "emigration" could be modelled explicitly, the alternative of allowing for a slight possible doming in the commercial selectivity function is an adequate and likely simpler approach to implement; for example by modifying the logistic form above a certain length by a multiplicative negative exponential term whose parameter is either fixed or estimated when fitting the assessment model to the data. This may result in improved fits to the data, and would also impact estimates of abundance in absolute terms and relative to the unfished level. However even if the fit is improved, care should be taken before basing conclusions on results that may indicate relatively large cryptic components of large paua; such results should in the first instance be seen as motivation to seek independent evidence for the existence of these cryptic animals. An alternative explanation for this feature in the data is that M increases with age, and the consequences of such an assumption might also be explored.*

**R- 11**. **[M/L]** Fitting separate selectivity curves for the 1990s and the 2000s should be investigated.

**Rationale:** *There is some indication in the residuals from fits to catch at length data of a change in selectivity over time; the possible impact of this on assessment results should be checked.*

## 5. Recruitment

Note there is a recommendation in the 'Growth' section (3 R- 6) to begin introducing recruits into smaller size classes down to 2 mm so as to eliminate artificial time-lags between spawning biomass estimates and consequent recruitment levels.

**R- 12**. **[H]** The value of SigmaR ($\sigma_R$), the standard deviation of the residuals of the logs of recruitment about the stock-recruitment curve, should be set no lower than 0.4, both in the model fitting process and for projections. This should replace the current practice of sampling from the last 10 years of recruitment residuals as estimated in the assessment.

**Rationale:** *The use of the last 10 years for sampling recruitment variation for projections is flawed as this variation will be biased low due to the smearing of cohorts across length classes in the assessment due to implausibly wide variation around the mean growth* *increment at size. This smearing of cohorts will hence underestimate the extent of variability to be expected in future trends in abundance. Since there are no known direct estimates of the extent of this variability in paua populations, a value of 0.4 or higher is suggested on the basis of general indications for fish populations. Nevertheless, the last 10 years of the residuals from the assessment should be inspected for evidence of systematic patterns of recruitment above or below average (as predicted by the stock-recruitment curve estimated), to allow account to be taken of this in projections if necessary.*

**R- 13**. **[H]** Sensitivity to alternative values for the stock-recruitment curve steepness (*h*) should be explored.

**Rationale:** *Given the likely little information content of the data concerning the value of the steepness parameter h, the approach of assuming a best estimate of h=0.75 is not unreasonable. However the implications of the associated uncertainty should also be explored, for example either by sensitivity tests to alternative values of h=0.5 and h=1.0, or by assuming a uniform prior U[0.5;1.0] over that range.*

**R- 14**. **[M/L]** Within the MCMC, stock recruitment residuals should be estimated at least from the year in which the available time series of catches commences, and sensitivity of results to possible catches before this should also be checked.

**Rationale:** *While MPD estimates are not affected by assuming such residuals to be zero for years before the CPUE or catch-at-length data provides information on their size, this suggestion allows for full reflection of these uncertainties in the results from a Bayesian assessment. Present custom is to commence assessments with a deterministic unfished equilibrium structure in the first year of the assessment when the available time series of catches commences; sensitivity to this should be checked, both by taking account of possible catches before this time, and also by allowing for non-equilibrium size structure as a result of recruitment variability. The latter can be checked by starting the assessment in a year some time (e.g. 30 years) before the catch series commences, with deterministic unfished equilibrium assumed for that earlier year and the recruitment variability thereafter providing a non-equilibrium structure when catches commence.*

## 6. **Catch**

**R- 15**. **[H]** Uncertainty about the magnitude and trends in the non-commercial catch is high, and should be considered in model sensitivity runs.

**Rationale**: *During the review meeting it was suggested by industry members that the illegal paua catch is in the range of 200-300 t, or about 20-30% of the commercial catch. This is much higher than the illegal catches assumed for the stock assessments (about 50 t total for PAU 3, PAU 5A, PAU 5B, PAU 5D, and PAU 7).*

*The best estimates of New Zealand recreational catch come from a 2012 national large-scale multi-species survey (LSMS); however the broad-based nature of this survey resulted in very poor estimates of some species in some areas. For example, during the review the Panel heard a comment that PAU 3 recreational catch was at least an order of magnitude higher than the estimate from the LSMS survey. Anecdotal evidence can be useful to determine alternative catch data streams to use in sensitivity runs, but care must be taken regarding the plausibility assigned to such alternative scenarios.*

*It is important to note that differences in assumed trends in the non-commercial catches will generally have a larger impact on assessment results than revisions of the average magnitude of these removals. This is especially important for New Zealand paua, where there is very little information on the current level of non-commercial catches, let alone their historical trends.*

**R- 16**. **[L]** Monitor changes in the Minimum Harvest Size (MHS) relative to the magnitude of recreational catch in each QMA to see if the recreational fishery needs to be treated as a separate fishery with its own selectivity function.

**Rationale:** *Historically both commercial and recreational catches have operated under the same Minimum Legal Size (MLS) constraints and the model assumption of a common selectivity for these fisheries has been appropriate, in particular as there are no length frequency data for the recreational fishery. However, as commercial fisheries in some QMAs now operate with a MHS that is larger than the MLS, the selectivity of the recreational fisheries likely differs from the commercial fishery. If the recreational fisheries are small relative to the commercial fisheries, or if the MLS-MHS differentials are small, not modelling the difference in selectivity is unlikely to introduce much bias in the assessment. This appears to be the case for QMAs that currently operate under MHSs that differ from the MLS, but should be considered when new assessments are conducted in case there are changes.*

## 7. Assessment Scale

**R- 17**. **[H/M]** The effect of aggregating data from a number of populations that differ in their growth, maturity, productivity and exploitation histories, and treating the resultant data as if they are from a single population (in a stock assessment model) should be simulation tested to evaluate the robustness of the assessment model to this type of misspecification. An overview of the perceived process is as follows.

1) Define an operating model that is comprised of a number of populations which differ in their dynamics (5 to 10 populations should be adequate; the range in dynamics among the populations should be based on actual data from one of the paua QMAs).

2) Define a process to fish each of the operating model populations over a specified number of years. (Sensitivity to fishing behaviour should be explored, including scenarios that differ in absolute and relative exploitation rates and trends among the populations.)
3) Specify a sampling process for collecting LF data, growth data and catch-effort data from the populations (again, this needs to be aligned with actual paua data such that there are differences in how the populations are sampled and resulting data may be biased relative to the meta-populations).
4) Analyse the resultant data with a simple one-stock length-based stock assessment model.
5) Compare results from the assessment model with those from the operating model.

The simulation model can also be used to test the proposed process of selecting only a subset of tagging data (representing the areas that have produced most of the catch) to inform growth in the assessment model.

**Rationale**: *The only way to determine if the current QMA-level stock assessments are robust to the complex paua population structure that underlies paua assessments is through simulation testing.*

*This type of simulation testing is a complex, time-intensive process. Expediency in pursuing this objective may be achieved through modification of the operating model that is currently being used for the PAU 7 MSE work. That model is already structured to deal with multiple populations that differ in their growth, maturity, and recruitment dynamics. However, more realistic models of the fishing process (how effort is allocated amongst the populations) and a data collection module would need to be developed.*

**R- 18**. **[M]** Where possible, move to stock assessment units that are more aligned to the paua population structure (areas with distinct growth, maturity, or other aspects of productivity). In some cases this may be at the General Statistical Area level, as much of the historical data can be summarised at that level.

**Rationale**: *QMA level stock assessments are not ideal for paua. However for some of the QMAs they are probably the best that can be achieved at this time because of data limitations (that is, the inability to disaggregate catch and catch-effort data to finer geographic scales). More consistent stock assessments have resulted when QMA-level assessments were replaced with ones that better partitioned the within-QMA variability (for example, splitting PAU 5A into a northern and a southern region, and removing the east and west coasts from the PAU 7 stock assessment).*

## 8. **CPUE**

**R- 19**. **[H]** Assessment model sensitivity to the assumption of linearity between CPUE and exploitable biomass should be investigated for each stock assessment (as currently modelled using a power parameter), and should be considered for the base model formulation. Sensitivity should be investigated either by estimating the power parameter (in an MCMC with a U[0.5;1.5] prior), or by fixing it at low to high values (0.5 and 1.5).

**Rationale**: *CPUE data have a large influence in providing abundance trend information in the paua stock assessments. For example, removing the PCELR data series from the 2013 PAU 5B stock assessment resulted in a decrease in current status from 42% to 32% $B_0$.*

*Deviation in the assumption of linearity between CPUE and stock abundance will result in stock reconstruction bias, and there are a number of factors associated with paua biology and the paua fisheries that are likely to lead to some degree of non-linearity in this relationship.*

**R- 20**. **[H]** Modify the assessment model so that fits to the CPUE indices are calculated after 50% of the fishing and natural mortality have occurred.

**Rationale**: *The model dynamics are structured such that the following processes occur sequentially through a year: fishing mortality, natural mortality, growth, and recruitment. Currently, the CPUE indices are fitted to the vulnerable biomass calculated after 50% of the catch is taken. The proposed alternative is commonly used when fishing occurs through most of a year.*

**R- 21**. **[H/M]** Robustness to the CPUE standardisation assumptions should be fully investigated by developing alternative CPUE series to test in model sensitivity runs. Alternative series potentially include: PCELR data collapsed to the CELR format to form a single CPUE series; standardising CELR data by diver day instead of by diver hour; and for PAU 5B, including data from all Statistical Area 25 and 30 observations into the CELR standardisation. Unless there is clearly no effect of the alternative standardisation approach, the alternative CPUE series should be fitted in the assessment model as sensitivities.

**Rationale**: *The CPUE indices have a large effect on model estimates of abundance, in particular the recent trends in abundance. As such, model sensitivity to alternative CPUE indices will likely show more variability in the estimates of recent trends than other sensitivity runs.*

*For the PAU 5B CELR standardisation, virtually all of the Area 25 and 30 catch-effort data for 1990 – 1995 are excluded from the standardisation because these areas are partially outside of PAU 5B. Given that Area 25/30 represents over half of the PAU 5B catch, if CPUE trends in these areas differ from those of Areas 27/28, the standardised CPUE will not reflect abundance trends. An approach to check for this would be to conduct a CELR standardisation* *that includes all Area 25 and Area 30 catch-effort records (approximately 75% of the catch from these areas is attributed to PAU 5B).*

*The selection of data records for the CELR standardisation (using diver hours as the fishing duration measure) may introduce bias. Records are selected where the number of divers is 1, or the number of divers is 2 or greater and the number of hours fished is 8 or greater. The data for single divers often have median dive times of about 4 hours, which suggests that many records with legitimate dive times (i.e. 2 divers and less than 8 hours fished) would be eliminated. This is a problem, in terms of bias, only if catch rates for short duration days differ from long duration days. The only way to ensure unbiased data to evaluate if dive hours per day has changed over time, or if there is correlation between catch rates and fishing hours/day, is to restrict the data set to records that represent a single diver. Any other process will retain some erroneous records and remove some correct records.*

**R- 22**. **[H/M]** The Research Diver Survey Indices (RDSI), and associated LF data (RDLF), should be used in the paua assessment base model formulations, rather than in sensitivity trials.

**Rationale:** *Although the existence of problems with the RDSI as an index of abundance have been noted, these problems will certainly be less than those associated with the commercial CPUE data. The primary issue with the RDSI is that it is based on timed swims rather than specified areas (i.e. catch per unit time, rather than catch per unit area), which may lead to non-linearity in the RDSI-abundance index. However, commercial CPUE indices are also based on catch per unit time, and may additionally be influenced by factors such as serial depletion which are not a problem for the RDSI. Accordingly, there is no basis for rejecting the RDSI while accepting commercial CPUE for use in the assessment models.*

*Including these indices in the stock assessments appears to have little effect (as indicated by sensitivity tests), as the uncertainty in the RDSI indices is large. Their inclusion may nevertheless have value in assessing the degree of agreement between LFs from the survey (RDLF) and from commercial fisheries as a check on the asymptotic fishery selectivity assumption. Note however that the RDLF sampling should be checked to ensure that the sampling design resulted in representative samples.*

**R- 23**. **[M]** The number of parameters associated with the smoothed line used to estimate the CV of CPUE data series (for weighting within the stock assessment model) results in a bias correction component (determined by number of data points and hence the degrees of freedom associated with the spline), and this needs to multiply the CV estimate.

**Rationale**: *Using the Francis weighting approach for the abundance index data, the CVs for the paua CPUE series are estimated based on residuals from smoothed curves (splines) fitted* *to the observations. Using this approach, the CVs calculated from the residuals need to be adjusted for the degrees of freedom associated with the smoothing. The resultant CV estimates should be more plausible than some of the very low values currently estimated.*

**R- 24**. **[M]** Documentation of factors that may influence the efficiency of paua fishers (introduction of boat boys, GPS units, underwater scooters, management changes resulting from data logger use, etc.) should be documented, for potential inclusion in future stock assessments.

**Rationale**: *Changes in fishing efficiency is one of the factors that may distort the relationship between fishery CPUE and abundance. While some of these factors are captured in the CPUE data, others need to be documented based on oral histories of the fishery. This is especially important with regard the advent of the GPS data-logger technology. There may be many different influences that data loggers exert upon diver behaviour.*

## 9. Data Stream Weighting

**R- 25**. **[M]** As a sensitivity, alternative data weighting strategies should be considered that avoid the use of iterative re-weighting required by the use of the multinomial (e.g. the 'Punt-Kennedy' (1997) approach).

**Rationale:** *The Francis weighting approach is currently being implemented in the various paua stock assessments. While this captures the intuition that the index of relative abundance should not be overwhelmed by the length frequency information, the use of the multinomial error structure with the catch sampling data automatically implies that iterative re-weighting will be necessary. To avoid this requirement it is possible to use alternative error structures for the distribution data and a relatively simple alternative would be to use the approach described by Punt and Kennedy (1997).*

## 10. Miscellaneous

**R- 26**: **[M]** Set the maximum allowed exploitation rate in the assessment model at 0.9. If that bound is limiting in the MPD fit, explore higher values to investigate the effect of the artificial limit.

Rationale: *Bounding the exploitation rate with a maximum level results in an artificial constraint on the assessment (unless it acts only through early stages of the minimisation to get the stock into an appropriate biomass range). If the assessment is at a realistically determined maximum bound at the MPD, this suggests some form of model misspecification. (e.g. growth and recruitment to the selected population throughout the fishing year, which may be better captured with a model with more time steps in a year).*

## 11. GPS Data Loggers

**R- 27**. A target of 100% participation would need to be achieved to use the GPS data-logger information as a means of assessing the different paua stocks at a relatively fine scale.

**R- 28.** The advent of the GPS data-logger information may alter diver behaviour in ways that will potentially invalidate the use of classical CPUE data as an index of relative abundance. In the longer term, effort needs to be directed at developing a fine scale assessment regime using the GPS data to assess each stock so as to provide advice on sustainable catch levels and recovering depleted stocks.

**Comments:** *There are already many remarkable outcomes from the GPS data logger project. The advent of, for example, the 'dashboard' in PAU 3 opens the opportunity for, at least, improved effectiveness of the fishing effort by the divers involved; and that is even if they do not decide to cooperate in how they fish the total quota available each year. One of the major challenges in fishing and managing paua fisheries world-wide is how best to distribute effort (and thereby catch) across each quota management area in a manner that reflects the abundance of the resident paua. Failure to do this has contributed greatly tomany such fisheries becoming stressed or damaged in a manner that was completely unintentional. The use of the GPS data-logger information, which appears to have been made much simpler given the interface developed in New Zealand, provides an excellent means of avoiding such negative situations.*

*While this is a very positive outcome it does seem likely to have unintended consequences, some of which may be disruptive to how these fisheries are currently assessed and managed. The GPS data-loggers and how the information can be presented provide the means of changing how the divers operate such that they may become more effective in their fishing operations. These improvements would arise through the divers becoming capable of avoiding areas that have been heavily fished or that have relatively low CPUE without them having to go there to discover this. While this is of potentially great benefit it would also have the effect of changing the meaning of diver CPUE, whether it is estimated using the PCELR or the GPS data-logger information. It might be expected that if divers use the GPS data-logger information effectively then their CPUE would increase over previous years (assuming the total catch coming from a resource is sustainable; this is an important assumption). In effect, especially once a fishery became sustainably fished, the fishery dependent data derived from such a fishery would become more biased than classical fishery dependent data (obtained in the absence of knowledge about the current spatial dynamics of the fishery) and thereby start bringing the outputs from classical fishery stock assessment models into question.*

*However, at the same time as unintentionally undermining the usual means of stock assessment for these fisheries, the GPS data-logger project also provides the means for an alternative approach to the assessment and management of the resources. The GPS project is providing empirical data directly relating to the extent and intensity of the fishery, which in turn reflects the relative success of the fishery through time and across the distribution of fishing. Currently in Australia, in Tasmania and potentially in New South Wales, such alternative approaches are being developed. In New Zealand, given the current progress that has been made, it would be beneficial to begin the development of alternative ways of assessing and providing management advice for the fisheries using the GPS data-logger technology.*

*Such an approach is more akin to the 'management procedures' in current use within South Africa, which utilise data from and about each fishery, generating management responses in ways that have been shown to be appropriate. Given the fine-scale geographical character of the GPS data this would allow the automation of fine-scale stock status, in terms of new stock performance measures from the GPS data, leading to the relatively fine-scale recommendations of suitable catches by area that should be implementable by a suitably involved industry. Larger scale management requirements (from legislation, such as the setting of TAC levels) can also be accommodated through the summing of the recommended catches from smaller more local areas. The full details of such arrangements are still being developed and researched in Australia so a detailed description is not yet possible. However, area based, fishery-extent based, time-based, and diver-based fishery status performance measures are currently under investigation to determine which exhibits the greatest contrast in association with apparent changes in a stock's relative abundance. All of these might be considered for use in New Zealand.*

*The potential of the GPS technology to interfere and eventually invalidate the current approach to assessment and management needs to be recognised and actions taken soon to develop a viable alternative (ideally without restricting any growth in the relative efficiency of the dive fishery). Of course to be fully effective this would require the uptake by divers of the use of the GPS data-loggers to be a very high proportion of divers (ideally 100%). The GPS technology and expertise already present within New Zealand and Australia suggests this is an obvious direction to include when considering such alternatives.*

## 12. **Bibliography**

Fu, D. (2015) Paua Stock Assessment model review March 2015.pdf. Presentation to the review committee.

Punt, A.E. and R.B. Kennedy (1997) Population modelling of Tasmanian rock lobster *Jasus edwardsii*, resources. *Marine and Freshwater Research* **48:** 967 – 980.

Sainsbury, K. J. (1982) Population dynamics and fishery management of the paua, *Haliotis iris* 1. Population structure, growth, reproduction, and mortality. *New Zealand Journal of Marine and Freshwater Research* **16:** 147 – 161

## 13. **Acknowledgements**

The review panel would like to thank Pamela Mace and Julie Hills of MPI, Dan Fu of NIWA, and the other participants in the open sessions of the review for their interest and helpful comments.

## 14. **Figures**

**Figures 4** and **6** were generated by Dan Fu following requests and questions from the review panel concerning how the size structure, growth description, and recruitment dynamics affected the unfished equilibrium size structure. The panel would like to thank Dan for his rapid and helpful response.

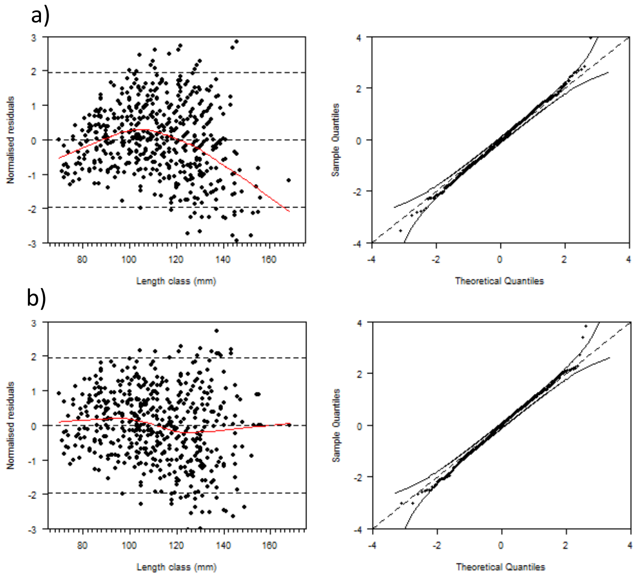



**Figure 1**. Residual fits from growth estimates using (a) the exponential growth model and (b) the inverse logistic each fitted to PAU 5 tagging data of annual increments. ref: PAU 5D 2012 stock assessment model 11 March 2013.

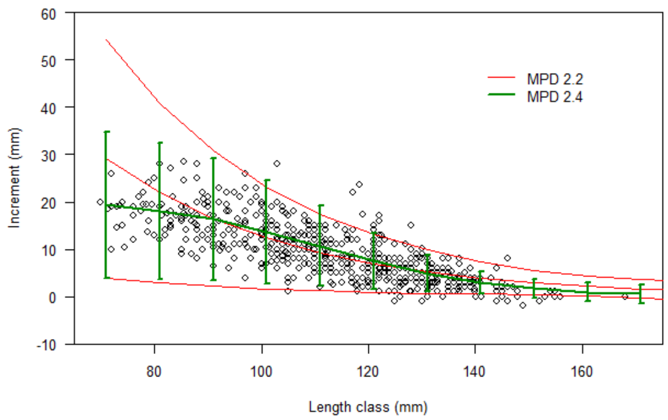



**Figure 2**. A comparison of the growth estimates and confidence bounds of two growth models (exponential and inverse logistic) fitted to PAU 5 tagging data of annual increments. Model MPD 2.2 is the exponential model (red line) and MPD 2.4 is the inverse logistic (green line). ref: PAU 5D 2012 stock assessment model, 11 March 2013.

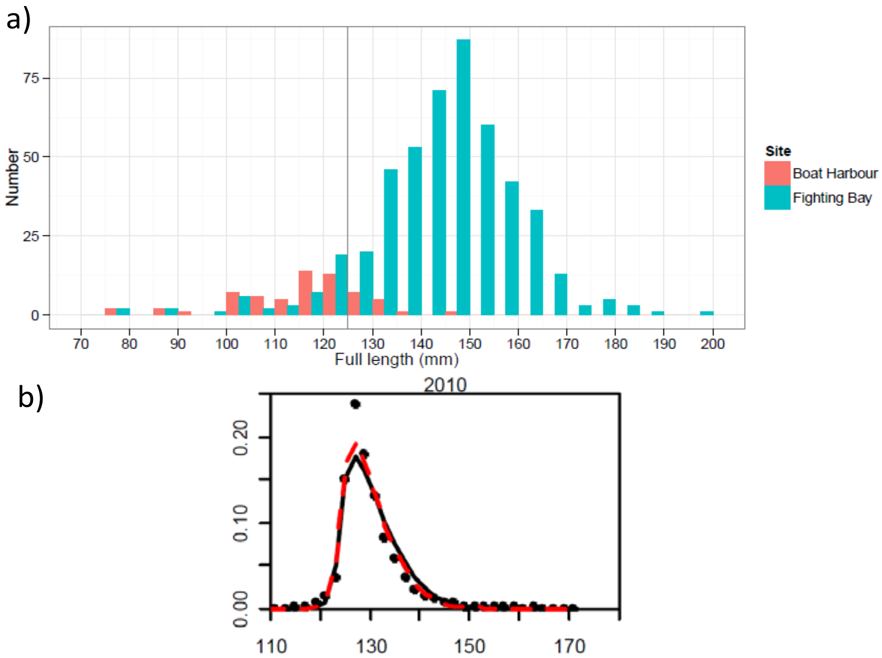



**Figure 3**. A comparison of length frequency distributions between an unfished and fished area in PAU 7. Plot a) is an unfished area from Fighting Bay (sampled in 2011 but previously unfished for approximately 17 years). Plot b) is from the commercial catch length frequency sampled in 2010 (Ref: the 2011 PAU 7 stock assessment Fu et al.).

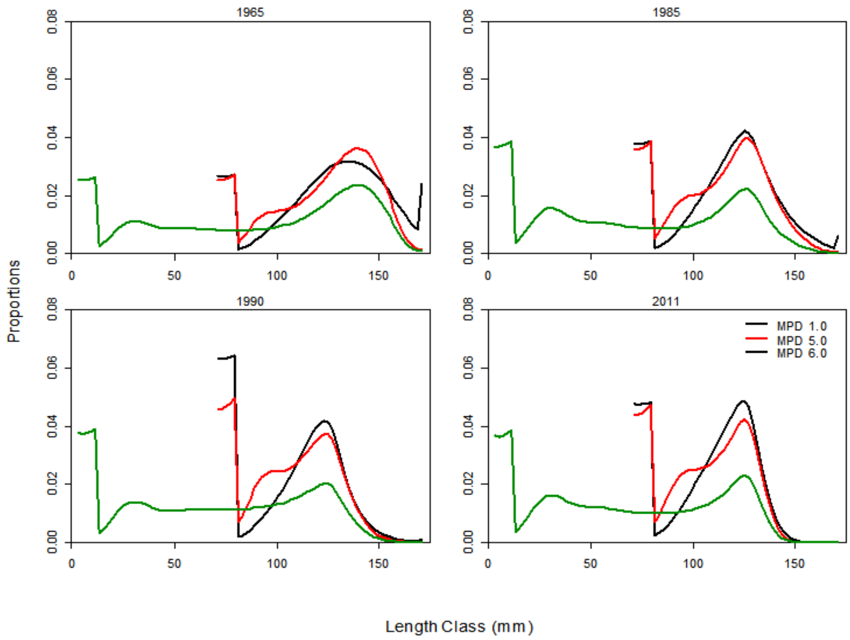



**Figure 4**. The equilibrium size distributions for different years of the PAU 7 stock using different growth increment curves. The black line is the 70 – 170 mm exponential, the red is the 70 – 170 mm inverse logistic, and the green line is the 2 – 170 mm inverse logistic. The green line is scaled from 2 – 170 mm rather than from 70 – 170 mm (copied from further analyses conducted by Dan Fu).

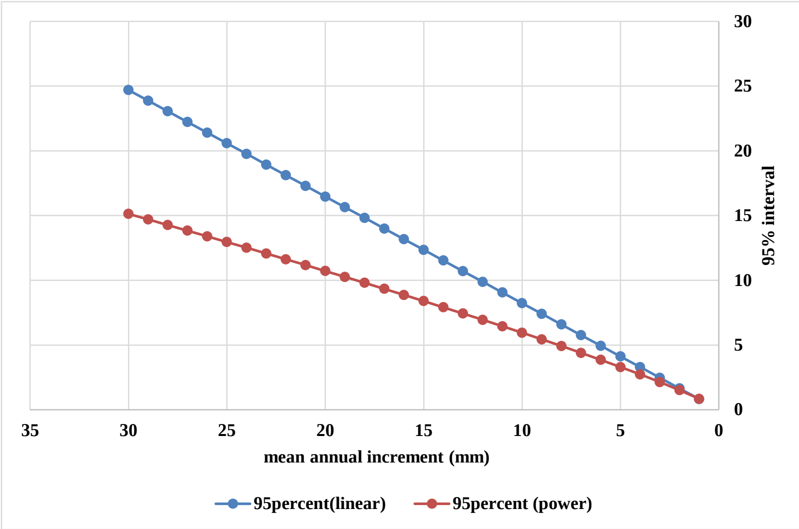



**Figure 5**. A comparison of the 95% confidence limits between the linear relationship (std. dev. = CV*L, blue line) compared to a power relationship (std. dev. = CV *$L^{\beta}$ , red line ), where CV = 0.42 and β = 0.85.

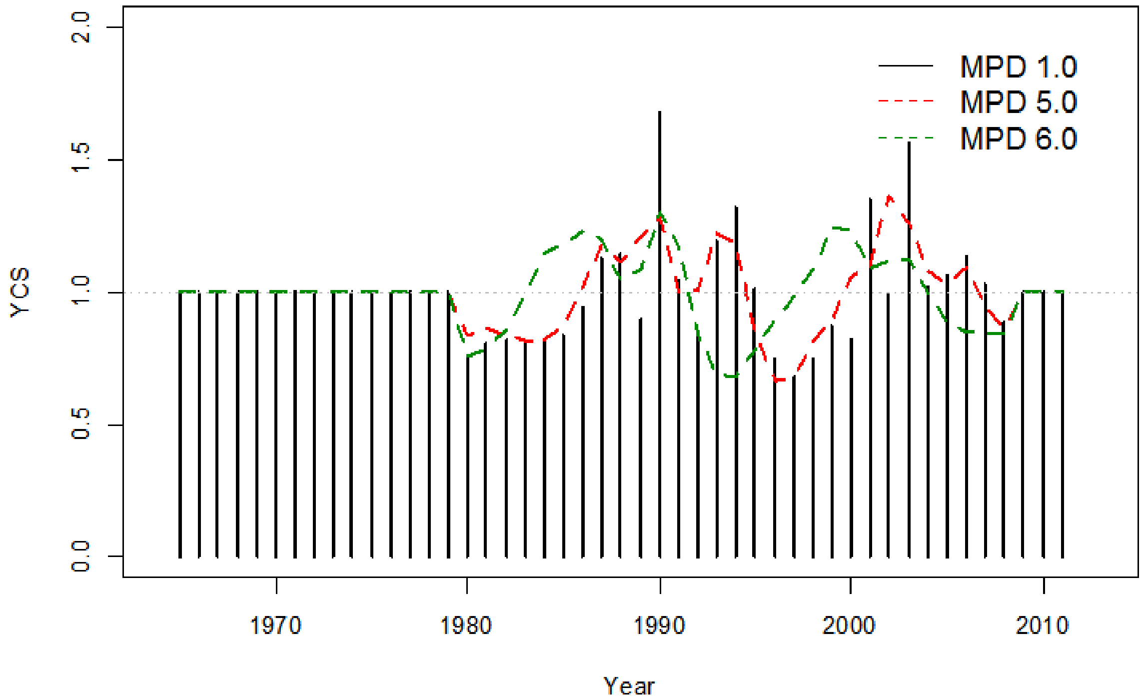



**Figure 6**. Recruitment deviations from alternative model specifications. MPD 1.0 is the 70 – 170 mm exponential, MPD 5.0 is the 70 – 170 mm inverse logistic, and the MPD 6.0 line is the 2 – 170 mm inverse logistic (copied from further analyses conducted by Dan Fu).

# Appendices. Background Materials

## 1. Terms of Reference

**Ministry for Primary Industries Terms of Reference for an independent review of the paua stock assessment model**

### 1. Background

Paua fisheries are high-valued, shared fisheries, harvested by commercial, customary, and recreational fishers. The fisheries occur in shallow waters (generally less than 10 m) around the coastline of New Zealand and all sectors generally fish the same areas. The combined current total allowable commercial catch (TACC) is 1058 t and it is estimated that across all sectors (recreational, commercial, customary) about 1,500 t of paua are taken each fishing year. Most of the catch is from the Wairarapa coast southwards, including the Chatham Islands. Virtually all the commercial catch is the black-footed paua, *Haliotis iris*.

There are large recreational fisheries for paua and illegal catch is also a problem. Estimates of the level of customary, recreational and illegal catch are highly uncertain but most likely differ considerable among different Quota Management Areas (QMAs). New estimates of recreational catch in some paua QMAs are available from the most recent "Large Scale, Multispecies recreational Survey (2012)". Data for levels of customary catch are available for several QMAs.

Black foot paua, *Haliotis iris* (hereafter paua), are distributed throughout New Zealand's coastline forming aggregations on rocky reefs and hard substrates, extending from the inter-tidal zone to about 20-30 m in water depth. Generally, juvenile paua are found in shallow sub-tidal areas, and adults are found in deeper water. Recruitment appears to be variable between years as well as within years. Even though multiple spawning events may occur throughout a year, it appears that reproductive success may be effectively zero in particular years or recruitment may only result from one of the spawning events (Hooker and Creese 1995; McShane and Naylor 1996). Both mitochondrial and microsatellite markers have revealed high levels of genetic diversity within paua, and weak but significant genetic population structure (Will & Gemmell 2008). The potential pattern of genetic structure for paua includes 1) a genetic split between the Chatham Islands and the North and South Islands and 2) a genetic split between the North and South Islands across the Cook Strait region.

Differences in growth rate and maximum size have been found in paua populations throughout New Zealand (Naylor et al 2006). This variability has been attributed largely to variability in sea surface temperatures (SST), with the fastest growth in paua being observed in areas with lower mean monthly maximum SST, and the slowest growth observed in areas with higher mean monthly maximum SST. Naylor et al (2006) also observed decreasing size at maturity with increasing temperature. Overall there is a lack of knowledge about the life history parameters, biology and behaviour of paua and about the variability of these parameters.

Under the 'National Fisheries Plan for Inshore Shellfish' the management objectives for most paua stocks (PAU 1, PAU 2, PAU 3, PAU 4, PAU 5A, PAU 5B, PAU 5D and PAU 7) are to:

- Maximise the overall social, economic and cultural benefit obtained from each stock, and
- Maintain the biomass of each stock at or above $B_{MSY}$ (or accepted proxy)

Paua were introduced into the QMS in the 1986-87 fishing year and split into 11 Management Areas or QMAs (Figure 1). Each QMA is managed as a single stock with its own total allowable catch (TAC) and/or total allowable commercial catch (TACC) (Table 1).

For commercial and recreational fishers, all QMAs have the same minimum legal size of 125 mm with one local area exception (Taranaki, where the recreational MLS is 85 mm). The recreational bag limit is 10 paua per person per day across all of New Zealand with one local area exception (the Kaikoura marine area, where the bag limit for recreational fishers is 5 paua per person per day). Apart from PAU 4 where UBA gear is allowed, hand gathering is the only method of extraction. There is no size limit or bag limit for customary fishers but all customary fishing must be done under a customary fishing permit.

The extent to which the status of the stocks is monitored and the extent to which changes are made to the way specific management tools are implemented, varies significantly between the different QMAs. Most QMAs with high TACCs and active commercial fisheries are considerably richer in fisheries data (includes catch, CPUE, growth and length at maturity data, and length frequency data from the commercial catch). Commercial catch by fishing year and QMA is shown in Figure 2. The commercial fishing year for paua is from 1 October to 30 September.

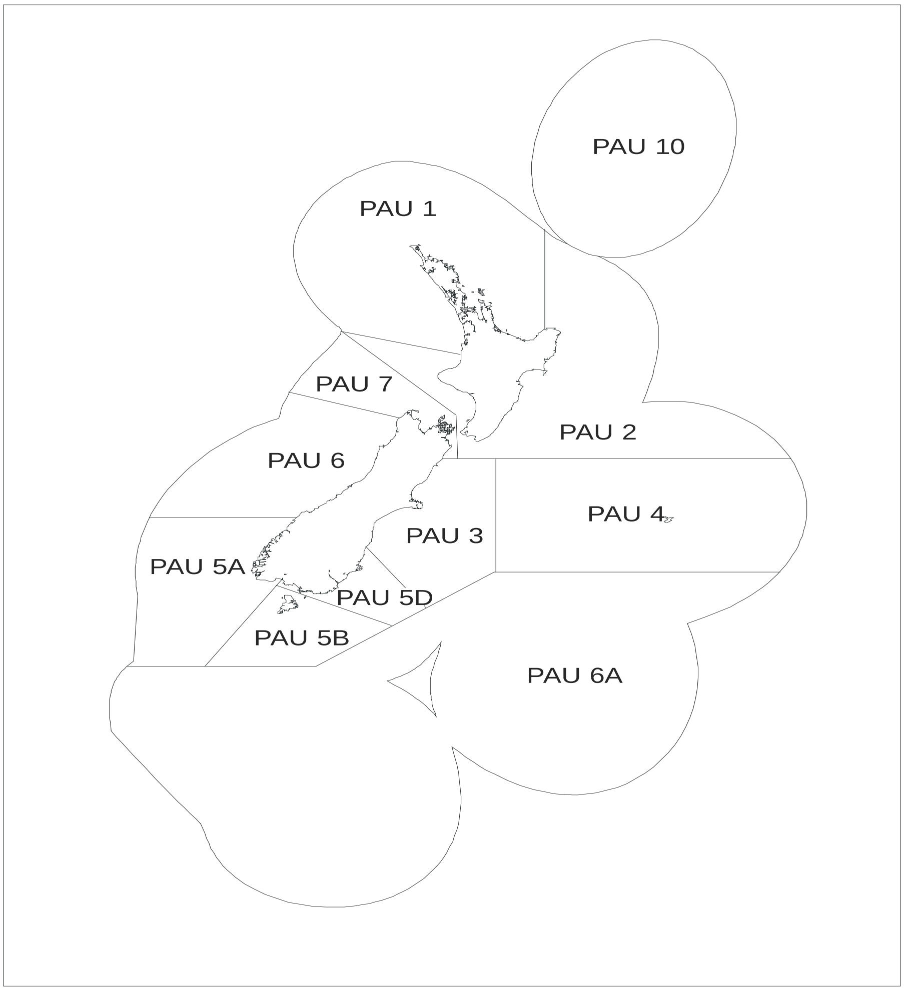
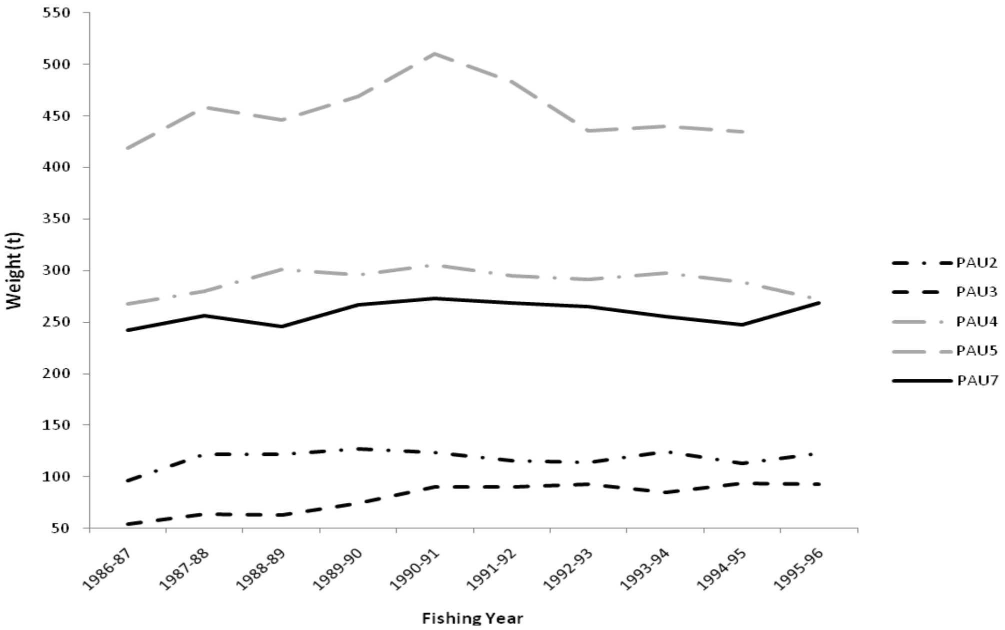



**Figure 1. Paua Management Areas.**

**Table 1:** History of TACs, TACCs, recreational catches, customary catches and other sources of mortality.

| QMA | Date | TAC (t) | TACC (t) | Recreational catch (estimate used in stock assessment model) | Customary catch (estimate used in stock assessment model) | Other sources of mortality (estimate used in stock assessment model) |
|---|---|---|---|---|---|---|
| 1 | 1986-88 | | 1 | | | |
| | 1988-now | | 1.93 | | | |
| 2 | 1986-89 | | 100 | | | |
| | 1989-now | | 121.19 | | | |
| 3 | 1986-95 | | 57 | | | |
| | 1995-now | | 91.6 | | | |
| 4 | 1986-95 | | 261 | | | |
| | 1995-now | | 326 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | 1986-91 | | 445 | On 1 October 1995 PAU 5 was split into 3 new QMAs PAU 5A, PAU 5B and PAU 5D | | |
| | 1991-94 | | 492 | | | |
| | 1994-95 | | 442.8 | | | |
| 5A | 1995-now | | 148.98 | | | |
| 5B | 1995-99 | | 148.98 | | | |
| | 1999-00 | 155.9 | 143.98 | 6 | 6 | - |
| | 2000-02 | 124.87 | 112.18 | 6 | 6 | - |
| | 2002-now | 105 | 90 | 6 | 6 | 3 |
| 5D | 1995-02 | | 148.98 | | | |
| | 2002-03 | 159 | 114 | 22 | 3 | 20 |
| | 2003-now | 134 | 89 | 22 | 3 | 20 |
| 6 | | | 1 | | | |
| 7 | 1986-89 | | 250 | | | |
| | 1989-01 | | 267.48 | | | |
| | 2001-02 | 273.73 | 240.73 | 15 | 15 | 3 |
| | 2002-now | 220.24 | 187.24 | 15 | 15 | 3 |



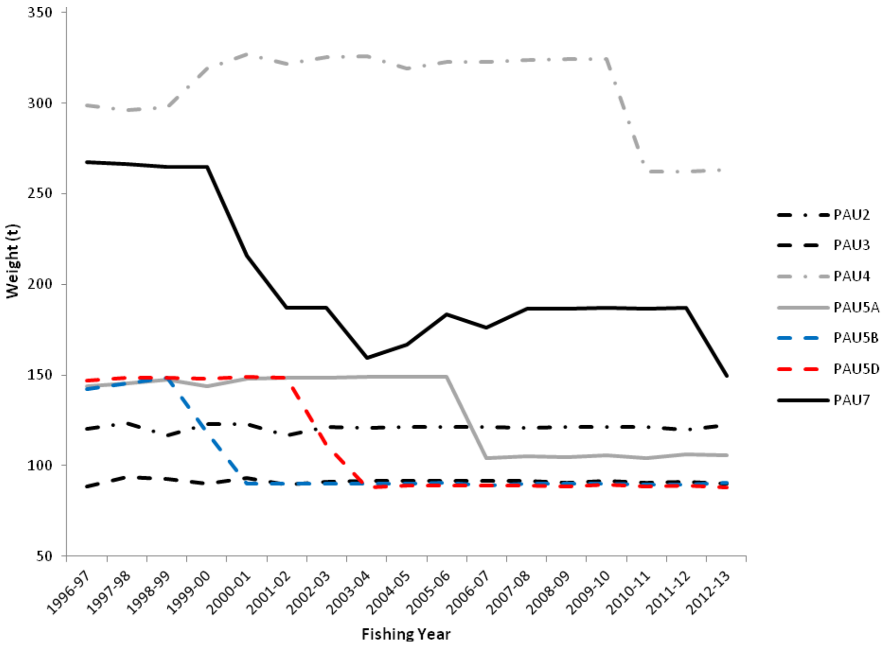



**Figure 2. Historical landings for the major paua QMAs from 1983–84 to 1995–96 (top) and from 1996–97 to present (lower).**

One of the key tools now being used to assist with setting appropriate TACs/TACCs is the Harvest Strategy Standard (HSS). The HSS operates by setting specific target and limit reference points for each paua QMA. The HSS consists of three core elements:

a. A specified target around which the fishery or stock should fluctuate with at least a 50% probability of being "above"[1] the target over time. A target is a desired biomass level or fishing mortality rate, or a catch or suitable proxies for each of these. Targets should be based on maximum sustainable yield (MSY)-compatible reference points; for example, $B_{MSY}$, $F_{MSY}$, some level of $\%B_0$, or proxies for each of these. **The default target for QMAs where the status of the stocks is estimated using the paua stock assessment model is currently 40% $B_0$**.

b. A soft limit, which is a reference point that triggers the requirement for a formal time-constrained rebuilding plan. **The default soft limit for QMAs where the status of the stocks is estimated using the paua stock assessment model is currently 20% $B_0$.**

c. A hard limit, which is a reference point below which a fishery should be considered for closure. **The default hard limit for QMAs where the status of the stocks is estimated using the paua stock assessment model is currently 10% $B_0$**.

The HSS is informed by the results from the **Length based Bayesian stock assessment model.** Stock assessments have not been conducted for all QMAs. As yet no decision rules have been developed for paua fisheries. Stock assessments using the length-based model are conducted every three years for PAU 5A, PAU 5B, PAU 5D and PAU 7. The last assessment undertaken in PAU 4 was done in 2004 and was rejected by the Shellfish Working Group (SFWG) which believed the lack of reliable CPUE data caused unacceptably

[1] Means above biomass management targets, but below fishing mortality targets

high levels of uncertainty in the model outputs. No assessments have been undertaken in PAU 2 due to lack of contrast in the CPUE data. The first assessment in PAU 3 was undertaken in 2013 and was accepted as reliable by the SFWG noting that when interpreting the model outputs, the degree of uncertainty due to lack of contrast in the CPUE data needs to be considered. A history of surveys and results can be seen in Table 2.

The Length-based Bayesian stock assessment model was first developed in 1999 by Breen et al for the stock assessments of PAU 5B and PAU 5D and has undergone a number of changes in subsequent paua assessments. Documents providing a description of the original model structure, assumptions, parameters, input data, model outputs and the progression of changes made over the years include Breen et al 2000 (NZFAR 2000/33) and Fu 2014 (NZFAR 2014/45). These will be included in the Background Documents.

Data inputs into the model are:

- Catch history
- CPUE
- Growth from tag-recapture experiments
- Length at maturity
- Commercial catch length frequency

Fisheries-independent abundance and length frequency data are no longer used in assessments. In 2009 and 2010 several reviews were conducted by Cordue (2009) and Haist (2010) to assess; i) the reliability of the research diver survey index as a proxy for abundance; and ii) whether the RDS data, when used in the paua stock assessment models, results in model outputs that do not adequately reflect the status of the stocks. The reviews concluded that:

- Due to inappropriate survey design the RDS data appear to be of very limited use for constructing relative abundance indices.
- There was clear non-linearity in the RDS index, the form of which is unclear and should be potentially complex.
- CVs of RDS index ‘year’ effects are likely to be underestimated, especially at low densities.
- Different abundance trends among strata reduce the reliability of RDS indices, and the CVs are likely not to be informative about this.
- It is unlikely that the assessment model can determine the true non-linearity of the RDS index-abundance relationship because of the high variability in the RDS indices.
- The non-linearity observed in the RDS indices is likely to be more extreme at low densities, so the RDSI is likely to mask trends when it is most critical to observe them.
- Existing RDS data is likely to be most useful at the research stratum level.

The amount of data available and the quality of the data varies between QMAs. CPUE is standardised but standardisation procedures have varied between QMAs and subsequent assessments of the same QMA. Information on input data for the 2000 assessment can be found in Breen et al 2000 (NZFAR 2000/33). Information on input data for the Fu 2014 assessment of PAU 5B can be found in Fu 2014 (NZFAR 2014/43).

Advances in technology have resulted in the development of Data Loggers that allow CPUE from the paua fisheries to be recorded at the spatial scale of a dive event in almost real time. Two data loggers have been developed for use by commercial paua divers; these are a turtle unit and a boat unit. Turtle units are worn on the back of each diver and record date, time, latitude and longitude, depth and water temperature. These units allow catch to be recorded at the dive event spatial scale. The Boat Units are positioned on each boat and record the date, time, latitude and longitude, and are used to log each catch bag that comes aboard the boat, the diver the catch bag belongs to, estimated catch and sea conditions. These units have been expanded to house a satellite modem that can be used as a Vessel Monitoring System transponder and will also allow the uploading of each day's data to the paua catch database. Data sets from each of the Data Logger units are checked and corrected for any errors that arise. The data from each unit are aligned and processed and transferred to the reporting website where they can be visualised by end users in numeric and map form.

The aim of the datalogger programme is to collect catch and effort data at spatial scales far finer than those currently used (i.e. paua statistical areas). It is hoped that recording catch and effort at finer spatial scales (e.g. over the area of a diver event, over the area of a reef, or over several hectares) will provide data that allow a greater understanding of the productivity and distribution of paua stocks, and of how paua respond to fishing pressure and to various management actions.
It is believed that use of data loggers and the finer temporal and spatial scale data that can be collected will provide reliable information on:

- The size of commercial fisheries in terms of the actual areas fished,
- How paua stocks respond to fishing pressure, that is, whether the area fished within a QMA is expanding or contracting,
- How specific areas within a QMA respond to fishing pressure. Some areas may display high levels of productivity over time with biomass rebuilding in a timely manner once the area has been fished down, while other areas may rebuild slowly or not at all. The finer the spatial scale at which we collect data relevant to evaluating impacts on productivity, the more strategically commercial fishers can manage their harvesting behaviour to allow for utilisation while maintaining both short and long term sustainability,
- How fishing behaviour changes with increasing or declining biomass,
- Whether or not serial depletion may be occurring, and
- Aspects of diver behaviour (e.g. changes in: actual time spent on the bottom, depth of dives, the size of the area fished to obtain a certain amount of catch, and the number of times an area is revisited) that could be used to develop reliable standardised indices of relative abundance.

To date, data from the loggers that have been collected and analysed are providing comprehensive descriptions of the spatial extent of the fisheries and some preliminary information on relationships between diver behaviour and changes in the amount of catch taken and CPUE. Research focused on determining how much information can be extracted from the data loggers and how reliable this information is likely to be for estimating productivity, abundance, response and sustainability of the fisheries is ongoing.

Use of the diver data loggers and Boat Units by paua divers and ACE holders has been steadily increasing over the last three years and several projects (PAU2010-05 and PAU2011-03) evaluating the relationship between diver behaviour and levels of catch and CPUE have been completed. It is envisaged that the use of the data loggers will provide better quality catch and effort data to feed into the stock assessment model, and that by knowing the actual distribution of commercial fisheries, research sampling can be designed more effectively.

**Table 2.** Recent survey and stock assessment information for each paua QMA.

| QMA | Type of survey or assessment | Date | Comments |
|---|---|---|---|
| PAU 1 | No surveys or assessments have been undertaken | | Research at Goat Island Hooker and Creese (1995). |
| PAU 2 | CPUE standardisation | 2014 | Between 1990 and 2001 there was a slight increase in the standardised CPUE taken from Catch-Effort Landing Records (CELRs). During this period catch and effort was recorded over three General Statistical Areas within the QMA. From 2002 to present there has been essentially no overall change in CPUE taken from Paua CELRs (PCELRs). During this time catch and effort has been reported at a much finer spatial scale of 25 statistical areas. |
| PAU 3 | Quantitative assessment using a Bayesian length based model | 2013 | For the 2013 stock assessment nine model runs were conducted. The SFWG agreed on a base case model which estimated M within the model but fixed the growth parameters as providing a reliable estimate of the status of the stocks in PAU 3 with the caveat that the model most likely underestimated uncertainty in growth but adequately estimated uncertainty in natural mortality. |
| PAU 4 | Quantitative assessment using a Bayesian length based model | 2004 | In February 2010 the SFWG agreed that due to the lack of adequate data as input into the Bayesian length-based model, a stock assessment for PAU 4 using this model was not appropriate. Other performance indicators that could be used as reference points around which to assess the status of the stocks are being evaluated for use in PAU 4. |
| PAU 5A | Quantitative assessment using a Bayesian length based model | 2010 | The 2010 stock assessment was conducted over two subareas of the QMA. The SFWG was satisfied that the stock assessment for both the Southern and Northern areas was reliable based on the available data. It was agreed by the SFWG that the range of estimated indicators for both the base case and hyperstability models used in the |

| | | | |
|---|---|---|---|
| | | | Northern area assessment were acceptable, but where within the range of estimates the actual status of the fishery is located was not clear. |
| PAU 5B | Quantitative assessment using a Bayesian length based model | 2013 | The SFWG were satisfied that the stock assessment provided a reliable estimate of the status of the stocks in PAU 5B. Sensitivity trials addressed uncertainties associated with various aspects of the input data and model assumptions. |
| PAU 5D | Quantitative assessment using a Bayesian length based model | 2012 | Four assessment runs were presented and all were considered to be equally plausible. All runs showed that it was Very Unlikely the stock will fall below the soft or hard limits over the next three years at current levels of catch, and suggested that biomass would increase. However, the four runs differed in their assessment of the status of the stock relative to the target. |
| PAU 6 | Biomass estimate | 1996 | This fishery has a TACC of 1 t. |
| PAU 7 | Quantitative assessment using a Bayesian length based model | 2012 | The SFWG agreed that the stock assessment was reliable based on the available data. Median spawning stock biomass was estimated to be 22% $B_0$. Results suggested an increase to 23.4% $B_0$ over the following three years at current levels of catch. |
| PAU 10 | No surveys or assessments have been undertaken (This is an administrative “stock” only and paua are unlikely to occur in commercial quantities in this area) | | |

**Research**
For detailed information on past, current and potential future research for the paua fisheries refer to the ‘SFWG Research Itinerary 2015-2020’.

**2. Terms of Reference**

- An independent, external, expert panel comprising Vivian Haist (Canada), Dr Doug Butterworth (South Africa), Dr Malcolm Haddon (CSIRO) and Dr Fay Helidoniotis (Tasmania) will be convened. Collectively, the panel has scientific expertise in Bayesian stock assessment models, length-based models, paua biology, and the utility of real-time data loggers.

- Panel members must have no connection with the original work and must declare any actual or possible conflicts of interest that might affect their ability to come to an objective view of the model structure and results and any alternative approaches.

- The lead researcher for recent paua stock assessments, Dr Dan Fu, will assist with the review and the Fisheries Stock Assessment Manager (Dr Kevin Sullivan), the Chair of the Shellfish Working Group (Julie Hills) and the Principal Advisor Fisheries Science (Dr Pamela Mace) will also participate.

- The primary objectives for the expert panel are to:

    1. Provide advice to the Ministry for Primary Industries on the quality and reliability of the current length-based Bayesian paua stock assessment models used to determine stock status for key paua stocks. Specifically:

        - *Inputs:* the extent to which the data, modelling assumptions, structure, priors, and penalties are appropriate (including assessment of both biological and fisheries components)
        - *Implementation*: whether the modelling has been implemented using best practice methods or, where other approaches or approximations have been used, the extent to which these could bias the results
        - *Sensitivities*: the choice and execution of sensitivity runs and the extent to which these can be relied upon to describe the full uncertainty in the modelling results (including an evaluation of the likely sensitivity of the results and conclusions to modelling choices not formally assessed through sensitivity trials)
        - *Reliability*: noting that information to inform fisheries management is often uncertain, the extent to which the results can be relied upon as a basis for setting the catch limit for paua
        - *Improvements to modelling*: any improvements that could (or must) be made to the modelling to increase the reliability of the results for future management decision making – including the potential use of alternative models or model structures
        - *Improvements to data and research*: other key areas of research or data collection that could decrease uncertainty or increase the utility of the modelling for future management decision making, taking particular account of variability in the productivity of paua populations within and between QMAs, variability in the amount and quality of data within and between QMAs and the development and use of data loggers.

2. Provide advice to the Ministry for Primary Industries on how to, from the data logger data, develop reliable abundance indices or other information that can be used in the assessment and/or management of paua stocks.

The expert panel will summarise their findings and any recommendations in a report to the Principal Advisor Fisheries Science, Ministry for Primary Industries. Where consensus cannot be reached by the external reviewers, any differences of opinion should be recorded in their report.

**3. Background documents**

The following documents will provide relevant background information:

i. Stock assessment PAU 5B & PAU 5D. New Zealand Fisheries Assessment Report 2000/33 http://cs.fish.govt.nz/forums/thread/10630.aspx
ii. Abraham, E.R. (2012). Paua catch per unit effort from logger data. Final Research Report for Ministry for Primary Industries project PAU2010-03 http://cs.fish.govt.nz/forums/thread/10631.aspx
iii. Stock assessment PAU 7. New Zealand Fisheries Assessment Report 2012/27 http://cs.fish.govt.nz/forums/thread/10632.aspx
iv. Stock assessment PAU 7 Data inputs. New Zealand Fisheries Assessment Report 2012/26 http://cs.fish.govt.nz/forums/thread/10633.aspx
v. Haist (2013) Review of commercial catch length frequency sampling methodologies http://cs.fish.govt.nz/forums/thread/10634.aspx
vi. Stock assessment PAU 3. New Zealand Fisheries Assessment Report 2014/44 http://cs.fish.govt.nz/forums/thread/10635.aspx
vii. Stock assessment PAU 3 Data inputs. New Zealand Fisheries Assessment Report 2014/42 http://cs.fish.govt.nz/forums/thread/10636.aspx
viii. Stock assessment PAU 5B. New Zealand Fisheries Assessment Report 2014/45 http://cs.fish.govt.nz/forums/thread/10637.aspx
ix. Stock assessment PAU 5B Data inputs. New Zealand Fisheries Assessment Report 2014/43 http://cs.fish.govt.nz/forums/thread/10638.aspx
x. Neubauer et al (2014) Using GPS logger data to monitor change in the PAU 7 fishery http://cs.fish.govt.nz/forums/thread/10639.aspx
xi. Neubauer et al (2014) Assessing the performance of paua fisheries using GPS logger data http://cs.fish.govt.nz/forums/thread/10640.aspx
xii. The May 2014 Plenary Report for paua http://fs.fish.govt.nz/Page.aspx?pk=113&dk=23540
xiii. Shellfish Working Group Paua Research Itinerary 2015-2020 http://cs.fish.govt.nz/forums/thread/10641.aspx
xiv. V Haist (2010) Research Diver Survey Index review http://cs.fish.govt.nz/forums/10717/PostAttachment.aspx
xv. P Cordue (2009) Analysis of PAU 5A Research Diver Survey Index and PCELR Data http://cs.fish.govt.nz/forums/10718/PostAttachment.aspx

(Presentations will be loaded onto the review website as soon as they become available). (Note: Additional documents may be added to this list).

## 4. Format for review

The format for the review will be a workshop involving the independent external expert reviewers ("the Panel"), key players and other interested parties in Wellington, New Zealand to discuss the data, analyses and results in detail over a period of five days. The review will start with a number of presentations to ensure a common understanding of the work (about 1.5-2 days), and will be followed by a period of contemplation by the Panel, focused discussions with lead researchers or other parties (at the Panel's discretion), and drafting of a report containing the Panel's conclusions and recommendations (2–3 days). The Panel will present a draft version of their findings to interested parties on the last day to receive feedback and suggested corrections on matters of fact. The Panel may, at their discretion, reflect such feedback in their report. The aim is to have a near-final version of the Panel's report by the end of the week, although it could take an additional 1-3 weeks or so until the final version is available. The final version will be made publically available once completed to the satisfaction of the review panel, but drafts will not be circulated.

## 5. Timetable

The workshop is set down for 9-13 March 2015 and will be held in the Allen Boardroom, National Institute for Water and Atmospheric Research (NIWA), Greta Point, Wellington, New Zealand. Dr Pamela Mace, Principal Advisor Fisheries Science, MPI, will chair the open sessions.

| | | |
|---|---|---|
| Monday 9 March | Presentations on:<br>• MSE modelling for PAU 7<br>• development of performance indicators and reference points from the data logger data<br>• commercial fisheries<br>• CPUE standardisation<br>• stock assessment modelling of paua | Open session |
| Tuesday 10 March a.m. | Presentations conclude | Open session |
| Tuesday 10 March p.m. | Panel confers with individual researchers or works alone | Panel's discretion |
| Wednesday 11 March | Panel confers with individuals or works alone | Panel's discretion |
| Thursday 12 March | Panel works on review | Closed session |
| Friday 13 March a.m. | Panel presents draft findings | Open session |
| Friday 13 March p.m. | Panel concludes review | Closed session |

It is anticipated that the review can be concluded by 5 pm on Friday 13 March, although final drafting of the report may take place over subsequent days.

**Ministry for Primary Industries Terms of Reference for an independent review of the paua stock assessment model**

Allen Boardroom, NIWA, Greta Point, Evans Bay Parade, Wellington

Chair: Dr Pamela Mace, DDI (04) 819 4266, email Pamela.Mace@mpi.govt.nz

**AGENDA**

**Monday 9 March 2015 (starting 09:30)**

1. Introductions and general arrangements for the review (Pamela Mace, Julie Hills)

2. Presentations:

**Tuesday 10 March 2015 (starting 09:30)**

1. Presentations continue as required

2. Panel in session: Panel deliberations with presenters or others at their discretion

**Wednesday 11 March 2015**

Panel in session: Panel deliberations with presenters or others at their discretion

**Thursday 12 March 2015**

Panel in session: Panel in closed session (but may have discussions with presenters or others at their discretion)

**Friday 13 March 2015 (starting 09:30)**

**Conclusions and recommendations**

Panel presents draft conclusions and recommendations to interested parties for general impressions and corrections on matters of fact (open session)

Panel concludes deliberations (closed session)

It is anticipated that the open session on Friday 13 March will be completed by noon.

## 2. Attendance at the Open Sessions of the Independent Review of the Paua Stock Assessment Model

Independent Expert Panel

Dr Doug Butterworth (University of Cape Town, South Africa)
Dr Malcolm Haddon (Commonwealth Scientific and Industrial Research Organisation, Tasmania, Australia)
Vivian Haist (Fisheries Science Consultant, Nanaimo, British Columbia, Canada)
Dr Fay Helidoniotis (Commonwealth Scientific and Industrial Research Organisation, Tasmania, Australia)

Ministry for Primary Industries

Pamela Mace (Meeting Chair)
Julie Hills (Shellfish Working Group Chair)
Kevin Sullivan (Science Manager, Stock Assessments)
Erin Breen (Shellfish Inshore Manager)
John Annala, Annie Galland, Marine Pomerade

Research Providers

NIWA: Dan Fu (Paua stock assessment scientist), Rosemary Hurst, Reyn Naylor, Ian Tuck
Breen Consulting: Paul Breen
Dragonfly Science: Philipp Neubauer
Trophia: Nokome Bentley

Paua Industry

Paua Industry Council Limited: Barry Chandler, Jeremy Cooper, Mark Janis, Tom McCowan, Storm Stanley
PAU 7 Management Action Committee (PauaMac 7): Mark Barcello, Barry Chandler, Tim McLeod