Developing a Framework for Prioritising Pest Management Policy

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Executive Summary

- Quantitatively prioritising pest management policies is an excellent approach for transparent, robust, and defendable decision-making. Other government agencies, particularly in the Oceanic region, are also adopting this approach.

- The system developed in *Excel* by the Auckland Regional Council is a suitable structure for prioritising their pest management policies in the forthcoming Regional Pest Management Strategy

- Although all species analysed have a reduced range, some are known pests (impact management) while others are possible pests (risk management).

- The ordinal system used to assign scores to variables needs to be better defined, including ‘anchor points’ for boundaries between levels. Variables prioritised for cost and benefit need to be exactly defined. This makes for repeatable, transparent and defendable analysis.

- Calculation of environmental risks associated with each species incorporates an arbitrary scaling factor (here 3.33) which was used to scale final calculations down to the original ordinal scale. Because of this, comparisons are not able to be made between species, and only relative cost-benefit (rather than overall positive or negative) can be interpreted.

- Uncertainty is pivotal in the decision-making process, and its incorporation allows us to make confidence statements for the final assignment of policy rankings (measured as percentage confidence). First uncertainty must be estimated for individual scores, then uncertainty must be estimated around the final policy rankings.

- The method developed in this paper assumes a normal distribution of uncertainty about the assigned scores, and uses 10,000 simulations to generate final policy rankings and percentage confidence. This method can be used in future by the Auckland Regional Council.

- For six of the ten species, there was high confidence (>80%) for the assigned policy direction.

- For ferrets and blue-tongued skinks, policy direction remained split between HGA and surveillance. Here it will be necessary to further prioritise by either minimising costs or maximising benefits.

- For feral goats, the incorporation of uncertainty significantly altered policy choice. HGA was the preferred policy, though with only 43% support it may be necessary to undertake further investigation into policy options and their relative costs and benefits. For possums it will be necessary to select control areas or existing programmes on a site-by-site basis using a similar framework

Background

The Auckland Regional Council (ARC) engaged the Centre for Biodiversity and Biosecurity (CBB) to review its quantitative decision making process for policy prioritisation within the forthcoming Regional Pest Management Strategy (RPMS). Subsequent to early discussions, the CBB also undertook uncertainty analysis on the final policy rankings. The methodology developed in Microsoft Excel demonstrated ten invasive or possibly invasive terrestrial animal species with a reduced range in the Auckland region.

The goal of this process is to prioritise policy direction from up to five available options in the RPMS by identifying the policy with the highest relative cost-benefit score that the ARC can then recommend for implementation in the RPMS.

The approach of pest management authorities is increasingly toward quantitative, transparent decision making rather than previous subjective decision making processes. This approach was most commonly first undertaken with respect to weed management, such as by the Cooperative Research Centre in Australia who have been prioritising noxious weed management in New South Wales since 2003. Local government in New Zealand already has in place a system which can prioritise aspects of weed management. Since 2005 Biosecurity New Zealand has had a dedicated ‘risk analysis team’ for border security and threat identification. Hewitt *et al.* (2004) describe marine pest management in New Zealand, in particular developing a risk management framework as an aid to decision-making and operational planning.The Department of Natural Resources and the Environment in Victoria, Australia have recently put a lot of investment into pest prioritisation (see ‘*Victorian Pest Management: a framework for action*’ and references therein), and Weiss and McLaren (2002) further describe this process in their paper. In the United Kingdom the Department for the Environment, Food and Rural Affairs (DEFRA) has recently implemented pest risk assessment and policy on non-native species. Cook *et al.* (2004) also describe a method of carrying out biosecurity risk profiling for the United Kingdom by comparing pest incursions under present circumstances with those under future conditions. Some of these references focus on preventing arrival rather than managing spread, which is a different issue in risk management, but the cost-benefit policy prioritisation aspects are transferable.

Overall Strategy

Quantitatively prioritising policies is an excellent approach for making transparent decision-making. We do question the degree to which policies for established pests (e.g. goats and possums) can be treated alongside those for unestablished pests, but in terms of this analysis established pests appear to have been controlled to the point where they are effectively re-establishing range. Outside of this situation established pests should be treated in an impact management framework while establishing pests should be treated in a risk (of establishment and spread) management framework (i.e. precautionary approach) as undertaken here.

Many exotic species have been introduced to the Auckland region, though only some of these will become naturalised, and a further small proportion of these may become pest species. We are assuming the list of species given here for policy prioritisation is just a random subset of species representing different scenarios. A separate robust process if required to identify which species should be evaluated.

Structure

Scores for original variables were assigned on an ordinal scale (categories; but where each category is known to be qualitatively higher or lower than other values) of <5, 10, >15. The absolute value of these scores were apparently arbitrary, yet the numbers subsequently calculated (e.g. 23) indicates a higher degree of precision than is likely to be the case. A truly ordinal scale is set at exact scales (i.e. no < or >), and so should have lower and upper bounds (e.g. 0, 5, 10, 15, 20). Certainty was assigned on a scale of 1-5, with one being low uncertainty, and 5 being high uncertainty.

We have not attempted to review the actual scores for any of the species used. Their derivation and associated certainty is presented in an additional paper by the Auckland Regional Council. Here we are focusing on the framework used rather than specific examples. Once the framework has been adequately structured, it would be productive to evaluate the appropriateness of individual scores. Some research has already been undertaken on a number of these species within the Auckland region.

As we interpret it the prioritisation spreadsheet has seven 'boxes'. The first estimates potential impacts of species through loss of regional values (the converse of benefits should the species be absent). The following five boxes present policy directions; '*No Change to RPMS*', '*Hauraki Gulf Area*' (offshore islands), '*Surveillance*', '*Control Areas*' and '*Existing Programmes'*. The final box condenses the cost-benefit estimates from each of the previous four policies.

Impact values

The first box assigns each species an impact value ('risk of loss of regional values') which was calculated from the formula:

$$\frac{\textit{current and potential impact} \times (\textit{likely spread by 2012} + \textit{likelihood of human introduction})}{3.33}$$

which simplifies to

$$\frac{\textit{impact} \times (\textit{natural spread} + \textit{human spread})}{\textit{constant}}$$

where natural spread can be interpreted as the biological parameters such as intrinsic growth rate and dispersal rates, and human spread can be interpreted as likelihood of establishment outside of captivity or elements of long-distance transport.

In decision-making processes addition of variables tends to be a conservative estimate whereas multiplication tends to be a generous estimate. In this case the addition of dispersal factors (natural + human) is probably suitable.

The constant (here 3.33) has been chosen to scale the combined ordinal values back to a suitable range (0-30) for comparison with other variables classified on the ordinal scale. This begins to blur the distinction between ordinal (categorical) and continuous variables (only the latter can truly be mathematically manipulated to create values outside the original range), however as the variable is held constant across calculations it will have no effect on final prioritisations ***within*** species. The arbitrary constant will however have an effect on comparisons ***between*** ratings of species, once these ratings have been estimated using other ordinal scale variables. This is irrelevant for the current analysis where the goal is ranking of cost-benefit ratings within species, but means that any comparison of ratings between species requires understanding of the effect the constant has. A sensitivity analysis across a range of constant values could achieve this (should prioritisation between species be required).

Again it should be noted that the ratings themselves are generally uninterpretable values (i.e. whether they are positive or negative is dependent on the value of the scaling constant), but it is their ranking with respect to one another, within a species, that is the final interpretable output.

Cost-benefit

Cost-benefit for each of five policy directions consists of

(environmental + commercial benefits) – (environmental impacts + financial costs [individual + council])

which simplifies to the underlying

benefit – cost

Usually if *benefit – cost* is a positive value this suggests a net gain, and if negative suggests a net loss. However as discussed earlier the introduction of a scaling constant distorts the final values, and hence only the rankings of policies (i.e. that policy 1 will have less overall cost than policy 2) is interpretable.

This is a standard and appropriate approach, which works well in this context. However, the suite of variables used here to classify different types of benefits and costs needs specific definition in order to make the process understandable and transparent, and hence defendable. i.e. what constitutes an individual cost? What environmental benefits have been considered (which relates back to earlier definitions in the first box)? Auckland Regional Council has subsequently provided an additional document which details individual variables, their associated uncertainty and comments.

As well as defining variables it is equally important to make clear statements about ‘anchor points’ for boundaries between ordinal values (i.e. 5 to 10). Anchor points are commonly used in sociology surveys, e.g. smoking 5 cigarettes a day is low, while 6-10 is moderate and everything above is high. This makes classification of values a much more repeatable and defendable process. Additionally the ability to assign scoring categories should be reflected in perceived certainty (see later).

Certainty

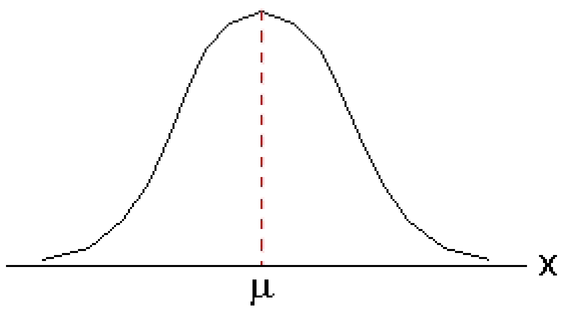
The key to any decision model is the way in which (un)certainty is treated. The current analysis initially incorporated no uncertainty into the assignment of scores, hence assuming that they were all 100% accurate. This was unlikely and so following early discussions uncertainty values for each score were estimated by Auckland Regional Council biosecurity staff and used to estimate the overall uncertainty in final policy rankings. In this analysis the key question is the effect that certainty of assigned scores has on the ranking of policy options. i.e. when uncertainty is incorporated, is it possible that two policy rankings may overlap, hence meaning it is not clear which policy option is superior (e.g. policy 1: -5 to 5; policy 2: 0 to 10). Uncertainty becomes compounded across values and hence final cost-benefit estimates incorporate all the uncertainty of their constituent values. Understanding how uncertainty around specific types of information influences the confidence with which policy options can be adopted also allows any investment to improve information (i.e. reduce its uncertainty) to be targeted (e.g. through review or research).

The first step is to incorporate uncertainty into score assignments, which can be done in different ways. The second step is then to estimate and rank policies with uncertainty incorporated, which can also be done in different ways.

Score uncertainty

Score uncertainty was measured on a scale 1-5. These were treated as variance estimates around a score (i.e. score ± uncertainty). A low uncertainty of one means the assigned score is perceived as very accurate. A high uncertainty of 5 would be large enough for a score to cross anchor points into a different category.

Uncertainty around a score is not constant, and the true value of a score is most likely to be found around the assigned value. We assumed that the true score followed a normal distribution (Fig. 1), most likely taking a middle value around the mean (assigned score) but possibly as an outlier at the extreme range of the uncertainty. e.g. 10 ± 2 lies in the range 8 – 12, but most likely 10.



The normal curve

Ranking uncertainty

Once uncertainty has been assigned to each score the final cost-benefit estimates for each policy option can have an uncertainty associated with them (e.g. policy 1: -5 to 5; policy 2: 0 to 10). This can be calculated empirically by simulation of many random scores within the range of each score's uncertainty. Simulation would calculate scores for all values based on their value (mean) and uncertainty (variance) across the spreadsheet. This is repeated 10,000 times (for robustness) and each time a different value for every score would be obtained. Most commonly middle values around each score will be obtained, but with 10,000 simulations occasionally an extreme score with high uncertainty will be obtained. Following this it is necessary to calculate the final confidence in the highest ranking policy option. The goal is to have a highest-ranking policy, which is consistently higher ranking than all other policies, even with uncertainty. If the final uncertainty of the highest-ranking policy does not overlap with that of the second highest, then it is clearly the highest-ranking policy. However if the uncertainty ranges do overlap then it is necessary to calculate your confidence in the highest-ranking policy actually being so.

In the method we have used, for each simulation we have a final ranking of policies. If the same policy for a particular species is always relatively highest ranked, in all 10,000 simulations, then we can be 100% sure this is the highest ranking policy, including uncertainty. If policy 1 ranks highest in 8,000 simulations, and policy 2 in the other 2,000, then we have 80% support for policy 1, and 20% support for policy 2.

If it is found that there is not a high confidence in the highest-ranking policy option, then it will be necessary to either refine the uncertainty for that species through review or research, or else to select a policy direction contingent on other factors (e.g. the policy that maximises benefit, or minimises cost).

Excel worksheet

We used the supplied ARC worksheet with uncertainty values to perform policy prioritisation and more specifically uncertainty analysis with regards to these final values. For ease of calculation we have divided the spreadsheet into three worksheets; one for species parameters, one for policies and one for final rankings.

For each score and uncertainty, we create a new column where we randomly generate a new score from the normal distribution treating the assigned score as the mean and the uncertainty as the variance. To do this we used the Excel code:

*= score + [(rand() + rand() + rand() + rand() + rand() + rand() + rand() + rand() + rand() + rand() + rand() + rand()) – 6] * uncertainty*

This works through statistical theory whereby the process of generating exactly twelve random numbers (distributed evenly from 0-1) and subtracting 6 creates a random number drawn from the Normal distribution with mean zero and variance one (i.e. N ~ [0,1]). This relies upon asymptotic normal theory and the variance of the sum of 12 uniform distribution numbers equating to the variance of the standard normal distribution.

These new sample scores (samples in that they change every time the worksheet is refreshed using F9 key) are manipulated using the inherent spreadsheet formula developed by ARC to create new scores across all variables, and specifically the final policy ranking. When F9 is pressed all sample scores will change. Following this it is necessary to download and install the *Excel* add-in ‘Poptools’ (http://www.cse.csiro.au/poptools/), where we will use the Poptools > Simulation Tools > Monte Carlo analysis menu. This specifically allows us simulation for *x* times (i.e. 10,000). This is functionally equivalent to holding down the refresh (F9) key 10,000 times, but we can also record final average scores across all 10,000 trials.

First a cell or column with a sample value (one that changes with refresh) is highlighted. Then we select Monte Carlo analysis and only need to change the number of replicates to 10,000 and select a cell to act as the output cell. Then we click enter and are provided with the mean, variance, lower and upper confidence limits, number of iterations (simulations) and computation time. We are only interested here in the mean and variance of 10,000 simulations.

In order to estimate percentage confidence, we must create a 0 or 1 tag for being the highest ranking policy. If for one simulation (i.e. one refresh of the screen) a ranking is highest, it is assigned a value of 1, else it is assigned 0. This is done by ranking the final policy scores across a species using the rank function in *Excel*. If we then run the simulation 10,000 times, we have calculated the proportion of simulations where this was the highest ranking policy (e.g. for three simulations (1 + 1 + 0) / 3 = 0.66 or 66%). We have now obtained percentage confidence in each policy being ranked number one compared to all other options. These results are presented in Table 1 as percentage confidence in each policy option.

Species common name	***Species scientific name***	*"Do Nothing"*	*"HGA"*	*"Surveillance"*	*"Control Areas"*	*"Existing Programmes"*
Brown bullhead catfish	*Ameiurus nebulosus*	16		84		
Ferret	*Mustela furo*	3	48	49		
Rainbow skink	*Lampropholis delicata*	0	94	6		
Blue tongued skink	*Tiliqua scincoides, Tiliqua nigrolutea*	0	50	50		
Red-eared slider turtle	*Trachemys scripta elegans*		90	9		
Bearded dragon	*Pogona vitticeps, P.barbata*	93	7	0		
Iguana	*Iguana iguana*	93	7	0		
Feral goat	*Capra hircus*	28	43			27
Possum	*Trichosurus vulpecula*	5			47	46
Argentine ants	*Linepithema humile*	0	100			

Table 1: Policy ranking with uncertainty incorporated after 10,000 simulations. Shading represents the highest-ranking policy. HGA = Hauraki Gulf Controlled Area

For six of the ten species the highest ranking policy with uncertainty considered remained the same as without uncertainty. This is not surprising, and supports the robustness of the policy rankings. For the ferret confidence is split almost equally between HGA and Surveillance, despite HGA being favoured when uncertainty was not incorporated. Clearly the uncertainty involved in policy ranking for the ferret can not distinguish between these two policies. For the blue-tongued skink confidence is also split equally between HGA and Surveillance, as it was without uncertainty. For these two species the ARC will be required to prioritise a policy direction based on some other function, such as maximising benefits or minimising costs for the final policy. For feral goats, we have 43% support for HGA, 28% for do nothing and 27% for the existing programme. This result differs markedly from the policy ranking without uncertainty, where HGA and existing programme were equal. For this species, the inclusion of uncertainty has changed the interpretation of the final policy rankings, probably as a function of the environmental benefits being divided by 3 for existing programmes. Because of the low support (<50%) for any policy direction for feral goats, we recommend further investigation into this species and the relative costs and benefits of different policy options. For the possum, confidence is also split almost equally between control areas and existing programme, reflecting their equal cost-benefit values. The difference between policies lies in where the cost is assigned (individuals versus council). For the possum it would be most appropriate for the council to assign policy ranking actions on a site-by-site basis, where costs and environmental benefits may have site-specific nuances which tip the favour towards one policy over the other. This could be modelled in a site-specific framework using the same spreadsheet by entering the new costs for a site, and getting percentage confidence for each policy under site-specific conditions. For site-by-site application it would be better to move to a more resolute scale of 1-15 inclusive for estimating cost and benefits.

A lot of the uncertainty included in the analysis cancels out during cost-benefit calculation, and so it is not surprising that most policies remained similarly ranked. We now however, have very strong confidences assigned to these policy selections which are quantitative, robust, transparent and defendable. It should be noted that for '*environmental benefits*' in each policy option, the uncertainty was taken from the species parameters worksheet sample calculation and not the second (redundant) uncertainty assigned here (asterixed columns). Some data also appeared to be missing from the '*existing programme*' box and was entered following data in the previous policy boxes.

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