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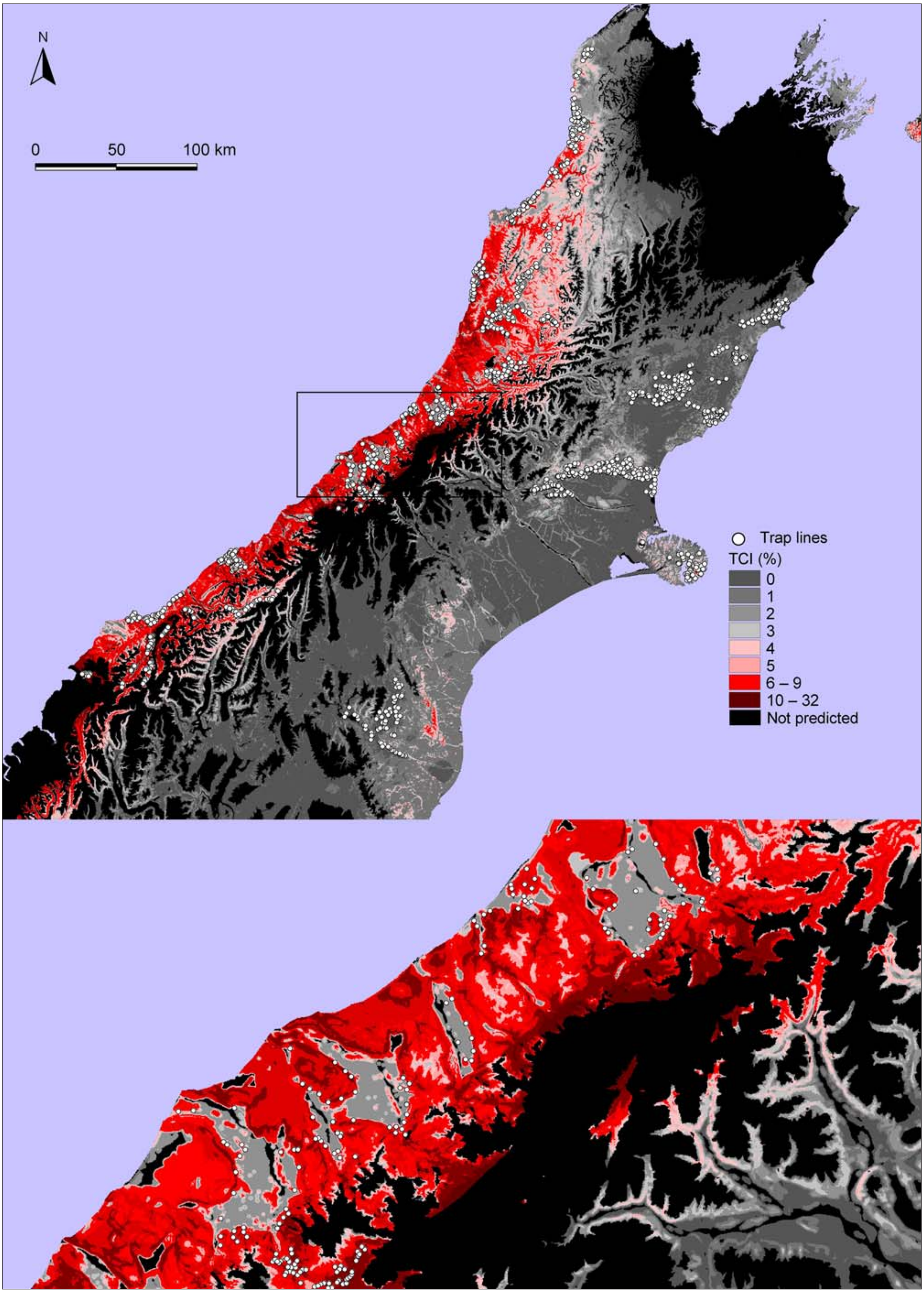

Figure 14. Pattern of post-control TCIs as predicted from the post-control model in Fig.12. Also shown are the locations of the trap lines used to produce the model in Fig. 12.

woody vegetation in a 300-m radius (WOOD300) up to c. 40%. TCI varied with distance to pasture (DISTPAST), with the relationship having a similar shape to that for uncontrolled possum populations. As discussed above (see Section 5.4.1), this result is somewhat different from what we expected and may reflect the range of areas sampled or the previous effects of hunting pressure from fur trappers.

Mean annual solar radiation (MAS) and the amount of woody vegetation in a 300-m radius (WOOD300) had the strongest effect on post-control TCIs (Fig. 13). Together with other factors, these predictor variables help to describe the overall 'habitat'.

Figure 14 shows the predicted TCIs for the post-control model applied to the West Coast and Canterbury regions. Overall, post-control possum densities are likely to be markedly lower in Canterbury compared with the West Coast and this undoubtedly reflects a similar pattern in their initial uncontrolled densities (see Figs 6 and 7). However, as noted previously, there were few (uncontrolled survey) data for much of Canterbury and there will be habitats in which post-control TCIs are likely to be higher than indicated here. The smaller West Coast area at the bottom of Fig. 14 shows the lowest post-control possum densities coinciding with grassland, grassland–scrub, and grassland–forest vegetation associations. Those areas with the highest predicted post-control TCIs were almost exclusively podocarp–broadleaved forests.

Post-control deviance model

This model included only one variable, the amount of woody vegetation in a 300-m radius (Fig. 15), which was only barely significant and overall explained only 1% of the variation in the deviation of individual-line TCIs from the survey mean TCI. Therefore, the spatial variables used in this study were not useful in explaining the variation of TCIs among trap lines within individual post-control trap-catch surveys. This result also confirms that almost all of the 20% explained variation in the post-control model is accounting for between-survey variation, not within-survey variation.

This result could be an effect of the spatial predictor variables used in the GRASP analyses. That is, at the within-survey scale, there is likely to be little variation in the actual predictor variables we considered (cf. the levels of variation in the same predictor variables between surveys). Furthermore, there may be factors or variables operating at a local level (i.e. within a survey) that we have not considered. An example of this is aspect. Survey lines on north-facing, warm slopes with preferred vegetation communities are more likely to be characterised by higher TCIs than lines on south-facing, colder slopes with poor or sparse vegetation cover. Therefore, the current sults are most useful for predicting broad (e.g. regional) patterns of abundance but should be used with caution in localised (e.g. specific area) contexts.

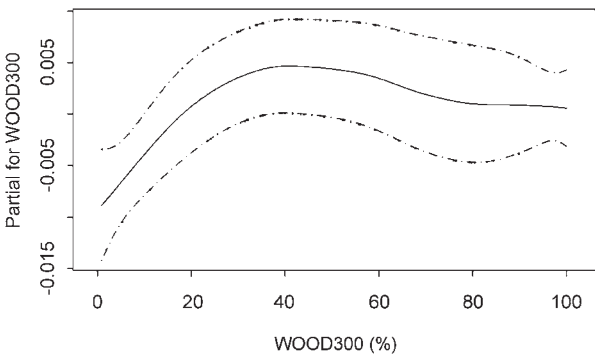

Figure 15. Model of variation in individual-line TCIs from the survey mean TCI for trap-catch surveys in control areas. (See Table 1 for an explanation of the predictor variable WOOD300.)

5.4.4 Combined effects of control

Figure 16 shows an overall prediction of TCIs for part of the West Coast region, incorporating three of the models described above (i.e. uncontrolled, pre-maintenance control, post-control). The data used and the areas for which each model was used to predict TCIs are shown in Fig. 17. The lowest TCIs were predicted on and around farmland (where previous control efforts have tended to be concentrated). The combined result also suggests that possum densities are uniformly high (30–50% TCI) throughout most parts of the area where no control has occurred. This result needs to be tested further.

5.5 APPLICABILITY AND RELEVANCE OF THE GRASP MODELS

Although the maps showing possum relative densities in Figs 6 and 7 for uncontrolled (or pre-control) populations are New Zealand-wide in their coverage, for those areas and/or habitats with few or no data (see Fig. 2), the degree of uncertainty is high and, therefore, these results must be interpreted with caution (these areas generally coincide with those identified as data gaps in Table 3). Nevertheless, the general patterns produced by the model appear to make biological sense and are supported by previous studies where absolute or relative possum densities have been measured or estimated.

Clearly, the models developed here require further refinement. Additional data, particularly from those areas already identified as significant geographic or environmental gaps, are likely to offer the greatest improvements. Ultimately, the essential test of the applicability and relevance of the models' predictions will be to ground-truth them in a range of areas. However, it should be remembered that not only do possum densities in New Zealand vary greatly between different major habitat types, but that within each broad vegetation type there is much unexplained variation also (Efford 2000). Therefore, in terms of their scientific relevance and potential usefulness as management tools, the models described here (or similar models) may only ever be realistic and applicable at a broader scale. There may be factors that essentially 'operate' over a smaller (local) scale and which we have not taken into account (e.g. soil fertility, local vegetation species diversity, availability of nesting sites) that in reality account for a considerable degree of the variation in (uncontrolled) possum densities and, to a lesser extent, population recovery rates following control. The post-control deviance model result provides some indication that there are factors operating that cause variation in possum densities (as measured by TCIs) that we have not considered here.

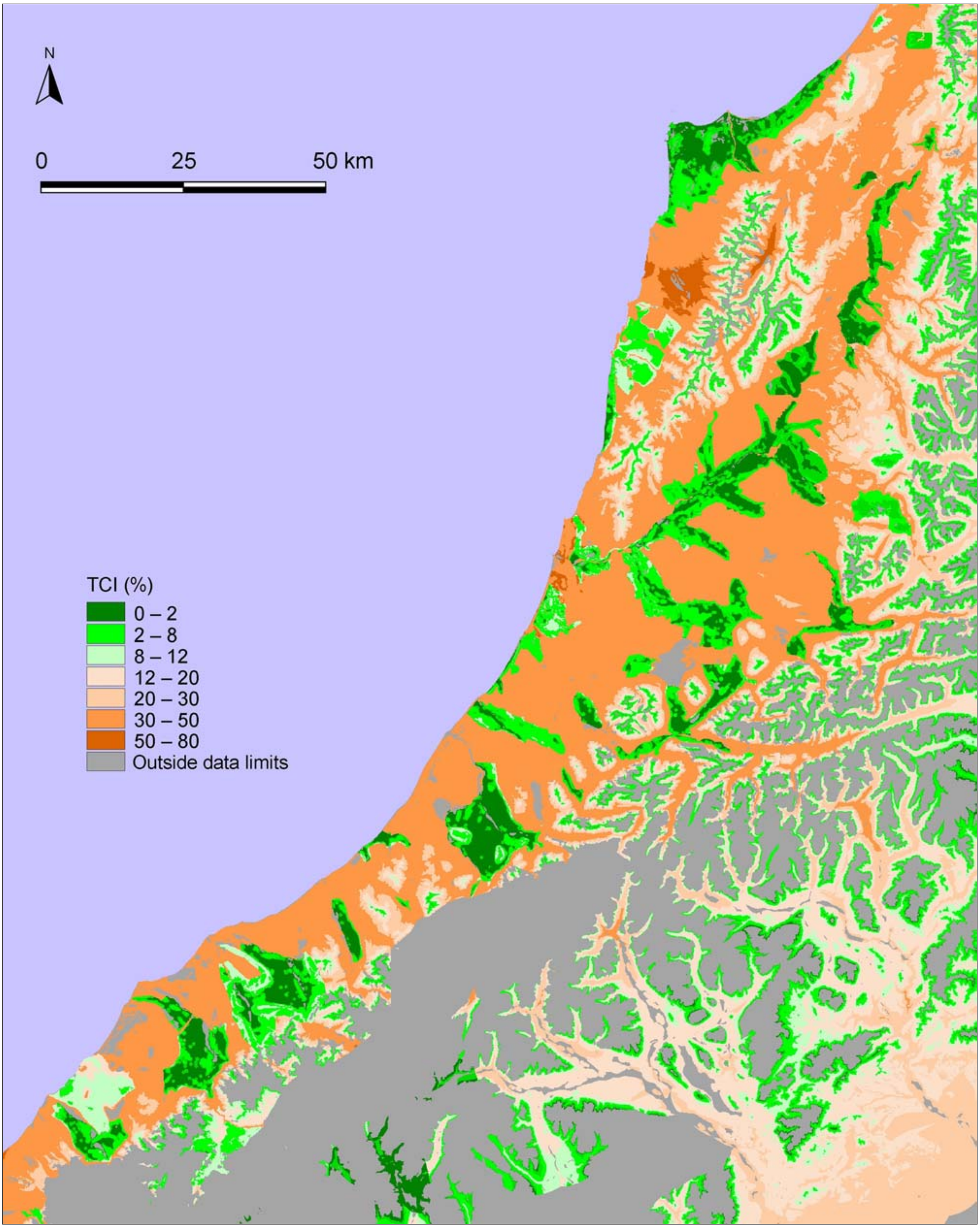

Figure 16. Overall TCI predictions for a portion of the West Coast region for possum population surveys conducted in January.

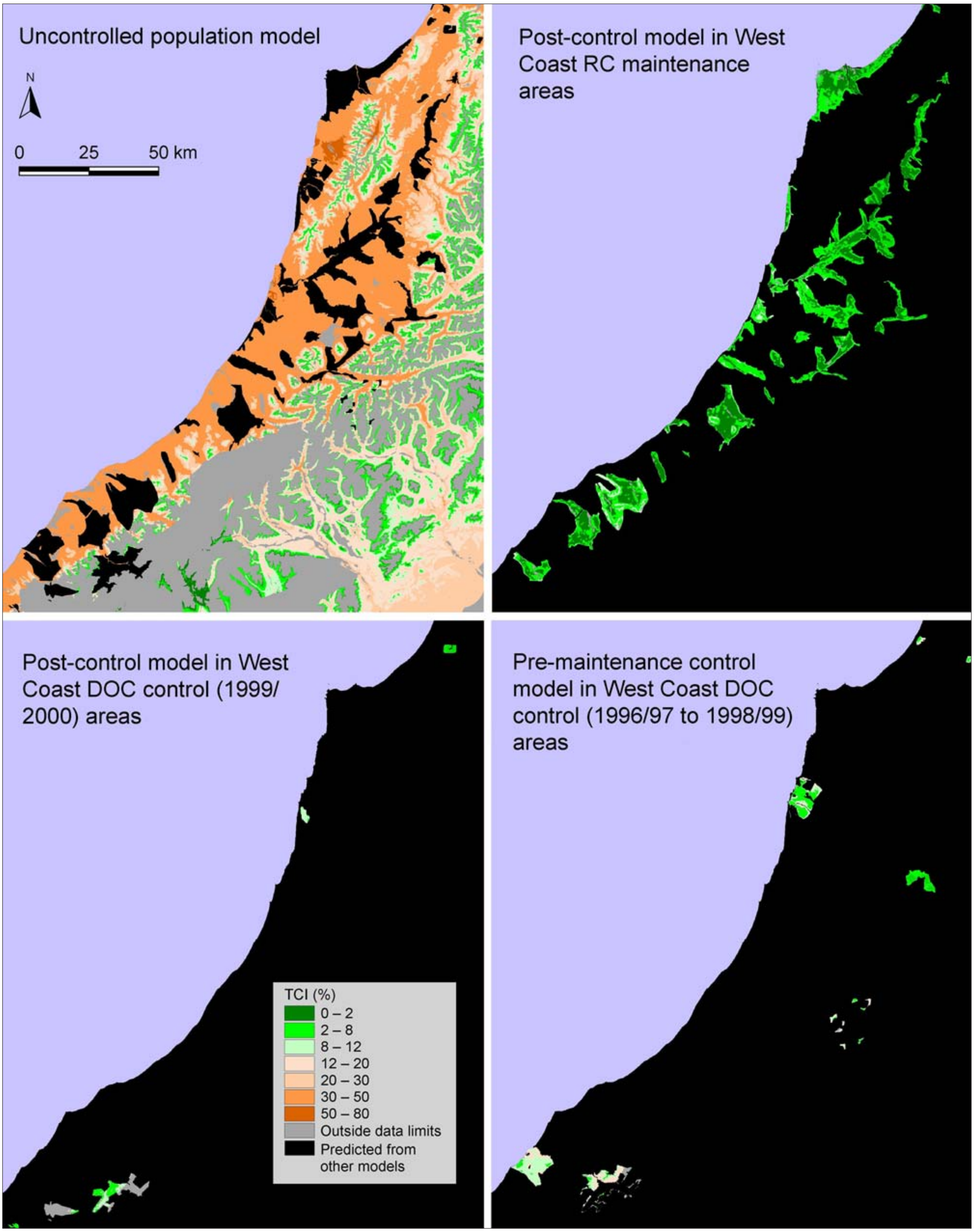

Figure 17. Four 'components' of the prediction in Fig. 16. These four 'components' are derived from three different models, shown in Figs 4, 9, and 12.

5.6 DATA STANDARDS AND BEST-PRACTICE GUIDELINES

The use of standardised procedures and consistent data standards for monitoring possum populations and recording and storing data from such monitoring is fundamental to using this information reliably for statistical analyses and population modelling, and to maximising the benefits of collecting such data. Furthermore, similar procedures and data standards should also apply to control operation information since, typically, most possum population monitoring is now carried out directly in association with specific control operations. The need for integrating information from these two key facets of possum management, and the opportunity for modelling and analysing patterns over time, mean that the same system and data formats should be used both for the population monitoring data and for the control operation data.

5.6.1 Possum population monitoring

Trap-catch monitoring issues

Although clear guidelines exist for possum population monitoring (i.e. the NPCA Protocol), there is considerable variation in the extent to which these guidelines have been applied and the level and quality at which monitoring data are reported. Furthermore, since the Protocol was introduced in 1996, a number of incremental changes and additions have been made to it, largely driven by the need to monitor low-density possum populations being controlled for bovine-Tb. Although most of these recent changes have not taken into account DOC's current and future monitoring needs (but rather have been driven by the Animal Health Board's Tb-control perspective), some of the changes have produced benefits from DOC's perspective. For example, the change from 20-trap lines to 10-trap lines increases coverage and improves local representativeness, generally with a corresponding increase in the precision of the resulting population estimates.

One recent change that was specifically driven by DOC's needs is the move to use raised-set traps in areas where native ground-dwelling birds (i.e. kiwi and weka) are at risk. This is now a requirement in some conservancies (e.g. West Coast) and applies also to Animal Health Board-funded monitoring (associated with Tb eradication) on West Coast conservation land. Although three studies (Thomson et al. 1996; Thomas & Brown 2000; Nugent et al. 2001) have indicated that catch rates are lower with raised-set traps, the actual relationship between trap-catch rates on raised-set traps compared with ground-set traps (as shown in Fig. 8) has not been quantified elsewhere and, therefore, comparisons of results that include both set types should be treated with caution (this situation mostly relates to Animal Health Board-funded Tb-control work). While Fig. 8 provides some indication of the relationship between ground-set and raised-set trap-catch rates, this result was obtained using empirical data from uncontrolled populations and, therefore, generally in the moderate- to high-density range. However, the current situation is that possum populations in many areas (particularly those critical in terms of conservation- and Tb-related control) are under relatively intensive control and are, therefore, in the lower-density range. It is important to determine the true nature of the relationship between ground-set and raised-set trap-catch rates over the lower-density range.

Furthermore, unlike ground-set traps, there are currently no specific standards[5] for raised sets. As with some other aspects of applying the trap-catch technique, a variety of raised-set types (i.e. devices) and trap heights are in use. From a survey of DOC area offices and field centres, Thomas & Brown (2000) found that Scott boards (66% of the total) were the most commonly used device and 70 cm the most common height (45% of the total). However, more recently, there has been an increase in the use of simple nail-based raised sets. Furthermore, the need to raise traps to 70 cm has been questioned by some DOC staff since traps set lower can probably also exclude native birds at risk while potentially increasing effectiveness for catching possums.

If maximum use is to be made of trap-catch monitoring data, then consideration needs to be given to reducing the number of variations in use, particularly for raised-set trapping (in terms of the devices and trap heights used). This is particularly important if trap-catch data are used to monitor (and model) population trends over time. Furthermore, reliable comparisons between the largely ground-set-based historical data and the more recent (and future) combinations of ground-set and raised-set trapping data will require research to establish reliably the relationship between ground- and raised-set trap-catch rates. The need for robust comparisons is further reason to reduce the number of 'officially approved' variations to a manageable number.

Trap-catch data recording and reporting

For each possum population monitoring survey, the data that need to be recorded are shown below.

- Treatment area/block name*
- Size of the treatment area/block (ha)
- Name of person in charge of designing the monitoring/key management contact
- Name of person in charge of supervising the monitoring/key field operative contact*
- Survey type (pre-control, post-control, maintenance, trend)
- Start date of survey*
- Finish date of survey
- Number of lines in the survey
- Was a standard line bearing used?
- Line bearing (if only one used)
- Was a map with trap-line locations filed?
- NZMS 260 series map sheet name
- Number of traps per line
- Trap type used
- Set type used (ground/raised)
- Device name (for raised sets)

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[5] Since this project was initiated, Landcare Research has been commissioned by the Animal Health Board to develop a standard specification for raised-set trapping to be included in the NPCA Protocol.

- Trap height (cm, for raised sets)
- Between-trap spacing (m)
- Was lure used?
- Lure type
- Number of trap nights monitored (for the survey)
- Were the trap nights consecutive?
- Weather for night 1†
- Weather for night 2†
- Weather for night 3†

* Common variable (linking this and one or more other tables).

† This can be scored on a simple subjective scale.

Appendix 3 contains information on trap-catch monitoring survey variables, potential data formats and an example of the data and, where applicable, a brief explanation of the variable.

For each individual trap line, the data that need to be recorded are listed below (note that this assumes that the number of traps per line is fixed).

- Treatment area/block name*
- Name of person in charge of conducting the monitoring/key field operative contact
- Start date of survey*
- Trap-line number
- Trap-line start point—7-digit easting
- Trap-line start point—7-digit northing
- Direction of line (magnetic bearing)
- Number of trap nights (for the line)
- Number of possums caught
- Number of sprung traps (possum escapes)
- Number of sprung traps (unknown)
- Number of rats caught
- Number of other non-targets caught
- List other non-targets

* Common variable (linking this and one or more other tables).

Appendix 4 contains a listing for individual trap-line variables, potential data formats and, where applicable, a brief explanation of the variable.

For simplicity and storage efficiency, data for the monitoring survey as a whole and data for individual trap lines within a survey are best stored in separate tables within a database. However, the two tables need to be linked through one or more common variables. Standardisation of the linking variables is fundamental to being able to integrate these data for analytical and modelling purposes.

All trap lines within a survey must be the same in terms of when they are monitored, their length (i.e. number of traps and between-trap interval), and the trap-set type used. If these conditions do not hold (i.e. are not totally applicable across all lines within a survey), then the data recorded are unlikely to reflect the reality on the ground. If one or more of the above (or any other key) variables are not uniform across a survey, then the data should be recorded and reported in such a way as to represent separate (but internally consistent) surveys.

Trap-line location data are of key importance and this element of the information set with respect to monitoring surveys can serve to illustrate the care and detail required when formulating data standards. Ideally, trap-line locations should be recorded using a global positioning system (GPS) device. These are now in relatively common use by most organisations and individuals involved in possum population monitoring. The actual location data recorded should include both the line origin (i.e. the grid co-ordinates of the start point) and the direction of the line (i.e. as a magnetic bearing). Grid co-ordinates must be recorded according to a single standard (e.g. the NZMG projection based on the New Zealand Geodetic Datum (NZGD) 1949). Northings and eastings must be recorded to seven digits and the units of measurement must be metric. All such GPS-generated co-ordinates should be transferred and saved as electronic text files in a standard format. Trap-line data sheets need to be designed with the above in mind and, where necessary, provide guidelines and/or examples for ensuring that the correct data are collected and that these data are recorded in the appropriate way.

5.6.2 Control operation information

DOC has recently established guidelines for recording, evaluating, and communicating animal-pest operational activities and results in a written format (Lawless 2002). With a few exceptions, an operational report must be written for all DOC pest operations (including those targeted at possums) following this SOP. The only exception with respect to possum control is for those operations that are carried out on behalf of other organisations (principally the Animal Health Board). The SOP also specifies a time frame for completing operational reports.

The operational reporting for animal pests SOP (Lawless 2002) contains detailed instructions with respect to the standards that must be followed in terms of the structure and content of operational reports, including standard terminology. There is overlap between some of the information required by the SOP and that required for our analyses and, where applicable, we have adopted the same terminology as used in the SOP.

For GRASP analyses requiring control operation data, the information that needs to be recorded in a standardised way is listed below.

- Treatment area/block name*
- Size of the treatment area/block (ha)
- Start date of the control operation
- Finish date of the control operation
- Control operation type (aerial or ground)
- Bait type
- Was pre-feeding used?
- Pre-feed sowing rate (if applicable)

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* Common variable (linking this and one or more other tables).

- Toxic bait sowing rate
- Toxin used
- Toxic loading
- Map showing control operation boundary(ies)

For each of the variables listed above, a standard data format needs to be established. This is not covered in the SOP for operational reporting. Appendix 5 contains a listing for control operation variables, potential data formats and, where applicable, a brief explanation of the variable for where control operation data are collected. As with the monitoring survey and individual trap-line data, the table containing the control operation information should be linked to the other tables using one or more common variables, again reinforcing the fundamental need for simple and consistent data standards to enable and ensure the seamless integration of population monitoring data and control operation information. The standardisation of these linking variables is fundamental to being able to integrate these data for analytical and modelling purposes.

In addition, a key element of the information that must be recorded in relation to control operations is the spatial representation of the control area. At the lowest level, this information is in map form with the boundaries of the treatment area (and sometimes blocks and/or strata within this area) delineated. Ultimately, for incorporating control operation information into the post-control GRASP models, this information must be available as one (or more) polygons in a GIS.

The need for the seamless integration of all population monitoring data and control operation information cannot be emphasised enough. For example, wild animal populations do not recognise land tenure (or other legal) boundaries and different agencies are involved in the management and control of these populations. Furthermore, in some instances more than one government (or other) agency will be involved with managing possum or other pest populations in a particular area. Therefore, whatever system is developed and used for recording, reporting, and storing population monitoring and related control information needs to be established and maintained in such a way that it is useful to all relevant agencies.

5.6.3 Collation and storage of data

As noted, there are many ways in which control operation and possum population monitoring data and results are collated and stored. Clearly, this raises issues of incompatibility and inefficiencies in terms of making the most effective use of these data (e.g. better understanding the pest species and improving overall control efficiency, assessments of possum population trends over time, comparisons between similar areas under varying management regimes). Therefore, as with recording and reporting, there need to be basic guidelines, consistent across all conservancies and any other agencies that might contribute information, for the way in which data are collated and stored.

Within each conservancy there should be a single location (and accountable person) where hard and electronic copies of all data are collated and stored. In addition to using standardised formats and templates for the various data, there should also be standardisation of the collation procedures and the storage systems used (i.e. timetable for reporting control and monitoring data, filing details including file numbers, coversheets, etc.).

5.6.4 Standardisation between agencies

Any standards used for monitoring possum populations and recording and reporting monitoring results, reporting control operation details, and collating and storing these data should be consistent between the two key organisations involved in possum management (i.e. DOC and the Animal Health Board). This would enable the seamless integration of control and possum population information from these sources. Given that many Animal Health Board-funded control operations (and related monitoring) occur on conservation land and given that Animal Health Board-funded work comprises the bulk of the control and monitoring activities undertaken, it would seem prudent for DOC to consult and/or liaise closely with the Animal Health Board in terms of future changes and developments in this area. Furthermore, what is happening in terms of possum population management in areas adjacent to conservation land (where the possum habitat is contiguous, or near to it) is also relevant to possum population management on the actual conservation land.

6. Conclusions

Retrospective data collection from a range of sources is unlikely to provide a representative sample, either in a geographic or habitat sense, or cover the complete range of pest densities and management contexts. However, the GRASP framework helps to deal with the problems associated with using non-representative data. GRASP combines the power of advanced spatial analyses with the advantages of extensive spatial information managed in a GIS, and provides a framework for taking localised measurements, such as the individual trap-line data from trap-catch surveys (as used here), and developing regional- and national-scale predictions of pest distributions and densities.

The GRASP framework and the resulting analyses can potentially provide important and useful information for pest and conservation management, including:

- An understanding of the behaviour of abundance indices, such as TCI, and the effects of variables such as season and trap-set type on such indices
- Robust spatial predictions of pest abundance (in the form of maps) across entire regions or nationwide
- A description of the regional- or national-scale relationships between pest abundance and spatial variables such as climate or land use, to provide insight on regional and national patterns of pest distribution and the key environmental drivers of pest abundance
- Estimates of the potential benefits of pest control where site-based condition assessment is not possible or practicable
- More effective identification of conservation-related control priorities and hence better determination of where future control should be targeted

There is a vast amount of possum population monitoring data potentially available but its utility is currently limited by its inconsistent quality and the difficulties associated with collecting it (i.e. it would take considerable time and effort to locate, access, and standardise). Nevertheless, obtaining at least some of these data is essential for improving the accuracy and reliability of the models developed here. Therefore, at a strategic level, it may be worth investing further resources in obtaining more of the recent historical data; and in establishing an ongoing sampling programme designed to collect possum abundance data from a representative range of areas or habitats. Priority should be given to collecting data from geographic and environmental 'gaps', particularly where possum populations have not been controlled, since this will lead to the greatest improvements in the ability of the models to predict possum densities under different management scenarios.

The rationale for improving the accuracy and reliability of the uncontrolled possum population model is that it forms the basis for all subsequent comparisons over time. Refining the uncontrolled model is also likely to offer further insight into the key environmental factors affecting possum (and possibly other pest) densities, and enable more detailed and area-specific estimates of the densities that could be expected in the absence of control and how long previously controlled possum populations might take to reach such densities. This could eventually lead to an improved understanding of the relative impacts of management and environmental influences on possum populations. Another benefit of refining the uncontrolled model is identifying where key tactical places might be for targeting future control operations to halt or slow the spread of possums (or some other pest species). These would be indicated on the uncontrolled population model as relatively low-density areas and might suggest the presence of some spatial (i.e. geographic) or environmental (-factor) 'gorges'. Targeted control in such areas might provide a cost-effective means of stopping pests from reaching more favoured or vulnerable areas or habitats.

Despite needing further refinement, the models developed here are useful for several reasons, including highlighting some of the key factors accounting for variation in the TCI (the principal indicator of possum population abundance) at a broad (e.g. regional) level. However, the result for the post-control deviance model highlights the limitation of such models in accounting for variation at a localised level and suggests that the indicative results at such localised levels should be interpreted with caution.

One of the key uses of the GRASP models is to estimate the difference made by possum control where site-based condition assessment is not possible or practicable. The uncontrolled possum population model essentially predicts 'potential abundance expected without control in about 10 years' (although possums may take longer to fully recover and/or reach 'equilibrium' or uncontrolled densities in some places). The impacts of possums on the biota can be estimated via the presumed or known functional relationships between possum abundance and loss of various sectors of the biota. The difference between this and current possum abundance (which should be no more than possums at 'equilibrium' at any point), taking control history into account, can then form the basis for determining the difference (i.e. benefits) made by control. While these benefits are essentially assessed on a set of possum abundance/vegetation loss relationships derived from empirical data from possum impacts studies, they could be refined and validated by monitoring possum abundance/vegetation recovery relationships in a representative range of areas or habitats following control. Therefore, the models developed here could form an essential element of ongoing or future adaptive management.

The GRASP framework allows a better understanding of the factors affecting the TCI (such as trap-set type or seasonal influences). Improved knowledge of the effects of these factors is useful for better interpreting TCI values in relation to actual possum abundance, specific control operation targets and outcomes, and conservation (and Tb) effects at various densities. Investigating the overall efficacy of control operations, and predicting the expected post-control abundance under a range of control scenarios is also possible. This could include an increased understanding of factors like pre-feeding and other control operation variables, and ultimately lead to the development of more effective control strategies and more robust predictions of the likely benefits of control expenditure for an area.

The failure of the post-control deviance model to explain and predict variation in post-control TCIs within the context of specific control operations is disappointing. As discussed above, this may have resulted from one or more key parameters or factors (such as aspect) not being included in the current post-control deviance model. Further development of this model leading to improved understanding of the variance in post-control possum densities could have important implications for predicting the local distribution of conservation benefits and potentially could also have important implications for Tb epidemiology (by predicting where the highest post-control possum densities are likely to be found).

Given that most current large-scale control operations are Animal Health Board-driven and that many of these operations occur on conservation land, there would be considerable advantages in ensuring that possum population monitoring and control information from these operations also is able to be used for modelling. Furthermore, many Animal Health Board-funded control operations (and related monitoring) that do not occur on conservation land will nevertheless still be important, particularly where the possum populations constitute 'reservoirs' for immigration to adjacent or nearby conservation land. Therefore, the Department should consider liaising with the Animal Health Board in order to establish data standards and reporting procedures so that the exchange of possum monitoring, control operation, and other related information can occur seamlessly.

Given the wide variation in terms of possum monitoring data recording and storage procedures between conservancies, there is an immediate need to establish explicit protocols and guidelines for ensuring that all relevant information is captured and stored in an efficient, standardised, and readily accessible way. The recently developed SOP for operational reporting (animal pests) helps to address this need with respect to control operation information. However, the data requirements for GRASP modelling and analyses require specific formats to be followed for recording essential data.

The costs of developing, instituting, and ensuring that data recording, reporting, and storage systems are complied with are likely to be insignificant when compared with the costs of actual control and monitoring, and yet the use of these data has the potential to result in considerable savings or, alternatively, increased effectiveness of such ongoing possum management. Any formal policies and procedures (and resulting standards) with respect to possum population monitoring data and control operation information need to be national in their coverage. This will enable the greatest possible use to be made of these data. Furthermore, any standards should be developed in consultation with the Animal Health Board since, ultimately, more effective possum management in New Zealand will rely on the seamless integration of DOC and Animal Health Board control.

From our experience, it is apparent that simple guidelines and instructions would be of questionable effectiveness for ensuring complete and efficient collection, recording, and storage of possum population monitoring data and control operation information. Given the need to link possum population monitoring data and control operation information for GRASP analyses, an efficient approach might be to design a system to capture all the required data in a standardised format that would establish the required links, provide a common data platform, and identify missing data during the data-entry process. Such a system could be web-based and include separate modules for possum population monitoring data and control operation information.

Whatever system is finally adopted needs to be sufficiently formalised to ensure there is little or no room for misinterpretation or any variation in how such standards are applied. One option is for potential policies, standards, and procedures to be incorporated into something along the lines of key performance indicators (KPIs) so that: they are given sufficient attention at appropriate levels of the organisation (and do not just languish in some conservancies because the relevant staff neither support nor properly understand the need for adequate systems); these KPIs (or similar) are incorporated into annual business plans so that they become an integral part of annual reporting and assessing performance monitoring; and within each conservancy there is one or more staff positions with delegated responsibility for ensuring that the relevant systems and procedures are complied with.

7. Recommendations

Based on our models and this report, the authors recommend:

- Priority should be given to, first, validating, and secondly, improving the accuracy and reliability of the uncontrolled population model since it forms the basis for all subsequent analyses, including determining what the key environmental drivers of possum density are and how possum populations might be expected to recover under various control scenarios.
- DOC should consider investing further resources in: obtaining some of the recent historical data; and/or establishing an ongoing sampling programme designed to collect possum abundance data from a representative range of areas/habitats. Any further sampling should concentrate on areas that

constitute geographic and/or environmental 'gaps' and where possum populations are unlikely to have been harvested to any significant extent.

- Recording and reporting of both possum population monitoring data and control operation data should be standardised to ensure that all relevant information is captured and stored in an efficient and readily accessible way, and one in which the various forms of data can be integrated to further refine the GRASP models and related analyses.
- Potential availability and usefulness of a large amount of information related to Animal Health Board-funded activities needs to be considered. The Department should liaise with the Animal Health Board to ensure that any standards developed for possum population monitoring data and control operation information are common in order to enable the seamless integration of such information from both agencies.

8. Acknowledgements

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Appendix 1

NOMINAL LOCATIONS FOR ADDITIONAL TRAP-CATCH SURVEYS

Table A1.1 provides nominal locations for additional monitoring surveys of possum populations to supplement existing trap-catch data for uncontrolled populations. The objective is to improve the overall national prediction of TCIs in uncontrolled possum populations by obtaining additional trap-catch data from areas currently with few or no data.

How the locations were chosen

We used a random sampling procedure, guided by the predicted trap-line densities shown in Fig. 2. While this process resulted in more locations in areas with low, existing trap-line densities, some locations in areas with higher sampling densities were also selected.

All points on a 1-km^2 grid coverage of New Zealand were used as potential survey locations. The following variables were obtained for each location: predicted trap-line density, land cover (from the LCDB), and whether the location was inside or outside conservation land. The initial set of potential survey locations consisted of 267 306 locations. Locations with the following land covers were excluded (using information from the LCDB): urban, urban open space, inland water (lakes and rivers), and mines and dumps. Following the exclusion of these locations, 260 971 potential locations remained.

A sample of 200 locations was randomly chosen from this set. Samples were chosen with higher probability in areas with fewer existing TCI data, and lower probability in areas with more existing TCI data. This was accomplished by making the probability of random selection relative to the inverse of the predicted trap-line density. However, some areas are mapped as outside the data limits (zero plot density) or have predicted plot densities very near zero, which would give infinite values when taking the inverse. Because of this, an arbitrary decision was made to define any location with a trap-line density of less than 1/1000 as a location with 'few or no data', and to set all locations in this category to a sampling density of 1/1000. This resulted in a 20-fold variation between potential candidate locations in their probability of being chosen in the sample, and for 68% of the chosen locations to be in areas with 'few or no data' and the remainder to be chosen from areas with 'some' data.

How to use the table

Each location gives the nominal centre of a trap-catch survey that will improve the existing prediction of TCIs for uncontrolled possum populations. However, surveys should not be conducted if they are located in areas that have experienced possum control in the last 10 years. If a decision was made to conduct a certain number of surveys (such as 100), then that number of locations should be chosen randomly, rather than selecting the most convenient locations.

Each survey should consist of a cluster of at least five trap lines within 1 km of the centre, established according to the NPCA Protocol, with the first line located at the centre. Note that this may result in many lines being situated in locations that are unusual for trap-catch surveys, but that this is an essential element of the supplementary survey process (i.e. to obtain TCI data from places that are rarely surveyed). Sometimes there may be no need to conduct the actual survey if it is certain that the trap lines would yield 0% trap catch, for example, on Great Barrier Island (which has not been colonised) or on snow- or ice-covered alpine areas (which are outside the environmental limits of possums). In these instances, the survey results for the five trap lines can be reported as 0% TCI. However, classifying such 'pseudo-lines' should be done cautiously to avoid assuming that possums are not present in an area when in fact they may be (albeit at very low densities, as in some agricultural lands).

TABLE A1.1. NOMINAL LOCATIONS FOR ADDITIONAL TRAP-CATCH SURVEYS.

SURVEY NO.	EASTING	NORTHING	DOC	SURVEY NO.	EASTING	NORTHING	DOC
1	2599050	5981950	N	51	2927050	6291950	N
2	2644050	6557950	N	52	2308050	5615950	Y
3	2959050	6279950	N	53	2153050	5400950	N
4	2893050	6297950	N	54	2147050	5464950	N
5	2709050	6459950	N	55	2298050	5646950	N
6	2839050	6233950	N	56	2776050	6123950	N
7	2503050	5921950	N	57	2598050	6185950	N
8	2266050	5573950	N	58	2557050	6689950	N
9	2661050	6529950	N	59	2044050	5533950	Y
10	2278050	5770950	Y	60	2591050	6605950	N
11	2603050	6651950	N	61	2356050	5745950	N
12	2350050	5811950	N	62	2485050	5970950	N
13	2329050	5524950	N	63	2477050	6043950	Y
14	2944050	6327950	N	64	2239050	5609950	N
15	2783050	6309950	N	65	2314050	5488950	N
16	2401050	5759950	N	66	2702050	6333950	N
17	2694050	6439950	N	67	2954050	6269950	N
18	2146050	5446950	N	68	2212050	5588950	N
19	2505050	5889950	N	69	2146050	5407950	N
20	2239050	5483950	N	70	2128050	5432950	N
21	2235050	5439950	N	71	2796050	6359950	N
22	2671050	6418950	N	72	2431050	5810950	N
23	2721050	6174950	N	73	2758050	6115950	N
24	2776050	6389950	N	74	2790050	6128950	N
25	2730050	6025950	N	75	2858050	6213950	N
26	2771050	6341950	N	76	2643050	6538950	N
27	2754050	6389950	N	77	2497050	6018950	N
28	2339050	5793950	Y	78	2766050	6214950	Y
29	2155050	5532950	Y	79	2712050	6437950	N
30	2524050	5948950	N	80	2383050	5750950	N
31	2556050	6628950	N	81	2281050	5610950	N
32	2716050	6282950	N	82	2319050	5682950	N
33	2942050	6276950	N	83	2294050	5681950	N
34	2800050	6256950	N	84	2242050	5497950	N
35	2519050	6708950	N	85	2907050	6327950	N
36	2697050	6304950	N	86	2385050	5864950	N
37	2510050	5885950	N	87	2726050	6386950	N
38	2232050	5574950	N	88	2376050	5745950	N
39	2304050	5760950	Y	89	2297050	5677950	N
40	2116050	5361950	Y	90	2648050	6555950	N
41	2123050	5625950	Y	91	2532050	5910950	N
42	2435050	5837950	Y	92	2598050	6583950	N
43	2560050	5951950	N	93	2886050	6335950	N
44	2500050	5985950	N	94	2236050	5598950	N
45	2264050	5701950	N	95	2731050	6384950	N
46	2730050	6542950	N	96	2487050	6740950	Y
47	2803050	6347950	N	97	2736050	6098950	N
48	2487050	5748950	N	98	2053050	5524950	Y
49	2075050	5509950	Y	99	2868050	6241950	N
50	2608050	6598950	N	100	2191050	5603950	N

SURVEY NO.	EASTING	NORTHING	DOC	SURVEY NO.	EASTING	NORTHING	DOC
101	2173050	5616950	Y	151	2621050	6561950	N
102	2415050	5821950	Y	152	2581050	6675950	N
103	2678050	6143950	N	153	2837050	6337950	N
104	2351050	5697950	N	154	2936050	6251950	N
105	2766050	6441950	N	155	2694050	6395950	N
106	2228050	5559950	N	156	2625050	6195950	N
107	2486050	6048950	N	157	2184050	5438950	N
108	2134050	5457950	N	158	2372050	5663950	N
109	2800050	6317950	N	159	2060050	5451950	Y
110	2505050	5928950	Y	160	2640050	6250950	N
111	2494050	5819950	N	161	2286050	5558950	N
112	2525050	5952950	Y	162	2846050	6257950	Y
113	2729050	6215950	Y	163	2692050	6052950	N
114	2222050	5615950	N	164	2758050	6388950	N
115	2268050	5722950	Y	165	2734050	6335950	N
116	2519050	5983950	N	166	2161050	5404950	N
117	2766050	6074950	N	167	2690050	6420950	N
118	2168050	5543950	N	168	2533050	5899950	N
119	2966050	6364950	N	169	2252050	5535950	N
120	2143050	5349950	N	170	2247050	5517950	N
121	2729050	6405950	N	171	2076050	5483950	Y
122	2634050	6228950	N	172	2126050	5423950	N
123	2616050	6202950	N	173	2156050	5417950	N
124	2804050	6179950	N	174	2568050	5999950	N
125	2294050	5684950	N	175	2206050	5396950	Y
126	2742050	6488950	N	176	2461050	6039950	Y
127	2442050	5923950	Y	177	2553050	6660950	N
128	2510050	5912950	Y	178	2610050	6231950	N
129	2128050	5437950	N	179	2942050	6342950	Y
130	2618050	6216950	N	180	2747050	6106950	N
131	2737050	6049950	N	181	2268050	5635950	N
132	2279050	5614950	N	182	2381050	5670950	N
133	2560050	5896950	N	183	2270050	5699950	N
134	2841050	6209950	N	184	2855050	6336950	N
135	2263050	5476950	N	185	2729050	6555950	Y
136	2473050	5795950	N	186	2843050	6177950	N
137	2985050	6378950	N	187	2324050	5743950	Y
138	2906050	6315950	N	188	2073050	5480950	Y
139	2101050	5335950	Y	189	2799050	6278950	N
140	2306050	5542950	N	190	2066050	5500950	Y
141	2555050	6667950	Y	191	2168050	5603950	N
142	2319050	5772950	Y	192	2062050	5472950	Y
143	2839050	6312950	N	193	2543050	5883950	N
144	2278050	5493950	N	194	2210050	5641950	Y
145	2552050	6639950	N	195	2228050	5563950	N
146	2267050	5700950	N	196	2638050	6627950	N
147	2289050	5593950	N	197	2169050	5618950	Y
148	2180050	5485950	N	198	2621050	6528950	N
149	2183050	5485950	N	199	2272050	5455950	N
150	2707050	6425950	N	200	2677050	6348950	N

Appendix 2

CALCULATION OF TRAP-CATCH INDEX CORRECTION GRAPHS FROM THE GENERALISED ADDITIVE MODELS (GAMS)

While there are excellent reasons to use logistic regressions to model trap-catch rates, they suffer from the drawback of being difficult to interpret. Nevertheless, the regression models can be translated back into TCI probabilities or percentages. A logistic model is typically used to model probabilities, which necessarily need to be in the range 0 to 1. To keep the prediction of the probability within this range, instead of modelling the probability of something happening (i.e. a possum getting caught in a trap) we modelled the logit, which is the natural log of the probability of it happening.

Let p = proportion of trap nights with possums, then:

$$\text{logit} = \ln [\, p \,/\, (1 - p) \,]$$

One of the difficulties in trying to understand seasonal or trap set-type effects is that you have a predicted logit value for one effect and a different logit for the other effect. Therefore, let logit1 be the winter model and logit2 be the summer model. We then find the difference between them (on the logit scale):

$$\text{logit2} = \text{logit1} + d$$

where d is the difference between the two curves in the additive predictor scale.

Substituting into the equation for logits:

$$\ln [\, p2 \,/\, (1 - p2) \,] = \ln [\, p1 \,/\, (1 - p1) \,] + d$$

and solving for $p2$, gives

$$p2 = [\, p1 * \exp(d) \,] \,/\, [\, 1 - p1 + p2 * \exp(d) \,]$$

This tells us how the summer TCI ($p2$) should relate to the winter TCI ($p1$). This formula was used to generate the curves in Fig. 8. The d values used in the equations were obtained from the model in Fig. 4 by reading the difference between summer and winter (or between ground- and raised-sets) on the y-axis. This gave the following values:

ground = 0.1 raised = –0.8 d = –0.9

winter = –0.2 summer = 0.4 d = 0.6

The axes were multiplied by 100 to convert the probabilities into % TCI.

Appendix 3

MONITORING SURVEY DATA

POTENTIAL DATA FORMATS, AN EXAMPLE OF THE DATA AND, WHERE APPLICABLE, A BRIEF EXPLANATION OF THE VARIABLE WITH RESPECT TO RECORDING AND REPORTING A WIDE RANGE OF INFORMATION FROM A POSSUM POPULATION MONITORING SURVEY.

VARIABLE	POTENTIAL FORMAT*	EXAMPLE	EXPLANATION/NOTES
Area name	Text (20)	Taramakau Flat	Should be unique
Size of the management area (ha)	Numeric (8)	1420	
Size of the treatment area (ha)	Numeric (8)	760	
Name of person in charge of designing the monitoring/key management contact	Text (20)	John Smith	
Name of person in charge of supervising the monitoring/key field operative contact	Text (20)	Michael Jones	
Survey type (pre-control, post-control, maintenance, trend)	Text (15)	Post	Default = post
Start date of survey	Date (10)	10/08/01	
Finish date of survey	Date (10)	18/09/01	
Number of lines in the survey	Numeric (3)	46	
Was a standard line bearing used?	Y/N	Y	Default = Y
Line bearing (if only one used)	Numeric (3)	140	
Was a map with trap-line locations filed?	Y/N	Y	Default = Y
NZMS 260 series map sheet name	Text (5)	T17	
Number of traps per line	Numeric (2)	10	Default = 10
Trap type used	Text (10)	Victor no. 1 hard	
Set type used (ground/raised)	Text (10)	Raised	Default = ground
Device name (for raised-set traps)	Text (15)	Scott board	
Set height (cm, for raised-set traps)	Numeric (3)	70	
Between-trap spacing (m)	Numeric (2)	20	Default = 20
Was lure used?	Y/N	Y	Default = Y
Lure type	Text (15)	Flour	Default = flour and icing sugar
Number of trap-nights monitored (for the survey)	Numeric (3)	3	Default = 3
Were the trap nights consecutive?	Y/N	Y	Default = Y
Weather for night 1†	Text (50)	Fine, warm, light wind	Precipitation, temperature, wind
Weather for night 2†	Text (50)	Fine, warm, no wind	Precipitation, temperature, wind
Weather for night 3†	Text (50)	Fine, cool, light wind	Precipitation, temperature, wind

* The number in brackets refers to the size of that variable's field.

† This can be scored on some simple subjective scale.

Using software such as MS Access, some or all of the possible options for some of the text variables can be pre-entered and presented as drop-down menus where the cursor is in that field. This not only saves time but also eliminates the possibility of typing errors. For example, for the 'set type used' variable, the drop-down menu would include 'ground' and 'raised'.

Appendix 4

TRAP-LINE DATA

POTENTIAL DATA FORMATS, AN EXAMPLE OF THE DATA AND, WHERE APPLICABLE, A BRIEF EXPLANATION OF THE VARIABLE WITH RESPECT TO RECORDING AND REPORTING POSSUM POPULATION MONITORING DATA FROM INDIVIDUAL TRAP LINES.

VARIABLE	POTENTIAL FORMAT*	EXAMPLE	EXPLANATION/NOTES
Area name	Text (20)	Taramakau	Same as in survey data table
Name of person in charge of conducting the monitoring/key field operative contact	Text (20)	Michael Jones	
Start date of survey	Date (10)	10/08/01	Same as in survey data table
Trap-line number	Numeric (3)	25	
7-digit easting†	Numeric (7)	2690589	
7-digit northing†	Numeric (7)	6370266	
Direction of line	Numeric (3)	210	
Number of trap nights (for the line)	Numeric (3)	3	Default = 3
Number of possums caught	Numeric (2)	3	Default = 0
Number of sprung traps (possum)	Numeric (2)	1	Default = 0
Number of sprung traps (unknown)	Numeric (2)	2	Default = 0
Number of rats caught	Numeric (2)	2	Default = 0
Number of other non-targets caught	Numeric (2)	0	Default = 0
List other non-targets	Text (50)	Hedgehog (2)	Species (and number)

* The number in brackets refers to the size of that variable's field.

† Trap-line start points must be recorded using a global positioning system (GPS) device, and the easting and northing coordinates need to conform to the New Zealand Geodetic Datum 1949 with the units of measurement in metric.

Appendix 5

CONTROL OPERATION DATA

POTENTIAL DATA FORMATS, AN EXAMPLE OF THE DATA AND, WHERE APPLICABLE, A BRIEF EXPLANATION OF THE VARIABLE WITH RESPECT TO RECORDING AND REPORTING A WIDE RANGE OF INFORMATION FROM A POSSUM CONTROL OPERATION

VARIABLE	POTENTIAL FORMAT*	EXAMPLE	EXPLANATION/NOTES
Area name	Text (20)	Taramakau	Same as in survey data and trap-line data tables
Size of the management area (ha)	Numeric (8)	1420	Same as in survey data table
Size of the treatment area (ha)	Numeric (8)	760	Same as in survey data table
Start date of the control operation	Date (10)	12/08/01	
Finish date of the control operation	Date (10)	16/08/01	
Control operation type (aerial or ground)	Text (10)	Aerial	
Bait type	Text (10)	Carrot	
Was pre-feeding used?	Y/N	Y	Default = Y
Pre-feed sowing rate (if applicable)	Numeric (5)	5	
Sowing rate (kg/ha)	Numeric (5)	10	
Toxin used	Text (20)	1080	
Toxic loading (mg/kg)	Numeric (5)	0.08	

* The number in brackets refers to the size of that variable's field.