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Tussock moth eradication – a success story from New Zealand

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Abstract. Between 1996 and 1998 an eradication programme was undertaken in Auckland's eastern suburbs against the newly established lymantriid moth, *Orgyia thyellina.* The operation involved the aerial application of Btk over 4000 hectares of suburban Auckland and ground spraying of all known infested sites. Key components of the programme were: accurate definition of the infested area, quarantine action to prevent further spread, aerial and ground application of Btk, intensive monitoring using live female moths and a synthetic pheromone, strong science input to every facet of the programme, and a major communications initiative. *Orgyia thyellina* was declared eradicated in June 1998 and has not reappeared since then. Operation Ever Green, as the programme was named, was the first ever successful eradication of a forest pest established in an urban area, worldwide.

1. Introduction

On the 17 April 1996, the white spotted tussock moth, *Orgyia thyellina* (Lepidoptera: Lymantriidae) was found to be established in Auckland's eastern suburbs. The insect, native to Japan, Korea, China and Taiwan, where its hosts include oak, elm, willow, larch, apple, cherry, pear, plum, chestnut, walnut and mulberry, has three generations a year, the third generation females being flightless and laying diapausing eggs. In Auckland the final generation was emerging, mating and laying eggs on pupal cases and adjacent host plants and buildings, when the infestation was detected. The overwintering period, which would last until the spring hatch of diapausing eggs, would prove to be a bonus for scientists and managers evaluating response options and devising strategies. It gave time for strategies to be argued, field data to be collected, wide science and operational input, and the exploration of public health and community acceptance issues.

1.1. International Cooperation

The post-detection phase of the *Orgyia* programme was characterized by outstanding international cooperation, which was to continue for the duration of the operation. Lymantriid specialist, Dr Paul Schaefer of the USDA, confirmed the identification and provided much background material at very short notice. Staff at the USDA Otis Laboratory were unstinting in advice and rearing materials, and collaboration with Gerhard Gries at Simon Frazer University in Canada delivered the synthetic pheromone, critical to the successful final stages of the programme. Major contributions by overseas specialists were also made to the health impact assessment for Btk spraying.

1.2. Delineation Survey

An infestation delineation survey was initiated immediately following the detection and was completed two weeks later. It found the infestation to be confined to a 7 km^2 area, with most of the insect population within a 1 km^2 area, and focused on two 'hot spots'. To ensure an adequate buffer, the final operational area covered 40 km^2 (4000 ha) centered on the known infestation. Hundreds of larvae and pupae were present throughout residential properties, parks and reserves across a suburban area of low ridges and gullies, many containing shrubland and waste ground. The pest distribution data and host records gathered from the delineation survey were primary inputs to the deliberations of the Initial Response Group.

1.3. Initial Response Group

An Initial Response Group, which included science, government and forestry sector representation, was charged with evaluating the new establishment and recommending a course of action to the Government. The group considered all aspects of the new incursion including potential impacts on plantation, urban and indigenous forests, options for response and their associated benefits and costs, and the likelihood of success. The group recommended an attempt to eradicate the pest be undertaken. On the 22nd July 1996, the Government accepted this recommendation and Operation Ever Green was underway.

1.4. Regulatory Environment

The need to address and meet legislative and regulatory requirements in implementing the operation was recognized immediately eradication became the primary goal. The regula-

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tory environment for similar operations will be country specific, however, the generic areas to which regulations might apply are likely to be common, and need to be progressed at an early stage, so they do not impede the biologically driven operational programme.

The use of chemicals, which seemed inevitable in the Auckland situation, requires health impacts to be addressed, particularly if large numbers of people in an urban environment will be affected. The degree of exposure of the human population is likely to be the major influence on the choice of control agent and the method of application will also have its regulatory requirements, particularly if aerial application is involved. Aircraft operations may have to conform to aviation regulations. In operations such as that carried out in Auckland, project staff invariably require access to private land, sometimes against the wishes of the owner, and need appropriate authorization. To prevent the spread of a pest or disease a quarantine on the movement of host material and other risk goods may be necessary. And finally, the question of funding will arise on almost every occasion pest eradication is undertaken.

1.5. Project Management

A project management team was established by the Ministry of Forestry to oversee the eradication operation and ensure the integration of operational, scientific and public relations components. A Science Panel was set up by Government to provide independent science and technical advice to Ministers, while a Science Advisory Group was formed to work within the project on a day-to-day basis. A Community Advisory Group was charged with representing community concerns and interests, while the Ministry of Health managed the health impact assessment of aerial spraying with Btk.

The balance of this paper discusses in more detail the strategy persued, key science inputs, the operation itself, public health issues, and communication, and concludes with a discussion of the key elements contributing to its success.

2. Eradication Strategy

The eradication strategy was based on the aggressive use of Btk *(Bacillus thuringiensis* var. *kurstaki)* and was designed to be responsive to both new knowledge and the changing field situation. It would be delivered by a strongly integrated project team of science, operational and policy expertise, dedicated to vigorous community interaction and openness (Hosking and Holden, 1998).

The strategy incorporated six key elements:

- definition of infestation
- prevention of spread
- application of pesticide
- intensive monitoring
- strong science input
- communication initiative

2.1. Infestation Zone Definition

The extent of the infestation was determined using the classical delimiting survey approach of extensive searching over a large area, with continual redefinition as new infestations were identified. The risk of the programme being subverted by undetected populations outside the treatment area was well recognised.

The survey began by including the greater Auckland area, and focussed on easily accessible known hosts in public parks and reserves, as well as suburban gardens. Teams of trained surveyors recorded all sites visited and plant species examined. As the margins of the infestation became better defined, intensive searches on a property by property basis were undertaken with particular attention being paid to outlier detections. The infestation was found to extend over approximately 7 km^2, an area which did not change in the course of the programme. A treatment buffer zone extended this area to 40 km^2. The insect population information collected during the survey strongly suggested the establishment of *Orgyia* had occurred within a 3 km^2 'hot' zone in Auckland's eastern suburbs.

2.2. Prevention of Spread

The risk of spread by natural dispersal was low due to the appearance of flightless female moths and the onset of the overwintering period. However, the risk of insects being carried out of the zone by human activity was very real, and a number of restrictive measures were put in place to prevent such an occurrence.

As well as pupating and laying eggs on vegetation, *Orgyia* utilizes sites on buildings, garden furniture, fences etc., any of which might be moved out of the area. Field staff followed up on all possible household movements from the infested area with site visits, and carried out premovement inspections of buildings and household effects. However, the greatest risk of spread was considered to be from the movement of garden waste and its disposal outside the area. This risk was tackled by providing a disposal site within the treatment area, controlled by programme staff, and open to people living within the 7 km^2 infested zone.

2.3. Btk Application

The primary response strategy was the aerial and ground application of *Bacillus thuringiensis* var. *kurstaki* (Btk). The choice of this biopesticide was relatively easy given its past use against gypsy moth in the USA, its long history of use without non-target effects, its approval for use in organic production systems, its high specificity to Lepidoptera, and its availability in the quantity and formulation (Foray 48B) required.

The Btk was applied across the 4000 ha treatment zone by DC6 aircraft at 5 litre/ha, with all known infestations also being ground sprayed. To ensure the susceptible first 3 larval instars received at least 2 applications, spray intervals could not exceed 7 days.

2.4. Monitoring

All stages of the field operation were subjected to rigorous monitoring, including Btk deposition, insect field population response, and human health effects. Spray deposition data were collected for each aerial application and included droplet size distribution. Early sprays also included bioassays using field exposed rose plants.

The insect field population was monitored through direct observation of known infested sites, and through a network of caged live female moths in sticky traps. Male attraction by caged females was replaced by pheromone traps when a synthetic pheromone became available. Human health impacts were monitored through a dedicated health surveillance programme. All monitoring was formalized through its specification within the Operation Ever Green operating plan.

2.5. Science

Science input was considered a key element of the strategy and focused on the development of specific tools such as pheromones, and population models, and the application of the best science to ensure the integrity of operational decisions.

Science input was delivered through a Ministerial Science Panel and a Science Advisory Group, which included expertise from a number of universities and research institutes as well as private research organizations. Specialist areas represented within these groups included entomology, insect pathology, pesticide application, modelling and biometrics, pheromone research, pesticides, botany and public health.

2.6. Communications

The ability to undertake the eradication operation was dependant on its acceptance by the affected community. A communication strategy was built around openness and responsiveness with strong interaction with people and organizations within the spray area. The primary objective of the communication strategy was to create a climate of acceptance so that the operations team and scientists could get on with their jobs. The eradication operation was intrusive and prolonged and a vigorous communication initiative was considered essential to the implementation of the best possible programme on the ground.

3. Scientific Support

New Zealand's forest protection strategy has historically embraced strong science input, primarily through the Forest Health Group of Forest Research. Once again this group formed the nucleus of science support for Operation Ever Green but the programme spread its net, both nationally and internationally, far wider than Forest Research. It brought together a range of specialists including entomologists, insect pathologists, population modellers, spray application experts, pheromone researchers, botanists, soil scientists and medical and public health experts. The science support was delivered by three main avenues:

- an overview by a Science Panel,
- delivery and day-to-day management through a Science Advisory Group, and
- specific science inputs to the programme.

3.1. Science Panel

A panel of experts was established by the Ministry for Research Science and Technology to evaluate the science on which the eradication programme was based, and monitor the effectiveness of science input. The Panel was only partially successful in its proposed role largely because it was divorced from the operation on the ground, and it became increasingly a playing field for interdepartmental politics and scientific one upmanship. It lacked strong leadership and clear vision and its role was eventually overtaken by the Science Advisory Group.

3.2. Science Advisory Group

This group was established to work as an integral part of the operational team providing scientific rigour, advice and evaluation of all aspects of the programme. It included a wide range of scientific expertise including staff directly involved in the programme. Most importantly its open meetings included operational staff, and worked by consensus decision making. Equally important, the committee met every 2 or 3 weeks in the course of the operation to review data and strategies and debate new initiatives. All decisions were documented and the underlying reasoning recorded. The group undoubtedly made a major contribution to the programme's ultimate success.

3.3. Specific Science Inputs

As well as the ongoing scientific evaluation of the strategy, the programme required a number of specific science initiatives, delivering research outputs under pressure, for immediate incorporation into the field operation.

3.3.1. Feeding trials and insect rearing. The maintenance of a rearing colony delivering thousands of insects a week for host testing, insecticide evaluation, spray bioassays, pheromone development etc., was in itself a major science initiative. Insects were reared on artificial diets and foliage in a controlled environment quarantine facility. The rearing of thousands of larvae as a continuous process posed major logistical difficulties in obtaining fresh foliage and fine tuning the artificial diet. The crowded rearing facilities inevitably led to a virus outbreak, which put the major colony at risk. The problem was only overcome by line rearing of individual larvae and meticulous attention to sterile procedures. The quarantine population was arguably the project's greatest scientific asset, without it all monitoring would have ceased and the evaluation of progress towards eradication would not have been possible.

The rearing programme was integrated with host feeding trials designed to determine the risk from the insect to forestry, horticulture and the environment. The susceptibility of indigenous plant species was of particular interest. Host preference centered on the Rosaceae, rose, apple and raspberry being most favoured, but the insect completed its development on hosts as diverse as *Pinus radiata* and *Eucalyptus nitens.*

3.3.2. Embryological Development. Egg hatch, and resulting recruitment of caterpillars to the population, was the primary driver of the frequency and duration of aerial spraying. The hoped for synchronous egg hatch could not be guaranteed, and in fact failed to occur. Prior to egg hatch a study monitoring the embryological development of the field population at weekly intervals was initiated. The study was used to predict the proportion and development stage of the population yet to hatch, and ultimately when spraying could cease. Unfortunately, the egg masses hatched over a 70-day period which led to a much extended spray programme.

3.3.3. Btk Persistence. The persistence of Btk activity on foliage was important in determining the frequency of sprays. As a general rule a 7-day interval was aimed for, modified according to weather conditions, because of its effect on Btk on foliage, and its likely impact on the spray operation. Bioassays, and measurement of Btk activity on foliage, suggested that the 7-day interval could have been considerably extended under most weather conditions. Late in the programme researchers developed techniques which might be used in future programmes, for 'just in time' spray application. A biological, rather than an arbitrary time interval, spray timing strategy might have halved the number of sprays in the white spotted tussock moth programme.

3.3.4. Population Modelling. Location data for all detections, by both visual searching and trap catches, was used to model the population distribution and develop probability contours for different levels of infestation. Models were constructed for individual seasons and for the total known period of the infestation. The probability contours were used to define treatment zones, in particular that area subjected to helicopter spraying of Btk in the latter part of the programme. In hindsight, it was recognised that spatial positioning of site information could have been improved had GPS technology been used. Any similar operation in the future would have all site information tied to GPS coordinates, including visits and activities on individual sites, vegetation, pest population, trap catches etc.

3.3.5. Pheromone Development. For most new incursions visual searching as a method for defining and monitoring infestations is of limited value, and is labour intensive, particularly when populations of the target species are low. However, in most instances it is the only technique available in the early stages of incursion management. Where the incursion involves an insect known to utilize pheromones for mating attraction, the use of natural and synthetic attractants can introduce much greater rigour and confidence into the detection and monitoring strategy. In the case of white spotted tussock moth, lymantriids were well known for their use of pheromones and a vigorous research programme was initiated to identify and synthesize the attractant. While this process was going on, live caged females were used in necessarily limited numbers, because of their limited availability and the added risk of using live insects.

Rapid progress on pheromone identification was made through the outstanding collaboration of John Clearwater in New Zealand and Gerhard Grise at Simon Frazer University in Canada (Gries *et al.*, 1999). The abdominal tips of female moths were extracted in hexane and the supernatant shipped to Canada. Analysis and synthesis was carried out in Canada and synthetic chemicals returned to New Zealand for testing, initially in a wind tunnel and later in a large field cage. It took less than 11 months for this research team to produce a synthetic lure that outperformed female moths! Thousands of commercial trap lures, baited with a mixture of (z)-6-Heneicosen-11-one and (z)-6-Heneicosen-9-one (thyellinone), were deployed throughout Auckland's eastern suburbs over the summer of 1997 – 1998.

3.3.6. Spray Application. The spraying of Btk involved the use of three aircraft types and two configurations of ground sprayers, each requiring its own specification to ensure maximum coverage of all vegetation and most effective droplet size. For aerial spraying the most effective bout width (separation between flight lines), and a droplet spectrum which minimized very small droplets (less than 50 microns), were critical to success. Controlled spraying trials were undertaken to examine actual spray deposition relative to that predicted by computer software (Ray *et al.*, 1999). Spray droplet size was measured to determine an equipment setup which would deliver droplets in the 50 – 150 micron range. Using this data a specification was developed for each aircraft of bout width and spray equipment setup which would produce spray deposition within an acceptable coefficient of variation.

4. The Operation

4.1. Spray Application

The field operation involved the aerial and ground application of Foray 48B, a commercial formulation of Btk used against gypsy moth in the United States. The pesticide was applied over an area of 4000 hectares, using a DC6 aircraft fitted with a conventional boom and nozzle spray system, undiluted at a rate of 5ℓ/ha. The aircraft flew at a height of 60 m, and at a ground speed of 200 knots, to give an effective swath width of 120 metres. A total of 9 spray applications were made at approximately weekly intervals between October and December 1996. A helicopter operation, tackling non-residential gullies, cliffs and bush areas, where spray deposition was likely to be inadequate, was integrated with the DC6 spraying. A Hughes 500C aircraft fitted with a boom and nozzle spray system was used, delivering a nominal 20 ℓ/ha of Foray 48B diluted 1:4 with water. In the final stages of the operation the aerial spray focused on a 300 ha 'hot zone' using a BK 117 helicopter applying undiluted Foray 48B through AU5000 rotary atomisers. A total of 14 such sprays were applied between January and April 1997.

Ground spraying of all known infested sites (in excess of 500 properties) was carried out between October 1996 and April 1997 in concert with aerial spraying, effectively doubling spray application to the 'hot zone'. The spray was applied using mistblowers, initially diluted 1:9 with water through a standard wind shear atomizer. Towards the end of the programme undiluted Foray 48B was applied through AU8000 rotary atomisers.

4.1.1. Aircraft Swath Pattern Calibration. A computer-based aerial application model, FSCBG (Teske *et al.*, 1993), was used to identify the bout width giving a spray deposit with a coefficient of variation (CV) of 30%. In the field a line of Mylar traps was laid out at right angles to the wind, and two others parallel to the wind and 50 m apart. The aircraft was flown over the mid point of the line spraying to the operational specification. Trap deposits were measured using standard methods, and the computer software SpraySafe Manager (Ray *et al.*, 1999) used to determine the relationship between measured swath pattern and the calculated CV of deposit as the bout width was systematically varied.

4.1.2. Spray Droplet Sizing. Research by Bryan and Yendol (1988) had shown that droplets of Btk in the range 50–150 microns were the most effective against gypsy moth larvae. Spray equipment was set up to produce droplet spectra in which the size of droplets lay within this range by exposing magnesium oxide coated microscope slides (May 1950) and measuring the resulting droplets.

4.1.3. Operational Spray Deposit Monitoring. Spray droplets from aerial spray operations were collected on bond paper stapled to cardboard cards. The traps were laid, in large open areas, at approximately 10m intervals perpendicular to flight lines. After spraying traps were returned to the laboratory and treated using standard methods to reveal spray droplets. Droplets in five sample areas totalling 31.25 cm^2 were counted on each trap.

4.1.4. Bioassays. Early in the spray programme large numbers of potted roses and young pine seedlings were exposed throughout the spray zone to directly measure the efficacy of spray in a wide range of situations. Plants were exposed in the open, under vegetation, under the eves of buildings, in the lee of buildings, and in any other situations where deposition might be expected to be less than desirable. After spraying, plants were returned to a quarantine facility and larvae of 3^{rd} instar or less allowed to feed on them.

The combination of pre-spray trials and operational monitoring allowed careful management and adjustment of the field operation to ensure the highest possible impact on the target pest.

4.2. Insect Rearing Programme

The insect rearing programme was central to the success of the field operation, providing the basic material for insecticide efficacy trials, live female moth monitoring capability, pheromone development and evaluation, and host risk assessment. Without a continuous and adequate supply of all stages of the insect, the field operation would have been seriously compromised.

The primary rearing facility was the Forest Research Quarantine Laboratory in Rotorua, 250 km south of the operational area. Field collected egg batches were used to initiate the colony with larvae being fed fresh foliage, primarily rose, apple, plum *(Rosaceae)* and oak *(Fagaceae).* However, with the colony producing over 2000 pupae a week the move to an artificial diet became a priority. A move that was given added impetus by the emergence of a cytoplasmic polyhedral viral infection which collapsed the colony to delivering just 300 pupae a week. The artificial diet used for gypsy moth, *Lymantria dispar,* proved suitable for *Orgyia thyellina,* and with support from the United States Department of Agriculture, the colony was revived to the production of about 5000 insects a week.

4.2.1. Insecticide efficacy. An evaluation of the efficacy of Btk against *Orgyia thyellina* was carried out under laboratory conditions for all insect stages. The susceptibility of different larval instars was important in determining the interval between sprays in the field. It was found that susceptibility decreased after the 3rd larval instar when exposed at the recommended rate of 5 ℓ (60 BIU) per hectare for Foray 48B against gypsy moth. To ensure all larvae received at least two applications of Btk before they reached the 4th instar, a spray interval of 7 to 10 days was required. The insecticide Mimic (Tebufenozide), an insect moulting hormone mimic, was also evaluated but never used in the programme.

4.2.2. Live Moth monitoring. While work progressed on the identification and development of a synthetic pheromone, field population monitoring depended on the deployment of caged live female moths. The programme aimed to maintain an array of 350 traps across the known infested area, with moths replenished every 3 to 5 days. The supply of female moths for field monitoring was a priority for the rearing programme over the 1996–97 spring and summer. Pupae were segregated by sex in the rearing facility and the females transported to a secure Auckland laboratory within the spray zone, and the moths allowed to emerge. The female moths were wing-clipped for greater security and inserted singly into steel mesh cages which were then deployed in sticky Delta traps.

Monitoring using live female moths was severely reduced when the virus attacked the rearing colony, with only a dozen traps maintained in the field. As progress was made in the development of a synthetic pheromone, large numbers of both male and female moths were used in the evaluation of synthesized products. A secure field cage was used to compare the attractiveness of compounds with that of caged females using free flying male moths. With the production of the synthetic pheromone, all caged female moths were withdrawn.

4.2.3. Host assessment. Determining the likely impact of *O. thyellina* on major components of New Zealand's exotic and indigenous flora was a key objective of the insect rearing programme. Information on host range and impact might become critical to future strategies if early success in eradication was not achieved. The host testing programme used standard protocols for determining host specificity, and focused first on New Zealand relatives of known host groups such as the Rosaceae, Ericaceae and Moraceae. It also evaluated important indigenous, commercial and amenity forestry species and other cultivated plants. By the end of the programme the host range extended to over 40 species of varying preference, with plants most at risk in the families; Aceraceae, Fagaceae, Salicaceae, Betulaceae, Rosaceae and Fabaceae.

5. Public Health

A number of public health issues needed to be addressed before the proposed strategy could proceed. Although the obvious issue was the safety of Btk, there were a number of other public health concerns associated with the programme. There were risks from the operation of aircraft at low altitude over populated areas, there were concerns at the widespread deployment of synthetic sex attractants, and there were public health risks from the moth itself.

5.1. Risks from Btk

An environmental impact assessment (Ministry of Forestry 1996) and a health risk assessment (Jenner Consultants Ltd

1996) underpinned the public health strategy. There was also a formal requirement by Government for health surveillance to be undertaken. The health risk assessment incorporated a plan for risk management and communication on public health matters. Based on 30 years use of Btk against gypsy moth in the USA, and its widespread use in agriculture and home gardens, the pesticide was considered very low risk to humans. Two major clinical studies of human populations exposed to aerial application of Btk, one in Oregon in 1985–86 (Green *et al.*, 1990) and the other in Vancouver in 1992 (Noble *et al.*, 1992), found no adverse effects on the exposed communities. The inert ingredients used in the formulation of Foray 48B, were similarly considered unlikely to produce any adverse effects.

5.2. Health Surveillance

The health surveillance programme was made up of five main components; self reported health concerns, sentinel general medical practitioners, review of other health data, birth outcomes, and a register of exposure. Self reported health concerns were followed up by a process of interview, additional medical information and medical review. A total of 375 reports were followed up but the process did not identify any significant diseases attributable to the spraying. The most frequently reported single concern was 'fear of unspecified future disease'. Two medical practices, one at the heart of the infested area and one near the perimeter of the spray zone, participated in a review of patient notes and computer practice records for 'before', 'during DC6', 'during helicopter' and 'after' spraying. The review revealed no adverse patterns of consultation, in particular in relation to asthma, chronic fatigue syndrome, auto immune disorders, lower respiratory problems, and headache, eye, skin, or upper respiratory symptoms. Other health data reviewed related to accidents, anaphylaxis, birth defects, birth weight and gestational age, measles, miningococial disease and infections with Btk. No anomalies associated with the spray programme were found. A specific study was made of birth outcomes due to concerns raised in the media of babies being born too soon and too small. Such concerns were shown to be unfounded. Because of widespread community concern about the potential of future diseases, a voluntary register was established for all individuals exposed to the spray, and placed in the National Archives to assist any future scientific health studies. The health surveillance programme revealed no adverse health patterns at a population level.

5.3. Other Risks

The development and deployment of a synthetic pheromone in thousands of Delta traps required some explanation to the local community, already sensitive to chemical exposure. However, the very small amounts of an essentially naturally occurring chemical allayed any fears and no resistance to the programme occurred. An important public health risk was that posed by the insect itself. The long hairs of caterpillars cause eye, skin and respiratory irritation to many people on contact with old larval skins and pupal cases. The urticating hairs can produce hypersensitivity after repeated exposure and some research workers managing the primary colony at Forest Research had to be withdrawn from the programme because of adverse reaction. High populations of lymantriid moths in some parts of the USA and Europe have in the past led to forest closures to limit the risk to the public.

6. Communication

Communication was recognised as a key element of the eradication strategy from the earliest planning stage. Lack of public support for the proposed programme was seen as the greatest threat to its successful implementation. It was also recognised that the risk of support being withdrawn would probably rise the longer activity continued. For this reason, communication was an integral part of project planning and management.

6.1. Communication Strategy

The communications strategy had to reach a diverse range of audiences within the 80,000 directly affected residents, such as those with specific health concerns, school children, non-English speakers and local authorities. It also had to address the wider community including news media, health authorities, politicians, environmental groups and New Zealanders as a whole.

The objectives of the communication strategy were deceptively simple:

- To ensure that all spray zone residents were:
  - clear that the pest was a real threat,
  - reassured of the safety of the operation,
  - fully informed of developments, and
  - supportive of the spraying.
- To create a climate of acceptance so that the operations team and scientists could get on with their jobs.

These objectives would only be met by a strategy comprehensive in its scope but flexible enough to accommodate, and respond to, the inevitable operational glitches, indeterminate duration of the programme, and the possibility the news from the field would not always be good. The then Minister of Forests, John Falloon, characterized the principle of openness when he told a community meeting 'whatever I know, you will know'. No information would be withheld, either good or bad. No attempt would be made to control or direct debate, and research results, impact assessments, and progress monitoring, would not only be made freely available but would be actively disseminated.

Inclusiveness and cooperation would characterise the relationship between the project team and the diverse community groups affected by the operation. The objective would be to generate ownership and acceptance of a common goal so that those affected would feel they were making a contribution through the inconvenience and restrictions they had imposed upon them. The cooperation principle was given added profile by a requirement that those staff and contractors seconded to the operation were to live, and be visible, within the spray zone.

6.2. The Implementation

To determine if appropriate concerns and issues were being addressed, a telephone survey was undertaken of residents in the spray zone, the results reinforcing the proposed strategy. Further, in order to gain maximum local input, and hopefully engender strong support, an independent Community Advisory Group was established.

Technical reports emanating from the operation and research programmes, such as the Environmental and Health Risk Assessments, were made widely available, and their findings summarized in a dedicated series of information leaflets under the banner *Inform*. This series was also used to discuss specific technical issues such as pheromone trapping, the choice of Btk, and health issues. Posters of the insect's life cycle, biological data, and resource materials were produced for schools. Displays covering all aspects of the programme were assembled for use in libraries, malls and supermarkets, and to provide supporting information for public meetings. Health authorities assisted in the preparation of publications specific to health issues. Billboards were rented at key roadside junctions to advise when spraying would be undertaken, and posters were put up throughout the spray zone. Individually addressed letters were sent to residents subjected to ground spraying and aircraft banners indicating spray intentions on 'spray days' were made.

Both the national and local profile of the programme was strongly influenced by the interest of the news media. A comprehensive media initiative was embedded within the communication strategy and focused on making the programme as accessible as possible to the news media through press releases, briefings and interviews. A public release of 1000 specially bred butterflies, to counter the impact of Btk on existing populations, allowed the media to focus on the highly specific nature of the pesticide being used.

A free phone line provided three standard interactive response messages and frequent updates of when spraying would occur and what areas would be affected. Callers could also speak directly with trained operators who could offer specialist callback by doctors, field staff, or members of the science team. Automatic fax lists were developed for a wide range of groups and individuals, to advise of spray timetables and last minute changes, and allow exposure to be minimized or avoided by leaving the spray area. In the later stages of the programme a website was established which carried frequently updated and extensive information on the eradication programme.

With the increase in aerial sprays from the originally proposed five to twenty-three, along with the addition of extensive and repeated ground spraying, there was no surprise at some opposition becoming evident as the programme progressed. Indeed, strident opposition had been expected from the beginning. This opposition involved a small fraction of the affected population and focused primarily on the proposed spray programme for the 1997-98 summer. The science group advising the programme believed there was a possibility a small, but undetected, residual population of moths existed, and that pre-emptive spraying should be undertaken for the spring emergence. Concerned residents expressed their views through a group having its origins in Canada, the Society Targeting Overuse of Pesticides (STOP). As a result of representations from STOP, the Science Advisory Group agreed to support the slightly more risky strategy of intensive pheromone trapping to identify any residual population, before contemplating further spraying.

6.3. The Outcome

In June 1998, based on all the monitoring and scientific evidence, the white spotted tussock moth was declared eradicated from the known infested area and a final newsletter expressing the thanks of the project team was sent to affected residents. No evidence of the persistence of the insect, either within or outside of this area, has been found since that time. There is no doubt the communication strategy made a critical contribution to the success of the programme. The key attributes which made this contribution possible were; the integration of the communication strategy into the overall programme at the highest level, the allocation of realistic resources for its implementation, the responsiveness and flexibility of the programme itself to address community concerns, and an openness which ensured full disclosure and no hidden agendas.

7. Elements of Success

7.1. Commitment and Leadership

The programme was led by example, no task was considered too hard and when battles were fought they were fought from the top (Hosking 1998). Dynamic leadership enabled a rapid response without enthusiasm being sapped by the fear of failure. People thrived on their commitment to the team and the programme, unclouded by personal agendas or allegiances.

7.2. Quality Science

Operation Ever Green sought out and welcomed the highest quality science and technical input from both within New Zealand and overseas. The Science Advisory Group included university and Government research institute staff, specialists from private companies, and independent consultants. All gave the needs of the programme the highest priority, coming together at a day's notice when urgent decisions had to be made.

7.3. Operational Capability

Core staff for Operation Ever Green came from the Ministry of Forestry and were familiar with forestry scale operations of aerial spraying, pest and disease survey, and operation monitoring. This experience proved invaluable to the field operation and the logistics of getting an eradication strategy underway, with links already established to science expertise in such areas as aerial spray application, population monitoring, insect rearing, pesticide evaluation, and survey design. This experience was critical in allowing a rapid and confident response.

7.4. Communication

Eradication programmes in populated areas are virtually impossible without community support. Operation Ever Green was in constant dialogue with the affected community, as well as the affected forestry and agriculture sectors, and the Government. A lot of energy was focused on listening, and providing information, to the community. Despite the inconvenience of quarantine restrictions and repeated spraying, the community remained supportive of the programme until the end.

And finally, it was people who made Operation Ever Green the success it was. From the spray truck driver who arrived half an hour early just to make sure the aircraft wasn't held up, to the basketball team that folded the pheromone traps, from international colleagues who moved pheromone identification to the top of their list, to the medical practitioners who allowed monitoring of patient records, and of course the people of Auckland's eastern suburbs who put the national interest ahead of local sacrifices.

7.5. Postscript

One of the disappointments of Operation Ever Green was the failure to gain recognition of this outstanding achievement, particularly at a political level. A failure reflected in the lack of Government support for the publication of a comprehensive monograph as a reference for future incursion response both within New Zealand and for colleagues overseas. The present paper goes some way towards addressing this deficiency, but does not include the level of detail a more comprehensive work could offer to those tackling similar problems in the future.

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