



The New Zealand Perspective: Evidence Reporting using Bayesian Statistics

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Specialist Science Solutions

Manaaki Tangata Taiao Hoki
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Forensic Science in New Zealand

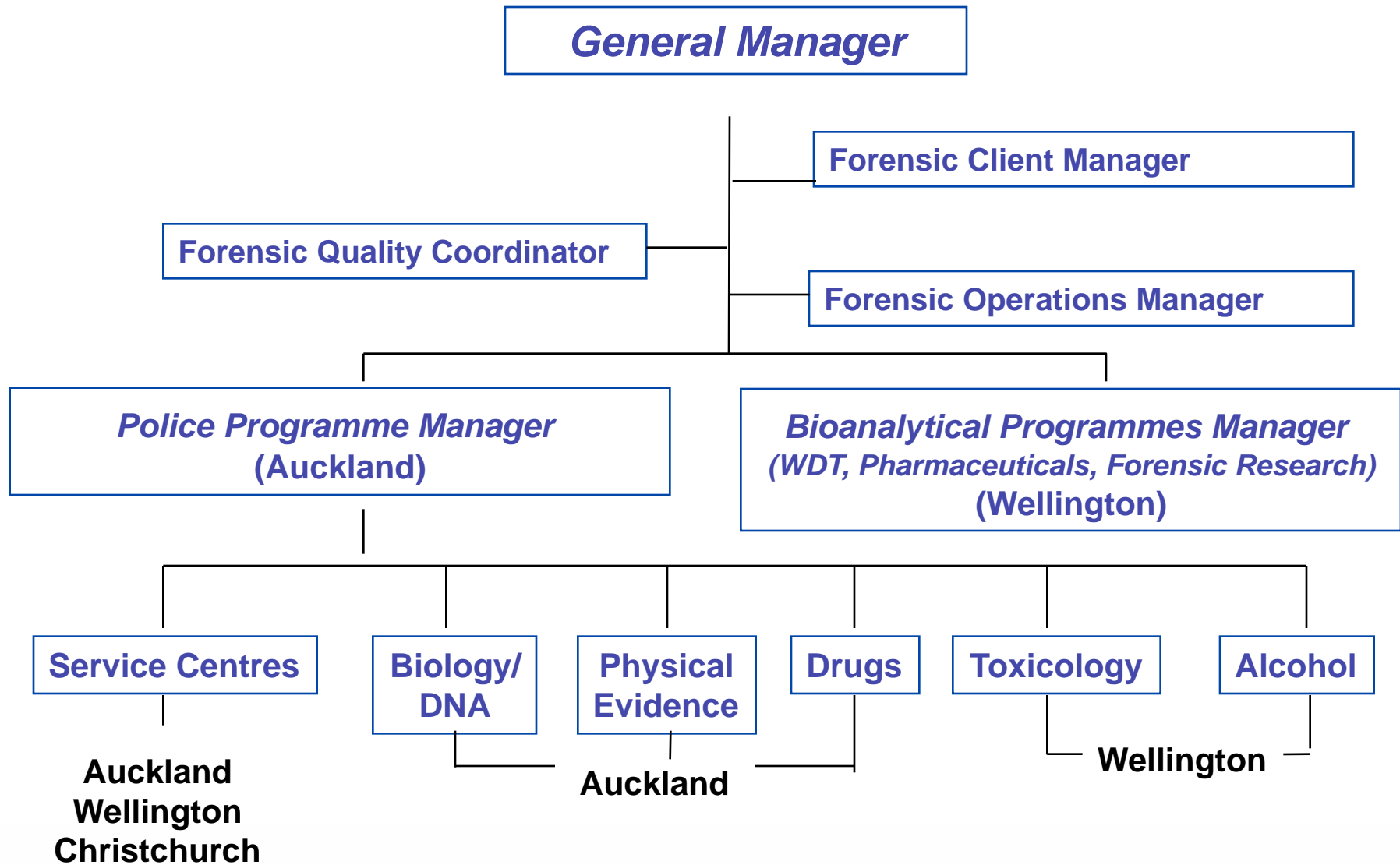
- ESR is the sole forensic provider to the NZ Police &
- Custodian of the NZ National DNA databank.
- NZ has one police force, divided into 12 districts
- Population ~ 4 million



Forensic Science in New Zealand

- **ESR is a CRI (Crown Research Institute)**
- **Government owned, not government funded.**
- **Operated as a commercial company**
- **Charge a fee for forensic services to the NZ Police**
- **Expected to return a dividend to shareholder (government).**
- **ASCLD/LAB International Accreditation**

Forensic Business Group Structure



Physical Evidence Group

- Conducts trace evidence analyses including glass, paint, fibres, hydrocarbon fuels, lubricants, tapes, explosives and substance identification.
- Also shoeprints, toolmarks and firearms examinations.
- 4 scientists, 2 technicians and 1 administrator.
- ~300 cases per year.
- Research links include MSc and PhD students from University of Auckland



Bayesian Statistics – the Likelihood Ratio

- Majority of evidence types assessed using a Likelihood Ratio (LR) approach
- LR involves assessing the evidence under two competing hypotheses:
 - $p(E|H_p)$ – probability of finding the evidence if the prosecution hypothesis is true
 - $p(E|H_d)$ – probability of finding the evidence if the defence hypothesis is true



Bayes Theorem

$$\frac{p(Hp | E)}{p(Hd | E)} = \frac{p(E | Hp)}{p(E | Hd)} \times \frac{p(Hp)}{p(Hd)}$$

Posterior odds

Likelihood Ratio

Prior odds

Calculating LR



- **Objective:** includes frequency data, transfer and persistence surveys relevant to scenario
- **Subjective:** less 'hard' data available, based on analyst's opinion/experience

Numerical and Verbal Scales

Numerical	Verbal
1	Inconclusive
1 - 10	Slightly supports
10 - 100	Supports
100 – 1,000	Strongly supports
1,000 – 1,000,000	Very strongly supports
1,000,000+	Extremely strong evidence (usually DNA only)

Glass Example:

- Find on sweatshirt from Mr A, 5 fragments that 'match' a broken window and 4 non-matching fragments (one group).

LR is:

$$\frac{\Pr(E | H_p)}{\Pr(E | H_d)} = \frac{P_1 T_5}{2 P_2 S_5 f_1} + T_0$$



Glass Example:

- **Where:**
 - P_x = Probability of x groups of glass being found on clothing
 - S_x = Probability that a group of glass on clothing is size x
 - f_x = Coincidence frequency of group of glass (e.g. 2%)
 - T_x = Probability that x fragments of glass will be transferred, retained and recovered given case scenario (~ 3 hours)
- All of these factors are reasonably well established for ‘breaking window’ glass cases.
- ‘Activity’ level interpretation – includes P, S and T terms
- ‘Source’ level interpretation would include only frequency

Glass Example: Statement

Explain in general terms the interpretation process:

- In assessing the evidence, consideration is given to how common it is to have glass on the clothing, the amount of glass on the clothing and how common the refractive index of this glass is among other glass sources.
- The significance of this analysis and comparison is assessed in terms of how likely it would be to obtain this glass evidence if the clothing was close to the breaking window as opposed to the clothing not being close to the breaking window.

Glass Example: Statement

- LR = 321, strongly supports

Statement wording:

- In my opinion, the finding of five matching fragments of glass on the clothing from Mr A strongly supports the suggestion that he was close to breaking window at ...
- I have chosen the term 'strongly supports' from the following scale: inconclusive, slightly supports, supports, strongly supports, very strongly supports and conclusive.

Glass Example: Statement

- Usually don't report LR numerical value, just verbal scale
- State that other sources for matching glass are possible
- Also report coincidence frequencies
- Refer to likelihood ratio approach in general terms only.

Glass Example: Court

- **Prosecution focuses on:**
 - Transfer & persistence factors
 - Discuss what would be expected to be found on the clothing given the time delay, type of clothing etc
 - Unusual to find large groups of glass on clothing of people not involved in breaking objects
- **Defence focuses on:**
 - Evidence is not conclusive
 - Other sources are possible
 - Alternative scenarios presented
 - Possibility of secondary transfer
- **Court discussion focussed on general interpretation, rather than specific LR questions.**
- **May give examples of types of results with lower and higher LRs**



Second glass example:

- Find on sweatshirt from Mr A, 1 fragment that 'matches' a broken window and 4 non-matching fragments (one group).

LR = 8, slightly supports

$$\frac{\Pr(E | H_p)}{\Pr(E | H_d)} = \frac{P_1 T_1}{2 P_2 S_1 f_1} + T_0$$

- Same scenario as previously, less matching glass, lower LR, weaker evidence

Other types of trace evidence

- May not have appropriate surveys to calculate a LR
- Use of framework to assist subjective interpretation
- Consider:
 - Probability of finding evidence given prosecution's scenario
 - Probability of finding evidence given defence's scenario (i.e. no connection to event)
- LR focuses analyst on considering probability of the evidence given alternative scenarios, not the probability of guilt/not guilty (ultimate issue).
- Same interpretation scale used for most evidence types

Paint Evidence:

- More subjective interpretation
- No NZ databases for coincidence frequency
- Consider colour (e.g. white common), number of matching layers, whether original vehicle paint etc.
- Consider number and types of analyses performed and their results
- Subjective opinion of the analyst



Paint Evidence: Examples

Slightly supports	Smear of one layer of paint, chemical analysis complicated by background
Supports	One layer of matching paint
Strongly supports	Two layers of matching paint or original vehicle paint match
Very strongly supports	More layers of matching paint
Conclusive	>6 layers of matching paint

Fibre Evidence:



- **Transfer and persistence studies**
 - Variation with fibre/clothing type
 - Vary with specific scenario, e.g. type of contact, time delay
- **Background fibre populations**
 - Cinema seats, t-shirts,
- **Coincidence frequencies**
 - Common vs. rare fibres
- **Can use above surveys and ‘case specific’ trials to assist in subjective assessment of evidence.**

Fibre Evidence: Example

Slightly supports	A small number of one type of matching fibres
Supports	A large number of one type of matching fibres, or a small number of two types of matching fibres
Strongly supports	A large number of two types of matching fibres
Very strongly supports	Multiple types of matching fibres

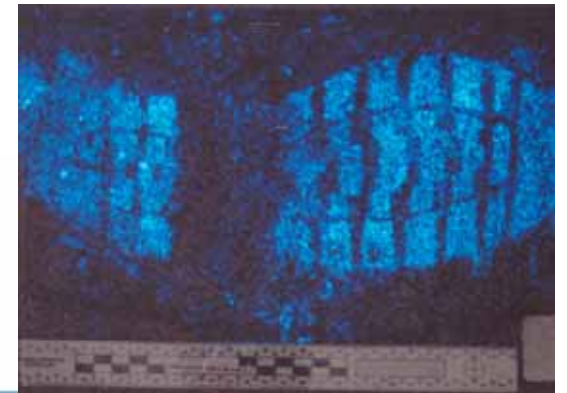
Shoeprint Evidence: Example

Slightly supports	Small partial print, common sole pattern
Supports	Pattern and size match (may be stronger if distribution / sales figures available)
Strongly supports	Pattern, size and some wear match
Very strongly supports	Pattern, size, wear and some damage match
Conclusive	Pattern, size, wear and considerable damage features match



Combining Evidence:

- Can multiply LR_s to assess weight of combined evidence
- For a glass and shoeprint case
 - Glass LR = 65
 - Shoeprint – supports
 - Subjectively assess combined evidence as strongly supports



Advantages of Likelihood Ratio Approach:

- Establishes a logical framework to assess different types of evidence at the activity level
- Provides a scale that is used across a wide range of evidence types, i.e. trace evidence, marks, DNA
- For trace evidence types with established surveys, e.g. glass
 - Consistency of results between cases and between analysts
 - Useful for assisting new staff
 - Experienced staff find that the LR results tend to mirror what their subjective assessment would have been
 - Ability to combine different evidence types



Advantages of Likelihood Ratio Approach:

- For trace evidence types without the relevant surveys:
 - Framework guides thought process
 - Ensures consideration of competing hypotheses
 - Can include some survey data where possible, e.g. coincidence frequencies

Disadvantages of Likelihood Ratio Approach:

- Lack of survey data for most evidence types
- Survey data may not be appropriate to case scenario
- Need to define H_p (often known) and H_d (may not be known)
- May not perform well for overly complex cases
- Involves statistics!



Any Questions?

