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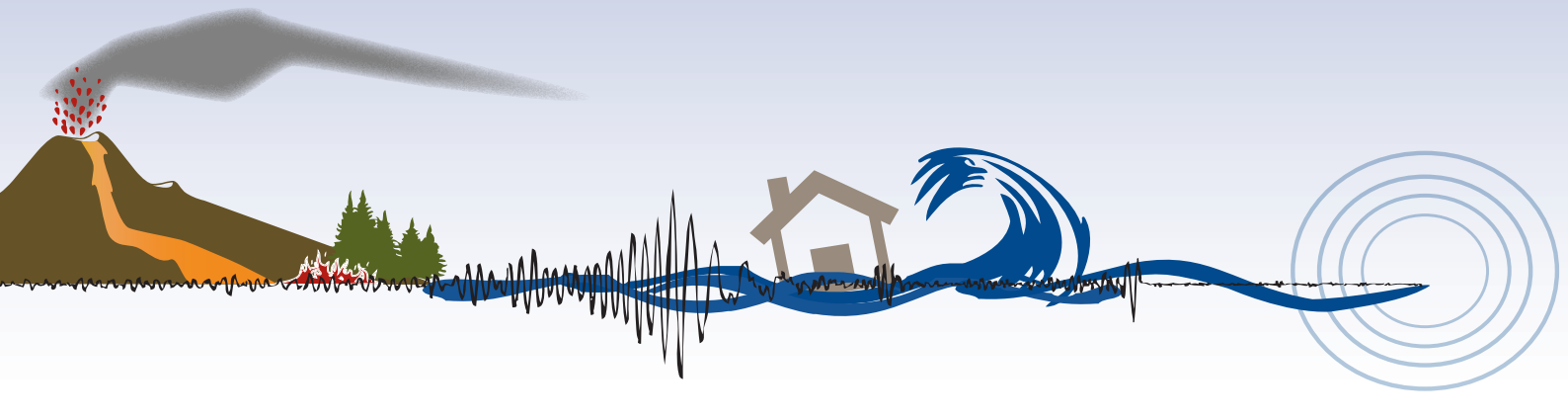

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Social adjustment in New Zealand and Philippine emergency responders: A test of main and moderating effects of received social support

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Abstract

This study examined the influence of received social support on the social adjustment of emergency responders. Emergency responders (N = 223) from New Zealand and the Philippines answered an online questionnaire measuring demographic variables, duty-related traumatic exposure, social support received from different sources, and social adjustment (i.e., social and occupational impairment, posttraumatic growth in interpersonal relationships). Results of hierarchical regression analyses showed that a greater amount of received social support from supervisors and a greater amount of received emotional support were both associated with lower levels of social and occupational impairment. Additionally, higher amounts of support received from family and supervisors, as well as from all sources combined, predicted higher posttraumatic growth scores in the domain of interpersonal relationships. Received social support was not observed to moderate the effects of traumatic exposure on social adjustment. Findings were generally consistent with the main effect model of social support and underscored the differential effects of the various components of received social support on social adjustment dimensions.

Keywords: *social adjustment, posttraumatic growth, social and occupational impairment, received social support, emergency responders*

The psychological consequences of being exposed to emergencies are widely documented in the literature (Bonanno, Brewin, Kaniasty, & La Greca, 2010; Norris et al., 2002). These adverse effects of exposure to potentially traumatic events (PTE) are observed both at the level of psychological symptomatology and the level of interpersonal domains. Some emergencies may disturb social structures (van Ommeren, Saxena, & Saraceno, 2005) and permeate the different layers of the social fabric (Fritz, 1961). This disturbance may include the disruption of the individuals' social adjustment, which traverses both psychological and sociological domains. Social adjustment refers to the performance of social roles, such as spousal functions, occupational roles, and satisfaction with social relationships (Larson, 1993). Norris et al. (2002) summarised extensive documentation of how these critical events affect the psychological and social functioning of victims/survivors; however, the same cannot be said about potentially traumatic experiences of emergency responders (Carmassi et al., 2016). Emergency responders are generally tasked to protect and preserve life, property, and the environment during and in the aftermath of critical events (Prati & Pietrantoni, 2010b). Although social adjustment studies on emergency responders are few (Carmassi et al., 2016), these studies suggest that having social support is positively associated with healthy social adjustment following exposure to traumatic events. Healthy social adjustment may be in the form of posttraumatic growth (PTG), which is the experience of positive change as a result of exposure to hardships such as PTEs (Tedeschi & Calhoun, 2004).

Social support has been consistently found to be related to positive psychological outcomes following exposure to emergencies and other traumatic events (Bonanno et al., 2010; Hobfoll et al., 2007; Kaniasty, de Terte, Guilaran, & Bennett, 2020). This umbrella

construct refers to social interactions that provide actual assistance and embed people in a network of social relationships that are perceived to be loving and caring (Hobfoll & Stokes, 1988). Highlighted in this definition are three distinctive facets (Kaniasty & Norris, 2009): *received social support*, referring to the actual support received; *perceived social support*, referring to the appraisal of availability and quality of support; and *social embeddedness*, referring to integration in a supportive network.

Originally, social support was expected to have stress-buffering effects (Cohen & Wills, 1985) as a resource that only benefits health under stressful conditions. As a stress buffer, it was found to dampen the negative effects of traumatic exposure on psychological outcomes. A key statistical indicator of buffering effects is when no difference in psychological distress is observed if social support level is high, while such difference is amplified in conditions where social support level is low (e.g., Pow, King, Stephenson, & DeLongis, 2017). Research on people in high-risk occupations, such as the military or fire service, showed that following exposure to work-related traumatic events, those with low social support were particularly vulnerable to posttraumatic stress disorder whereas those with more adequate levels of social support were shielded against harmful posttraumatic psychological reactions (de Terte & Stephens 2014; Kaspersen, Matthiesen, & Gunnar Götestam, 2003; Schwarzer, Bowler, & Cone, 2014). However, buffering effects were not always observed and the weight of evidence suggests that social support frequently contributes to psychological outcomes directly and independently of the level of exposure to stressors (Cohen, Gottlieb, & Underwood, 2000; Kawachi & Berkman, 2001; La Rocco & Jones, 1978).

Social support is usually associated with better adjustment after exposure to critical incidents (Hobfoll et al., 2007). However, this observation more often than not refers to the effect of perceived social support (Guner, Sevimli, Bulduk, & Orakci, 2014) or social support in general (Inoue, Funk, Wann, Yoshida, & Nakazawa, 2015). On the other hand, evidence for the ability of received social support to affect adjustment has been less consistent (Thoits, 2011). The received social support-positive outcome association is not always observed, which may be due to incompatibility between the stressor and the support received (Cutrona & Russell, 1990). This may manifest as a mismatch between the need of the recipient and the support provided in terms of quality, quantity, and form (Rini & Dunkel Schetter, 2010). The inconsistency of the effectiveness of received social support may also be attributed to the effects of other moderators, such as the source of received social support (French, Dumani, Allen, & Shockley, 2018). These factors are thought by researchers to influence the magnitude, or even the direction, of the effect of received social support on psychological outcomes.

Despite mixed findings about received social support, this facet is still thought to be more reflective of reality in terms of the level of social support (Haber, Cohen, & Baltes, 2007; Hobfoll, 2009). Received social support is usually measured by asking about the specific supportive behaviours received from others during a specific period of time. In contrast, perceived social support typically refers to peoples' appraisal of the ability and readiness of their interpersonal contacts to provide support. More importantly, in the aftermath of critical incidents, individuals and their social and professional networks mobilise actual social support to provide aid to those affected (e.g., Shang et al., 2019), which results in concrete intervention activities. Therefore, it is imperative to know the characteristics of received social support that contribute to positive social adjustment, including posttraumatic growth in interpersonal relationships and the absence of occupational impairment. Accordingly, the present study aimed to answer the following questions: (1) Does received social support predict social and occupational impairment (SOI) in emergency responders? (2) Does received social support predict posttraumatic growth in interpersonal relationships (PTG-IR) in emergency responders? (3) Does received social support moderate the association between duty-related traumatic exposure and SOI in emergency responders? and (4) Does received social support moderate the association between duty-related traumatic exposure and PTG-IR. Furthermore, this study tested the different effects of different sources (i.e., family, co-workers, supervisor) and types (i.e., emotional, tangible, informational) of support on social adjustment.

Methods

Participants

The study involved 223 emergency responders based in New Zealand (87%, *n* = 195) and in the Philippines (13%, *n* = 28) who were affiliated with emergency response organisations. Most participants were males

(77%, *n* = 171) and the mean age of the sample was 43.19 years (*SD* = 12.12). Sixty-eight percent identified themselves as New Zealanders of European ethnicity (*n* = 152), 13% identified as Asian (*n* = 29), and 10% considered themselves as New Zealanders of mixed or Māori ethnicities (*n* = 22). The remaining 9% reported their ethnic origin as Australia/Oceania or Europe/North America. The majority of the participants were affiliated with the fire service (70%, *n* = 157), followed by those working in the medical services (16%, *n* = 36), emergency/disaster management organisations (6%, *n* = 13), the police force (5%, *n* = 10), and in other emergency response groups (3%, *n* = 7).

Procedure

Recruitment and data collection for this cross-sectional study were conducted for 7 months, beginning 1 May 2017. Participant recruitment was conducted primarily through social media platforms. Information about the study was also disseminated through communications within different emergency response organisations such as through announcements within the fire service. Due to this web-based data collection method, the response rate could not be computed. The completion rate (valid cases divided by the number of participants who gave consent) was 52%. *A priori* power analysis, f^2 =.15, α =.05, β =.80, k =10, suggested a minimum sample size of 118; the actual total sample size of 223 far exceeds that estimate. This power analysis treated the interaction term for the moderation analysis as one of the predictors, following the fixed effects model. The actual sample size (N = 223) showed sensitivity to at least f^2 = .08 (F_{crit} = 1.88).

Measures

Outcome variables. Two dimensions of social adjustment were assessed: social and occupational impairment (SOI) and posttraumatic growth in interpersonal relationships (PTG-IR). The five-item Work and Social Adjustment Scale (WSAS; Mundt, Marks, Shear, & Greist, 2002) was used to measure social and occupational impairment and functioning. For this study, the items were anchored on "experiences at work": for example, "Because of my experiences at work, my ability to work is impaired". The items were answered using a nine-point scale (0 - 8), with a higher score indicating more severe impairment. The WSAS scale had a Cronbach's alpha of .88, above the threshold of .7 (Nunnaly, 1978).

The extent of positive interpersonal changes following exposure to traumatic job-related stressors was measured with the seven-item subscale from the Posttraumatic Growth Inventory (PTGI; Tedeschi & Calhoun, 1996) labelled "Relating to Others" (Taku, Cann, Calhoun, & Tedeschi, 2008). Respondents answered these items (e.g., "I have a greater sense of closeness with others") using a six-point Likert-style rating system (0 = "I did not experience this as a result of my work;" 5 = "I experienced this change to a very

Table 1
Frequency exposure to the different events in the LEC-5 that are duty-related, lifetime, and the duty-related event participants considered the worst

LEC-5 Event	Duty-related		Lifetime		Worst duty-related event	
	n	%	*n*	%	*n*	%
1. Disaster caused by natural hazards	193	86.55	144	64.57	42	18.83
2. Fire or explosion	186	83.41	107	47.98	12	5.38
3. Transportation accident	191	85.65	177	79.37	37	16.59
4. Serious accident at work, home, or during recreational activity	157	70.40	107	47.98	3	1.35
5. Exposure to toxic substances	154	69.06	38	17.04	2	0.90
6. Physical assault	86	38.57	126	56.50	2	0.90
7. Assault with a weapon	65	29.15	38	17.04	3	1.35
8. Sexual assault	18	8.07	42	18.83	5	2.24
9. Other unwanted or uncomfortable sexual experience	23	10.31	40	17.94	1	0.45
10. Combat or exposure to a war-zone	8	3.59	27	12.11	1	0.45
11. Captivity	7	3.14	2	0.008	0	0
12. Life-threatening illness or injury	131	58.74	99	44.40	9	4.04
13. Severe human suffering	80	35.87	37	16.59	7	3.14
14. Sudden violent death	155	69.51	81	36.32	57	25.56
15. Sudden accidental death	168	75.34	96	43.05	34	15.25
16. Serious injury, harm, or death you caused to someone else	49	21.97	20	8.97	2	0.90

great degree as a result of my work"). This subscale had a Cronbach's alpha of .91.

Predictor variables. The study captured duty-related traumatic exposure (TE) using the Life Events Checklist for Diagnostic and Statistical Manual of Mental Disorders (DSM) fifth edition (LEC-5; Weathers et al., 2013). The measure lists traumatic events (16 specific events and one open-response item, see Table 1). For the purpose of the present research, the original scale delivery was modified. Participants indicated, in sequence, the events to which they have been exposed (1) in their lifetime (LEC-5 lifetime: "Which of these events were you exposed to outside of your work as an emergency/disaster responder?"), and (2) in their work as emergency responders (LEC-5 duty-related: "Which of these events were you exposed to as part of your work as an emergency/disaster responder?"). The LEC-5 lifetime index enumerated trauma exposure outside the participants' work in emergency response. The LEC-5 duty-related trauma exposure index was the main predictor variable in the study. The previous version of this instrument (based on DSM-IV) was reported to have an average kappa reliability coefficient of .61 and a test-retest reliability coefficient of .82, above the thresholds of .4 and .6, respectively (Gray, Litz, Hsu, & Lombardo, 2004).

Received social support was measured using the recipient version of the Berlin Social Support Scale (BSSS; Schwarzer & Schulz, 2000). The original agreement-disagreement continuum of the scale was modified in this study to reflect a frequency response continuum where 1 = "never" and 5 = "always". Receiving support from three sources was assessed, which included a close family member, co-workers, and immediate supervisor, each with 14 items such as "My close family member expressed concern over my condition". The total score of received social support was based on the average of family, co-workers, and supervisor support subscales. In addition, the BSSS items allowed for assessing three types of received social support for each source: emotional (9 items), informational (2 items), and tangible (3 items). Reliability coefficients for scores on all combinations of BSSS items in the present study were as follows: total received support (42 items, α = .95), family support (α = .94), peer support (α =.92), supervisor support (α = .94), emotional support (α = .92), instrumental support (α =.84), and informational support (α = .79).

Acknowledging the importance of a long research tradition of conceptualizing social support as appraisals of support availability, the present study also assessed perceived social support. Perceived social support was measured using the Interpersonal Support Evaluation List (ISEL-12; Cohen, Mermelstein, Karmarck, & Hoberman, 1985). This scale measures the perception of availability of support with statements such as "There is someone I can turn to for advice about handling problems with my family" and a four-point response scale where 1 is "definitely false" and 4 is "definitely true". Cronbach's alpha for the perceived social support scale in the current study was .88.

Statistical control variables. Statistical analyses controlled for the effects of gender, years of service, civil status, ethnicity, normative stressful events, and lifetime traumatic exposure (TE). Gender was coded "0" for male and "1" for female. Civil status was coded "1" for those with partners; otherwise, it was coded "0." Year of first entry to the profession was used as a proxy measure for the length of service in the emergency response sector. Participant ethnicity was coded "1" for those who identified themselves as New Zealanders of European decent, and "0" for those who identified with other ethnicities. Normative stressful life events such as moving/changing residence or a break up with a close friend, experienced in the past 12 months, were assessed with the Life Events List (LEL; Cohen, Tyrrell, & Smith 1991; Common Cold Project, n.d.).

Statistical Analyses

The main and moderating effects of received social support on social adjustment of emergency responders were tested using hierarchical regression analyses. There are two outcome variables in the analyses: SOI and PTG-IR. These two outcome variables have the same set of predictors entered in the regression equation in a hierarchical fashion. All models included gender, age, civil status, and ethnicity. Model 2 added lifetime exposure to traumatic events and the number of normative stressful life events in the past 12 months. These general stressor-related measures were entered early in the model in order to isolate the effects of the emergency context trauma experiences. Hence, the LEC-5 duty-related trauma exposure was entered next, along with received social support, in Model 3. Model 4 included the interactions of these two variables. Finally, to assess the impact of received social support on the outcomes when perceived social support is accounted

for, the score of perceived social support was added in Model 5.

This hierarchy of analysis was performed for total received social support and the different sources and types of received social support. Regression analyses were also checked for multicollinearity using tolerance and variance inflation factors; no significant overlaps in variance explanation among predictors were found. All regression models were tested using SPSS Version 25. No outliers were found in the analyses, where casewise deletion (3 standard deviations) was implemented.

Treatment of missing data. Analysis of the missing data was performed by running missing values analysis (MVA). The missing data pattern was tested using Little's MCAR Chi-square through 400 iterations of the expectation-maximization (EM) algorithms, where no significant pattern was found. Missing data were treated using the multiple imputation-Markov chain Monte Carlo (MI-MCMC). To ensure the preservation of statistical power, five imputations were generated (Graham, Olchowski, & Gilreath, 2007). Imputation was performed at the scale level, and only cases with at least 95% completion were included in the dataset.

Results

Correlations

Means, standard deviations, and zero-order correlations between the study variables are shown in Tables 2 and 3. Neither lifetime TE nor duty-related TE were correlated with social and occupational impairment (SOI). However, duty-related TE was negatively correlated with posttraumatic growth in interpersonal relationships (PTG-IR). Whereas lifetime TE was not correlated with received nor perceived social support, duty-related TE was negatively correlated with total received social support and was negatively correlated with received social support variables, except received informational support. Furthermore, with the exception of informational support, received social support variables were significantly negatively correlated with SOI. Received social support variables were positively correlated with PTG-IR. Perceived social support was negatively correlated with SOI and positively related to PTG-IR. Correlations between received support subscales and perceived support ranged from .32 to .52.

Effects of Received Social Support on Social and Occupational Impairment (SOI)

Tables 4a and 4b show the results of hierarchical regression models predicting SOI across the measures of received social support aggregated by sources and types. Results showed main effects of total score of received social support on SOI, when controlling for the effects of the demographic variables and traumatic exposure. Receiving more of different types of social support from all the sources was associated with lower SOI scores. The influence of the amount of the overall social support received on SOI remained statistically significant even with the addition of perceived social support in the last block of the hierarchical regression equation (B = -1.05, SE = 0.48, p = .029).

Analyses of the different sources of received social support revealed that work-related sources (i.e., co-worker and supervisor) of social support predicted social and occupational impairment; higher amounts of received support from these sources were associated with better social and occupational functioning. However, when the effect of perceived social support was considered, only the B coefficient for the supervisor received support remained significant, B = -1.17, SE = 0.46, p = .011. Analyses by the different types of received social support showed that high amounts of

Table 2
Means and standard deviations of demographic and study variables

Variable	*n*	*M*	*SD*
Gender[a]	219	0.22	0.41
Years of Service	222	18.11	13.45
Civil status[b]	223	1.79	0.41
Ethnicity[c]	223	0.68	0.47
Lifetime TE	223	5.50	3.14
Normative Stress	223	4.65	3.15
Duty-related TE	223	7.58	3.32
Global RSS	222	3.30	0.68
Family RSS	221	3.53	0.89
Co-worker RSS	220	3.29	0.78
Supervisor RSS	219	3.08	0.89
Emotional RSS	223	3.50	0.68
Tangible RSS	223	3.06	0.79
Informational RSS	223	2.76	0.87
Perceived SS	223	3.15	0.53
SOI	222	5.51	6.64
PTG-IR	220	2.60	1.30

Note. TE = traumatic exposure; RSS = received social support; SS = social support; SOI = social and occupational impairment; PTG-IR = posttraumatic growth in interpersonal relationships;
[a] Female = 1; [b] with partner = 1; [c] NZ-European = 1.

Table 3
Correlation matrix including demographic and study variables

	Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Gender[a]																
2.	Years of Service	-.34***															
3.	Civil status[b]	-.28***	.29***														
4.	Ethnicity[c]	-.15*	.25***	.00													
5.	Lifetime TE	-.02	.11	.02	.01												
6.	Normative Stress	.14*	-.28***	-.24***	-.01	.14*											
7.	Duty-related TE	-.18**	.13	.14*	.35***	.40***	.03										
8.	Global RSS	.12	-.22**	-.07	-.21**	-.00	.04	-.22**									
9.	Family RSS	.13	-.20**	.01	-.19**	-.03	.00	-.21**	.74***								
10.	Co-worker RSS	.08	-.04	-.10	-.16*	-.04	.02	-.16*	.82***	.36***							
11.	Supervisor RSS	.11	-.22**	-.12	-.17*	.04	.11	-.16*	.84***	.38***	.63***						
12.	Emotional RSS	.15*	-.22*	-.08	-.23**	-.01	.06	-.25***	.97***	.72***	.80***	.82***					
13.	Tangible RSS	.05	-.14*	-.04	-.16*	.01	-.01	-.18**	.89***	.68***	.71***	.74***	.80***				
14.	Informational RSS	.09	-.20*	-.07	-.13	.01	.06	-.12	.83***	.62***	.65***	.71***	.73***	.71***			
15.	Perceived SS	.07	-.08	.17*	-.11	-.04	-.06	-.08	.49***	.41***	.47***	.32***	.52***	.42***	.32***		
16.	SOI	.07	-.03	-.24***	.07	-.02	.12	.12	-.30***	-.19**	-.22**	-.27***	-.34***	-.23***	-.11	-.39***	
17.	PTG-IR	.14*	-.18**	-.18**	-.23**	-.09	.10	-.28***	.51***	.33***	.51***	.40***	.46***	.45***	.48***	.26***	-.02

Note. * = $p < .05$, ** = $p < .01$, *** = $p < .001$; correlations were calculated using imputed dataset; TE = traumatic exposure; RSS = received social support; SS = social support; SOI = social and occupational impairment; PTG-IR = posttraumatic growth in interpersonal relationships; [a] Female = 1; [b] with partner = 1; [c] NZ-European = 1.

emotional and tangible supports were associated with fewer impairment symptoms. However, when perceived social support was added into the models, only received emotional support remained significantly associated with SOI scores. Received informational support did not significantly predict impairment levels. Expected interaction effects between duty-related TE and received social support on SOI scores were not observed.

Effects of Received Social Support on Posttraumatic Growth in Interpersonal Relationships (PTG-IR)

Higher amounts of overall received social support positively predicted PTG-IR (Tables 5a and 5b). This effect remained statistically significant even when perceived social support was included in the final model ($B = 0.55$, $SE = 0.09$, $p < .001$). Regression analyses across different sources of received social support showed that both family and supervisor support were associated with reports of improvements in social relationships after traumatic exposure. These effects remained statistically significant after perceived social support was included in the models ($B = 0.22$, $SE = 0.10$, $p = .036$ and $B = 0.31$, $SE = 0.14$, $p = .048$, respectively). Received co-worker support was not found to predict PTG-IR scores. All three types of received social support, emotional, tangible, and informational, were also found to be associated with posttraumatic benefits in interpersonal relationships. Similarly, as in the analyses of SOI score, none of the received social support measures functioned as moderators of the relationship between with the duty-related TE and interpersonal posttraumatic growth of emergency responders.

Discussion

The findings of this study provide evidence for beneficial direct effects of receiving social support on social adjustment outcomes among professionals routinely involved in potentially traumatic circumstances. The findings are consistent with the main effect model of social support (Cohen et al., 2000) where social support is ubiquitously beneficial to people who receive it, irrespective of the level of their exposure to stressors.

The examination of the different support sources revealed that higher amounts of co-worker and supervisor social support predicted better social and occupational functioning. Similar findings have been observed in other studies with samples of professionals in related fields such as traffic enforcement (Baruch-Feldman, Brondolo, Ben-Dayan, & Schwartz, 2002). In addition, results of the current study show higher amounts of emotional and

Table 4a
Summary of hierarchical regression analyses of social and occupation impairment on received social support (N = 223)

Variable	Global RSS				Family RSS				Co-worker RSS				Supervisor RSS			
	r^2	*B (ΔF)*	*SE B*	*p*	r^2	*B (ΔF)*	*SE B*	*p*	r^2	*B (ΔF)*	*SE B*	*p*	r^2	*B (ΔF))*	*SE B*	*p*
Model 1	.06	(3.62)		.007	.06	(3.62)		.007	.06	(3.62)		.007	.06	(3.62)		.007
Gender[a]		0.49	1.14	.668		0.49	1.14	.668		0.49	1.14	.668		0.49	1.14	.668
Years of Service		0.21	0.49	.663		0.21	0.49	.663		0.21	0.49	.663		0.21	0.49	.663
Civil Status[b]		-3.87	1.14	.001		-3.87	1.14	.001		-3.87	1.14	.001		-3.87	1.14	.001
Ethnicity[c]		0.91	0.97	.347		0.91	0.97	.347		0.91	0.97	.347		0.91	0.97	.347
Model 2	.07	(0.69)		.503	.07	(0.69)		.503	.07	(0.69)		.503	.07	(0.69)		.503
Lifetime TE		-0.21	0.45	.637		-0.21	0.45	.637		-0.21	0.45	.637		-0.21	0.45	.637
Normative stress		0.53	0.47	.256		0.53	0.47	.256		0.53	0.47	.256		0.53	0.47	.256
Model 3	.17	(13.67)		<.001	.11	(5.17)		.006	.14	(9.11)		<.001	.16	(12.33)		<.001
Duty-related TE		0.95	0.50	.060		1.23	0.54	.023		0.97	0.52	.060		1.05	0.52	.043
RSS		-1.96	0.43	<.001		-0.74	0.57	.221		-1.24	0.51	.027		-1.77	0.47	<.001
Model 4	.17	(0.22)		.649	.11	(0.17)		.696	.14	(0.06)		.974	.17	(1.19)		.290
Duty-related TE X RSS		0.21	0.46	.649		0.18	0.46	.696		-0.01	0.43	.974		0.46	0.43	.290
Model 5	.23	(14.95)		<.001	.21	(27.31)		<.001	.22	(22.01)		<.001	.24	(19.76)		<.001
Perceived SS		-1.83	0.48	<.001		-2.29	0.44	<.001		-2.11	0.47	<.001		-1.94	0.44	<.001

Note: r^2 = total variance explained; *ΔF = F* for change in r^2; Unstandardized betas (*B*) in succeeding blocks include the effects of variables in the previous blocks; *SE B* = standard error of the beta; NZ-Euro = New Zealanders of European ethnicity; TE = traumatic exposure; RSS = received social support; SS =social support; [a] Female = 1; [b] with partner = 1; [c] NZ-European = 1.

Table 4b
Summary of hierarchical regression analyses of social and occupation impairment on received social support (N = 223)

Variable	Emotional RSS				Tangible RSS				Informational RSS			
	r^2	*B (ΔF)*	*SE B*	*p*	r^2	*B (ΔF)*	*SE B*	*p*	r^2	*B (ΔF)*	*SE B*	*p*
Model 1	.06	(3.62)		.007	.06	(3.62)		.007	.06	(3.62)		.007
Gender[a]		0.49	1.14	.668		0.49	1.14	.668		0.49	1.14	.668
Years of Service		0.21	0.49	.663		0.21	0.49	.663		0.21	0.49	.663
Civil Status[b]		-3.87	1.14	.001		-3.87	1.14	.001		-3.87	1.14	.001
Ethnicity[c]		0.91	0.97	.347		0.91	0.97	.347		0.91	0.97	.347
Model 2	.07	(0.69)		.503	.07	(0.69)		.503	.07	(0.69)		.503
Lifetime TE		-0.21	0.45	.637		-0.21	0.45	.637		-0.21	0.45	.637
Normative stress		0.53	0.47	.256		0.53	0.47	.256		0.53	0.47	.256
Model 3	.21	(18.42)		<.001	.14	(8.59)		<.001	.11	(4.40)		.013
Duty-related TE		0.77	0.50	.119		1.05	0.51	.041		1.23	0.52	.018
RSS		-2.35	0.43	<.001		-1.41	0.44	.001		-0.69	0.44	.119
Model 4	.21	(0.54)		.465	.14	(0.28)		.777	.11	(0.22)		.642
Duty-related TE X RSS		0.33	0.45	.465		-0.13	0.44	.777		0.23	0.50	.642
Model 5	.25	(10.80)		.001	.22	(21.40)		<.001	.22	(28.40)		<.001
Perceived SS		-1.57	0.48	.001		-2.12	0.46	<.001		-2.36	0.44	<.001

Note. r^2 = total variance explained; *ΔF = F* for change in r^2; Betas in succeeding blocks include the effects of variables in the previous blocks; *SE B* = standard error of the beta; NZ-Euro = New Zealanders of European ethnicity; TE = traumatic exposure; RSS = received social support; SS = social support; [a] Female = 1; [b] with partner = 1; [c] NZ-European = 1.

tangible support were associated with fewer functioning deficits in the social and occupational domains. Cutrona and Russell (1990) have argued that the type of social support is a crucial aspect of its effectiveness. They suggested that receiving emotional support helps an individual to sustain stressors that are beyond one's control, whereas receiving tangible support can assist an individual in dealing with stressors that one can control. It follows that emergency responders who receive assistance from work-related sources function

Table 5a
Summary of hierarchical regression analyses of posttraumatic growth in interpersonal relationships on received social support (N=223)

Variable	Global RSS				Family RSS				Co-worker RSS				Supervisor RSS			
	r^2	*B (ΔF)*	*SE B*	*p*	r^2	*B (ΔF)*	*SE B*	*p*	r^2	*B (ΔF)*	*SE B*	*p*	r^2	*B (ΔF)*	*SE B*	*p*
Model 1	.09	(5.56)		<.001	.09	(5.56)		<.001	.09	(5.56)		<.001	.09	(5.56)		<.001
Gender[a]		0.14	0.23	.545		0.14	0.23	.545		0.14	0.23	.545		0.14	0.23	.545
Years of Service		-0.09	0.09	.338		-0.09	0.09	.338		-0.09	0.09	.338		-0.09	0.09	.338
Civil Status[b]		-0.46	0.22	.036		-0.46	0.22	.036		-0.46	0.22	.036		-0.46	0.22	.036
Ethnicity[c]		-0.57	0.19	.002		-0.57	0.19	.002		-0.57	0.19	.002		-0.57	0.19	.002
Model 2	.10	(1.12)		.328	.10	(1.12)		.328	.10	(1.12)		.328	.10	(1.12)		.328
Lifetime TE		-0.12	0.09	.172		-0.12	0.09	.172		-0.12	0.09	.172		-0.12	0.09	.172
Normative stress		0.07	0.09	.406		0.07	0.09	.406		0.07	0.09	.406		0.07	0.09	.406
Model 3	.32	(33.61)		<.001	.20	(12.44)		<.001	.25	(21.61)		<.001	.22	(15.79)		<.001
Duty-related TE		-0.15	0.09	.097		-0.24	0.12	.042		-0.16	0.10	.101		-0.21	0.10	.031
RSS		0.59	0.08	<.001		0.28	0.12	.038		0.39	0.18	.078		0.38	0.14	.021
Model 4	.32	(1.97)		.173	.20	(1.66)		.223	.25	(0.34)		.711	.23	(3.51)		.071
Duty-related TE X RSS		-0.11	0.08	.173		-0.11	0.09	.223		-0.03	0.09	.711		-0.15	0.08	.071
Model 5	.32	(0.67)		.420	.24	(10.29)		.002	.27	(4.40)		.105	.26	(7.40)		.008
Perceived SS		0.07	0.09	.420		0.27	0.09	.002		0.18	0.11	.105		0.23	0.09	.008

Note: r^2 = total variance explained; *ΔF = F* for change in r^2; Betas in succeeding blocks include the effects of variables in the previous blocks; *SE B* = standard error of the beta; NZ-Euro = New Zealanders of European ethnicity; TE = traumatic exposure; RSS = received social support; SS = social support; [a] Female = 1; [b] with partner = 1; [c] NZ-European = 1.

Table 5b
Summary of hierarchical regression analyses of posttraumatic growth in interpersonal relationships on received social support (N=223)

Variable	Emotional RSS				Tangible RSS				Informational RSS			
	r^2	*B (ΔF)*	*SE B*	*p*	r^2	*B (ΔF)*	*SE B*	*p*	r^2	*B (ΔF)*	*SE B*	*p*
Model 1	.09	(5.56)		<.001	.09	(5.56)		<.001	.09	(5.56)		<.001
Gender[a]		0.14	0.23	.545		0.14	0.23	.545		0.14	0.23	.545
Years of Service		-0.09	0.09	.338		-0.09	0.09	.338		-0.09	0.09	.338
Civil Status[b]		-0.46	0.22	.036		-0.46	0.22	.036		-0.46	0.22	.036
Ethnicity[c]		-0.57	0.19	.002		-0.57	0.19	.002		-0.57	0.19	.002
Model 2	.10	(1.12)		.328	.10	(1.12)		.328	.10	(1.12)		.328
Lifetime TE		-0.12	0.09	.172		-0.12	0.09	.172		-0.12	0.09	.172
Normative stress		0.07	0.09	.406		0.07	0.09	.406		0.07	0.09	.406
Model 3	.27	(24.56)		<.001	.28	(27.21)		<.001	.31	(32.40)		<.001
Duty-related TE		-0.14	0.09	.130		-0.16	0.09	.073		-0.20	0.09	.028
RSS		0.52	0.08	<.001		0.53	0.08	<.001		0.57	0.08	<.001
Model 4	.28	(2.45)		.134	.29	(0.98)		.341	.31	(0.46)		.512
Duty-related TE X RSS		-0.13	0.09	.134		-0.08	0.08	.341		0.06	0.09	.512
Model 5	.28	(1.26)		.266	.30	(2.98)		.090	.33	(5.56)		.020
Perceived SS		0.10	0.09	.266		0.15	0.09	.090		0.19	0.08	.020

Note: r^2 = total variance explained; *ΔF = F* for change in r^2; Betas in succeeding blocks include the effects of variables in the previous blocks; *SE B* = standard error of the beta; NZ-Euro = New Zealanders of European ethnicity; TE = traumatic exposure; RSS = received social support; SS = social support; [a] Female = 1; [b] with partner = 1; [c] NZ-European = 1.

better at work than those who do not receive enough support. Furthermore, receiving emotional support such as words of comfort, non-judgemental interactions, and acceptance provides capacity to endure the potentially traumatising nature of their profession, whereas receiving tangible support such as assistance with tasks, money, and practical forms of aid may actually lighten the workload, strengthen the sense of camaraderie, and, in effect, improve social and occupational functioning.

The findings of this study also show that received social support directly influenced positive changes in interpersonal/social relationships after traumatic exposure. Previous research has shown that receiving social support from family influenced positive perceptions of meaning in life (Luszczynska, Pawlowska, Cieslak, Knoll, & Scholz, 2013; Schroevers, Helgeson, Sanderman, & Ranchor 2010), thereby strengthening social ties and improving relationships. Furthermore, studies in other trauma-exposed populations, such as earthquake survivors, have shown that the combination of high quality and high quantity of received social support resulted in high levels of posttraumatic growth in survivors of natural hazards (Shang et al., 2020).

The findings in this study contribute novel information regarding emergency responder groups; however, the association of received social support on posttraumatic growth has been observed in other populations. For example, a longitudinal study showed that cancer patients who received more emotional support, but did not perceive more emotional support, reported higher levels of posttraumatic growth (Schroevers et al., 2010). A positive correlation was also found between received social support and the PTG-IR subscale, but not with other PTGI indices, among Hurricane Katrina survivors living with HIV (Cieslak et al., 2009). Both studies pointed out that in terms of growth outcomes, receiving actual support matches the requirements of the stressor, similar to the social support effectiveness mechanism proposed by Cutrona and Russell (1990).

It is noteworthy that correlational analyses showed that high levels of duty-related traumatic exposure were associated with lower amounts of received social support. This is an unusual pattern of stress-support relationship because it is common to observe a positive correlation between the severity of stressful exposures and the amount of support received (Hobfoll, 2002; Kaniasty, 2020) This inverse correlation between duty-related traumatic exposure and received social support is interesting but also concerning. Duty-related traumatic exposure and, consequently, experience of distress, may deter emergency responders from seeking support, therefore receiving less support, from fear of being perceived as weak or vulnerable (Prati & Pietrantoni, 2010a). Troublingly, disclosures of psychological distress and help seeking are not valued in emergency response organisations and may even have negative consequences in terms of career advancement such as being promoted (Haugen, McCrillis, Smid, & Nijdam, 2017).

This social support disequilibrium—in this case, a state of shortage where high need for support is met with low amounts of provided support—may also be a case of social erosion (Shallcross, Arbisi, Polusny, Kramer, & Erbes, 2016). Social support shortage happens when experience of distress negatively affects the quality and/or quantity of social support. For example, experience of distress by emergency responders may contribute to relationship strain (Alvarez & Hunt, 2005). In the same manner, distress brought about by the increase of duty-related traumatic exposure may lead to the deterioration of social support. This shortage may also explain the negative correlation between duty-related traumatic exposure and PTG-IR scores found in this study. The erosion of relationship quality brought about by the increase in duty-related traumatic exposure may result in lost opportunity to develop posttraumatic growth in interpersonal relationships. These bivariate findings are consistent with some reports documenting a potential for relationship deterioration following exposure to traumatic events, particularly those affecting larger communities such as disasters (Bonanno et al. 2010; Kaniasty, 2020).

The current study is not without limitations. There are disproportionately more participants based in New Zealand than in the Philippines. There are also more firefighters than other types of emergency responders among the participants. This imbalance in the representations of the different subgroups of responders means the variable relationships observed in this study may reflect the psychological characteristics of these dominant groups in the sample. The cross-sectional design of the study also prevented us from making causal inferences. The mode of data gathering may also have introduced the possibility of selection bias. Without the response rate, the percent of nonresponse cannot be ascertained. Furthermore, the study was not sensitive enough to detect marginal effects due to sample size limitations. Shieh (2009) suggested employing random- instead of fixed-effects

models when performing moderated multiple regression analysis in order to detect interaction effects, especially when analysing continuous variables. The random effects model requires a larger sample size, which increases statistical power and produces more accurate results (Kelley & Maxwell, 2003). Notwithstanding these limitations, the study was able to examine associations of received social support with social adjustment outcomes, associations which are most often investigated by studies with emergency responders. On a practical note, results of this study may be useful for organisations when designing and implementing social support intervention programmes for emergency responders.

This study has shown that although receiving support is generally beneficial to emergency responders, there are certain types and certain sources of support that are linked to better outcomes. This research has also illustrated that while emergency response work is psychologically and socially taxing, emergency responders may gain psychological and social benefit from their work if they receive the right kind of support from the right kind of people. Future studies could explore the different dimensions and characteristics of received social support which lead to socio-psychological outcomes in the context of emergency responders and other similar professionals.

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Farmers' perceptions of options for pasture remediation and recovery following major tephra fall in New Zealand

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Abstract

Many regions around the world have farms surrounding potentially active volcanoes that have been dormant for decades to centuries. Without any recent experience, a new major eruption and tephra fall would present an unfamiliar soil and pasture remediation challenge. We interviewed 23 farmers from the volcanic North Island of New Zealand in order to gain insight into the current understanding of tephra fall risk and associated production recovery strategies needed for the pastoral agricultural sector. Of the interviewees, 26% had experienced past minor tephra falls on their farms while 70% believed they were at risk of experiencing future tephra fall. Around half of all interviewed farmers (48%), including one who had previously experienced tephra fall, provided suggestions for possible remediation techniques. The remaining half (52%) did not know what to do if tephra were to fall on their farm. The farmer-suggested remediation strategies are: 1) waiting for rainfall to wash away the tephra (for thin falls), 2) cultivation, 3) re-grassing, 4) ploughing, 5) using fertilizers, 6) flipping the upper 0.5 metres of tephra and soil, and 7) physical removal. A key barrier to effective recovery is lack of rapid access to appropriate knowledge during and following a tephra fall. These findings provide potentially useful treatment strategies for heavy tephra fall on pasture and a key reference amongst the farming community when considering farm system preparedness for (and recovery from) tephra fall.

Keywords: *tephra fall, soil remediation, pasture recovery, volcanic eruption, Mt Taranaki, Mt Ruapehu, Taupō, agriculture*

Tephra fall is the most common and widespread volcanic hazard following an explosive eruption. Tephra is the term used for fragmented material ejected from a volcano during a volcanic eruption (Thorarinsson, 1954) and is classified by size into ash (particles less than 2 millimetres), lapilli (2 to 64 mm), and blocks or bombs (more than 64 mm; Gilbert, Lane, Sparks, & Koyaguchi, 1991). Tephra is typically transported by wind in the form of ash clouds and deposited onto the exposed landscape. Tephra fall can damage many sectors of society including critical infrastructure and agricultural systems due to its abrasive, corrosive, and conductive potential (Craig, Wilson, Stewart, Outes et al., 2016; Wilson et al., 2012). Even small amounts of tephra can cause substantial problems, disrupting transportation, water supply, and water treatment systems, and leading to high clean-up costs (Blake, Deligne, Wilson, & Wilson, 2017; Blong, 1984; Cronin, Neall, Lecointre, Hedley, & Loganathan, 2003; Hayes, Wilson, Deligne, Cole, & Hughes, 2017). At greater thicknesses (more than 100 mm), tephra can cause structural damage to buildings, with falls of more than 500 mm often resulting in complete collapse (Blong, 2003; Jenkins et al., 2014; Spence et al., 1996).

Past studies on the effects of tephra on agricultural systems have largely focused on short-term impacts from small eruptions (Bitschene et al., 1993; Cronin et al., 2003; Cronin, Hedley, Neall, & Smith, 1998; Cook, Barron, Papendick, & Williams, 1981; Georgsson & Petursson, 1972; Inbar, Ostera, Parica, Remesal, & Salani, 1995; Johnston, Houghton, Neall, Ronan, & Paton, 2000; Rubin et al., 1994) and long-term recovery following large eruptions (e.g., of Mount Hudson in 1991, Wilson et al., 2012; and of Cordón Caulle in 2011, Craig, Wilson, Stewart, Outes et al., 2016). In the long term (decades to centuries), addition of volcanic material can have positive effects on drainage, aeration, fertility, and water retention of soil (Cook et al., 1981; Nanzyo, Shoji, & Dahlgren, 1993; Warkantin & Maeda, 1980). However, in the short-term, apart from the addition

of some beneficial nutrients such as sulphur (Cronin, Hedley, Smith, & Neall, 1997), physical impacts are likely to be negative (Wilson, Cole, Cronin, Stewart, & Johnston, 2011).

Volcanic soils are highly suited for agriculture and horticulture due to their high natural fertility, stability, good drainage characteristics, and high water-holding capacity (Annen & Wagner, 2003; Cronin et al., 1998; Shoji, Dahlgren, & Nanzyo, 1993; Wilson, Cole, Cronin et al., 2011). Past studies have shown that tephra fall can cause considerable immediate impacts on agricultural systems. The 1980 eruption of Mt St Helens, United States of America, resulted in tephra being dispersed across 391,000 square kilometres, burying pastures and crops and resulting in an estimated US$100 million worth of crop losses at the time (Cook et al., 1981; Johansen et al., 1981; Folsom, 1986; Lyons, 1986; Wilson, Cole, Cronin et al., 2011). The eruption of Mt Pinatubo, Philippines, in 1991 dispersed tephra more than 10 mm thick across 7,500 km^2. Over 962 km^2 of this was agricultural land that was seriously affected by tephra fall, with damage to crops, livestock, and fisheries producing a loss of US$86 million (Mercado, 1996; Wilson, Cole, Cronin et al., 2011).

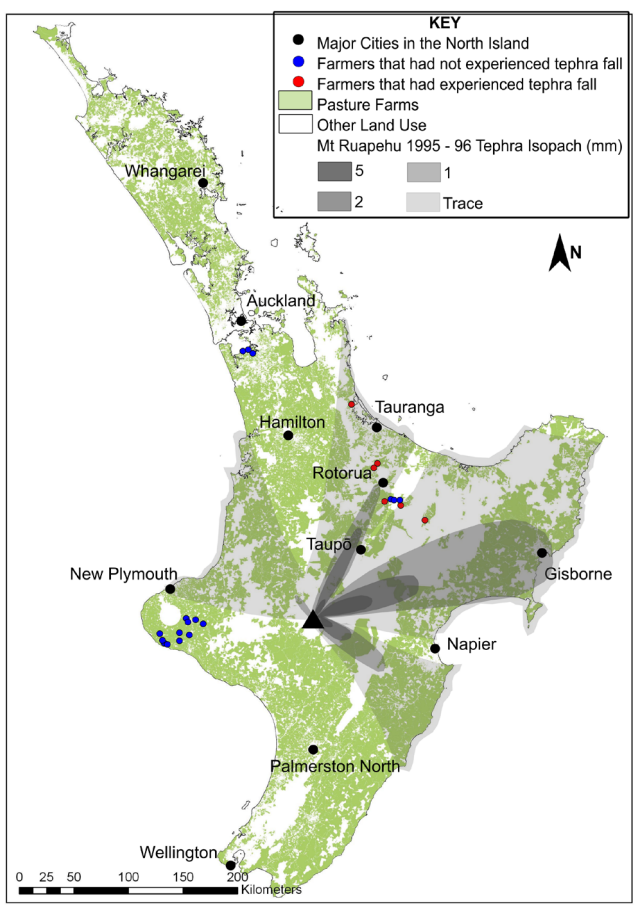

Figure 1. Isopachs in mm of the three largest 1995 and 1996 Ruapehu tephra falls (adapted from Cronin et al., 1998). Red dots show the farm locations of interviewed farmers who reported that they had experienced tephra fall in the past. Land use data from Agribase, (2018). Accessed 14th January 2019 at www.asurequality.com/our-solutions/agribase/.

In New Zealand, tephra falls associated with the 1995/1996 Mt Ruapehu eruption in the North Island covered more than 27,000 km^2 of primary production (Figure 1), causing starvation and fluorosis in thousands of livestock (Cronin et al., 1998). While there has been an increasing focus on documenting the impacts of tephra fall on agricultural systems in the published literature, there has been little focus on recovery strategies, including evaluation of pasture and crop rehabilitation strategies (Neild et al., 1998; Wilson & Cole, 2007; Wilson, Cole, Cronin et al., 2011). Available literature stresses the importance of adapting strategies to the diverse physical and chemical characteristics of tephra falls, the local soil and climatic factors, and the capacities (including knowledge, finance, and technology) of the farmer (Cook et al., 1981; Craig, Wilson, Stewart, Outes et al., 2016; Cronin et al., 1998; Folsom, 1986; Lyons, 1986; Wilson, Cole, Cronin et al., 2011).

Following the 1995/96 Mt Ruapehu eruption sequence, the influence of tephra on agriculture is a key unanswered question. Past studies have largely focused on the impacts of tephra on soil, flora, and fauna health (Craig, 2015). Further, the pastoral agricultural context of New Zealand has changed markedly since the Mt Ruapehu event, with dairying land use increasing by 42.4% between 2002 and 2016, to reach 2.6 million hectares. In 2016, the total area for all agriculture and horticulture use was 45.3% of New Zealand's total land area (12.1 million ha; StatsNZ, n.d.). Intensively farmed pastoral land is common across the soils of both volcanic and sedimentary parent material in New Zealand (Hewitt, Barringer, Forrester, & McNeill, 2010; Figure 1). In the event of large eruptions, such as might be expected from Mt Taranaki, it is estimated that more than 500 farms could be covered with more than 50 mm of tephra (Wilson, Gravley, Leonard, & Rowland, 2009). In this case, farmers would be faced with the difficult task of removing or rehabilitating tephra to return to production.

Tephra fall of less than 20 mm adds beneficial macro and micro-nutrients to the soil as well as influencing pH and adding harmful elements (Ayris & Delmelle 2012). Characteristics such as thickness, density, grain size, and composition of tephra influence the type and extent of impacts caused (Jenkins et al., 2015). Generally a thin

(less than 2 mm) coating of tephra can be washed away by rain, while tephra falls of 10 to 100 mm thickness may be remediated over one to five years by cultivation and in some cases may boost pasture growth (Craig, Wilson, Stewart, Villarossa et al., 2016). Cultivation prevents re-mobilization of tephra (e.g., by wind or into waterways) and promotes aeration and bioturbation (where plants or animals rework sediments) to encourage mixing of tephra into the soil (Neild et al., 1998). With thicker tephra falls, more intense remediation is needed to counter its low organic material content, low water holding capacity, low cation-exchange-capacity, and low natural fertility. The options for remediation are similar to cases of flood deposition where thick deposits smother the existing soil and pasture; however, flood silt deposits are generally more fertile, with higher organic content (Hefting et al., 2004; Lockaby, Wheat, & Clawson, 1996).

There have been few historical eruptions with major tephra falls to learn from in New Zealand. Studies on volcanic risk perception in other local communities with past experience of hazardous events are therefore important to consider: an approach also recommended in past work (e.g., Dominey-Howes & Minos-Minopoulos, 2004; Greene, Perry, & Lindell, 1981; Gregg, Houghton, Johnston, Paton, & Swanson, 2004; Lavigne et al., 2008; Murton & Shimabukuro, 1974; Perry, Lindell, & Greene, 1982). A study carried out by Jóhannesdóttir and Gísladóttir (2010) in the village of Vik in southern Iceland revealed that the interviewees were well aware of their volcanic risk, but their lack of mitigation, prevention, and preparedness was due to experiencing no similar hazardous event during their lifetime. According to a study carried out by Bird, Gísladóttir, and Dominey-Howes (2009) in south Iceland, an active response by the public (and farmers) during a volcanic emergency depends not only on their perception of the possible risk, but also their knowledge of preparedness actions.

Several key studies have been carried out on risk perception in New Zealand; these have found that knowledge of a hazard increases with the degree of expected maximum hazard, the degree of damage from prior events, and the amount of information available about the hazard (Johnston, Bebbington, Lai, Houghton, & Paton 1999). Paton, Millar, and Johnston (2001) concluded that, for Mt Ruapehu volcano, the perception of risk typically increases with people's proximity to the volcanic centre, the likelihood of a future disaster, the impact level, and past direct experience of hazards.

We infer from these past studies that farmers in New Zealand may be best able to respond to a volcanic crisis if they have an accurate perception of the risk, have past direct experience of volcanic eruptions, and if they have an understanding of appropriate preparedness and recovery measures. Indeed, the uncommon and complex nature of volcanic hazards necessitates access to expert information by affected communities in order to lead their risk management decisions (Paton, Smith, Daly, & Johnston, 2008).

Here, we present the results of semi-structured interviews with dairy and beef farmers from South Auckland, Bay of Plenty, Rotorua, and Taranaki districts in New Zealand to explore their views and perceptions of volcanic risk, tephra hazard, and possible consequences of tephra fall as well as perceptions of possible remediation techniques for recovering pastures and soils following tephra fall. As far as we are aware, this paper presents the first account of farmers' views on remediation of tephra-affected pastures and soils. The farmers' insights may guide future work on building farmer resilience and provide a basis for future field and laboratory testing of possible rehabilitation techniques.

Tephra Hazard in New Zealand

It has been estimated that about 25% of the world's historical and prehistorical eruptions with a volcanic explosivity index (VEI) of five or more were from the Central North Island of New Zealand. This region contains the world's highest concentration of youthful rhyolite volcanoes (Simkin & Siebert, 1994; see Figure 2). In the central North Island, andesitic volcanism started circa two million years ago and was joined by voluminous rhyolitic (plus minor basaltic and dacitic) activity from at least circa 1.6 million years ago (Wilson et al., 1995). Brief characteristics of different types of magma are given in Appendix 1 and a brief summary of past volcanic activity in New Zealand is given below.

The Taupō Volcanic Zone of New Zealand contains both andesitic stratovolcanoes (e.g., Mt Ruapehu and Mt Tongariro), built by comparatively frequent small eruptions, and predominantly rhyolitic calderas (e.g., Okataina and Taupō volcanic centres), which can produce much larger eruptions at longer intervals (Cole 1979; Wilson et al., 1984). There have been numerous recent and historical tephra-generating eruptions from the Taupō Volcanic Zone. Widespread tephra layers preserved in sedimentary records on the ring plain to the east of Mt Ruapehu reveal that this stratovolcano

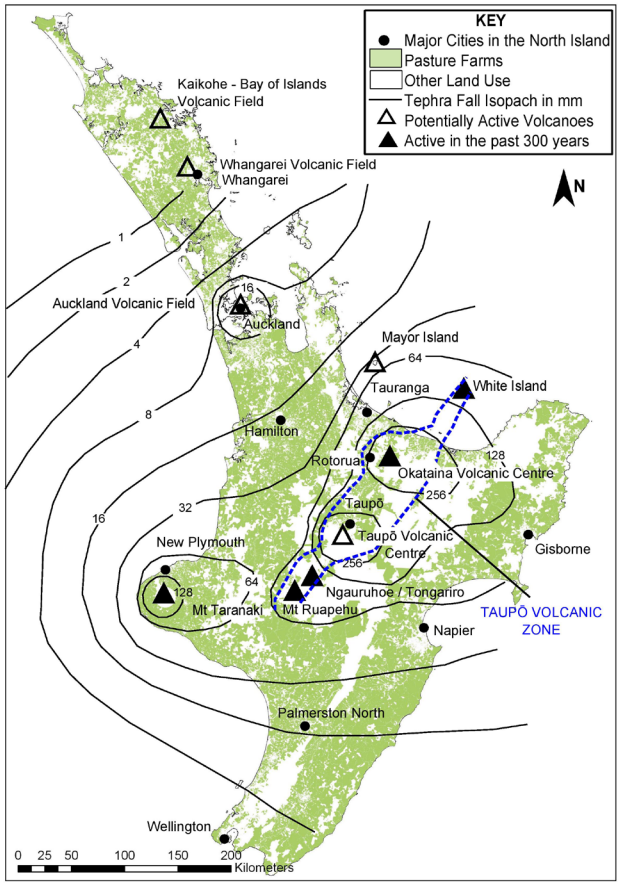

Figure 2. Tephra hazard map with tephra thickness in mm for a 10,000-year return period for all significant volcanic sources (adapted from Hurst & Smith 2010). Locations of potentially active volcanoes along with major towns in New Zealand's North Island are also shown. Land use data from Agribase (2018). Accessed 14th January 2019 at www.asurequality.com/our-solutions/agribase/.

has produced a total of 19 major eruptions, interspersed with smaller events, over the past circa 1,800 years (Moebis, Cronin, Neall, & Smith, 2011). The most recent eruption from Mt Ruapehu took place as a series of events between September 1995 and August 1996 (Cronin et al., 2003; Johnston et al., 2000; Newnham, Dirks, & Samaranayake, 2010). A large eruption on June 17, 1996 dispersed large amounts of volcanic tephra over a wide area reaching more than 300 km to the north and east of Mt Ruapehu (Figure 1). The eruption column reached an estimated 7 - 10 km, with the axis of tephra dispersal sweeping westwards across the central North Island as the wind direction shifted from SW to SE (Cronin et al., 2003). An estimated 7 million tons of tephra were dispersed, with light tephra falls over the nearby cities of Taupō and Rotorua (Cronin et al., 1998; Figure 1).

The adjacent Mt Tongariro of the Tongariro Volcanic Zone erupted suddenly at 2350 hours NZST on 6th August 2012 after being inactive for 115 years. The eruption occurred from the upper Te Maari Crater on the volcano's northern flanks, which was previously active in 1869, 1892, and 1896 - 1897 (Cronin et al., 2014). These past eruptions were short Vulcanian and phreatic explosions, releasing tephra plumes with wet surges and lahars; the approximately 400,000 cubic metres of tephra generated during the 2012 event was dispersed over a vast area (Cronin et. al., 2014).

The largest historical eruption from the Taupō Volcanic Zone was a basaltic Plinian eruption from Mt Tarawera and nearby Lake Rotomahana of the Okataina Volcanic Centre, in the early hours of 10 June, 1886 (Keam, 2016). The eruption started from the preexisting Tarawera rhyolite dome, producing a tephra column with a height estimated at 28 km (Walker, Self, & Wilson, 1984), and then extended into Lake Rotomahana. The eruption from this latter area was much more violent due to the interaction of water and deposited a thick layer of Rotomahana mud on surrounding areas. The whole eruption of about 2 km^3 lasted only a few hours during the morning of 10 June, 1886 (Keam, 2016). One of the most productive caldera systems in the world is the Taupō volcanic centre (Figure 2). The latest eruption from Taupō was in 232 ± 5 AD (Hogg, Lowe, Palmer, Boswijk, & Ramsey, 2012) and ejected 35 km^3 of magma (Potter, Scott, Jolly, Johnston, & Neall, 2015).

Mt Taranaki, a 2,518 metre high andesitic stratovolcano situated in the Taranaki region (Figure 2), has erupted over 220 times in the last 30,000 years (Damaschke, Cronin, Holt, Bebbington, & Hogg, 2017), spreading tephra over the surrounding areas and as far north as the city of Auckland (about 270 km away; Sandiford, Alloway, & Shane, 2001; Shane 2005). Mt Taranaki is located in the middle of an economically significant region of New Zealand, which contributes 10% of the country's total dairy land (Ballingall & Pambudi, 2017). According to the best currently available model for Mt Taranaki, it is estimated that there is a 33 – 42% chance of an eruption occurring within the next 50 years (Damaschke et al., 2017).

The basaltic Auckland Volcanic Field (AVF) has been active over the last circa 200,000 years and consists of 53 monogenetic (only erupting once) eruptive centres (Leonard et al., 2017). Lava flows and tephra falls are the most widespread deposits of the AVF (Kereszturi et al., 2014). Although there have been no historical eruptions from the AVF (i.e., since written records began), the most recent eruption, forming Rangitoto island about

600 years ago, was witnessed by early Māori. Future eruptions from the AVF are likely to be smaller than those from New Zealand's andesitic and rhyolite centres further south.

A Probabilistic Volcanic Hazard Model (PVHM) developed for New Zealand by Hurst and Smith (2010) estimates the likelihood of tephra deposits of any given thickness at any site, based on the frequency-magnitude relations of all significant volcanic sources and wind distribution statistics. They found that a typical 10,000-year period could result in the deposition of up to 300 mm of tephra in many central North Island locations (Figure 2).

The magnitude of possible eruptions that could affect agriculture in New Zealand ranges from minor andesitic events such as the 1995/1996 Mt Ruapehu eruptions, up to a major rhyolitic Plinian event, such as the 232 AD Taupō eruption (Wilson et al., 1995), which would eliminate agriculture in the central North Island for an extended time period. Mt Taranaki produces many events with typically low volume; however Torres-Orozco, Cronin, Pardo, and Palmer (2018) report a Plinian eruption every 300 years on average over the past 5,000 years.

Although New Zealand has a comprehensive monitoring network[1] and warning system for future eruptions, there are few mitigation measures for impacts to pasture under rapid accumulation of heavy tephra fall. During volcanic unrest periods, GNS Science release tephra fall prediction maps with their Volcanic Alert Bulletins. These show the likely tephra fall location and thickness for that particular day, given the current weather patterns, thus providing very short notice to farmers in the tephra hazard zone. If more time were available (e.g., months to years) possible preparatory measures could be taken, such as de-stocking or moving livestock. The cost of stock evacuation is exceptionally high (Wilson, Dantas, & Cole, 2009) and thus such a warning would likely need to have a high degree of certainty for the measures to be economically viable. This degree of certainty is highly unlikely with current technology and understanding of volcanoes. Far more likely is that only a few days to hours of warning will be possible, and so little can be done other than to evacuate livestock. Post-tephra fall remediation and pasture recovery thus becomes a key recovery consideration.

1 https://www.geonet.org.nz/volcano/

Method

Semi-structured Interviews

Our study used semi-structured interviews, a widely used method of data collection within the social sciences (Bradford & Cullen, 2013). Such interviews are valuable because they allow researchers to explore subjective viewpoints (Flick, 2009) and to gather in-depth accounts of people's experiences. Typically, an interview schedule is used, which enables the researcher to address a defined topic while allowing the respondent to answer in his or her own terms and to discuss issues and topics pertinent to them (Choak, 2013). In this sense, the interview should resemble a flowing conversation (Rubin & Rubin 2011; Choak, 2013). The methodological components of the interview were approved by the University of Auckland human participation ethics committee (Reference number: 016940).

In this study, 23 farmers from South Auckland, Bay of Plenty, Rotorua, and Taranaki districts were interviewed. The regions were selected due to their susceptibility to tephra fall from Taupō Volcanic Zone and Taranaki volcanoes (Figures 1 and 2). According to the PVHM model developed by Hurst and Smith (2010) for New Zealand, 10,000-year return period eruptions are capable of depositing up to 300 mm thick tephra falls over most of the central North Island. The participants themselves were selected by snowball sampling with the help of Dairy NZ (an industry research organization) and the Taranaki Regional Council. Dairy NZ has regular meetings with their farmer groups; we were invited to attend a meeting at Karaka in the Auckland region on July 5th, 2016, where a brief introduction to the study was given to the farmers present. This encouraged the immediate participation of two farmers. Dairy NZ subsequently wrote to their farmer groups seeking participants for the study, which resulted in two more farmer participants; these two farmers then spread the word about the research within their network, resulting in a further eight farmer participants. The Taranaki Regional Council assisted by spreading the word about this study amongst farmers in their region; those interested in participating then gave their contact details to the council and were subsequently contacted by the researchers to arrange the interview.

A participant information sheet and consent form were signed by all interviewed farmers before the interview and participants were informed that they could withdraw from the study at any point. Eleven farmers were

interviewed face-to-face and 12 over the phone, with every interview voice recorded. The interviews were carried out between July and November 2016, with each interview lasting between 20 minutes to 1 hour. The farmers' answers were recorded in an Excel spreadsheet under the appropriate headings and analysed semi-quantitatively. The interview questions consisted of a few closed and mostly open-ended questions that can be summarized and grouped into the following three areas (see Appendix 2 for the full list of questions).

General farmer profile. The first group of questions obtained general information from the farmer and solicited information such as when they started their farming career, whether they were first generation farmers, how many hectares they farmed, what kind of farming they practiced (dairy of beef), what kind of pasture mix they grew on their farm, whether they had tried growing any other crop on their farm, and which crop had been most consistent in terms of making a profit. Farmers were also asked how their farming style had evolved during their time farming, what important changes they had implemented or encountered on their farm, and how these changes affected productivity and profitability. They were also asked if their farm had experienced any natural hazard events other than volcanic tephra fall (e.g., flood, landslide, earthquake, snow, drought).

Farmer experiences and perceptions of tephra fall hazard. The second group of questions were based on farmers' past encounters with tephra fall on their farm, if any. They were asked if they had experienced tephra fall and if so, when. They were also asked if they considered their farm at risk of receiving heavy tephra fall and what other types of hazards might be associated with a volcanic eruption.

Farmer thoughts on strategies to combat tephra fall effects. The third group of questions was designed to explore farmers' thoughts on techniques for remediating tephra-affected soils. All farmers were asked to speculate what they thought could be done if they were faced with light tephra fall (0 to 10 mm in thickness) and medium to heavy tephra fall (10 to 300 mm in thickness) covering their pasture. If they had experienced any natural hazard events other than tephra fall (e.g., flood, drought) or soil damage or poor fertility, they were asked how they recovered from the resulting effects.

Results

General Farmer Profile

Of the 23 farmers interviewed, 21 were dairy farmers and two were dairy and beef farmers. The majority of farmers were highly experienced in dairy farming, with the most experienced farmer having 58 years' experience and the least experienced 7 years. The farms ranged in size from 60 ha to 640 ha. The livestock count per farmer ranged from 170 to 1,825 dairy cows. All farm production systems were centered on growing pasture for either direct livestock consumption or to make supplementary feed, which can then be fed to livestock during low pasture growth periods (e.g., winter) or high-energy demand periods (e.g., calving and milking). The majority of the interviewed farmers used a ryegrass (*lolium multiflorum*) and clover (*trifolium repens*) mix as their dominant pasture type, with two farmers growing chicory (*cichorium intybus*), plantain (*plantago lanceolate*), and lucerne (*medicago sativa*) as supplementary feed along with ryegrass and clover mix. Seventeen farmers had experienced the effects of non-volcanic natural hazards on their farm; in order of most-to-least experienced hazard (number of affected farmers in parentheses): drought (10), floods (4), wind/storm/cyclone (4), snow/pugging (3), earthquake/heavy rainfall (2), and landslide/infertile soil/coastal erosion (1). See Supplementary file 1.

Farmer Experiences and Perceptions of Tephra Fall Hazard

Of the 23 farmers who were interviewed, only six (five dairy and one dairy and beef farmer, all from the Bay of Plenty region) had experienced tephra fall on their farms during the 1995/96 eruption of Mt Ruapehu (Figure 1). These six farmers reported receiving tephra in various thicknesses, including less than 1 mm, a "very light dusting" (two farmers), 10 mm, 15 – 25 mm, and a "quite reasonable" amount.

Sixteen of the farmers (around 70%) stated that heavy tephra fall is a possible threat to their farms, while six (26%) believed that they were free from this hazard, and one was unsure (see Figure 3). The 16 farmers who agreed their farms were at risk of heavy tephra fall included five who had already experienced tephra fall on their farm. Interestingly, the remaining farmer who had already experienced tephra fall on their farm believed this was a rare, once in a lifetime situation. We acknowledge that the expected frequency of thin tephra falls in the North Island of New Zealand is much

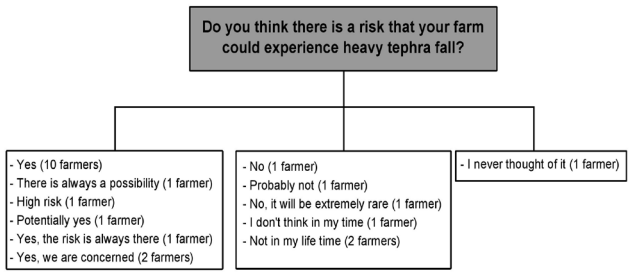

Figure 3. Schematic illustration of farmer responses to the question: "Do you think there is a risk that your farm could experience heavy tephra fall?"

greater than for thick tephra falls. Nine of the 16 farmers who considered their farm at risk of heavy tephra fall described additional possible volcanic hazards and impacts (see Figure 4).

Farmer Thoughts on Strategies to Combat Tephra Fall Effects

The six farmers who experienced the 1995/96 Mt Ruapehu eruption did not notice any adverse effects on the soil or on their farm and waited for rainfall to wash the tephra coat from the pasture. Around half of all interviewed farmers (11; 48%), including one who had previously experienced tephra fall, provided suggestions for possible remediation techniques. The remaining half (12; 52%) did not know what to do if tephra were to fall on their farm. Of the 16 farmers who identified heavy tephra fall as a risk to their farm, nine were able to suggest possible remediation measures. Overall, the following possible remediation techniques were suggested (with the number of farmers mentioning the technique in parentheses).

Rainfall/Irrigation (9 farmers): In the event of light tephra fall, participants suggested that they would wait for rainfall to wash tephra from pasture. In this case, the farmers anticipate that the grass and soil would return to their original conditions and could continue to be used as before. Depending on the season, participants also considered irrigating the tephra-affected soil as a recovery option. Irrigation would also have the effect of washing away much of the tephra settled on the pasture.

	Farmer								
	1	2	3	4	5	6	7	8	9
Volcanic Hazards									
Pyroclastic flows	✔								
Tephra fall	✔	✔	✔	✔	✔	✔	✔	✔	✔
Lava flows			✔			✔		✔	
Lahars		✔				✔			✔
Possible Impacts									
Damage to infrastructure				✔					
Rise in atmospheric temp.					✔				
Pollution of waterways					✔				
Disruption of electricity							✔		
Disruption of water supply							✔	✔	
Disruption of transportation							✔		
Threat to livestock							✔		
Disruption of feed transport				✔					

Figure 4. Volcanic hazards and possible impacts identified by the nine farmers who also considered their farm at risk of heavy tephra fall.

Using fertilizers (2 farmers): Two farmers recognized that tephra fall could cause an imbalance of soil nutrients and suggested that this could be remediated by targeted fertilizer mixtures.

Cultivation/Re-grassing (8 farmers): In the event of thick tephra fall, farmers thought that re-grassing or cultivating the affected paddock would be useful. In this method the whole paddock would be sprayed with herbicide (if needed), followed by tilling to produce a good seed bed.

Ploughing (3 farmers): For medium to thick tephra fall, farmers recommended ploughing as a possible recovery technique. It was suggested that ploughing 6 to 10 inches (approximately 10 to 15 cm) below the top-soil and mixing the tephra with soil would reduce the toxicity of tephra and reduce its impacts.

Machine removal (3 farmers): Three of the farmers thought that, in the case of heavy tephra fall conditions (where tephra forms a thick coat over the pasture soils), excavating or grading the tephra using heavy machinery would be the only option left to recover the pasture.

Flipping (1 farmer): One participant, from the Bay of Plenty, practised flipping on his farm in order to bring back to the surface the buried layers that were once fertile top soils prior to the 232 ± 5 AD Taupō eruption (Hogg et al., 2012). This reportedly gave excellent pasture growth and soil fertility results. Flipping is a method where a large excavator is used to invert the soil profile, bringing the 1 to 1.5 m deep sub-soil to the top. The dairy farmer who practised flipping gained an increase of 40% dry matter over his normal soil. The farmer suggested that flipping could be an ideal remediation strategy for heavy tephra fall.

Farmers also suggested a few remediation strategies that they had used, or were aware of, to recover soils following other adverse natural events, suggesting these may also be useful in the remediation of tephra affected soils.

Organic fertilizer/Cow-shed effluent/Chicken manure (13 farmers): Over half of the farmers interviewed sprayed their cow-shed washings onto paddocks, which helps enhance pasture growth, increases organic nutrients in the soil, and also increases the number and growth of worms in soil. They stated that this method can be utilised to increase organic nutrient levels in the soil, which is likely to drop even after light tephra fall.

Liming (9 farmers): Over a third of interviewed farmers practised liming on their farm to maintain the pH of soil to enhance grass growth. Their comments suggested that considering the acidic nature of tephra, liming could be an appropriate recovery method following tephra fall.

Different grass mix (2 farmers): Farmers suggested that using a different grass mix would be useful in order to recover light tephra-affected soil. It was suggested that a mix of ryegrass, clover, and chicory gave good results with respect to pasture growth. The farmers used this technique to overcome the damage caused by pugging and heavy rainfall. They perceived that using different grass mix on tephra can be useful as different grass types can vary in their tolerance to soil conditions.

It is also worth noting that several farmers mentioned other response strategies such as de-stocking the farm and/or providing external or supplementary feed (Supplementary file 1). These suggestions highlighted that pasture rehabilitation must be considered in the wider context of the recovery of the farming system as a whole.

Discussion

Extreme natural hazard events such as flooding, landslides, or deposition of volcanic material such as tephra fall may completely disturb or bury soils. In cases of extreme volcanic deposition, farmers must abandon the land (Wilson, Gravely et al., 2009). There are several global examples where thick volcanic tephra fall has forced temporary abandonment of farms, including eruptions at Hekla volcano, Iceland (Thorarinsson 1979), and Vulcan Hudson, Chile (Bitschene et al. 1993; Scasso, Corbella, & Tiberi, 1994). In other situations, physical or biological remediation of the new tephra-covered soils may be possible.

Following the 1943 to 1956 eruption of Volcán de Parícutin, Mexico, farmers discovered that they could recover production by cultivating tephra into the underlying soil (Luhr, Simkin, & Cuasay, 1993; Ort et al., 2008; Rees & Grayson, 1979). Following the 1991 eruption of Vulcan Hudson in Chile, over 1 m of tephra was deposited around 20 to 40 km from the volcano (Wilson, Cole, Stewart, Cronin, & Johnston, 2011). The farmers in this area tried different remediation strategies to recover pastures, such as applying fertilizers and sowing different types of grasses including indigenous and foreign ryegrasses and red and white clovers. While the grass had moderate success, adding fertilizer alone did not help due to rapid leaching (Wilson, Cole, Cronin et al., 2011). Other farmers in the area spread hay over the tephra to increase the organic content of the soil, which helped but was expensive (Wilson, Cole, Cronin et al., 2011). Areas with light tephra fall (10 mm) were able to be rehabilitated rapidly by just irrigation (Wilson, Cole, Cronin et al., 2011). Areas further away from the volcano received 200 to 300 mm of tephra, which was ploughed using tractor-mounted ploughs or rotary hoes. Other farmers tilled the thick tephra deposits into the soil using rakes and shovels, which was effective and led to higher yields within two to three years (Wilson, Cole, Cronin et al., 2011). It is clear from past experience around the world that remediation strategies need to be designed based on the individual context, taking into consideration factors such as farming system, climate, soil type, farm topography, tephra chemistry, thickness and grain size, and availability of fertilizers, labour, and machinery. This array of possible contexts means that tailoring remediation measures to specific events may be challenging. This study attempts to fill this gap by shedding light on farmer perceptions of potentially useful treatment strategies for heavy tephra fall on pasture in the New Zealand context.

Farmers' Perceptions of Tephra Fall Hazard

Sixteen of the 23 interviewed farmers (nearly 70%) considered heavy tephra fall as a possible threat in the future, yet only nine of these suggested potential mitigation strategies. Participants recognized the rarity of these events, noting none in the past 50 years. Farmers that experienced tephra fall had only experienced minor falls, which contributes to their overall perception of volcanic risk being low. This concurs with past work which has found that knowledge of a hazard is directly related to the proximity of the hazard source, degree of expected maximum hazard, the degree of damage, experience of prior events, and information available (Johnston et al., 1999; Paton et al., 2001).

Interestingly, the farmers who experienced tephra fall on their farms from the Mt Ruapehu 1995/1996 eruption perceived a range of tephra thicknesses from less than

1 mm to 15 to 25 mm, despite being located in the areas thought to have received trace amounts of tephra from this eruption (Figure 1). We believe this represents an over-reporting of tephra thickness by lay people, which was noted during this and other past eruptions in New Zealand.

Over half (12; 52%) of the farmers were unable to suggest remediation strategies and most had given the topic little thought. This may relate to a lack of past experience of volcanic eruptions coupled with a sense of not being vulnerable to this hazard. A sense of vulnerability encourages response to warnings and implementation of preventative measures (Johnston et al., 1999). Limón-Hernández et al. (2009) found communities at El Chichón volcano in Mexico needed a comprehensive educational programme long before an eruption to be prepared. This type of education would also be important for New Zealand farmers that may face major tephra falls in the future.

Farmer-suggested Remediation Techniques

Our survey results show that farmers acknowledged the importance of knowing effective tephra remediation strategies for pasture soils. Farmers suggested some conventional methods of remediation, such as cultivation, re-grassing, ploughing, and using fertilizer mix. One of the farmers suggested an unconventional method, potentially also the most expensive: namely, to excavate and invert (flip) the soil to expose the sub-soil. Below we discuss these strategies in the context of past work and provide a summary in Figure 5.

Six farmers who had experienced light tephra fall on their farm during the 1995/96 Mt Ruapehu eruption waited for rainfall to wash away the tephra. This also occurred in distal areas after the 1991 Vulcan Hudson eruption (Wilson, Cole, Cronin et al., 2011). In many small eruptions, this would be the only action needed, but it implies that supplementary feed is required during the waiting period.

Two farmers suggested applying fertilizers could speed up remediation, but we note that this was not effective when applied in the Upper Ibáñez valley after the 1991 eruption of Vulcan Hudson (Wilson, Cole, Cronin et al., 2011). However, different fertilizer and liming treatments have proven to be useful in boosting post-eruptive growth in the New Zealand context (Cronin et al., 1997).

Nearly 35% of participants supported cultivation/re-grassing to recover pasture soils following heavy tephra fall; this was effective at Volcán de Parícutin, Mexico (Luhr et al., 1993; Ort et al., 2008; Rees & Grayson, 1979), and in Chile and Argentina following eruptions (Wilson, Cole, Cronin et al., 2011). This also had the benefit of helping to stabilize the tephra from further redistribution (e.g., by wind or water). Ploughing heavy tephra-covered soil was suggested by our participants for heavy tephra fall and was also effective at Chile Chico, Los Antiguos, and Perito Moreno following the 1991 Hudson eruption (Wilson, Cole, Cronin et al., 2011). In practice, cultivation and ploughing can be considered a similar process: namely mixing the tephra with the soil in preparation for sowing of seeds. Treating these collectively, 11 (48%) farmers recommended this strategy. Indeed, such tilling of tephra into the upper soil horizon has proven to speed up recovery and pasture re-establishment (Craig, Wilson, Stewart, Villarossa et al., 2016).

Tephra thickness	Remediation strategy	Benefits
Light tephra fall (0 – 10 mm)	Rainfall / Irrigation*	Will help to wash away tephra (Wilson, Cole, Cronin et al., 2011)
	Organic fertilizer (cow shed effluent; chicken manure)	Will increase organic content (Wilson, Cole, Cronin et al., 2011); may not be available in large quantities if de-stocking has occurred
	Fertilizer	Supplies nutrients for pasture growth (Wilson, Cole, Cronin et al., 2011)
	Liming	May help increase the tephra pH levels as tephra is typically acidic
	Different grass mix*#	Some grasses may have higher tolerance toward tephra (Wilson, Cole, Cronin et al., 2011)
Medium to Heavy tephra fall (10 – 300 mm)	Cultivation*	Helps break the tephra layer and bring the buried soil to the top (Wilson, Cole, Cronin et al., 2011; Craig, Wilson, Stewart, Villarossa et al., 2016)
	Ploughing*	Helps mix tephra and underlying soil (Wilson, Cole, Cronin et al., 2011)
	Removal using heavy machinery*	Helps get rid of thick tephra layers (Wilson, Cole, Cronin et al., 2011)
	Flipping	Will bring sub-soils to the top and bury tephra

Figure 5. Remediation strategies that could be implemented for light and medium to heavy tephra fall based on farmer suggestions and literature review.
* = remediation strategies suggested by farmers that have shown success overseas according to the literature review.
# = has shown success for medium to heavy tephra fall overseas.

Removing thick tephra using heavy machinery was suggested by three of the farmers; this approach was also taken following the Hudson eruption where graders were used to scrape and remove the tephra (Wilson, Cole, Stewart et al., 2011). Excavation is one of the oldest remediation methods for contaminated soil (Lambert, Leven, & Green, 2000) and may be useful on smaller farms or for high-value crops. However, the average farm area amongst the interviewed farmers was 250 ha, thus removing the thick tephra from such large areas would be impractical and expensive. The advantage of this method is the complete removal of the contaminants (Wood, 1997), but the disadvantages include disposing of the removed tephra and the feasibility of this technique on many of New Zealand's rugged landscapes.

Thirteen farmers (57%) reported using organic fertilizers/manure/cow-shed effluent on their farms to recover soils degraded due to other causes such as pugging, floods, droughts, or erosion. Lal, Griffin, Apt, Lave, and Morgan (2004) reported that adding crop residues (green manure) into the soils not only increases the carbon content but also improves the soil structure. In the Upper Ibáñez valley, Vulcan Hudson, hay was used to increase the organic content of the tephra-affected soils, but it was expensive and only used in places where tephra was too thick to be cultivated (Wilson, Cole, Cronin et al., 2011). Hay is therefore unlikely to be a practical solution on large New Zealand farms. It is important to know how tephra would react to low-cost organic manure such as cow-shed effluent, which is readily available on most dairy farms. Another option might be chicken manure, a strategy suggested by one farmer for improving infertile soils (See Supplementary file 1). Any remediation strategy using effluent would be challenging on a large farm and may require imported effluent as well as additional machinery.

Two of the interviewed farmers suggested using different and hardier grass mixes to speed recovery. This showed success following thick tephra falls (more than 500 mm) from the 1991 Vulcan Hudson eruption, especially the indigenous grasses and a variety of foreign ryegrasses and red and white clovers (Wilson, Cole, Cronin et al., 2011). This is similar to a basic form of phytoremediation, which is often used to stabilize mine tailings and prevent leaching of pollutants (Fellet, Marchiol, Delle Vedove, & Peressotti, 2011). This may need to be carried out in conjunction with other remediation methods such as cultivation and fertilization in order for the pasture to establish.

Conclusions and Recommendations

New Zealand, especially the middle portions of the North Island, is at risk from heavy tephra fall, with many volcanoes capable of producing tephra fall more than 100 mm thick on pastures. It is important for the New Zealand agricultural sector to have a clear understanding of possible ways to recover from this volcanic hazard, prior to an eruption. There are only a few studies of rehabilitation of pasture following thick tephra falls in the literature, and none of these are from New Zealand. It is therefore equally important to investigate potentially useful local options. Although our study used a small sample which limits the generalizability and strength of conclusions, our findings usefully illuminate farmers' perceptions of tephra fall hazard and present insight into their experiences and thoughts on effective rehabilitation methods. We have prepared a preliminary guide to possible rehabilitation strategies for tephra-affected pasture based on the results of our study together with information from the literature (see Figure 5). Some of the strategies have only been suggested by farmers and it is unclear whether they will indeed work. On the other hand, many of the recovery strategies suggested by farmers have proven effective in other parts of the world. We thus provide preliminary insights and recommend further research to test these suggested remediation techniques on New Zealand pasture soils under simulated heavy tephra fall. While we acknowledge that pasture remediation is just one aspect of farming system recovery following a volcanic eruption, we believe our study has the potential to raise awareness amongst the farming community of tephra fall hazard and to prompt the development of possible preparedness strategies for the farming system as a whole.

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Appendices

Appendix 1: Characteristics of magmas

Typical characteristics (silica content, viscosity, gas content, eruption style, landforms, and hazards) of basalt, andesite, and rhyolite magmas. PDC stands for pyroclastic density current (Lindsay, Thompson, Shane, 2016).

Magma Type	Silica content	Viscosity	Gas content	Eruption style	Landforms	Typical hazards
Basalt	Low (45 – 55%)	Low (flows easily)	Typically low	Typically effusive	Shield volcano, scoria cone, lava field, maar	Lava flow, PDC (base surge), ballistics, tephra fall
Andesite	Intermediate (55 – 63%)	Intermediate (resistant to flow)	Typically intermediate	Typically explosive	Stratovolcano	Lava flow, PDC, lahar, ballistics, tephra fall, debris, avalanche
Rhyolite	High (>70%)	High (extremely resistant to flow)	Typically high (4 – 6%)	Very explosive	Lava dome, caldera	PDC, lahar, ballistics, tephra fall

Appendix 2: Interview questions (Initial interviews)

1) When did you start farming?
2) Are you a first generation farm owner or has your family been in farming in the past?
3) How many hectares is this farm?
4) What kind of farming is practised in your farm?
5) What pasture species/mixtures do you grow? Have you tried growing any other forage crops or pasture mixes?
6) What has been your most consistent crop in terms of making a good profit?
7) What is the livestock count of your farm?
8) Has your farm been affected by any volcanic activity since you began farming there?
9) Have you ever encountered any volcanic ashfall on your farm?
10) Do you think there is a risk that your farm could experience heavy tephra fall?
11) What do you think that are the potential risks of the nearest volcano on your farm?
12) What would you do if your farm received 1mm, 100mm or >300mm of ashfall?
13) Have you ever faced any major disturbance in the soil fertility of your farm?
14) Have you ever faced serious infertility / erosion / landslide / flooding / drought in your farm soil? How serious was it?
15) Have you encountered any other natural disaster on your farm?
16) What are the remediation or recovery practices practised by you in order to repair the infertile/un-productive/ damaged soil?
17) Have you faced any threat to your livestock due to the nearest volcano or any other natural phenomenon (e.g. weather, flood, drought etc)?
18) What was the biggest change you encountered during your years farming?
19) What would you say have been the biggest changes you've implemented on your own farm since you've been farming here? Do they correspond with what you think the biggest changes have been in the industry during that time?
20) Have you seen a change in your land since you first started farming?
21) Are there any differences between your farm now and your farm when you had started farming?

Closing the research-practice gap in emergency services organisations

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Abstract

This paper outlines research conducted in Australia and New Zealand into what enables and constrains emergency services agencies to utilise research to support organisational learning and evidence-informed practice. At a time when emergency services agencies are under increasing scrutiny, being able to demonstrate the link between research and theory to practice is ever more critical. This paper reports on a mixed methods approach that includes findings from a survey of 190 participants from 29 emergency services agencies on the degree to which they perceived their agencies engaged in a number of important processes in research utilisation. Agencies had different approaches to keep up to date with research advances. In collaboration with participants from the AFAC KIRUN group, an examination of the activities described by participants identified four developmental levels of what we have called research utilisation maturity (basic, developing, established, and leading). Organisations at high levels of utilisation maturity reported higher levels of perceived effectiveness on disseminating, assessing, and evaluating research as well as monitoring and communicating changes made as a result of the research (e.g., to policy, training, or practice). Practitioners experienced barriers associated with connecting research outcomes to agency business, understanding the meaning and implications for practice, and feeling confident about assessing research findings or addressing implications for practice. Where research utilisation maturity was higher, ratings on learning were higher and barriers experienced lower. Subsequent collaboration with a practitioner group has led to the co-creation of a self-assessment research utilisation tool that agencies can use to diagnose their capability and processes to support utilising research evidence in their practice. It is important to recognise that change and innovation is developmental and requires adjustments to governance processes, job responsibilities, and participation in communities-of-practice. More work is needed to better understand the enablers and constraints to utilising research to support development of evidence-informed practice, particularly in the emergency management sector.

Keywords: *Research-practice, research utilisation, learning organisations, fire and emergency services, emergency management*

Learning in emergency services organisations can come from a range of contexts: after-action reviews, often held at the end of an emergency event in an endeavour to improve practice (Vinnell, Orchiston, Becker, & Johnston, 2019); externally-led inquiries (Royal Commissions of Inquiry in Australia and in New Zealand; the TAG review into how New Zealand responds to disasters and emergencies: MCDEM, 2017); engagement in practice-led research projects (Hatton, Kipp, Brown, & Seville, 2017); and researcher-stakeholder collaborations (Huggins & Johnston, 2015; Kay et al., 2019). Indeed, in the emergency services sector we have seen a growing interest in learning. Participation in forums like the Australasian Fire and Emergency Services Authorities Council (AFAC) Lessons Management Forum continues to increase and similar forums are now occurring in New Zealand.

In many countries, sector innovation is supported by government policies and initiatives that fund research institutions to take a collaborative approach to research and development. These research centres produce ideas and outputs that can be adopted and applied by organisations. However, studies examining how research outcomes lead to learning, including enablers and constraints, appear limited to the medical field in general (Elliott & Popay 2000; Kothari, Birch, &

Charles, 2005) and nursing in particular (Carrion, Woods, & Norman, 2004; Retsas, 2000). As researchers and practitioners, we have a particular interest in understanding what enables and constrains emergency services organisations from learning, and in particular from adopting, research insights and incorporating these into practice.

Although using research to inform practice sounds straightforward, as Kay et al. (2019) point out negotiating this in the "real" world is not as simple as it might seem. This is because research scientists often produce findings in journal papers which are not easily or directly usable for practitioners. Moreover, decision-makers often face barriers to integrating research information into everyday practice. Yet the need to do so has never been greater; over the past decade there has been increasing scrutiny on emergency management organisations to justify actions (Boin & t'Hart, 2010; Eburn & Dovers, 2015). There is an urgent need for these organisations to learn about learning to innovate (Adams, Colebatch, & Walker, 2015). One way to do this is to actively engage in utilising research outcomes from partnerships with researchers and their institutions. The current paper investigates the problem of why insights from research are not better utilised by emergency services organisations. It aims to contribute to a better understanding of what enables and constrains emergency services organisations from learning to improve their capability.

Literature Review

The value of utilising research is well established (e.g., Brown & Frame, 2016; Cutler, 2008; Dearing, 2009). This is particularly so in an emergency services context. A good bond between researchers' findings and practice enables:

- co-creation of new knowledge (Brown et al., 2019);
- the number of strategies to support resilience to be increased (Doyle, Becker, Neely, Johnston, & Pepperell, 2015; Retsas 2000);
- a better understanding of resilience and enhanced capability (Brown et al, 2019; Vahanvati, 2020);
- improved emergency services response and management capability (Brooks, Curnin, Owen, & Boldeman, 2019; Owen, Hayes, Brooks, Scott, & Conway, 2018); and
- research effectiveness at agency and sector levels to be evaluated and demonstrated (Spiekermann, Kienberger, Norton, Briones, & Weichselgartner, 2015; Taylor, Ryan, & Johnston, 2020).

Studies of utilisation and the barriers that need to be overcome (e.g., Carrion et al., 2004; Kothari et al., 2005) suggest that research is used through a process by which new information or new ideas are communicated through certain channels, over time and among members of a social system. The process includes:

- disseminating new ideas or findings among members of a social system (Brown & Frame, 2016; Hemsley-Brown, 2004);
- assessing and evaluating the ideas in terms of their relevance to members of the social system (Carrion et al., 2004);
- implementing changes that may be needed (Brown et al., 2019; Elliott & Popay, 2000);
- monitoring the effects of the changes put in place (Taylor et al., 2020); and
- reporting outcomes of changes made as a result of the new idea (Doyle et al., 2015; Kay et al., 2019; Standing et al., 2016).

In summary, research is only one of several ingredients for successful improvements in practice and, in many respects, only the start of the process. Utilisation from research does not magically follow from research outputs. What is needed is a systematic follow-through from research insights to consider the implications and to develop processes that support review and, where needed, implementation and change.

Method

In Australia, the Bushfire and Natural Hazards Co-operative Research Centre (BNHCRC) and the AFAC have a continuing interest in enhancing research utilisation. Emergency services organisations have been regularly surveyed as part of a wider longitudinal study to assess how they use research to gain maximum benefit from their investment. Having gained research ethics approval to conduct the investigations (University of Tasmania Social Sciences Ethics Approval H0010741), surveys have been conducted every two years since 2010. The early surveys revealed opportunities to improve communication, engagement, and collaboration. Subsequent research utilisation policy focused on these areas.

The structure of items in the survey included the degree to which the research outcomes link to the organisation's strategic plan and core business; strategies to:

- disseminate the research within the agency;
- **a**ssess and evaluate the impact of the research in agency practice;
- implement any agency changes that may be needed;
- put in place monitoring processes to track changes; and
- add value to the outcomes of any changes made as a result of the research.

In this way, some of the items follow the sequence of activities found to be important in learning from research utilisation. For example, new information first needs to be disseminated and read, then assessed and evaluated for its possible impact on existing practice, and any changes needed based on the new knowledge need to be implemented, tracked, and evaluated.

The 2018 survey was distributed to 47 emergency services management agencies in Australia. Agency contacts were requested to distribute the survey to five to 15 people, using the following stratified sample:

- Senior management: the most senior person in the organisation responsible for the following areas: communications; training and development; operations; community safety; and knowledge management, innovation, and research;
- Five middle managers including regional operational and non-operational personnel (e.g., district managers); and
- Five people in operational or front-line service positions (e.g., volunteers, field operations personnel, community education officers, training instructors).

The purpose of this sampling method was to target personnel who could reasonably be expected to:

- have an understanding of the strategic planning of the agency;
- have some awareness and involvement in BNHCRC activities; and
- be responsible for implementing any changes needed based on research evidence.

Participants

The response yielded 190 returns from 29 agencies. The participation rate of 63% is good for online surveys of this type (Barach & Holtom, 2008). The median number of years that survey participants have been in the industry was 19, and the median number of years within the agency was 12, thus demonstrating the level of experience of those responding. Participants were asked a free text question to describe their role and answers from 122 participants were able to be coded. Of the participants who answered the question about their working role, 11 (6%) were in senior management positions (e.g., Directors), 70 (37%) were in middle management roles (e.g., District Managers), and 41 (22%) had front line responsibilities (e.g., training instructors). There were 38 responses that were not codifiable (e.g., “fire”, “operations”) and 20 participants (15%) did not answer the question.

Materials and Procedure

This method section and the following results outline four sections of survey findings. Section 1 includes answers to a qualitative question: “What strategies does your agency have in place to keep up to date with research?”. In the survey, we defined research as a systematic approach to answering a question or testing an hypothesis using a systematic study; that is, the researcher enquires into a problem, systematically collects data, and analyses these to develop findings to advance knowledge. Participants were advised that doing research in this way is distinguished from gathering general information through reading a book or surfing the internet.

Sections 2 to 4 contained quantitative questions which included: (2) participant perceptions of agreement with a statement about their organisations as learning organisations, (3) their levels of perceived effectiveness of their agencies in processes known to be important in research utilisation, and (4) levels of agreement with statements indicating barriers to research utilisation.

Section 2: Perceptions of learning in organisations. Participants were asked to rate the levels of agreement (on a Likert scale between 1 and 7 with the option of “can’t answer”) with the statement: “My home agency exemplifies a learning organisation”. In the survey, a learning organisation was defined as one where personnel were able to learn from the experience of members of the organisation or emergency services community through processes of reflection, sense-making, and action to develop new ways of acting which can lead to an increased capacity to act differently in the environment (after Kolb, 2014).

Section 3: Research utilisation processes. Participants were asked to rate the perceived effectiveness of their agency (on a Likert-type scale between 1 and 7 with the option of “can’t answer”) in terms of its processes to:

- disseminate research within the agency;
- assess and evaluate the impact of the research in agency practice;

- implement any agency changes that may be needed;
- put in place monitoring processes to track changes; and
- make the most of the outcomes of any changes made as a result of research.

Section 4: Barriers to research utilisation. Participants were also asked to provide an assessment of the degree to which key barriers might be impeding research utilisation. The barriers section included 15 items adapted from research undertaken in the health sector. Funk and her colleagues (1991) used the "Barriers to research implementation" questionnaire to diagnose areas that can be targeted to enhance change toward evidence-based work practice in the nursing sector. This work has been widely replicated by Baernholdt and Lang (2007), Elliot and Mihalic (2004), Helmsley-Brown and Oplatka (2005), and LaPierre, Ritchey, and Newhouse (2004) and provides a useful template. The question asked participants to consider each of 15 statements adapted for the emergency services sector and to rate (on a scale between 1 to 7 where 1 = "not a barrier" and 7 = "very much so") the degree to which they experienced the barrier in their workplace. The 15 statements are:

1) Implications for practice are not made clear;
2) The reports are hard to read;
3) Most people in this agency don't know about the research;
4) Agency personnel don't have the capacity to think strategically about what the research may mean for our business;
5) There is too much change happening in this agency already, we don't need more to be considered;
6) It is not clear what change is needed;
7) We need a change advocate within the agency to take the implications forward;
8) The impacts of the research for the agency need to be better articulated;
9) We need cooperation from other stakeholders in the industry for successful implementation;
10) The amount of research information is overwhelming;
11) Personnel don't feel capable of evaluating the quality of the research;
12) The research is hard to find;
13) It is not clear who is dealing with what research in our agency;
14) As an agency we don't have an effective process for translating the research for our personnel; and
15) The agency hasn't developed the appropriate assessment strategies to consider implications of the research.

Limitations

It should be noted that coding used to develop the levels of research utilisation maturity were empirically derived from the qualitative comments provided by participants. This means that the levels were based on only what the participant had reported in their comments, meaning that the participant's agency may be more active than was articulated in the comment. This may indicate a need to further investigate using other methods what is happening in agencies so others may learn from what actions personnel are taking to gain benefit from research.

Results

Analysis of Qualitative Data

A total of 140 participants provided codable answers to the question "What strategies does your agency have in place to keep up to date with research?". An initial review of the comments indicated that participants were describing qualitatively different types of activities and processes. A subsample of 30 of the comments were coded and discussed between the authors, drawing on research utilisation practice and innovation found in other sectors such as health (Baernholdt & Lang, 2007). Based on this subsample, a series of codes were developed and then reapplied to the 30 comments. Once the coders achieved an inter-rater reliability of 88%, all of the remaining comments were coded and all 140 responses were reviewed and discussed. The codes were then inserted into the survey dataset for further analysis.

These codes were also discussed with members of the AFAC Knowledge Innovation Research Utilisation Network (KIRUN), with whom the following indicators of *research utilisation maturity* were co-constructed. We define research utilisation maturity as including the processes and systems in place within organisations to make the most of their investment in research. Research utilisation maturity, therefore, is about using research in practice to support the agency's decision making, to drive innovation, highlight gaps and opportunities, and deliver the desired or improved results. The four levels of research utilisation maturity were defined as:

Basic: There are pockets of research utilisation however these are not systematically organised. Attempts to keep up to date with research depend on individual effort.

Developing: Some systems and processes are documented which enables research to be disseminated. There is limited evidence of analysis or impact assessment.

Established: There are systematic processes in place for reviewing and utilising research (e.g., dissemination and review either through job responsibilities or an internal research committee).

Leading: There is evidence of using research proactively. Operational and strategic decisions are informed by assessing research using formal research utilisation processes. These processes and systems are widely understood.

Table 1 details the four codes that emerged from the data as indicators of research utilisation maturity together with examples from the data. The total number of responses coded to the utilisation maturity level is included in the first column.

Once the responses to the qualitative question were coded, the codes were then reinserted into the overall dataset and the utilisation maturity levels were then used to analyse the quantitative responses.

Perceptions of Agencies as Learning Organisations

When considering if their organisations were learning organisations, the mean for the entire data set was 4.3 out of 7. Figure 1 shows the mean differences on perceptions of agencies as learning organisations for agencies at different levels of organisational maturity according to the coding of the qualitative themes. Figure 1 illustrates the link between how the responses to the qualitative question outlining the processes in place to keep up to date with research and coded to different levels of research utilisation maturity are associated with perceptions of organisational learning. In short, those reporting more established and leading indicators of research utilisation maturity were also reporting higher levels of organisational learning. The difference is most apparent between those responses coded to a "basic" level and those reported as developing, established, or leading. This difference was statistically significant, $F(3, 135) = 14.195$, $p < .001$, $\omega = .47$, indicating that as research utilisation maturity increases so too does organisational learning. At issue then, is what is it that those reporting basic levels of research utilisation maturity might do differently?

Research Utilisation Processes

Responses coded to the utilisation maturity framework also yielded statistically significant results for perceptions of effectiveness in: (1) disseminating research, (2) assessing and evaluating research implementing

Table 1
Research utilisation maturity codes and examples from the survey.

Level	Description	Examples in data
1: Basic *n* = 29 (21%)	Systems are ad hoc and unsystematic. Attempts to keep up to date with research depend on individual effort.	"Undefined, not clearly communicated within communications. Nil business unit assigned to research and development." "…the onus for keeping up to date is largely upon individuals maintaining an interest, or subscribing to emails."
2: Developing *n* = 70 (50%)	Some systems and processes are documented which enables research to be disseminated. There is little or no evidence of analysis or impact assessment. No evidence of how the findings are translated or connected to operational activities.	"We have two people that email CRC updates to staff." "Lots of material is distributed via our portal and email to keep staff and volunteers informed."
3: Established *n* = 22 (22%)	There are established processes in place for reviewing research (e.g., dissemination and review either through job responsibilities or an internal research committee).	"Developed a research committee." "SMEs [subject matter experts] appointed as capability custodians to ensure up to date best practice."
4: Leading *n* = 10 (7%)	There is evidence of active connections between research and operational activities. Operational and strategic decisions are informed by assessing research using formal research utilisation processes. These processes and systems are widely understood and embedded in multiple areas of practice.	"… a process of ensuring results are read by key specialist staff involved in program design and delivery, are interpreted and analysed for their implications and relevance and then used to inform decision-making and strategy through numerous internal fora." "Alignment of evidence-based decision-making in the planning phases of annual planning and the development of indicators around causal factors that inform emergent risk."

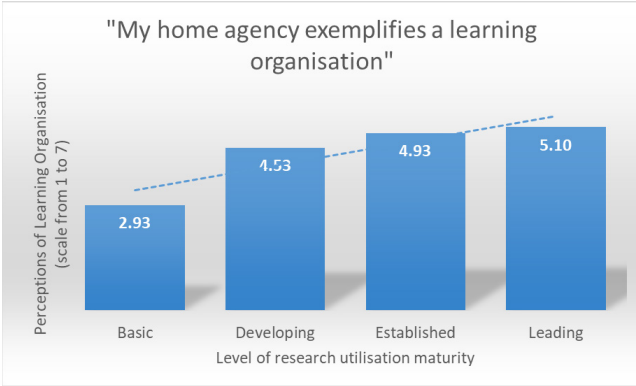

Figure 1. Mean comparisons for perceptions of learning organisation across levels of research utilisation maturity.

any changes needed, (3) putting in place monitoring processes to track changes, and (4) making the most of research outcomes (see Figure 2). Figure 2 illustrates the ways in which those coded at a basic level of organisational maturity were consistently reporting statistically significantly lower levels of effectiveness of a range of strategies associated with utilising research. These included differences in perceptions of how effective the agency is in disseminating research[1], in the ability to assess and evaluate its potential impact for practice[2], in being able to implement changes[3], in monitoring and evaluating any changes made[4], or making the most out of the changes introduced[5]. These represent important capabilities in being able to close the research-practice gap.

Analysing Barriers to Research Utilisation

A factor analysis was conducted of the 15 barriers to research utilisation using Principal Components Analysis and Varimax (orthogonal) rotation, with factor loadings (weightings) above .40 visible (as per Field, 2017) and with items sorted to reflect the relative strength of loadings per factor. The Kaiser-Meyer-Olkin (KMO) measure verified the sampling adequacy for the analysis, KMO = .781, as "very good", according to Field (2017). Four dimensions were identified and in combination explained 61% of the variance in response patterns, above the standard of 50% (Field, 2017).

1 Analysis of Variance between groups for "Disseminate the research within the agency", $F(3, 137) = 19.799$, $p < .001$, $\omega = .53$

2 Analysis of Variance between groups for "Assess and evaluate the impact of the research in agency practice", $F(3, 128) = 13.785$, $p < .001$, $\omega = .47$

3 Analysis of Variance between groups for "Implement any agency changes that may be needed", $F(3, 131) = 15.027$, $p < .001$, $\omega = .49$

4 Analysis of Variance between groups for "Put in place monitoring processes to track changes", $F(3, 128) = 10.329$, $p < .001$, $\omega = .42$

5 Analysis of Variance between groups for "Make the most of any changes made as a result of research", $F(3, 128) = 10.662$, $p < .001$, $\omega = .42$

Table 2 shows the factor loadings after rotation for the dimensions and where items with loading less than .40 were not included. The items that cluster together suggest that the first factor represents barriers relating to agencies connecting research outputs to their business, the second factor represents barriers associated with making sense of the implications and its consequences for practice and limits to change, the third factor represents barriers to accessing and understanding the research, and the fourth factor represents research evaluation capability.

First factor: Structural barriers to connecting research with agency business. The first factor (accounting for 34% of the response pattern) includes items that relate to the internal processes that agencies have in place to assess, analyse, and evaluate what the research means for their business (see Table 2). This barrier indicates a need to address internal governance processes for increasing the effectiveness and efficiency of connecting research to agency business. This includes defining the initial problem, transforming research output into meaning for agency practice through systematic assessment processes. This requires clarity and visibility about who is responsible for value-adding to research outputs for the agency. The agency may need to ensure that the personnel engaged in various projects are communicated to a coordination point.

Second factor: Barriers to understanding the meaning and implications for change. The second factor (accounting for 10% of the response pattern) relates to the need to overcome barriers to understanding the implications of research for practice and arrangements to support the changes needed in an agency and for the sector (see Table 2). This suggests a need to support prioritisation of necessary changes and ways to

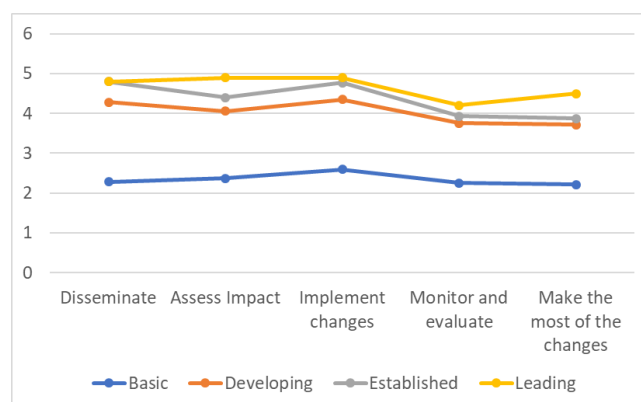

Figure 2. Mean comparisons for utilisation processes across levels of research utilisation maturity.

interconnect potentially disparate research outputs. This factor also connects to the next factor about ensuring research is visible for access and understanding.

Third factor: Barriers to access research and capacity to assess. The third factor (accounting for 9% of the response pattern) relates to the ability and confidence of participants to assess and evaluate the research reports and outputs (see Table 2). It may be that barriers to accessing the research and its meaning connects the first two factors. It indicates a need to build capability to be able to read, assess, and critically evaluate the quality of the research so that the findings can be trusted.

Fourth factor: Barriers to capability and capacity to address implications. The fourth factor (accounting for 7% of the response pattern) relates to the ability and confidence of participants to evaluate the research and to find the space to think about what it means for the future (see Table 2). However, as has already been discussed, assessing the implications of research for practice is not easy to address as the implications will change for different agencies and even different functional units within the agency. It is thus critical to acknowledge that developing a capacity to better understand the implications for practice will require significant effort and a targeted strategic approach.

Comparing factor scores and research utilisation maturity. The results from the potential barriers to research utilisation are interesting in that they provide insights into the challenges facing the emergency services industry. The analysis suggests that for significant leverage from utilisation to occur there is a need to build agency and industry capability in assessment and evaluation of potential impacts, as well as in processes of sense-making and assessment and evaluation. The findings also point to the need for research providers to have a greater understanding of the fire and emergency industry and a willingness to engage with practitioners in co-constructing meaning from findings for research investment to have greater impact.

An analysis was also made of the barriers reported as the combined factor scores for each of the four dimensions. Standardised scores were computed for each of the factors, where factors are normalised with a mean of 50 and a standard deviation of 10 and then mean differences are computed for those coded to each level of research utilisation maturity. This analysis indicated that those with higher levels of utilisation maturity

Table 2
Barrier items grouped into factors.

	1	2	3	4
The agency hasn't developed the appropriate assessment strategies to consider the implications of the research	0.812			
As an agency we don't have an effective process for translating the research for our personnel	0.808			
It is not clear who is dealing with what research in our agency	0.776			
The impacts of the research for the agency need to be better articulated		0.753		
We need cooperation from other stakeholders in the industry for successful implementation		0.696		
We need a change advocate within the agency to take the research implications forward	0.458	0.643		
The amount of research information is overwhelming		0.551		
There is too much change happening in this agency already, we don't need more to be considered		0.478		
Implications for practice are not made clear			0.758	
The reports are hard to read			0.741	
Most people in this agency don't know about the research			0.678	
Personnel don't feel capable of evaluating the quality of the research				0.814
Agency personnel don't have the capacity to think strategically about what the research may mean for our business				0.750
It is not clear what change is needed				0.460

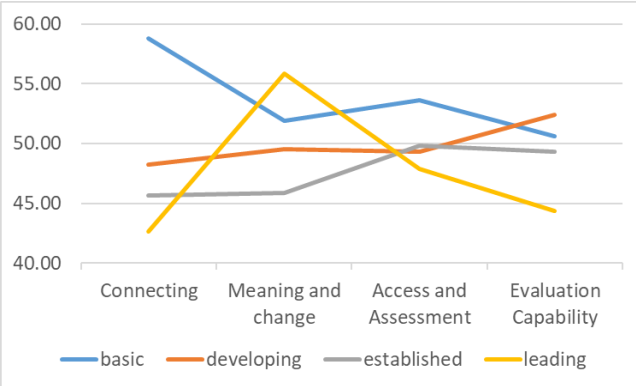

Figure 3. Levels of organisational maturity and barrier factors standardised scores.

reported lower levels of concern with the barriers (see Figure 3). It should be noted however that only one of the factors (Factor 1) is statistically significant[6], so the findings are indicative only of a descriptive trend but one which is worthy of further investigation.

We also speculate a relationship between the factors. Figure 3 suggests the biggest barrier for those personnel reflecting a basic level of maturity is "connecting research to agency business", which is reported lowest by those reflecting a higher "leading" level of research maturity. For those personnel reporting practices indicative of leading in research maturity the highest barrier experienced is in the factor relating to making meaning from the findings and their implications for change. This fits with personnel who are directly engaged in exploring the implications and what they mean for their practice. While these personnel are able to connect research outcomes to agency business, they still need help with consideration of the implications for change. For those reporting at a basic level of maturity, if it is not possible to connect research to the business, then considering implications is moot. We speculate that overcoming the barriers reflected in the third and fourth factors (access to the research and evaluation capability to assess its credibility) are intermediate steps between connecting and considering meaning and implications.

Discussion

Research Utilisation Maturity in Practice

What are organisations which are engaging in research utilisation doing that is different from those which are operating at a basic research utilisation maturity? The authors have continued to work with a national practitioner group, the AFAC (KIRUN), and in 2019 developed and trialled a self-assessment tool that practitioners can use to diagnose and self-assess their organisation's research utilisation maturity. Part of the validation of this tool included a review conducted by one of the authors (Krusel) who undertook an analysis of case studies published by AFAC during the period 2015-2017. This review triangulated the key indicators listed below as important critical success factors where research has led to clear, usable industry impact.

The tool has five sub-sections (see Figure 4) and guidelines for its use have also been developed (AFAC, n.d.). Participants reporting higher research utilisation maturity indicate that their agencies had:

Established governance processes: They have established governance processes in place. In this way, their business goals include research review (e.g., such as having a research review committee and a research framework as part of their business strategy). They also ensure that there are active connections between research engagement and operations.

Utilisation embedded into job roles: People have responsibilities for learning and review built into their job roles and into their group work. There is a widespread expectation that all personnel are responsible for learning and innovation will adopt evidence-informed processes. This is supported by resourcing for professional development opportunities.

Active testing of outputs: They are also actively engaged in testing of outputs, rather than accepting off-the-shelf products. In this way they transform the outputs so they are fit for purpose. They consult widely and know where to go for help and can access networks of expertise (internal or external to the agency) if needed.

Communities of practice: They are actively engaged in agency and industry communities of practice (including other industries such as health) to learn from and innovate. They recognise that there are no magic solutions and they are able to articulate what is not known, problematic, or uncertain which needs further investigation. They also recognise that learning is a process of continuous improvement.

For personnel within agencies experiencing a basic level of organisational maturity there are some actions available. The first step is to make research activity visible so that it can be employed in discussions about operational or strategic planning and capability and in

6 Analysis of Variance between groups for "Barriers in assessing and connecting research to agency business", $F(3, 126) = 9.059$, $p < .001$, $\omega = .48$

Research Utilisation (RU) Maturity Matrix

Element of research utilisation / Maturity		Basic *Pockets of research utilisation; not systematically organised*	Developing *Some systematic recognition and commitment to using research*	Established *Using research systematically*	Leading *Using research proactively to add value to our business and community*
Structure and Governance	Structure	Individual focus Not core job	Reactive Limited follow up	Strategic, planned, & systematic "Problem solving"	Risk taking Agile "'Problem seeking"
	Governance	No systematic quality assurance	Project based Spasmodic & unconnected	Programmatic Active management Alignment to strategy	Organisational transformational change
People		Individuals bring skills Limited research literacy	Person designated Some research literacy Some interest in building skills	In job roles Opportunity to develop skills	Questioning and innovation expected Continual improvement, change, & anticipation
Culture		Small pockets Value contested	Limited in reach & resourcing Little challenge of status quo	Value widely acknowledged Limited to "safe" questioning	Everyone values
Support systems and processes	Financial, physical, and resources for people	Individual influence	Stand-alone unit Limited connection to business Limited implementation	Capacity to make change Business as Usual (BAU)	Core business People mobile, diverse, & inclusive Borders are permeable within & external
	Policies, procedures, and doctrine (PPD)	Tacit Locally organised	Limited reach across business	Codified & clearly accessible Cross referenced	Fully embedded & regularly updated with feedback loops
	Communication, engagement, participation & collaboration	Through passionate individuals Not resourced	Dissemination one-way "End users" not linked to organisational processes Knowledge held as "power"	Widespread engagement Internal and some external to organisation	Collaboration between researchers & practitioners Widespread integration Internal and external collaboration
Products		Sit on the shelf Not used when individuals leave	One – off, tied to specific project Short-lived	Products are user friendly, fit for purpose, easily accessible, widely known, & actively incorporated into BAU. Widely disseminated & resourced & may have a cost/benefit assessment (link to systems). They are likely to be used in multiple applications	Testing & prototyping Transformed & applied beyond organisation / sector

Figure 4. Levels of Research Utilisation Maturity.

this way be linked to agency business. This may involve, for example, placing research as an agenda item on meetings so that it can be reported and recorded and thus contribute to corporate memory of the organisation. Another step is reviewing agency policy and doctrine for where the link to having an evidence-based practice is articulated. Inviting researchers to meetings to discuss their findings is also helpful as part of the problem is that, when faced with the findings from a complex research project, the implications for practice can be overwhelming. Researchers have a role to play here in assisting in meaning-making so that research outcomes can be considered in a staged way. It is important, therefore, that researchers step up and make findings both tangible and relevant for practitioners.

While the barriers included in the survey discussed here were focussed on considering research findings for practice it is important that agency personnel also consider the infrastructure their agency has in place for processing any research insights. This is where the self-assessment tool based on the research utilisation maturity levels discussed here and guidelines for its use become useful[7]. The guidelines provide a number of options practitioners can use to facilitate discussions about the level of infrastructure in place for the organisation to be ready to utilise research. Fire and Emergency New Zealand, for example, has used the self-assessment tool to contribute to framing research infrastructure needs to support future strategic planning (Z. Mounsey, personal communication, March 29, 2020).

Conclusion

This paper has discussed participant perceptions from 29 emergency services agencies on their use of research utilisation activities and practices. Participants reported that their agencies had different approaches to keep up to date with research advances. An examination of the activities described by respondents identified

7 www.afac.com.au/docs/default-source/ru/afac-rumm-guidelines.pdf?sfvrsn=2

four developmental levels of what, in collaboration with the AFAC KIRUN group, we have called *research utilisation maturity* (basic, developing, established, and leading). Those reporting that their agencies were low in research utilisation maturity reported less satisfaction with their agency's effectiveness in disseminating research, assessing and evaluating the implications of the findings, implementing any changes needed to monitor and track changes as a result of the research, and embedding the outcomes into practice. These participants also reported the most experience of the barrier to connecting research outputs to business. Those reporting activities associated with higher levels of research utilisation maturity reported higher levels of perceived effectiveness on disseminating, assessing, and evaluating research as well as monitoring and communicating changes. The results from the potential barriers to research utilisation section are interesting in that they provide insights into the challenges facing the emergency services sector. The analysis suggests that for significant leverage from utilisation to occur there is a need to build agency and sector-wide capability in assessment and evaluation of potential impacts, as well as in processes of sense-making and assessment and evaluation.

The findings align with research (e.g., Baumbusch et al., 2008; Paramonczyk, 2005) that suggests that to maximise the possibility of overcoming barriers to change for innovation what is needed are, in part, incremental adjustments to workplace practice brought about through an ongoing dialogue between researchers and practitioners. The findings also suggest it is no longer appropriate for researchers to remain isolated from the "real" practitioner world where their publicly funded research projects are intended to make a difference. Researchers have a responsibility to work at demonstrating relevance, facilitating meaning and implications for practitioners, and making their research accessible and transparent.

From this point of view, it will also be important to build bridges between different researcher and practitioner worlds. Understanding something of the different perceptions of researchers and practitioners would be important in order to better understand how the process of translating research findings into practice may be supported (Donaldson, Rutledge, & Ashley, 2004). Given the importance of a learning culture to support adaptation, innovation, and change within the industry, it would be useful in the future to continue to identify ways agencies can build cultures of learning. The existing findings provide some insights but do not explore the attributes that would enable the development of a learning and innovation culture.

In some circumstances it can take decades for research outcomes to translate into changes in practice (Chesla, 2008; Donaldson, et al., 2004). In the current context and for the emergency services sector in particular, these types of time lags between research and subsequent improvements are not acceptable. It is also imperative to develop the capacity to systematically understand what enables and constrains research uptake and end-user adoption. It has been argued that in industries based on evidence-based practice, the research process is in fact not complete until the impact and extent of innovation use are examined and understood (Donaldson et al., 2004; Lundblad, 2003). Given the importance in the industry (including supporting resilience in the face of litigious scrutiny for agencies) to be able to demonstrate evidence-based practice and to enable agility and responsiveness to change, then a better understanding of learning cultures within the industry would seem critical.

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