

1 **Going viral in PNG – exploring routes and circumstances of entry of**
2 **a rabies-infected dog into Papua New Guinea**

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12 **Abstract**

13 In this qualitative study implemented in November 2016, we elicited narratives about fictional
14 rabies incursions from key employees (n = 16) of the National Agriculture and Quarantine
15 Inspection Authority in Papua New Guinea (PNG) to explore the potential circumstances and
16 routes of entry of a rabies-infected dog, and direct rabies preparedness. Although PNG is rabies
17 free, proximity to rabies-endemic Indonesia poses a risk of introduction and it is expected that an
18 outbreak in PNG would have devastating human health impacts consistent with other countries
19 with similarly low human development indices and abundant free-roaming dogs. Participants
20 used their local and professional knowledge to create plausible narratives in response to
21 contextual, but fictitious, newspaper stories. An ethnographic content analysis was used to
22 extract themes and interpret the narratives. Themes were assessed in the context of their potential
23 influence on rabies preparedness in PNG against the social and political background of PNG and
24 relevant, published literature. Consistent themes included the ubiquity of trade and the
25 complexity of routes between Indonesia and PNG. Dog ownership seemed pragmatic – actors in
26 the narratives readily and rationally involved dogs in transactions in response to trade, exchange
27 or gifting opportunities. Consequently, dogs changed ownership frequently. The findings of this
28 study have important implications for rabies preparedness in PNG; there is potential for wide
29 geographic dissemination of rabies in dogs before outbreak detection. However, common
30 patterns of travel – trade of dogs via Papuan towns and use of traditional trade routes – do
31 provide opportunity for targeted surveillance and response in the event of an incursion.

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34 **Keywords**

35 Papua New Guinea, rabies, routes, risk assessment, fictional outbreak narratives, ethnographic
36 content analysis

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38 **Research highlights**

- 39 • Fictional newspaper stories elicited narratives about patterns of dog travel to PNG.
- 40 • Trade *en route* is ubiquitous; dogs are commodities that change ownership frequently.
- 41 • Rabies surveillance in PNG should target traditional trade centres and routes.
- 42 • Cultural beliefs are likely to mask rabies case detection in humans and dogs.

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48 **1. Introduction**

49 Canine-rabies is a high impact, zoonotic disease that is estimated to cause approximately
50 50,000 human deaths globally each year (Hampson et al., 2015). The World Health
51 Organization, World Organisation for Animal Health, Food and Agriculture Organization of the
52 United Nations and the Global Alliance for Rabies Control recently proposed a framework for
53 elimination of canine-mediated human rabies (WHO and OIE, 2016). Although the focus of this
54 framework is elimination in currently endemic regions, prevention of spread to historically or
55 recently rabies-free regions is also recognised as important to achieve global elimination.

56 South-east Asia is a region in which rabies spread is ongoing. For example, an outbreak
57 of rabies in dogs and humans was recently reported in Sarawak, Malaysia, on the island of
58 Borneo (ProMED-mail, 2017). This part of Malaysia shares a land border with the rabies-
59 endemic Kalimantan Provinces of Indonesia. Within the past two decades rabies has spread to
60 previously uninfected areas and provinces of Indonesia (Tenzin & Ward, 2012). Spread is
61 attributed to the movement of rabies-infected dogs facilitated by human activities (Putra et al.,
62 2013; Susetya et al., 2008; Windiyaningsih et al., 2004). Papua New Guinea (PNG) also shares a
63 land-border with Indonesia, and although the island of New Guinea is currently rabies-free, the
64 proximity of the rabies-endemic Indonesian provinces of Maluku and North Maluku and the
65 abundance of dog movement across New Guinea island pose a risk of rabies introduction
66 (Anonymous, 2017).

67 The human development index (HDI) of PNG is currently 0.516
68 (hdr.undp.org/en/countries/profiles/PNG, accessed 17.06.2017), ranked 154th globally. This low
69 HDI reflects an under-resourced education and health system, poor infrastructure outside the
70 major urban centres (Port Moresby, Lae and Madang) and low gross per capita income. Nearly

71 40% of the 7.6 million people in PNG live below the income poverty-line, most (87%) live in
72 rural locations, and the current life-expectancy at birth is 62 years. Hampson and colleagues
73 (2015) inferred that the probability that a person would receive rabies post-exposure prophylaxis
74 (PEP) was significantly lower in countries with low HDI. Consequently, establishment of rabies
75 in the domestic dog population in PNG would likely have a high impact; not only to individuals,
76 but also to the country due to lost productivity and the cost of PEP and control measures.
77 Prevention of a rabies incursion is therefore, a high priority for PNG and improving rabies
78 surveillance and response capacities are a current focus for activities of the National Agriculture
79 Quarantine and Inspection Authority (NAQIA).

80 A previous study in which employees from NAQIA in PNG participated in an expert-
81 elicitation workshop, identified potential routes of entry of a rabies-infected dog to PNG
82 (Anonymous, 2017). The structured methods used in this workshop allowed prioritisation of
83 routes for detailed risk assessment and subsequently, the comparative risk of three land and two
84 sea routes throughout coastal and border provinces in PNG were investigated (Anonymous,
85 2017). Overall, dog movement across the Papua Province–PNG land-border was estimated to
86 pose the greatest risk, especially those associated with hunting and traditional border crossers
87 (TBCs) in the South Fly District of Western Province, and associated with TBCs in the Vanimom-
88 Green River District in West Sepik Province. Due to the structured nature of the methods used in
89 the expert-elicitation workshop, only routes for which participants could make quantitative
90 estimates – for example, the annual number of commercial fishing boats arriving in PNG – could
91 be prioritised. During the workshop, participants also discussed aspects of land-border travel. For
92 example, they stated that ‘trans-migrants’ (foreign nationals who enter PNG illegally for
93 permanent residency) could also bring a rabies-infected dog to PNG, especially via the land-

94 border, and described how changes in industry such as increased oil palm plantations and
95 development of commercial fishing along the north coast attracted workers from Indonesia.
96 Given the length of the land-border (> 700 km), the limited control of immigration between
97 Papua Province and PNG and the estimated, comparatively high risk posed by land-routes
98 relative to sea routes, we considered that further investigation of the entry of dogs to PNG via the
99 land-border was warranted. Therefore, the objective of this study was to investigate the routes
100 and circumstances of dog entry to PNG from rabies-endemic Indonesian islands. We used
101 qualitative methods involving fictional newspaper reports of rabies incursions for participants to
102 respond to in order to elicit a set of outbreak narratives. We believe that the use of fictional
103 reports to elicit outbreak narratives is novel, and present this as an extension of established
104 methods in which outbreak narratives are used identify and describe the contexts and
105 consequences of disease epidemics (Leach & Scoones, 2013; Herring et al., 2010). In this body
106 of scholarship, the focus is on how the discourses surrounding a disease outbreak are:
107 “constructed, mobilized and interact, [to] selectively justify pathways of intervention and
108 response” (Leach and Tadros, 2014, 240).’ Rather than critically examine existing discourses, in
109 the current study, we have supplied participants with a series of simple descriptive narratives.
110 Drawing on their located knowledges, understandings and practices, participants were asked to
111 construct the underlying mobilities, exchanges and entanglements they believe most likely to
112 lead to specific outbreak outcomes.

113 Based on participants’ local knowledge and professional experiences as NAQIA officers,
114 each outbreak narrative describes a potential transmission route and set of circumstances that
115 they believed could lead to a rabies outbreak in specific locations in PNG. Consistent with the
116 tenets of ethnographic content analysis (ECA), we then interpreted the resulting narratives within

117 the social and political context of their production (Altheide, 1987). Drawing on both numerical
118 and narrative data, the ECA allowed us to elucidate patterns and develop detailed comparisons of
119 participants' causal interpretations of the events described in each newspaper report (Hsieh &
120 Shannon, 2005). This approach to narrative analysis is novel in the context of biosecurity
121 research, and builds on recent participatory work in One Health (Coffin et al., 2015; Scoones et
122 al., 2017). The information and hypotheses about mobility, connectedness and practices of
123 exchange generated from this study will complement quantitative risk assessments to direct
124 canine-rabies prevention, surveillance and incursion response strategies associated with rabies-
125 infected dog entry via the Papua Province–PNG land-border.

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127 2. Materials and Methods

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129 2.1. Survey

130 Participants were purposively selected from employees at NAQIA in PNG, based on their
131 region of work and years of experience in animal biosecurity. A questionnaire was designed to
132 investigate routes of rabies incursions between Indonesia and PNG, via the Papuan–PNG land
133 border (details below). The questionnaire was designed in SurveyMonkey™ and implemented
134 between 3/11/2015—17/11/2015.

135

136 2.1.1. Questionnaire design

137 PNG is canine-rabies free, and the questionnaire presented three fictitious rabies-
138 incursion scenarios at Madang town, Tabubil (Sisimakam) and South Fly District. Locations for
139 the incursions were chosen to maximise variation between scenarios. Scenario locations are
140 shown in Figure 1.

141 Madang town (population approximately 27,000) is located on the north coast of PNG
142 and is the capital of Madang Province. The Madang sea port is a ‘first port of entry’ for vessels
143 from international waters and is one of PNG’s largest fishing ports – there are several tuna
144 canneries in Madang. Sisimakam village is 24 km by road from Tabubil, a town with a
145 population of approximately 13,000, located in the landlocked North Fly District of Western
146 Province. Both Tabubil and Sisimakam are close to the Ok Tedi River (a tributary of the large
147 Fly River), which flows to form part of the Papuan–PNG border in a region in which there are
148 several refugee camps. Employment opportunities in this region include mining. As well as river
149 access to this region, both Tabubil and Kiunga (also in North Fly) have scheduled air services.

150 The South Fly District is also in Western Province and is adjacent to the Torres Strait, Australia.
151 This region has low population density (~1.9/km²) and, compared to Tabubil and Madang, is
152 relatively inaccessible. Activities in this region include deer hunting and trading (shopper-
153 crossing) from Papua Province, Indonesia, to Daru and Port Moresby.

154 Each scenario was presented as a report in a newspaper clipping and contained names of
155 participants to increase motivation and encourage contextual thinking about how such a fictitious
156 rabies incursion might have occurred (Supplementary material, S2—4). All reports were written
157 in English (one of three official languages of PNG), and all participants could read and write
158 English fluently.

159 In each of the fictitious scenarios contained in the newspaper articles, the incursion was
160 written to be the result of entry of a rabies-infected dog. Scenarios were developed so as to be
161 fact-based with an emphasis on descriptive content rather than emotive language; they varied in
162 geographic location, outcome (human or canine rabies) and the process by which rabies was
163 detected (following reports of unusual behaviour in dogs, and a hospitalized case in a child).

164 Although canine-rabies is endemic in parts of Indonesia, Papua Province (Figure 1) is
165 canine-rabies free. Therefore, participants were asked to narrate – in as much detail as possible –
166 the circumstances of the incursion, including the route via the Papuan–PNG border back to the
167 origin on a rabies-endemic island in Indonesia. Specific questions asked to inspire participant
168 narratives and draw out specific details included:

- 169 • ‘How did the dog get to [Madang]?’
- 170 • ‘What route did it take, who was it travelling with, and how did they travel?’
- 171 • ‘Do you think your route happens commonly?’

172 • ‘What other variations might happen on this route?’

173 Finally, participants were asked for any further comments about the circumstances
174 leading to the incursions. A copy of the questionnaire is included in the supplementary material
175 (S1).

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178 **2.2. Data Analysis**

179 Descriptive statistics summarised the length of narratives (word count) and the number of
180 narratives for each scenario. Qualitative analysis software (NVivo; QSR International Pty Ltd.
181 Version 11, 2015) was used to collate narratives for each scenario. Word frequency was analysed
182 for each scenario using a minimum word length of three letters and grouped stemmed words (for
183 example, ‘*infect*’ grouped with ‘*infected*’ and ‘*infection*’) to construct a rank order comparison.
184 Word frequency analyses were displayed as tree-maps (the area of each word’s rectangle is
185 proportional to the frequency of the word) to identify and compare the key actors, locations and
186 types of relationships/interactions contained in each of the 3 corpuses of outbreak narratives
187 (Krippendorff, 2004).

188 To extend and test our preliminary findings, the narratives were then read repeatedly by
189 the lead author and coded in NVivo according to categories developed from the earlier expert
190 workshop (Anonymous 2017). The categories were:

- 191 • routes of travel (including origin and border crossing location);
- 192 • modes of travel;
- 193 • reasons for travel and activities with which travelers were associated;
- 194 • the types of people involved in the narrative, and

195 • the purpose of the dog (when provided).

196 Consistent, divergent or unusual themes were identified within each category and
197 represented in a tabular matrix (Miles & Huberman, 1994). As part of the ECA, themes were
198 analysed in the context of available scholarly and grey literatures to add context to the events and
199 relationships described in each narrative, and to assess validity and develop hypotheses about the
200 routes and circumstances of potential rabies-infected dogs from Indonesia to PNG. The
201 implications of these hypotheses were considered in the context of incursion prevention,
202 surveillance and response strategies for canine-rabies in PNG. Regular discussions among the
203 authors served to generate additional lines of inquiry and test findings and insights as they
204 emerged (Stewart, 1998).

205

206 **3. Results**

207 **2.1 Participant and narrative characteristics**

208 The questionnaire response rate was 73% (n = 16). Of the 13 participants who provided
209 demographic information, most were male (n = 9, 69%), aged between 30 and 49 years, and had
210 lived in PNG all their life (Figure 2). These participants had a combined duration of employment
211 with NAQIA of 159 years (mean 13.3 years, median 6.5 years, range 1.5—34 years).

212 The length of transcripts ranged from 43—783 words (median 371) and participants
213 provided a total of 41 narratives and 7 additional comments about scenarios. Narratives about the
214 incursion in Madang were most common (n = 17; some participants provided more than one
215 possible route), followed by South Fly District (n = 13) and Tabubil (n = 11).

216

217 **2.2 Word frequency analysis**

218 Commonly used words that did not add to understanding the context of the incursion
219 (dog, rabies, infect, border, Madang, Tabubil, Western, Province) were removed from the word
220 frequency analysis. Tree-maps of the most frequent 100 words are included in the Supplementary
221 Material (Figures S5—S7).

222

223

224 **2.2.1 Madang narratives**

225 Locations mentioned in the narratives included Vanimo, Wutung, Jayapura, Wewak,
226 Aitape, Bogia, Batas and Bali (Figure 3, red markers). ‘Boat’ was the most frequently mentioned
227 mode of transport (1.33%), especially when combined with other sea and river transport
228 associated words (ships, vessel and sea; total combined 2.66%). Other modes of transport
229 included ‘car’ and ‘vehicle’ (combined 0.6%). ‘Logs’ (1.93%) was the single most frequently

230 mentioned activity-associated word, although ‘trading’ and associated words (‘purchase’,
231 ‘bought’, ‘business’, ‘goods’ and ‘products’) combined to 2.0 %. ‘Fish’ was infrequently
232 mentioned (0.27%), and ‘hunter’ and ‘hunting’ only had a combined frequency of 0.54%. Words
233 most likely associated with the purpose of the dog included ‘pet’ (0.73%), ‘birthday’ (0.27%)
234 and ‘fighting’ (0.27%). The most commonly mentioned people were ‘family’, ‘relatives’, and
235 ‘friend’ (combined 1.73%). Unusual words that were frequently mentioned included ‘back’
236 (0.93%) and ‘return’ (0.47%).

237

238 2.2.2 *Tabubil (Sisimakam) narratives*

239 Locations mentioned in the narratives included Merauke, Bali, Sulawesi, Yott, Bosset
240 and Kiunga (Figure 3, yellow markers). ‘Road’ (0.6%) was the most commonly mentioned
241 transport associated word but ‘boat’, ‘river’ and ‘vessels’ had a combined frequency of 1.2%.
242 ‘Trading’ (1.55%) was the single most frequently mentioned activity-associated word and the
243 combined frequency with ‘exchange’ was 2.15%. However, ‘hunting’ and ‘poaching’ were also
244 commonly mentioned activities (combined frequency 2.14 %). ‘Illegal’ (0.71%) was associated
245 with hunting or fishing, and animals that could be hunted included ‘deer’ (0.48%) and ‘dugong’
246 (0.36). ‘Log’ and ‘loggers’ combined frequency was 1.19 %, and ‘fishing’ was only 0.48%.
247 Words associated with military activity (‘military’, ‘civilian’ and ‘garrison’) had a combined
248 frequency of 1.32%. ‘Gift’ (0.71%) and ‘security’ (0.36%) were the most frequently mentioned
249 words that might be associated with the purpose of the dog, although ‘hunting’ (1.43%) might
250 also be associated with dog purpose. The most commonly mentioned people were ‘family’,
251 ‘relatives’, and ‘friend’ (combined 1.44%). ‘Traditional’ (0.71%) might be associated with
252 reasons for crossing the Papuan-PNG border. Unusual words included ‘shells’ (0.48%).

253

254 *2.2.3 South Fly District narratives*

255 Locations mentioned in the narratives included Merauke, Aru, Yowara, Bali, and Madang
256 (Figure 3, blue markers). The only transport-associated word was ‘walked’ (0.47%). ‘Hunting’
257 (1.88%) was the single most frequently mentioned activity-associated word and the combined
258 frequency with ‘hunter’ was 2.35%. ‘Fishing’ was also mentioned with high frequency (1.1%).
259 ‘Illegal’ (1.1%) might be associated with hunting or fishing, and animals that could be hunted
260 included ‘pig’ (0.47%). ‘Trading’ and ‘exchange’ had a combined frequency of 1.41%, but ‘log’
261 only had a frequency of 0.31%. Words associated with mining activity (‘alluvial’ and ‘miners’)
262 had a combined frequency of 0.94%. ‘Hunting’ (1.88%), ‘gifts’ (0.31%) and ‘companion’
263 (0.31%) were words that might be associated with the purpose of the dog. The most commonly
264 mentioned people were ‘family’, ‘brother’, and ‘friend’ (combined 1.72%), and ‘refugee’
265 (0.63%).

266

267 **2.3 Thematic analysis**

268 Consistent and divergent themes that were identified within each scenario are described
269 below. Table S8 contains excerpts that illustrate themes from narratives for each fictional
270 incursion location.

271

272 *2.3.1 Madang narratives*

273 The routes in the Madang narratives covered the widest geographic area of the three
274 incursion scenarios (Figure 3, red markers). Whilst most dogs came from islands in eastern
275 Indonesia, dogs also originated from Jakarta (traders with counterfeit goods) and Sumatra (trans-

276 migrants). Once dogs reached Papua, they most often travelled through Jayapura, and
277 occasionally Merauke, prior to crossing the Papuan–PNG border in the Vanimo region.

278 Once in PNG, routes to Madang generally followed rivers and the northern PNG
279 coastline. Consequently, boats were a common mode of travel and generally not, as might have
280 been expected, associated with fishing. This is consistent with word frequency analysis for the
281 Madang narratives in which it appeared that fishing was not a common activity with which dogs
282 were associated.

283 Overall, route complexity was a consistent theme in this scenario, particularly through
284 PNG where travel often involved multiple towns and modes of transport. For example, a traveler
285 from the border post at Wutung might go to Vanimo and board a ferry to Aitape. From Aitape,
286 they can travel to Angoram via Wewak, then along the Sepik River to Bogia by banana-boat and
287 on to Madang by car. Other locations that travelers passed through on the PNG mainland
288 included Maprik and Timbukte. Although routes were complex, participants frequently stated
289 that travelers were following traditional trade routes.

290 Reasons for travel commonly included trade – for example, bartering for betel nut and
291 counterfeit goods – amongst friends and relatives. The illegal nature of some activities appear to
292 have encouraged participants to increase the complexity of the routes described because travelers
293 bypassed border checks at Wutung to avoid inspections and government taxes (for example, by
294 traveling from Jayapura to Vanimo by banana-boat). Otherwise, the most common reason for
295 travel described by participants was the return of Indonesian workers to workplaces in or near
296 Madang – such as logging camps and the tuna cannery (fishing crews) – after visiting family in
297 Indonesia. The focus on the movements of migrant workers also influenced route complexity

298 because participants assumed that workers would travel the most economical routes and made
299 use of company transport, such as logging vessels, along the north coast of PNG.

300 Once the dog reached Madang, participants most often described the final purpose of the
301 dog as companionship, either in homes or in logging camps. However, in participants’
302 descriptions prior to reaching Madang, dogs changed ownership and purpose frequently along
303 routes. Participants often described exchange of the dog for goods in Papua by traders or
304 fishermen from Indonesian islands, followed by sale or exchange of the dog in Jayapura as a
305 guard dog, companion or hunting dog (pigs, cuscus and other wildlife) before reaching Madang.

306

307 2.3.2 *Tabubil (Sismakam) narratives*

308 Most routes to Tabubil originated in the northern Maluku islands. The most distant
309 origins were Bali and Sulawesi (Figure 3, yellow markers). Merauke was the most commonly
310 included Papuan town, although Bis Agats was also mentioned. Similar to the Madang
311 narratives, participants described traditional trade routes from Papua to PNG. These complex
312 routes commonly included refugee and military camps on the border with sections traveled by
313 road as well as in boats, particularly along the Fly River.

314 The most common reason given by participants for travel between Papua and the
315 Tabubil region was trade (often illegal), followed by hunting, family visits, refugee and military
316 movement and occasionally logging. Participants described how villagers in the region welcome
317 trade with the Papuans. Traded items included shells used to guard small agricultural plots
318 (‘gardens’), as well as dugong and turtle meat and other desirable goods such as fuel, batteries
319 and processed food. Participants stated that Papua–PNG intermarriage is common (for example,

320 between tribes in Yott in Papua and Sismakam in PNG), and cultural links between family and
321 friends throughout the region influenced travel for trade.

322 The final purpose of dogs was highly variable in the Tabubil narratives and included
323 companionship or work as a hunting, fighting or guard dog. Consistent with the Madang
324 narratives, dogs changed ownership and purpose frequently and often passed between owners
325 through trade or as gifts along routes.

326

327 2.3.3 *South Fly District narratives*

328 The southern Maluku Islands were the most common origin of dogs in the South Fly
329 incursion scenario, although the overall geographic extent was similar to the Tabubil scenario
330 (Figure 3, blue markers). Individual routes were again complex and variable, but appeared to
331 follow a pattern consistent with the Madang and Tabubil (Sisimakam) narratives in which
332 Papuan towns were trading hubs. Commonly, participants described hunters and fisherman
333 traveling from south-eastern Indonesian islands to a town in Papua – often Merauke, but also
334 Timika – for trading. Hunters then continued into South Fly District; otherwise dogs changed
335 ownership (often in exchange for basic goods) and were taken to South Fly District to hunt by
336 people with cultural connections who traveled between Papua and South Fly for trade. Routes
337 via refugee camps – for example, Sotar, Kaikok, and Yowara – were frequently mentioned as
338 border-crossing places.

339 Participants stated that this pattern (fishing from an Indonesian island, trading in a
340 Papuan hub town, travel via a border refugee camp then hunting in South Fly) was a common
341 pathway because these are traditional cultural and trade routes.

342 Although travel by boat was not specifically mentioned, accessing South Fly District via
343 the Bensbach River (for example, from Sotar) featured in narratives. The most common mode of
344 travel was on foot, and participants described walking routes (Merauke to Sotar) and extensive
345 hunting trails that covered most of South Fly and reached as far north as Kiunga.

346 The dominant reasons for travel were hunting (in Papua and South Fly District) and
347 fishing (from Indonesian islands around Papua). This was expected following word-frequency
348 analysis and was consistent with the pattern of travel described in narratives. Trade was a
349 common secondary activity in Papua. Traveling to South Fly for work on mines and logging
350 camps were less common reasons for travel.

351 Consequently, hunting was the most common purpose of dogs. Consistent with the
352 Tabubil and Madang narratives, dogs changed ownership frequently and were often traded in
353 Papua by fishermen who brought them as companions, or given as gifts to family members.

354

355

356 *2.3.4 Unusual themes*

357

358 Participants only twice mentioned illegal activities that were potentially known to
359 authorities. In a Madang narrative, a participant described how a puppy was carried in a bilum
360 (bag) via the border inspection post at Wutung, and in another narrative (South Fly District) a
361 garrison commander transported dogs to the border region on a military aircraft. The participant
362 who wrote the latter narrative went on to describe how, “the garrison commander ... has
363 assigned [his] civilian relatives to establish and operate a range of business ventures, including
364 poaching of wild deer to help feed his soldiers and their families, and his serving military
365 relatives to gather clandestine intelligence and provide security for his businesses.”

366 Knowledge of rabies amongst travelers was only mentioned in one narrative (South Fly)
367 in which an Indonesian national was said to have views against vaccination of dogs for rabies;
368 “The fishing vessel has two mixed-breed dogs that are owned by the captain who is also a dog
369 breeder. He doesn't believe in vaccination against rabies. Because he thinks he can easily gun
370 down his dogs if they'll have rabies. What he doesn't know is, these two dogs had previous fight
371 with other dogs in their village who are subclinical carriers of the virus.” Superstitious beliefs
372 were also mentioned, but rarely. In a Tabubil narrative, a participant described how “an exorcist
373 was engaged but the entire villager's family were infected and died. ... With strong belief in
374 sorcery the villagers vacated their village [in Papua] and migrated inland.”

375 From the perspective of spread of canine-rabies, a potentially valuable excerpt was the
376 reference to trade of dogs for meat between Sulawesi (a rabies endemic region of Indonesia) and
377 Merauke, Papua, in a Tabubil narrative. “There is an enormous dog meat trade in Sulawesi so
378 people go there to get the ‘best dogs’ compared to normal village dogs. They then resell the dogs
379 in the black-market at other areas, including Merauke, hence from Sulawesi they are taken by

380 boat to Merauke.” This was also the only reference in the narratives in which dogs were the
381 primary reason for trade and travel.

382 Generally, dog ownership was based on practical requirements and exchange of dogs was
383 pragmatic – if the dog was admired by higher ranking people or could be traded for goods or
384 money, the dog changed ownership. Therefore movement of dogs to join translocated relatives –
385 such as in the following extract – was rare; “The [Indonesian] logging company worker was
386 transferred to Madang... The worker’s family brought the dog with them when they
387 transmigrated from Sumatra to resettle in Sentani, and the natural thing for them to do is to drive
388 the animal to Batas and hand over the dog to their father who really misses the dog.”

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393 3. Discussion

394 Outbreak narratives can make explicit underlying sets of assumptions about the causal
395 pathways, networks of spread and attributions of blame for the emergence of infectious diseases
396 in new locations, populations or both (Dry & Leach, 2010). Acknowledging that past analyses of
397 outbreak narratives have been historically-focused and critically oriented, the participatory study
398 of narratives can also provide important prospective and descriptive insights into how individuals
399 and groups relate events at one place to what has occurred elsewhere (Leach & Scoones, 2013;
400 Weir & Mykhalovskiy, 2010). Analysis of the responses of NAQIA officers to fictional rabies
401 incursion scenarios identified consistent themes for reasons and activities associated with travel,
402 as well as patterns in the routes and modes of travel from rabies-endemic regions of Indonesia to
403 the locations. Generally, each incursion location had an activity with which it was commonly
404 associated, such as hunting in South Fly and logging in Madang. Despite this, trade dominated
405 the reasons and activities associated with travel throughout the narratives for all three incursion
406 scenarios; words such as trade, exchange, business, goods, products, gift, bought and purchase
407 were commonly and consistently used, and patterns of trade were evident on thematic analysis.
408 Even in South Fly, in which the primary activity with dogs appeared to be hunting, hunters
409 linked their activities with traders in Papua whose connections could be traced back to rabies-
410 endemic regions of Indonesia via other groups, such as fishermen.

411 The pervasiveness of trade throughout the narratives is consistent with the findings of a
412 recent study which examined the social value of the “grassroots” traders associated with betel nut
413 trade in PNG (Sharp, 2016). Sharp explains that trade – including monetised trade, exchange of
414 goods and gifting – has traditionally played a key role in defining individual identity and
415 structuring social relationships throughout Melanesia (Papua New Guinea, Fiji, Vanuatu and the

416 Solomon Islands). Using the betel nut trade as an example, he found that this is still a
417 fundamental activity in contemporary PNG; family relationships are reinforced and friendships
418 are defined through trade in an extensive network of marketplaces – from urban centres to
419 roadsides – throughout PNG. Consistent with these observations, we found that the most
420 common actors in narratives were family and friends, and that participants in the study also gave
421 detailed explanations about relationships and reasons for types of trade (monetised, exchange or
422 gifting) between these actors.

423 Given that trade is such a central activity, it is not surprising that dogs changed ownership
424 frequently during their travel from Indonesia to mainland PNG. This was also a consistent theme
425 between narratives for all incursion scenarios; it appeared that dogs were perceived as a
426 commodity and that their purpose was not fixed but instead defined by the dog’s owner. For
427 example, a dog who was the companion of an Indonesian fisherman could be traded in Merauke
428 and used as a hunting dog in South Fly District, or in Jayapura for use as a guard dog at a logging
429 camp in Madang Province. These frequent changes of ownership added further complexity to the
430 already apparently elaborate network of routes from rabies-endemic areas of Indonesia to PNG,
431 and are factors which have implications for disease spread (and therefore disease mitigation). For
432 example, there are likely to be increased opportunities for rabies spread by an infected dog
433 through exposure to a larger susceptible population, and tracing of potential dog and human
434 cases could become more difficult as the number of transactions – and thus alternate contact
435 networks – increases.

436 If the frequency and heterogeneity of exchange described by participants corresponds to
437 reality then it could be assumed that surveillance for disease would to be a difficult, if not
438 impossible, task. However, actors in the narratives often followed what were described as

439 “traditional trade routes”. For example, in the Madang narratives participants described an
440 established, high-volume betel nut trade route along the north coast of mainland PNG, as
441 corroborated by Sharp’s (2016) account of the networks for exchange of this highly valued
442 commodity. Allen and colleagues (1983) also describes traditional trade routes throughout the
443 region, involving commodities such as shells (consistent with Tabubil narratives), fish, baskets
444 and dogs’ teeth. In the current study, towns in Papua appeared to be centres for trading; Merauke
445 and Jayapura (both close to the Papuan–PNG border) were most common, but Timika and Bis
446 Agats (on the south Papuan coast) also featured in some narratives. Border crossing points were
447 specifically mentioned in the Madang narratives – often around the Wutung border post in West
448 Sepik Province in the north – and became more ‘diffuse’ with the more southern scenarios
449 (Tabubil and South Fly District) as specific points were not mentioned; rather, common
450 characteristics about crossing points were described – such as crossing via refugee camps and
451 military garrisons along the border into Western Province. Commonly, rivers such as the Fly,
452 Sepik and Bensbach were used for travel, as well as ferries on the north coast. Despite the
453 extensive web of potential movements of people and dogs, these consistent movement patterns
454 provide opportunity for targeted surveillance for rabies, for example in the Papuan trading towns,
455 refugee camps and river-side communities. Schram (2014) describes the construction of personal
456 identity in PNG in terms of geographic origin, common ancestry, kinship and the ‘Wantok
457 system’ (a broader and less formal recognition of ‘personal similarity’ than kinship). Common
458 identity provides a framework for social structure and underlies networks that interlink activities
459 such as trade and marriage (Benediktsson, 2002); for example, Sharp (2016) noted that in the
460 context of the betel nut trade, traders regularly return to the same communities. Therefore,

461 understanding social structure provides further opportunity to identify potential contacts and
462 regions of geographic spread of disease.

463 Network characteristics – for example the number of connections between traders in the
464 context of this study – can influence the speed of disease spread and the number of affected
465 individuals in disease outbreaks. Although Allen (1983) states that the dynamics of the links
466 between communities in PNG have yet to be demonstrated, he suggests (from Brookfield and
467 Hart, 1971) that there is a mechanism of people-movement that connects apparently isolated
468 groups into local, regional and national systems. We hypothesise that this is a small-world
469 network in which communities are socially clustered, yet there are few ‘degrees of separation’ (a
470 concept first proposed by Travers and Milgram, 1967) between communities in different social
471 clusters due to their trade links. The characteristics of small-world networks were originally
472 described by Watts and Strogatz (1998) and are a commonly encountered type of social network.
473 Christley et al (2005) found that infectious agents spread more rapidly but resulted in fewer
474 infected individuals in a small-world network compared with a random network. Therefore, in
475 the context of PNG, whilst rabies might have opportunity to spread rapidly through the trade
476 networks of PNG, an incursion might go unnoticed if only a small number of dogs and people
477 are affected in geographically disparate, but socially connected, locations. Widely dispersed
478 infection would present major challenges to rabies elimination.

479 Identifying whether trans-migrants from rabies-endemic areas of Indonesia to PNG are a
480 pathway for the introduction of rabies-infected dogs was an objective of this research. Despite
481 the emphasis placed on this possibility during the parent workshop, trans-migrants were only
482 specifically mentioned once in this study, in a narrative in which a family migrated from Sumatra
483 to Sentani (near Jayapura) to be close to a relative who worked in a logging camp near Madang.

484 However, travel of Indonesian workers between their Indonesian home and their workplace in
485 PNG was a common theme in the Madang narratives, and was associated with the logging and
486 fishing industries. These industries are rapidly expanding in northern PNG, as tuna canneries are
487 built in Madang Province and logging increases in the region. Consequently, it is plausible that
488 Indonesians seek work in these regions. This theme was not consistent between incursion
489 locations; foreign nationals working in other industries in Tabubil and South Fly District
490 narratives were less often mentioned despite mining operations close to the fictitious Tabubil
491 incursion. It is possible that this reflects recently expanding industries in northern mainland
492 PNG, and that participants in this survey were therefore more aware of foreign nationals seeking
493 work in this region. Foreign nationals in the narratives were not remarkable in that their routes to
494 PNG were similarly complex to other actors, and they usually acquired a dog through
495 transactions *en route*. However, the logging and fishing industries with which they were
496 associated involve changes in land use – in particular, agricultural intensification and
497 encroachment on natural landscapes – and expanding industry that could promote human
498 migration. In addition to the trade already mentioned, these are recognised drivers of emerging
499 infectious disease (Jones et al., 2013; Morse, 1995; Rogalski et al., 2017); therefore, these areas
500 should be targeted for general disease (and specifically rabies) surveillance.

501 Although there were only two examples about perceptions and beliefs associated with
502 rabies (these aspects were not requested in the questionnaire), they illustrated effects on people's
503 actions that could inadvertently promote a rabies outbreak. In a South Fly District narrative, a
504 fisherman perceived the risk of rabies from his dogs but believed that he could deal with the
505 outcome by shooting dogs after they became infectious and showed clinical signs, and in a
506 Tabubil narrative a community's beliefs led them to migrate after perceiving a rabies outbreak as

507 an act of sorcery. Beliefs about sorcery (defined as the intentional use of magical rituals to harm
508 individuals or benefit the sorcerer) and witchcraft (the unconscious capacity to cause harm) are
509 ubiquitous in Melanesian ontology, providing an explanatory framework for misfortune (Eves,
510 2013; Eves & Forsyth, 2015). Although there is a large body of literature about their influence on
511 society – particularly in the context of violence related to these beliefs and their use in promotion
512 of fear and mistrust (Van Heekeren, 2016) – information about the role that these beliefs play in
513 disease prevention and treatment in people in Melanesia is more limited. Studies demonstrate
514 that the influence on health outcomes could be substantial. Western medicine is generally
515 accepted as useful to treat signs and symptoms, but rectification of the cause of the malady
516 typically requires the intervention of a traditional healer (Byford & Veenstra, 2004; Macfarlane,
517 2009). Promotion of alternative explanations for illness and death, such as an understanding of
518 transmission and the nature of infectious disease spread, are an important part of general health
519 messaging, but history shows that the effective communication of emerging infectious disease
520 risks can be difficult to achieve in PNG (Anderson, 2008; Dundon, 2009). In the context of
521 rabies, the implications of movement of dogs without vaccination (from Indonesia) and the
522 concept of inapparent disease due to the potentially long incubation period might also be relevant
523 to at least supplement, and, possibly counteract contemporary misconceptions. Acknowledging
524 that acceptance of biomedical approaches to disease control and prevention can occur without
525 rejection of traditional knowledge systems (Lepowsky, 1990), a more comprehensive
526 understanding of the range of beliefs, perceptions, social roles, networks and structures, and their
527 influence on human-dog interactions and health outcomes is required to tailor messaging to
528 enhance rabies prevention, surveillance and response strategies in PNG.

529 There are obvious limitations associated with this study as well as ‘lessons learned’
530 during its implementation. A key feature was the online implementation of the survey. This
531 enabled participation by a larger group over a longer period of time (2 weeks) and from a
532 broader geographic background than could have been achieved in a workshop or with a limited
533 field-work budget. However, the survey required participants to have phones or computers and
534 internet access; attributes limited to only 7.9% of the PNG population (United Nations
535 Development Program, <http://hdr.undp.org/en/countries/profiles/PNG>, accessed 28.10.17), and
536 unlikely to include groups such as remote-region villagers or grass-roots traders who could
537 corroborate information. Employees of NAQIA were chosen because of their interest and
538 knowledge of biosecurity and rabies and the objective of this study: to obtain factual information
539 about routes and activities that could result in the introduction of a rabid dog to PNG.
540 Participants’ collective knowledge through their combined years of life and work in PNG was
541 considerable (> 150 years) and their origins and workplaces geographically diverse; although
542 their experiences might be similar and are potentially related through their common employment,
543 we believe that information from this group was most likely of greater value than a more diverse
544 sample of PNG’s population with internet access but with limited relevant knowledge. Providing
545 more than three incursion scenarios might also have provided further insights but could also have
546 resulted in a decreased response rate as participation became more onerous. The response rate in
547 the current study was remarkably high given the expected difficulty of internet access and poor
548 mobile phone coverage in PNG. Including participants’ names in the scenarios might have
549 augmented contextualization and enhanced motivation. In addition, participants’ involvement in
550 biosecurity – and hence their awareness of potential pathways for rabies introduction – is likely
551 to have assisted with recall of events and circumstances that could result in introduction of

552 canine-rabies, making participation straightforward. Although peer-reviewed literature supported
553 findings in this study, it is relatively scant which limited triangulation of the information
554 generated in this study. This is not surprising, given the difficulty of access to border regions –
555 comprehensive field-studies are resource intensive and logistically challenging. Inclusion of
556 field-work to conduct the survey as face-to-face interviews (for example, targeted to residents in
557 border refugee camps) to build on what could be considered as preliminary results generated in
558 this study would have been beneficial to triangulate information from participants, but was
559 beyond the scope of the current study. Therefore, this study provides background information
560 and generates hypotheses (for example, the network structure of movements and the targets for
561 surveillance) which can be further investigated for biosecurity purposes. Overall, elicitation of
562 fictional outbreak narratives was easier and more popular with participants in this study than we
563 expected, and we found that it enabled collection of detailed information. However, it should be
564 noted that online implementation of this method inherently limits participation to high socio-
565 economic groups when used in developing countries. Methods to triangulate information from
566 groups without access to the primary online survey should be included if relevant to the study
567 and resources allow.

568

569

570 **4. Conclusion**

571 Although the narratives in this story arose from fictitious accounts of incursions,
572 collective knowledge of the participants' life and work experiences in PNG was a rich source of
573 information about the potential routes and characteristics of entry of a rabies-infected dog to
574 PNG via the Papua-PNG land border. Routes and their supporting networks are likely to be
575 complex but the patterns of routes provide targets – trading centres, refugee camps and river-side
576 communities – for surveillance as well as tracing of potential incursions. Traditional beliefs and
577 practices need further investigation to understand and mitigate the social barriers that might exist
578 alongside logistic barriers (rugged terrain, poor infrastructure and limited health services) to
579 effective rabies prevention, surveillance and response in PNG. The novel methods used in this
580 study were straightforward to implement; we expect that these methods could be used for
581 biosecurity research in similarly information-scarce environments.

582

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- 671

672 **Figure captions**

673 Figure 1: Map showing locations of fictitious rabies-incursion scenarios in a study to identify
674 routes and circumstances of potential entry of a rabies-infected dog into Papua New Guinea from
675 rabies-endemic islands in Indonesia.

676

677 Figure 2: Demographics of participants in a study to investigate potential routes and
678 circumstances of a canine-rabies incursion in Papua New Guinea; a = age, b = sex, c = years
679 lived in PNG, d = years of employment with the National Agriculture and Quarantine Inspection
680 Authority.

681

682 Figure 3: Map showing locations mentioned in narratives in a study to identify potential routes
683 and circumstances of entry of a rabies-infected dog into Papua New Guinea.

684 **Supplementary material**

685

686 **Supplementary material captions**

687

688 S1: Copy of the questionnaire with newspaper stories removed (to protect the identity of
689 participants) from a study to identify potential routes and circumstances of entry of a rabies-
690 infected dog into Papua New Guinea.

691

692 S2: Fabricated newspaper clipping describing a fictitious rabies outbreak in Madang, Papua New
693 Guinea (PNG), from a study to identify potential routes and circumstances of entry of a rabies-
694 infected dog into PNG. Participants' names are anonymised.

695

696 S3: Fabricated newspaper clipping describing a fictitious rabies outbreak in Tabubil
697 (Sisimakam), Papua New Guinea (PNG), from a study to identify potential routes and
698 circumstances of entry of a rabies-infected dog into PNG. Participants' names are anonymised.

699

700 S4: Fabricated newspaper clipping describing a fictitious rabies outbreak in South Fly, Western
701 Province, Papua New Guinea (PNG), in a study to identify potential routes and circumstances of
702 entry of a rabies-infected dog into PNG. Participants' names are anonymised.

703

704 S5: Tree-map showing the 100 most frequent words in narratives about Madang in a study to
705 identify potential routes and circumstances of entry of a rabies-infected dog into Papua New

706 Guinea. Rectangle size is proportional to the frequency of the word in the Madang outbreak
707 narratives.

708

709 S6: Tree-map showing the 100 most frequent words in narratives about Tabubil (Sisimakam) in a
710 study to identify potential routes and circumstances of entry of a rabies-infected dog into Papua
711 New Guinea. Rectangle size is proportional to the frequency of the word in the Madang outbreak
712 narratives.

713

714 S7: Tree-map showing the 100 most frequent words in narratives about South Fly District,
715 Western Province, in a study to identify potential routes and circumstances of entry of a rabies-
716 infected dog into Papua New Guinea. Rectangle size is proportional to the frequency of the word
717 in the Madang outbreak narratives.

718 S8: Table of excerpts from narratives from each fictitious rabies outbreak location in a study to
719 identify potential routes and circumstances of entry of a rabies-infected dog into Papua New
720 Guinea.