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1 **Title:** Leptospirosis in French Polynesia: 11 years of surveillance data, 2007-2017

2

3 **Abstract**

4 Leptospirosis is a worldwide zoonosis with higher incidence in tropical areas and is a neglected
5 disease in the Pacific region. French Polynesia is a French overseas Territory located in the South
6 Pacific. Data on the epidemiology in French Polynesia are scarce. In this study, we described our
7 understanding of leptospirosis epidemiology in French Polynesia and discussed the prospects
8 concerning this disease and its surveillance to better address preventive actions. We reported 11 years
9 of surveillance data between January 1st 2007 and December 31st 2017. Over the study period 1,356
10 confirmed and probable leptospirosis cases were reported, the mean annual incidence rate was 46.0
11 (95%CI 43.6-48.5) cases per 100,000 inhabitants, we registered 864 (63.7%) hospitalisations, among
12 them, at least 270 (19.9%) were in intensive care unit and 24 (1.8%) patients died. Even if incidence of
13 leptospirosis is lower in French Polynesia compared to most of other Pacific countries and Territories,
14 our data confirms that the disease is highly endemic in our country. Despite all preventive measures,
15 leptospirosis remains a major public health concern in French Polynesia, highlighting the need to
16 maintain intensive leptospirosis surveillance, medical staff training and information of the general
17 population.

18 **Introduction**

19 Leptospirosis is a worldwide bacterial zoonosis, with a significant health burden on economically
20 vulnerable population [1–3]. It is a neglected tropical disease, especially in the Pacific Region [4–6].

21 Leptospirosis is caused by spirochetes of the genus *Leptospira*, bacteria belonging to the
22 *Leptospiraceae* family [7,8]. Many mammals' species, wild or domestic, can carry the pathogen.
23 Rodents are the main reservoir of *Leptospira* [1]. Epidemiology of leptospirosis is characterized in the
24 Pacific islands by a potentially important role of livestock farming animals [4].

25 Human contamination results from contact of abraded skin or mucous membranes with urine or tissues
26 of infected animals, directly or indirectly via contaminated water or wet soil [1,9,10]. Spectrum of the
27 disease range from subclinical infection as flu-like symptoms to severe disease with multi-visceral
28 complications like acute renal failure, pulmonary haemorrhage (Weil's disease), and death [1,9,11].
29 Treatment is based on early antibiotic therapy. The vaccine only protects against the serovar
30 Icterohaemorrhagiae, the most frequently responsible for severe human infections, and it must be
31 renewed every two years.

32 Annual worldwide incidence of leptospirosis is estimated at 1 million cases, with 5-15% of severe
33 diseases [12] and about 60,000 deaths [13]. Leptospirosis is responsible for 2.9 million Disability
34 Adjusted Life Years (DALYs) per annum with a preponderant occurrence among low and middle-

35 income tropical countries and males [2]. The burden of leptospirosis is underestimated because of high
36 proportion of sub-clinical and asymptomatic infections, lack of notification systems, and poor access
37 to accurate laboratory diagnosis in low and middle-income countries [1,14–16]. World Health
38 Organisation (WHO) created in 2009 the Leptospirosis Burden Epidemiology Reference Group
39 (LERG), with the goal to conduct research and develop policy targeted towards decreasing the burden
40 of leptospirosis [17].

41 Pacific Islands have highly favourable environmental conditions for transmission of leptospirosis: hot
42 and humid tropical and subtropical climate with high rainfall, recurrent flooding, poverty,
43 urbanization, local life style (barefoot walking, swimming), and occupational activities [15].
44 Knowledge of the global burden of leptospirosis in the Pacific region remains incomplete, principally
45 due to the lack of laboratory capacities to confirm cases.

46 French Polynesia (FP) is a French overseas Territory located in the South Pacific, constituted of five
47 archipelagos: Society, Marquesas, Tuamotu-Gambier and Austral Islands. The population is about
48 280 000 inhabitants (2017 census), spread in 72 inhabited islands with 70% of the population living
49 on Tahiti Island [18]. Few data on the epidemiology of leptospirosis in FP exist [4,19] with the first
50 human infections reported only in 1959 [20]. Number of reported cases per year between 2006 and
51 2012 ranged between 79 and 127 and the annual incidence between 30 and 49 cases per 100,000
52 inhabitants [21–23].

53 In this study, we described our understanding of leptospirosis epidemiology in FP and discussed the
54 prospects concerning this disease and its surveillance to better address preventive actions.

55 **Methods**

56 We reported 11 years of surveillance data between January 1st 2007 and December 31st 2017. In FP, all
57 probable and confirmed leptospirosis cases are collected by the local health authority (*Bureau de veille
58 sanitaire*), based on notification forms filled in by general practitioners, and laboratory results
59 provided by laboratories of the “*Institut Louis Malardé*” and of the “*Centre Hospitalier de la
60 Polynésie française*”.

61 **Case definition**

62 Confirmed case: leptospirosis symptoms with either isolation of bacteria by culture or of its DNA by
63 polymerase chain reaction (PCR) or seroconversion of specific immunoglobulin class M (IgM).

64 Probable case: leptospirosis symptoms and IgM detection ELISA on a single serum collected more
65 than 1 week post symptoms onset.

66 Excluded case: leptospirosis symptoms with PCR negative on sera collected within the first week post
67 symptoms onset or ELISA IgM negative on sera collected more than 1 week post symptoms onset.

68 Demographic data were provided by the FP statistic institute [24]. Population estimation along the
69 duration of the study was calculated using an exponential increase during two consecutive censuses.

70 All confirmed and probable cases were included in statistical analysis. Qualitative variables were
71 described using frequency and percentages. Quantitative variables were described using mean \pm
72 standard deviation [minimum-maximum]. Annual Incidence rates (AIRs), meaning number of cases
73 per 100,000 persons year (PY), were presented with 95% confidence intervals (95%CI), based on the
74 Poisson model. We used a Z test for comparing AIRs between genders and between archipelagos.
75 Relative Risks (RR) with corresponding 95% CI were computed. A p level of <0.05 was considered
76 statistically significant. All statistical analyses were performed using STATA® V13.1 software
77 (StataCorp LP, Lakeway Drive, College Station, Texas 77845 USA) for Windows. Mapping was done
78 using the QGIS® v2.18.1 software and Google Earth Pro®.

79 **Results**

80 Between 1 January 2007 and 31 December 2017, 1,356 leptospirosis cases were reported: 851 (62.8%)
81 confirmed and 505 (37.2%) probable. Over the study period the AIR was 46.0 (95%CI 43.6-48.5)
82 cases per 100,000 PY (Figure 1a). Median number of cases on decade was 109 with a peak in 2017
83 with 199 cases corresponding to an AIR of 72.1 (95%CI 62.5-82.9) cases per 100,000 PY.

84 A total of 1,032 (76.1%) cases were reported in men cases and 324 (23.9%) in women (sex ratio 3.2)
85 with an overall average age of 33.7 ± 16.2 [2-80] on men and 35.2 ± 17.8 [1-88] on women. Comparison
86 of AIRs showed a significant excess risk of contamination in men [68.5 (95%CI 64.4-72.8) cases per
87 100,000 PY] vs women [22.4 (95%CI 20.1-25) cases per 100,000 PY], RR=3.1 (IC 95% 2.7-
88 3.5), $p < 0.001$. The age group repartition showed the largest number of cases was [20-29] years with
89 332 (24.5%) cases representing a peak AIR of 66.8 (95%CI 59.8-74.4) cases per 100,000 PY. During
90 the whole period, cases were reported throughout the year, but mostly between January and May with
91 a noticeable decrease from August to December (Figure 1b).

92 **Geographical distribution**

93 Island of residence was available for 1,282 (94.5%) cases. The Society archipelago accounted for
94 95.5% of cases with an annual average of 114.7 ± 35.1 [74-192] cases. The AIRs per archipelago were
95 48.8 (95%CI 46.1-51.6) cases per 100,000 PY for the Society, 53 (95%CI 39.8-69.2) for the
96 Marquesas, 1.3 (95%CI 0.0-7.4) for the Austral, and 2.2 (95%CI 0.6-5.5) for the Tuamotu Gambier.
97 Map, number of cases, AIRs and RR by island in Society archipelago are presented in Table 1 and
98 Figure2.

99 Over the study period we recorded 864 (63.7%) hospitalisations; among them, at least 270 (19.9%)
100 were in intensive care unit and 24 (1.8%) died.

101 Information on risk factors for leptospirosis was obtained from 920 (67.8%) cases for occupational
102 risk, 885 (65.3%) cases for leisure activity, 835 (61.6%) cases for contact with animals, and 324
103 (23.9%) cases for high risk facilities (Table 2).

104 **Discussion**

105 The worldwide AIR of leptospirosis is about 15 cases per 100,000 PY; the highest incidence is
106 reported in the Oceania region with 150 cases per 100,000 PY and a mortality rate of 9.6 per 100,000
107 PY. In this region AIR of up to 844 cases per 100,000 PY over an 11-year period from 2004 to 2014
108 has been reported in Futuna [25], with a pic of 1,945 cases per 100,000 PY in 2008 [4]. The AIR of
109 leptospirosis in FP between 2007 and 2017 was 46.0 (95%CI 43.6-48.5) cases per 100,000 PY, in the
110 lower range of AIR reported in the region (40-270) [13]. This incidence is low compared with other
111 Pacific Islands, probably because, at the difference of FP, most of them are low and middle income
112 countries. However, AIR of leptospirosis in FP is most probably underestimated, especially in the
113 most remote islands (Marquesas, Tuamotu Gambier and Austral). Main factors responsible for
114 underestimation of leptospirosis in FP are misdiagnosis with other diseases, especially dengue, a high
115 number of cases with few symptoms, and geographic constraint (isolation, multiplicity of islands, lack
116 of medical personnel to carry out sampling, difficulties in accessing health care facilities, lack of
117 transport or communication within and between islands) [26]. Similar clinical symptoms between
118 leptospirosis and arboviral infection is a main issue during arboviral outbreaks, leading to undetection
119 of leptospirosis cases and delayed treatment, potentially responsible for fatal cases [27].

120 Over the period 2007-2012 we noticed low variation of AIR. A peak of incidence was recorded in
121 2010. At the end of January 2010, cyclonic depressions (OLI hurricane) caused heavy rainfall and
122 mudslides in many FP islands, especially in Tahiti [22]. These exceptional climatic conditions led to
123 an increase in the number of cases in the first quarter of 2010. The population was quickly made aware
124 by the local health authority of the probable increase in the risk of leptospirosis. Health professionals
125 were encouraged to collect blood sample of patients with acute fever and diffuse pain syndrome. From
126 2013, the AIR increased due to an increase in screening linked to an arbovirus's epidemic context.
127 Dengue and Zika epidemics occurred simultaneously between September 2013 and March 2014,
128 followed by a major Chikungunya epidemic between October 2014 and March 2015 [28,29]. These 3
129 arboviruses are the main differential diagnoses of leptospirosis in endemic areas [11,27].
130 Concomitantly, the development of affordable molecular diagnosis in FP increased the number of tests
131 and then the number of diagnosed cases. The significant increase of AIR in 2017 is mainly related to
132 the heavy rains and floods at the beginning of the year [30].

133 Leptospirosis is known to be seasonal, and strongly associated with rainfall in tropical settings [9].
134 The number of cases increases during the hot and rainy season and decreases during the cold and dry
135 season [31,32]. Heavy rains and floods are associated with a six-fold increased risk of developing
136 leptospirosis and are a direct cause of epidemics as for the year 2017 in our cohort [31]. In FP, rainfall
137 usually increases from December with a peak in January and then decreases until April. In our cohort
138 60% of cases occurred during the first 5 months of the year, cases increased from January with a peak
139 in March and remains high until June. Thus, the recrudescence of reported cases of leptospirosis seems
140 to be delayed by 2 months compared with the peak rainfall. This phenomenon had already been
141 observed in Futuna and Reunion Island [25,33]. In two studies in Mayotte, cases followed the
142 evolution of rainfall with a three-month delay. According to the authors, the importance of seasonal
143 peaks is more related to the number of consecutive months with heavy rains than to the total rainfall
144 [34,35]. The discrepancy observed between the incidence of leptospirosis and peak rainfall is
145 explained by the soaking of the soil after the peak rainfall, which favour leptospire survival in the
146 environment [33,35].

147 We have found a geographical disparity in the incidence of leptospirosis in FP. AIR were higher in
148 high islands: Leeward Islands, Windward Islands and Marquesas. In contrast, lower islands (atolls) of
149 the Tuamotu-Gambier were almost free of cases due to their geomorphology: coral atolls without
150 relief and very little fresh water standing on the surface, no river or sludge because of the very porous
151 soils, and low rainfall. In the high islands, the development of agricultural and industrial operation,
152 and higher population density create waste and activities that may attract rodents and thus increase the
153 risk of contamination [31,32]. In the Society archipelago, AIRs are higher in some Windward Islands
154 and in the south-east part of Tahiti which are agricultural regions and where the main pig, cattle, horse
155 and poultry farms are located.

156 Most cases occurred in males, in accordance with what is described elsewhere. It probably only
157 reflects higher exposure of the male population through agricultural, farming and outdoor leisure
158 activities. The highest AIR was in the [20-29] year's old class. Like sex ratio, a high number of cases
159 in young age's classes possibly reflects a frequent exposure of young active men involved in
160 agriculture and farming activities. However, the hypothesis that older classes are relatively protected
161 by the immunity resulting from previous exposures also deserves consideration.

162 The main risk factor for leptospirosis in FP is professional or private agricultural activity: prevention
163 measures should target this population. Secondary risk factors are mostly recreational with fresh water
164 contact during leisure time (barefoot walking in mud, river bathing, hiking, gardening or fishing).
165 Other factors such as contact with rats, pigs as well as dogs (large population of stray dogs), leaving in
166 poor sanitary condition or in family farms in semi-urban areas near watercourses, can contribute to the
167 transmission of the disease [4,19].

168 **Conclusion**

169 Leptospirosis is a major public health concern in FP where it will become soon a reportable disease.
170 All laboratories and medical facilities, including intensive care unit, are available to diagnose and care
171 cases. Prevention includes guidelines for healthcare workers, prevention measures for the general
172 population broadcasted by a bi-monthly bulletin, and a reminder of the risk sent to the media after
173 each heavy rainfall or flooding. In addition, following the WHO One Health approach, collaboration
174 between animal and human health has been initiated to struggle against zoonosis as leptospirosis.
175 Enhancement of rodents control by the improvement of waste management is needed. Despite all
176 preventive measures, leptospirosis remains highly endemic in our country, highlighting the need to
177 maintain leptospirosis surveillance, medical staff training and information of the general population.

178

179 **Figures and tables**

180 **Figure 1a:** Leptospirosis cases and annual incidence rates in French Polynesia, 2007-2017

181 **Figure 1b:** Cumulated monthly cases of 11 years of leptospirosis in French Polynesia, 2007-2017

182 **Table 1:** Leptospirosis cases, annual incidence rates (AIR) and relative risks (RR) by islands of
183 Society archipelago, 2007-2017

184 **Figure 2:** Map of Society archipelago with a focus on Tahiti island, annual incidence rate of
185 leptospirosis by island and municipality, 2007-2017

186 **Table 2:** Potential risk factors of leptospirosis, French Polynesia, 2007-2017

187

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- 267

Figure 1a: Leptospirosis cases and annual incidence rates in French Polynesia, 2007-2017

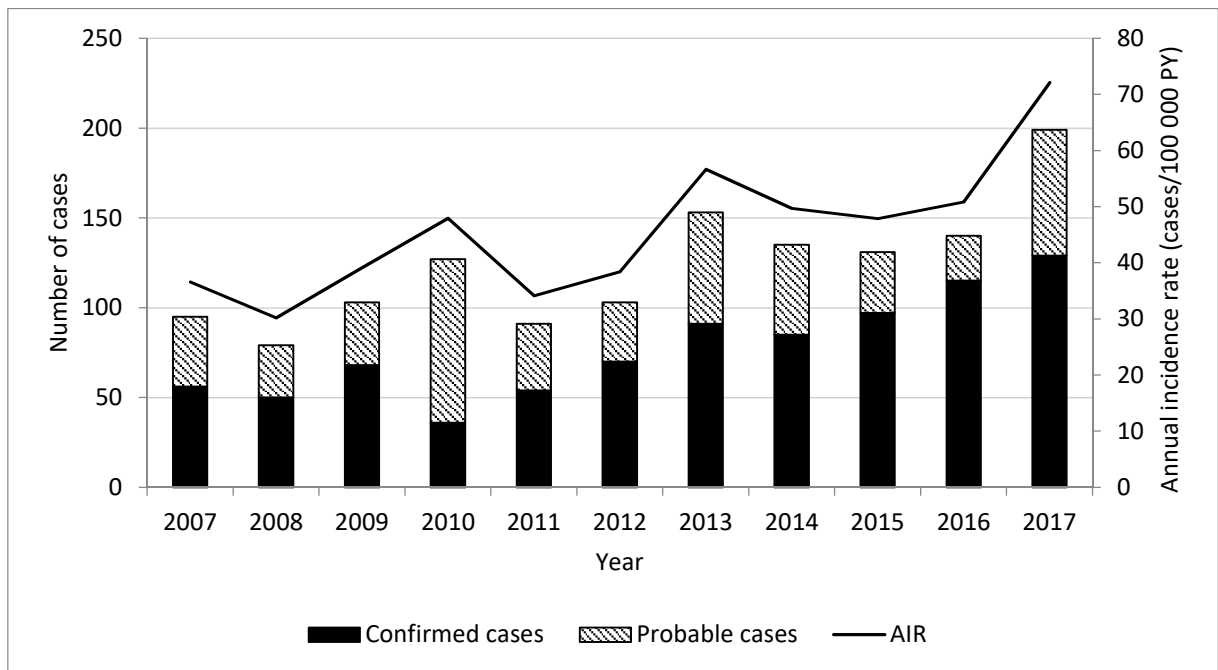
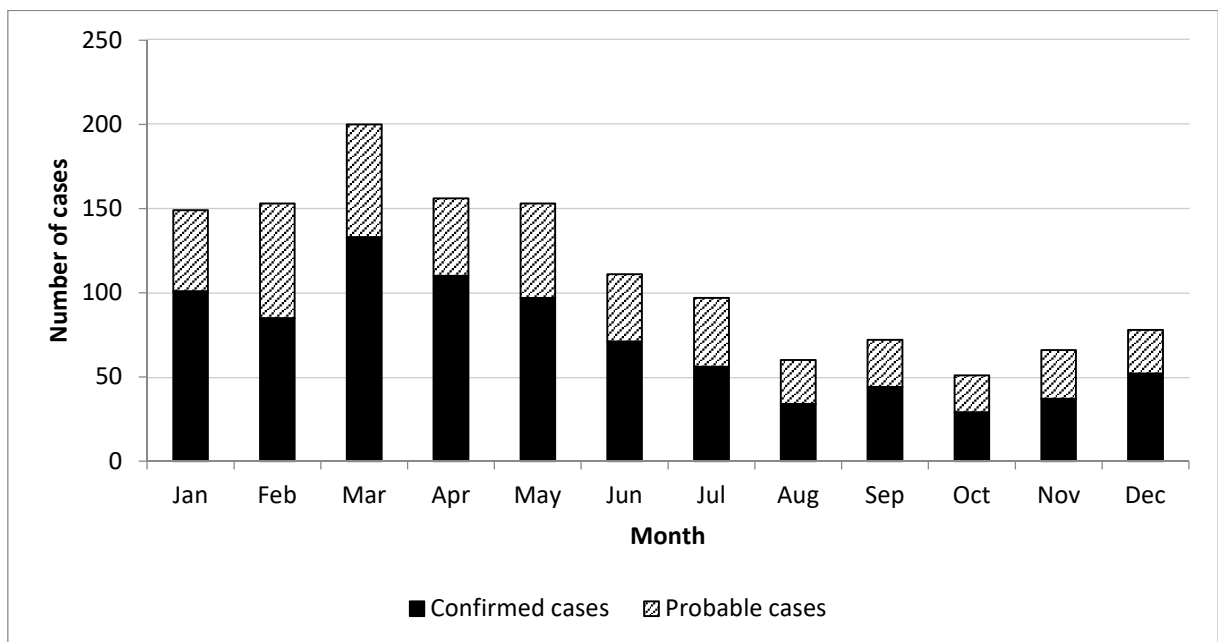


Figure 1b: Cumulated monthly cases of 11 years of leptospirosis in French Polynesia, 2007-2017



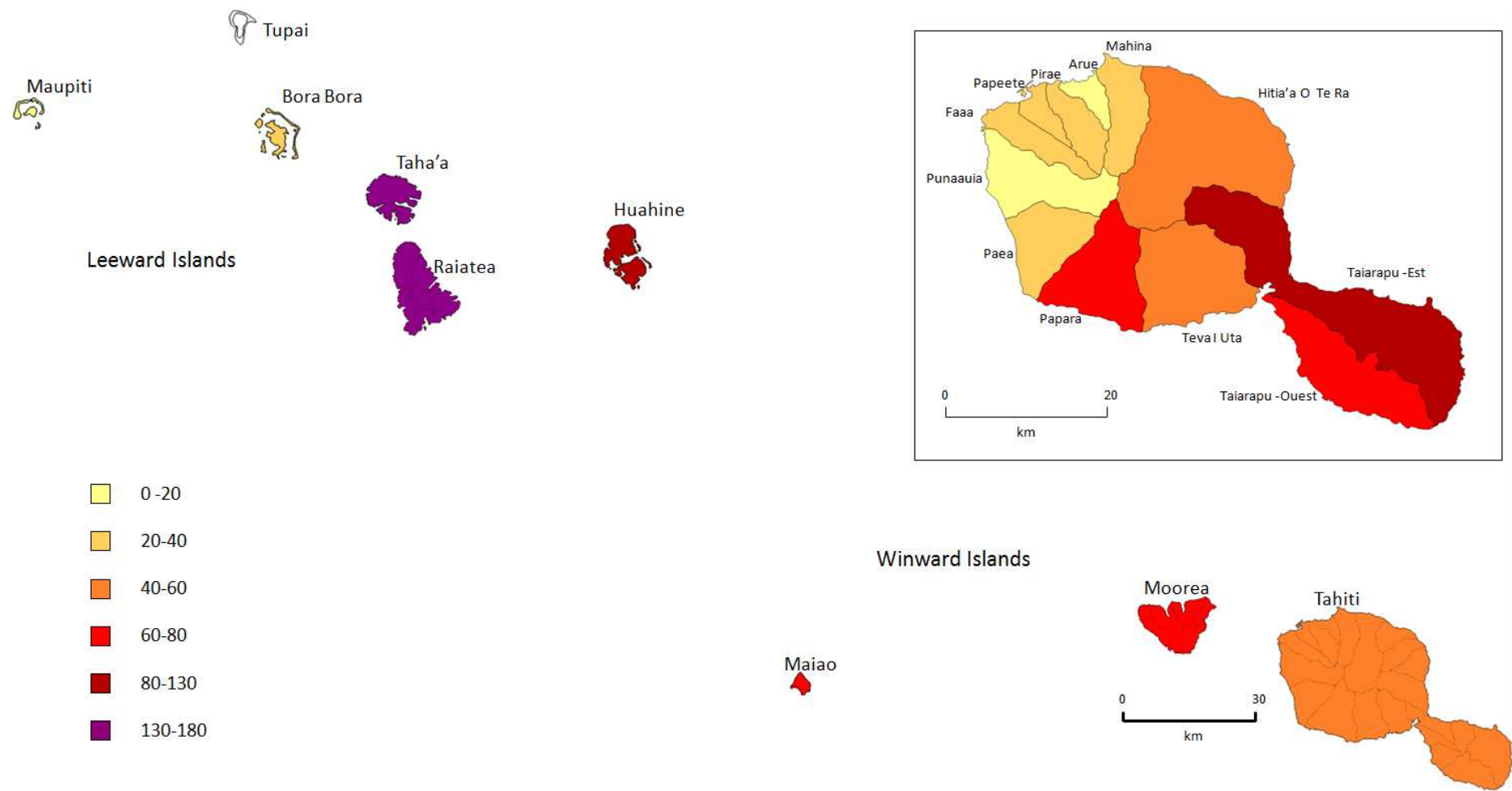


Figure 2: Map of Society archipelago with a focus on Tahiti island, annual incidence rate of leptospirosis by island and municipality, 2007-2017

1 **Table 1:** Leptospirosis cases, annual incidence rates (AIR) and relative risks (RR) by island of Society
 2 archipelago, 2007-2017

Islands	n (%)	AIR ^a (IC95%)	RR (IC95%)	p ^b
Tahiti	731 (57.9)	40.0 (37.1-43.0)	1.00 (reference group)	
Moorea - Maiao	121 (9.6)	63.8 (53.0-76.3)	1.6 (1.3-1.9)	<0.001
Raiatea	191 (15.1)	141.9 (132.3-163.5)	3.6 (3.0-4.2)	<0.001
Tahaa	94 (7.5)	163.7 (132.3-200.4)	4.1 (3.3-5.1)	<0.001
Huahine	87 (6.9)	125.5 (100.5-154.8)	3.1 (2.5-3.9)	<0.001
Bora-Bora	37 (2.9)	35.1 (24.7-48.3)	0.9 (0.6-1.2)	0.437
Maupiti	1 (0.1)	7.6 (0.2-42.4)	0.2 (0.03-1.4)	0.098

^aAIR : Annual Incidence Rate in number of cases per 100,000 persons year

^bComparison of relative risk with the reference group.

3 **Table 2:** Potential risk factors of leptospirosis, French Polynesia, 2007-2017

Category		Number of cases	Percentage over the total number of cases provided for this category	Missing values for this category	
Occupational risk	Farmer	383	41.6%		
	Sanitation and waste treatment	60	6.5%		
	Animal husbandry	134	14.6%	436	32.2%
	Cattle breeding	23	2.5%		
	Horse breeding	17	1.8%		
	Pig farming	43	4.7%		
Leisure activity / fresh water contact	Fishing	131	14.8%		
	Hunting	40	4.5%		
	Gardening	319	36.0%		
	Hiking	101	11.4%	471	34.7%
	Walking barefoot	497	56.2%		
	Fresh water swimming	277	31.3%		
	River mouth surfing	67	7.6%		
Contact with animals	Cats	292	35.0%		
	Dogs	466	55.8%	521	38.4%
	Rats	545	65.3%		
High risk facilities	Dump in the vicinity	126	38.9%	1032	76.1%
	Water abstraction	48	14.8%		