Public Health Prevention and Spatiotemporal Analysis of Human Leptospirosis in Mahasarakham Province, Thailand

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SANTÉ PUBLIQUE ET ANALYSE SPATIO-TEMPORELLE DE LA LEPTOSPIROSE HUMAINE DANS LA PROVINCE DE MAHASARAKHAM EN THAÏLANDE

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Introduction

La leptospirose est une maladie zoonotique d'intérêt majeur et est considérée comme étant une des zoonoses les plus répandue au monde (World Health Organization, 2007). Plus de 70000 cas de Leptospirose ont été détectés en Thaïlande depuis l'émergence de la maladie (Morand et al., 2018). La Leptospirose est endémique dans la province de Mahasarakham en Thaïlande et a causé la mort de patients. Cette étude a pour objectif de comprendre les causes des épidémies et d'améliorer les politiques de prévention et de contrôle à l'échelle de la Province. J'ai cherché à i) comprendre l'évolution des politiques de préventions et de contrôle de la leptospirose à différentes échelles, ii) comprendre les facteurs asscoiés avec les épidémies de leptospirose en analysant l'épidémiologie spaitale et temporelle des cas reportés entre 2004 et 2014, iii) analyser les connaissances, attitudes et pratiques des patients, des gens non touchés par la leptospiroses, des volontaires en santé publique et des chefs de communautés au niveau de leur perception de la leptospirose et de son contrôle dans la province de Mahasarakham. Ceci m'a permis de formuler des critiques et des recommandations pour améliorer le système de contrôle et de surveillance dans l'optique One Health.

Evolution de la santé publique préventive liée à la leptospirose dans la province de Mahasarakham (Thaïlande) dans une perspective One Health.

Depuis plus de 20 ans, le ministère de la santé publique et l'office provincial de santé publique de Mahasarakham ont établi et développé une politique de prévention et de contrôle de la leptospirose (Mahasarakham Provincial Public Health Office, 2000) ; néanmoins les épidémies sont toujours endémiques dans la province avec des incidences élevées.

J'ai utilisé une approche qualitative et une analyse critique de la manière dont les politiques et recommandations nationales sont transmises dans la province à différents niveaux administratifs dans une perspective One Health. A cette fin, j'ai collecté deux types de données. Le premier type de données consiste en une analyse de documents obtenus auprès de l'office de santé publique en Province: rapports de province, compte-rendus de réunions, manuels, articles, et documentation internet. Le second type de données consiste en l'interview de 26 personnels de différents services administratifs à différents niveau de la chaine de décision (personnels de santé publique, personnels des gouvernements locaux, personnels des services vétérinaire en province). Ces personnes ont développé des outils pour implémenter une politique de santé publique ou ont eu en charge le contrôle et la prévention de la leptospirose à un niveau territorial donné. J'ai par ailleurs participé à trois réunions en relation avec la prévention et le contrôle de la maladie dans la province de Mahasarakham Province et à une investigation de terrain, ce qui m'a permis de mieux comprendre la manière dont les politiques de prévention et de contrôle sont implémentées.

Les résultats de mon travail montrent que la Thaïlande a progressivement développé une politique de prévention et de contrôle qu'elle à transmis à l'échelle locale. A l'échelle nationale, les politiques de contrôle et de prévention sont organisées autour de lignes directrices claires en santé publique.

Avant 2003, la prévention et le contrôle de la leptospirose humaine sont à la charge des personnels de santé publique. Entre 2004 et 2010, la division chargée de l'épidémiologie du ministère de santé publique a été réformée et est dévenue le Bureau d'épidémiologie qui a été transféré au service de contrôle des maladies (Department of Disease Control). Cette instance a établi des directives concernant la prévention et le contrôle de la leptospirose et des équipes de surveillance et de réponse rapides sont mises sur pied (Surveillance and Rapid Response Team ou SRRT) ce qui permet aux personnels de santé publique de partager les connaissances et les resources entre sous-districts à l'échelle du district (Kumnuan Ungchusak et al., 2011). Malgré cela, ces directives n'incluaient la nécessité d'une coopération entre les services concernés par la leptospirose pour améliorer son contrôle et sa prévention. Après 2011, le district de renforcement de contrôle des maladies (District Strengthening Disease Control) est établi par le Bureau d'épidémiologie. Par ailleurs, le ministère de santé publique introduit le concept « One Health », qu'il place comme principe fondamental dans le plan national stratégique pour la gestion des maladies émergentes infectieuses. Les lignes directrices ont alors pour objectif de développer la coopération entre 4 parties, incluant les services de santé publique, les services vétérinaires, le département d'agriculture et l'administration des sous districts (Tambon) dans la prévention et le contrôle de la leptospirose . En 2015, le gouvernement Thaïlandais édicte le nouvel acte des maladies infectieuses et désigne plusieurs ministères et services gouvernementaux pour siéger au comité national des maladies contagieuses. Malgré cela, la responsabilité de prévention et du contrôle de la leptospirose restent principalement à la charge des personnels de santé publique. L'implémentation de la politique de contrôle et de prévention est établie par le ministère de santé publique, et les indicateurs concernant la performance du système de surveillance et de controle ne concernent que les services de santé publique et non les services de santé animale. Il apparait de cette étude que le comité national des maladies contagieuses doit coopérer pour développer des lignes directrices de coopérations entre les ministères impliqués dans la prévention et le contrôle de la leptospirose (et plus généralement des maladies zoonotiques) dans une approche One Health.

Au niveau de la Province, en 2000, l'office provincial de santé publique à Mahasarakham met en place une conférence pour partager les connaissances relatives à la prévention, au contrôle et au traitement de la leptospirose entre personnels de santé publique. Par ailleurs, la province met en place une grande campagne de prévention et de contrôle de la leptospirose en direction de la population (Mahasarakham Provincial Public Health Office, 2000). Après 2003, la prévention et le contrôle font partie des opérations de routines des personnels de santé publique, et la politique de prévention et de contrôle suit les lignes directrices du ministère de santé publique. Durant cette période, il n'y a néanmoins pas de passage des connaissances entre personnels de santé publique et populations locales. En 2015, le comité des maladies contagieuses de la province établit un plan pour faire en sorte que l'ensemble des secteurs et parties concernés soient impliqués dans les problèmes de santé. Malgré cela, le comité des maladies contagieuses de la province ne se sent pas concerné par la leptospirose et la coopération entre secteurs et parties à ce niveau n'est qu'occasionnelle. Il n'y a pas de développent d'indicateurs ou de lignes directrices en terme de cooperation pour la prévention et le contrôle de la leptospirose. Je suggère que le gouverneur de province devrait encourager le développement des savoirs et des compétences des personnels gouvernementaux pour favoriser une interopérabilité entre les services concernés par la prévention et le contrôle de la leptospirose. Le comité des maladies contagieuses de la province devrait également favoriser la participation des différents services impliqués pour établir des lignes directrices de coopération, des indicateurs de performance, et des actions spécifiques pour prévenir et contrôler la leptospirose.

Au niveau du sous-district, la prévention et le contrôle de la leptospirose ne sont développés que par les personnels de santé publique en suivant les lignes directrices pour le dispositif de renforcement de contrôle des maladies dans les districts. Ce dispositif ne permet pas une approche exhaustive des activités nécessaires à la prévention et au contrôle de la leptospirose. Ainsi, il y a un manque de lien pour assurer une prévention compréhensive des activités entre les différents services et parties concernés. Il existe un manque d'information de base établissant la manière dont chacun des services doit coopérer et il n y a pas d'indicateurs permettant d'évaluer l'approche One Health à ce niveau. Je suggère que la prévention et le contrôle de la leptospirose à l'échelle du sous district (Tambon) doit établir des lignes directrices réalistes se fondant sur l'approche One Health pour améliorer la gestion des risques et transformer les mots en actions (Binot and Morand, 2015). Les personnels gouvernementaux au niveau des sous districts doivent développer des connaissances et des compétences pour améliorer l'interopérabilité des services pour la gestion de la prévention et du contrôle de la leptospirose. Les services de santé publique et vétérinaires devraient signer des Memorandum of Understanding (MoU) à l'échelle des sous districts afin d'établir une approche plus participative pour la prévention et le contrôle de la leptospirose. De plus, à l'échelle locale (villages), les volontaires en santé et en gestion des élevages devraient participer au contrôle et la prévention de la leptospirose. Ils devraient développer des compétences dans le domaine de la surveillance de la leptospirose humaine et animale. De nos jours, la prévention et le contrôle sont plus actifs quand des cas de leptospirose sont rapportés aux autorités. La leptospirose est l'affaire des patients alors que les politiques de santé publique devraient couvrir l'ensemble de la population. Développer des comportements de prévention peut permettre de mieux protéger l'Homme des infections par les leptospires (World Health Organization, 2003). Ainsi, le service de santé publique doit améliorer la diffusion des connaissances, des changements d'attitudes et de pratique à l'égard des la leptospirose en utilisant des méthodes multidisciplinaires et participatives.

Il existe donc des manques dans les liens entre services (départements) pour assurer des actions de prévention contre les épidémies. La reconnaissance de l'approche One Health pour le contrôle et la prévention de la leptospirose pourrait réduire les risques d'infection et l'importance des épidémies. La province Mahaksarakham doit développer une coopération plus concrète entre les services concernés. Des études sont nécessaires à échelle locale pour proposer des lignes directrices locales et réalistes.

Déterminants agro-environnementaux de la Leptospirose humaine dans la province de Mahasarakham (Thaïlande), 2004 -2014: Une analyse rétrospective et spatiotemporelle.

J'ai analysé les incidences de Leptospirose humaine entre 2004 et 2014 dans la province de Mahasarakham dans le Nord-Est de la Thaïlande, dans l'objectif d'identifier les facteurs agronomiques et environnementaux qui pouvaient expliquer la distribution spatiotemporelle des cas de leptospirose. Différentes analyses ont été conduites : (1) j'ai analysé le patron d'autocorrélation des incidences de leptospiroses et produit des cartes par interpolation (méthodes de krigeage) ; (2) j'ai analysé les incidences d'un point de vue temporel et ai déterminé les patrons d'autocorélation temporel de la leptospirose afin de montrer des tendances et des saisonnalités ; (3) j'ai décrit la distribution temporelle à l'aide d'analyse d'ondelettes et ai cherché les corrélations entre leptospirose, pluviométrie et surfaces inondées ; (4) j'ai testé l'effet des changements de politiques du système de surveillance en santé publique en 2012 sur la dynamique temporelle ; (5) j'ai exploré les liens entre les cas de leptospiroses et différents facteurs agro-environnementaux à l'échelle des 133 sous districts de la province, en utilisant des modèles linéaires mixtes généralisés (GLMM) et ai sélectionné les meilleurs de ces modèles à l'aide du critère d'Akaike (AIC); (6), et finalement, j'ai utilisé un modèle additif généralisé pour prendre en compte la dynamique spatiotemporelle à partir des conclusions (1), (2), (3) et (4) en initiant ce modèle avec les facteurs retenus par les GLMM (5).

Les résultats montrent une faible autocorélation spatiale quand les incidences de leptospiroses sont regroupées sur l'ensemble de l'étendue temporelle analysée. Cette autocorrélation n'est significative que dans les 20 premiers km. Il y a une composante saisonnière importante : les cas les plus nombreux correspondent à la saison des pluies (Juin à Octobre) puis ce nombre décroit pendant l'hiver jusqu'à la fin de la saison sèche. Le décalage temporel entre cas de Leptospirose, pluviométrie et surfaces inondables n'excède pas un mois. Cela peut s'expliquer: Durant la saison des pluies, le sol est humide et permet aux bactéries leptospires de survivre en extérieur, tandis que les inondations permettent leur dispersion (Bharti et al., 2003). Par ailleurs, les résultats de l'analyse temporelle montrent une association entre pluviométrie, zones inondées et cas de leptospiroses. La faible autocorrélation spatiale (inférieure à 20 km) est en accord avec les autres études sur les maladies transmises par l'environnement autres que la leptospirose. Cette autocorrélation locale a augmenté néanmoins pendant les deux années où le nombre d'incidences était le plus élevé (2009 et 2012), mais la localisation des incidences change, ce qui suggère que des patrons de variation spatiale existent mais changent au cours du temps. Une autocorrélation positive a été trouvée entre sous districts voisins d'ordre 1 et 2, ce qui est également visible sur les interpolations obtenues par méthode de krigeage.

Le meilleur modèle (sélection de GLMM par AIC) montre que le nombre de cas de leptospiroses par district et par mois est significativement associé avec la densité de population par sous district, le mois, la pluviométrie, la pente moyenne, les étendues inondées, les répartitions des animaux domestiques, la densité du bétail (vaches), la densité des cochons, et par la politique de santé publique. Ces résultats sont confirmés par le modèle additif généralisé. Les résultats des GLM et des GAM montrent que la pente moyenne, la densité des populations, la densité en cochons, la densité en vaches et les surfaces inondées sont significativement associées avec le nombre de cas de leptospiroses dans un sous district donné.

Mes résultats montrent une association positive entre la densité en bovins (vaches dans le cas de Mahasarakham) et le nombre de cas de leptospirose. Les bovins sont bien connus comme réservoirs de leptospires (Adler and de la Peña Moctezuma, 2010; Chadsuthi et al., 2017) et une forte association entre densité en bovins et transmission de leptospirose a déjà été montrée (Mwachui et al., 2015). Les systèmes d'élevage en libre circulation peuvent favoriser la transmission de la leptospirose en explosant les êtres humains à des environnements contaminés par l'urine des bovins et par les leptospires (Rood et al., 2017). Dans les communauté rurales pauvres, les bovins apparaissent comme facteurs de transmission de leptospirose plus important que les rats (Barragan et al., 2017). Par ailleurs, les caractéristiques des zones de pâturage ont certainement un impact dans la concentration des leptospires dans l'environnement (Barragan et al., 2017 ; Suwancharoen et al., 2016). En Thaïlande, le serovar dominant (Shermani) est observé chez les bovins ainsi que chez les hommes (Chadsuthi et al., 2017). L'importance des bovins comme facteur expliquant la leptospirose dans la province de Mahasarakham trouve sa confirmation par le fait que les fermiers sont le public majoritaire à être infecté par la leptospirose. Actuellement, la prévention contre la leptospirose et les politiques de contrôles dans la province de Mahasarakham ne visent que les personnes. Il n'y a pas de politique spécifique concernant les animaux (Department of Disease Control, 2016). Le résultat de cette étude montre que l'augmentation de la densité des bovins est associée avec une augmentation des cas de leptospiroses humaines. Les services de santé publique, les services vétérinaires et les organisations gouvernementales locales (LGO) doivent coopérer d'avantage et partager une connaissance multidisciplinaire au niveau de la surveillance de la leptospirose chez l'homme et l'animal. En plus, ces instances doivent coopérer pour améliorer le système de veille sanitaire entretenue par les volontaires en matière de santé et d'élevage dans les villages. A l'échelle des sous districts où l'élevage des bovins est constaté, les services vétérinaires devraient procéder à des prélèvements aléatoires sur les bovins, et doivent faire respecter les règles sanitaires aux éleveurs. Les services de santé publique et vétérinaires doivent coopérer pour mettre en place des campagnes de prévention et éduquer la population concernant les moyens de prévention et de contrôle de la leptospirose chez l'homme et chez l'animal. Les organisations gouvernementales locales (LGO) pourraient amener leur soutien via des campagnes de vaccination préventive et la distribution de bottes étanches. La pente moyenne du sous district montre une association négative avec l'incidence de leptospirose humaine. Les reliefs plats permettent en effet la formation d'eaux stagnantes et sont associés avec la formation de larges aires inondées ce qui favorise la transmission des leptospires via l'eau contaminée (Gracie et al., 2014 ; Sulistyawati et al., 2016).

La densité humaine est associée de manière positive avec la proportion de cas de leptospirose ; ceci est un patron commun pour les maladies transmissibles par l'environnement (Antonovics, 2017). L'augmentation de la population humaine est un facteur important pour expliquer les maladies infectieuses en Asie du Sud-Est (Coker et al., 2011). Par ailleurs, la taille des populations et leur croissance sont typiquement associés avec une intensification des pratiques agricoles ce qui peut augmenter la transmission de la leptospirose (Lau et al., 2016).

Les résultats de mon étude montrent que l'environnement, le climat, et les animaux d'élevage contribuent à la transmission de la leptospirose chez l'Homme. Mes résultats montrent l'importance de l'élevage comme facteur favorisant la transmission de la leptospirose aux êtres humains et suggère qu'une collaboration importante entre services de santé publique et les services vétérinaires permettrait un meilleur contrôle de la leptospirose et des maladies humaines et animales dans une approche One Health.

Connaissances, attitudes et pratiques au sujet de la prévention et du contrôle de la leptospirose des patients, de leurs voisins, des volontaires en santé dans les villages et des chefs de villages et de sous districts dans la province de Mahasarakham en Thaïlande.

Bien que le ministère de la santé publique et que l'office de santé publique de la province Mahasarakham aient développé et implémenté une prévention de la leptospirose en augmentant la coopération dans les communautés locales, l'état des connaissances, des attitudes et des pratiques dans les communautés locales en matière de prévention et de connaissance de la leptospirose n'a pas encore été évaluée. Comprendre les connaissances individuelles, les attitudes et pratiques (Knowledge, Attitudes and Practices ou KAP) est important pour implémenter un meilleur contrôle et de meilleures politiques de santé publique.

Un questionnaire et une étude associée est conduite pour estimer les connaissances, les attitudes et les pratiques des patients, de leurs voisins, des volontaires de santé dans les villages, et des chefs de villages et de sous districts dans le domaine du contrôle de de la prévention de la leptospirose à l'échelle de la province de Mahasarakham en Thaïlande. Les données sont issues de questionnaires structurés pour 167 patients, 325 voisins de ces patients, 480 volontaires en santé dans les villages et 320 chefs de village et de sous district. Les questionnaires ont dans un premier temps été distribués à trois experts en santé publique afin d'évaluer leur faisabilité et leur qualité. Le caractère opérationnel des questionnaires a été évalué à l'aide de 30 interviews préliminaires dans chacun des groupes. Les questionnaires sont structurés en quatre sections : socio-démographie, connaissances, attitudes et pratiques. Des tests de type ANOVA, tests de student, tests de Tukey HSD, et du Chi 2 ont été utilisé pour comparer les connaissances, les attitudes et les pratiques. De plus, des "odd-ratios" ont été obtenus pour mesurer l'association entre les variables.

Les résultats de l'étude montrent que la plupart des patients et des chefs de village et de sous-districts sont des hommes (78.4% et 78.8%) mais que la plupart des voisins et des volontaires en santé sont des femmes (66.5% et 77.1%). La majorité des personnes interrogées avaient entre 41 et 60 ans.

La majorité des patients, de leurs voisins, des volontaires de santé dans les villages et des chefs de village ont une bonne connaissance (aux alentours de 70 %). Ce niveau de connaissance s'est amélioré si on compare nos résultats à une étude réalisée en milieu rural en Thaïlande dans des villages avec un fort taux d'endémisme de la maladie en 2006, qui trouva que seulement 20% des participants avaient un bon niveau de connaissance de la leptospirose (Wiwanitkit, 2006). Cela peut s'expliquer en partie: en 2000, la province de Mahasarakham a été choisie par le ministère de santé publique comme province pilote pour résoudre le problème des pics épidémiques de leptospirose. Elle a ainsi organisé une grande campagne à l'échelle de la province et tournée à l'égard de la population autour de la prévention et le contrôle de la leptospirose (Mahasarakham Provincial Public Health Office, 2000).

Plus de 50% des personnes interrogées dans tous les groupes considèrent que les rongeurs sont d'importants agents de transmission, ce qui montre que la campagne a réussie en ciblant les rongeurs comme réservoirs de la leptospirose. Cependant, seuls 29.8% des patients, 34.0% de leurs voisins, 57.5% des volontaires en santé dans les villages et 52.2% des chefs de villages et de sous districts savaient que les poules, les chiens, les chats et le bétail pouvait souffrir de leptospirose. De plus, la connaissance de la symptomatologie de la leptospirose n'est pas satisfaisante quels que soient les groupes. Seulement 60% des personnes interrogées ont correctement répondu aux questions relatives aux symptômes de la leptospirose. La plupart des personnes interrogées ne connaissent pas le temps d'incubation de la maladie. Bien que la campagne de santé publique concernant la leptospirose ait été importante dans la province de Mahasarakham, elle n’a pas couvert le problème de la leptospirose chez les animaux et sur ces symptômes. Ainsi, le ministère de santé publique et l’office provincial de santé publique de la province de Mahasarakham devraient produire de nouveaux médias permettant d’informer et d’améliorer les connaissances sur la leptospirose au niveau de son étiologie, de la manière dont elle se transmets, sur sa prophylaxie, ces symptômes et sur sa prévalence chez les animaux. Le manque de connaissances concernant le rôle des animaux domestiques et des élevages fermiers dans les communautés de la province de Mahasarakham doit être pris en compte en accord avec l’approche One Health.

La majorité des patients, de leurs voisins et des chefs de villages et de sous districts ont une attitude acceptable à l’égard de la leptospirose ce qui n’est pas le cas de la majorité des volontaires en santé dans les villages. Plus de la moitié des patients et de leurs voisins pensent que seuls les fermiers doivent se protéger contre la leptospirose. Seulement 21.5% des volontaires en santé dans les villages et 21.6% des chefs de villages et de sous-districts pensent que la leptospirose peut être présente dans leur communauté. Les personnels de santé publique devraient mieux faire comprendre les différents vecteurs de la leptospiroses et les mesures de prophylaxie et mieux informer et impliquer les chefs de villages et les volontaires en santé dans les villages. .

Il est intéressant de noter que les pratiques des patients les exposent plus au risque d’infection que leurs voisins ($P < 0.001$). Par exemple, 46.2% des voisins ne pêchent pas dans l'eau si ils ont des égratignures ou des blessures, tandis que 26.3% des patients poursuivent ce type d'activité. 52.3% des voisins portent des bottes quand ils travaillent dans des zones inondées contre seulement 27.5% des patients. Des résultats similaires ont été obtenus en Malaisie, où les mauvaises pratiques sont liées aux patients (51% portent des bottes, 43% des gants en latex et 20% portent des masques quand ils travaillent (Azfar et al., 2018)). D’autres études montrent que le port d’équipement de sécurité est rare (Shin-ichi, 2016) du fait de leur caractère inconfortable (Samarakoon and Gunawardena, 2013). Les patients qui ont déjà contracté la leptospirose ne motrent malheureusement pas d’amélioration dans leur comportement en terme de prophilaxie. Ainsi, ce groupe doit être une des premières cibles dans les communautés pour mieux les éduquer et éviter les infections répétées.

Presque 100% des volontaires de santé dans les villages ont conduit des activités de surveillance de leptospirose dans leur communauté et ont sensibilisé les publics sur les risques associés à la leptospirose quand ils ont trouvé des patients atteints dans leur communauté. Les volontaires n'ont pas pu tous mener toutes les activités de surveillance prévues comme la collection de certaines données locales. Le rôle des volontaires de santé dans les villages n'est pas suffisamment clairement défini au regard de la politique de surveillance définie par le ministère de santé publique. Ainsi le secteur de la santé doit établir un manuel à l'égard de ces volontaires contenant les connaissances concernant la leptospirose et des lignes directrices pour garantir sa prévention et son contrôle.

63.8% des chefs de villages et de sous districts ont organisé des réunions de prévention de la leptospirose à leur communauté et 74.7% ont participé à l'évaluation des activités de prévention dans leur communauté. 78.8% ont participé au plan de suivi de prévention à la leptospirose. Les chefs de villages et de sous districts ont un rôle important en organisant des activités qui permettent de limiter les risques de maladies; en outre ils planifient leur contrôle, et allouent un budget aux problèmes de santé dans la communauté (Department of Disease Control, 2016). Les chefs de villages et de sous districts devraient améliorer leur connaissances et compétences en terme de surveillance des maladies pour améliorer leur prévention et leur contrôle. Ils ont en effet un rôle important dans l'organisation d'activités permettant de prévenir des maladies grâce au plan de contrôle et au budget dont ils ont la charge.

La majorité des personnes interrogées ne suivent pas les pratiques recommandées pour limiter la transmission/l'infection par la leptospirose. Ces publics ont donc besoin d'un meilleur accompagnement fondé sur des travaux scientifiques afin de mieux comprendre les risques associés à la leptospirose et savoir comment s'en prémunir. Par ailleurs, la prévention et le contrôle de la leptospirose doit intégrer un engagement de la communauté locale et impliquer les gouvernements locaux en accord avec l'approche One Health.

Recommandations pour améliorer la coopération entre unités de service pour améliorer la prévention et le contrôle de la leptospirose.

J'ai utilisé les résultats des trois analyses précédentes pour établir des recommandations devant permettre une meilleure coopération entre les services de santé publique et vétérinaires pour la prévention et le contrôle de la leptospirose dans la province de Mahasarakham en Thaïlande. Ces recommandations ont été établies en considérant les stratégies, les régulations et les lois en vigueur en Thaïlande, ainsi que la documentation concernant le contrôle et la prévention de la leptospirose. Le caractère approprié, compréhensible et cohérent de ces recommandations a été soumis et validé par les personnels de santé publique en province, par l'agent responsable du réseau des Universités One Health en Thaïlande (THailand One Health University Network ou THOHUN) et par les enseignants de la faculté de santé publique de l'université de Mahasarakham.

La prévention et le contrôle de la leptospirose utilisant une approche One Health comprend trois composantes importantes: le management, la coordination et l'évaluation. Ces trois composantes intègrent le compartiment humain, animal et environnemental dans une perspective de coopération pour le contrôle et la prévention des maladies. Cette coopération permet de conduire une politique de prévention et de contrôle de manière efficace.

Les recommandations permettant d'améliorer la coopération entre services pour la gestion de la leptospirose sont les suivantes:

1) Développer les connaissances et les compétences des personnels gouvernementaux pour favoriser une interopérabilité entre les services dans le domaine de la prévention des maladies contagieuses à l'échelle de la province.

2) Etablir une base de donnée pour la surveillance de la maladie chez les humains et chez les animaux. Cette base de données permet d'assurer un lien entre les données collectées entre les différents services au sujet des épidémies humaines et animales.

3) Etablir des outils de surveillance à l'échelle des communautés locales.

4) Encourager tous les secteurs à l'échelle de la province qui pourraient être concernés par la leptospirose à établir une politique commune, à définir des indicateurs de performance, et à établir des actions en faveur de la prévention et le contrôle des épidémies.

5) Suivre et discuter les recommandations concernant la prévention et le contrôle de la leptospirose pour les ameliorer.

Les recommandations pour améliorer la coopération entre les différents services pour le contrôle et la prévention de la leptospirose à l'échelle des sous districts (Tambon) sont les suivantes :

1) Développer les connaissances et les compétences des personnels gouvernementaux pour favoriser une interopérabilité entre les serivces impliqués dans la prévention des maladies infectieuses à l'échelle du sous district.

2) Former les volontaires en santé et dans le domaine de la gestion des élevages à l'échelle des villages à l'utilisation des outils de surveillance.

3) Signer des Memorandum of Understanding (MoU) dans les communautés.

4) Developper la participation des publics, en particulier impliquer les volontaires de santé dans les villages et les chefs de villages dans la surveillance de la maladie chez les animaux et les humains.

5) Améliorer la connaissance, les attitudes et les pratiques des publics en utilisant une approche multidisciplinaire et participative.

6) Promouvoir l'élevage des animaux dans des conditions garantissant une bonne hygiène.

7) Contrôler les épidemies animales et humaines de manière jointe et integrée.

8) Suivre les directives et développer des reocommandations pour prévenir et contrôler la leptospirose.

Conclusion générale

La leptospirose est toujours présente dans la province de Mahasarakham. Le manque de coopération et de coordination entre différents services (santé, agriculture, et vétérinaires) ne permet pas d'établir une politique de prévention intégrée. Les facteurs associés avec les infections à la leptospirose sont complexes et multifactoriels, incluant la densité humaine, la densité du bétail, les précipitations pluviométriques, l'extension des surfaces inondables, et d'autres paramètres de géographie physique comme la pente moyenne. Par ailleurs, patients, voisins, volontaires en santé publique et chefs de communauté n'ont pas une compréhension correcte de la manière dont la maladie se transmet et doivent améliorer leurs pratiques et attitudes au regard de la prévention des infections. Cette amélioration des connaissances requiert un meilleur accès et une sensibilisation à l'ensemble des résultats scientifiques, parfois complexes. Pour gagner en efficacité, la prévention et le contrôle de la leptospirose doivent s'appuyer sur une meilleure collaboration entre le secteur de la santé publique et des services vétérinaires, tout en faisant participer activement les populations locales pour atteindre une approche de type One Health.

Chapter 1

Introduction

1. Historical Perspective of leptospirosis

Leptospirosis is an emerging zoonotic disease which is caused by spirochete bacteria called *Leptospira*, and humans are incidental hosts. Leptospirosis has many synonyms viz. "Weil's Disease", "Mud fever", "Pea Pickers Disease", "Canicola Fever", "Haemorrhagic Jaundice", "Infectious Jaundice", "Swineherd's Disease", "Swamp Fever", "European Swamp Fever", “Riesinger’s bilious typhoid”, “bilious or hepatic fever”, “hepatic typhoid”, “icteric typhoid”, “catarrhal icterus”, “febrile icterus” (Terpstra, 2006), “chee nu” or “pee rat” (Mahasarakham Provincial Public Health Office, 2000).

Before 1917

The first reported case of leptospirosis was in 1886 by Dr. Adolf Weil of Heidelberg University in Germany. He found a new disease which caused severe icteric illness and this illness is well known as Weil’s disease (Edwards and Domm, 1960). Many years later, in 1907 the etiologic agent was first examined in the kidney tissue of a patient dying, during a yellow fever outbreak. During the next thirty years, the name of Weil's disease was used in all parts of the world to describe a febrile illness with jaundice, in epidemic or endemic form (Alston and Brown, 1937). In 1907, Stimson demonstrated by silver staining spirochetes in the kidney tubules from a patient who reportedly died of yellow fever. Stimson named them *Spirochaeta interrogans* because of their resemblance to a question mark. Until 1915, Inada and Ido at the Imperial University in Kyushu, Japan announced the discovery of a new species of spirochete that was the pathogenic cause of Weil’s disease, and they named it *Spirochaeta icterohaemorrhagica japonica nov. sp.2.* from the blood of Japanese miners who got infectious jaundice. The illness was at that time well known in various parts of Japan as an epidemic and endemic occurrence characterized by conjunctival congestion, muscular pain, fever, jaundice, haemorrhagic diathesis, albuminuria, and a fairly high mortality rate, and this has been the usual form of the majority of instances of the disease in all countries (Inada et al., 1916). Hiibener and Reiter detected spirochetes in the blood of guinea pigs inoculated with the blood of infected soldiers and published an independent, but not prior, discovery that Weil's disease is caused by a spirochete (Alston and Brown, 1937).

Between 1917 and 1940

In 1917, Naguchi introduced the genus *Leptospira* on account of the difference in morphology and movement. He described the characteristic features of these organisms as long, slender, cylindrical, highly flexible filament with tightly set, regular, shallow spirals. In 1965, Pillot and Ryter proposed the family Leptospiraceae among the Order of Spirocheatales (World Health Organization, 2007).

Between 1941 and 1980

By the 1940s, leptospirosis in animals was recognized as an important veterinary problem as well as a source of infection to humans (World Health Organization, 2007). Between 1940 and 1950, there were cases retrospectively identified as leptospirosis in America. The most famous epidemic of North Carolina (1942) was presumed to be of viral etiology until 1952. The etiological agent involved in the epidemic was maintained by serial animal passages and was later recognized as leptospires by Gouchenour and were re-examined with antigens prepared from these strains, and a high level of agglutinating antibodies against *Leptospira* a*utumnalis* (Gochenour et al., 1952). During the period from the 1950s to the 1970s, much data on the ecology of leptospires in tropical countries were generated because of military operations in South East Asia. During the 1970s and the 80s, W.A. Ellis and colleagues in Northern Ireland found that leptospirosis transmission occurred in animals. During the same period, several studies conducted in various countries generated a lot of data on the dynamics of transmission of the disease in various domestic animal species. In addition, results of those studies showed that mammalian species including wild animals and aquatic mammals can harbor leptospires and can act as a source of infection for humans (Gochenour et al., 1952; World Health Organization, 2007).

Between 1981 until present

Microscopic Agglutination Test (MAT) or Martin and Pettit test was the gold standard for serodiagnosis of leptospirosis which was developed almost one century ago at the Pasteur Institute (World Health Organization, 2007). PCR has sensitivity and capacity to give an early diagnosis. PCR has thus been increasingly used for the diagnosis of leptospirosis. Nowadays, the MAT and PCR are the two techniques allowing to confirm the diagnosis of leptospirosis (Picardeau, 2013) Molecular typing methods such as pulsed-field gel electrophoresis (PFGE), multilocus variable-number tandem-repeat analysis (MLVA), multilocus sequence typing (MLST) were used to define species, clades, subclades, clonal groups of *Leptospira* (Guglielmini et al., 2019). Moreover, the Amino Acid Identity (AAI) and the Percentage Of Conserved Proteins (POCP) values were determined by using 16S rRNA and polyphosphate kinase (ppk) sequences to evaluate the diversity within the *Leptospira* genus (Vincent et al., 2019). Nowadays, more than 9,656 research papers related to leptospirosis were published in Medline database (Pubmed, 2019).

2. Human leptospirosis situation in the world

Human leptospirosis is recognized as an important infectious disease in the tropics with high disease incidence in 34 countries around the world as shown in Figure 1 (Costa et al., 2015). Although public health departments, livestock departments, and agriculture departments around the world tried to control this disease that can cause death, nowadays, there are new leptospirosis patients in countries which had never shown high leptospirosis prevalence (Bedard et al., 2014; Costa et al., 2015). Therefore, the epidemiology of leptospirosis may be linked with a changing environment as well as human lifestyle changes.

The annual reported leptospirosis incidence in the world ranges from 0.10 to 975.00 annual cases per 100,000 population. The annual morbidity and mortality due to leptospirosis worldwide were estimated to be 14.77 cases per 100,000 population (95% CI 4.38 – 25.03). The majority of leptospirosis cases and deaths occur in tropical regions with 73% of the world's leptospirosis cases and deaths occurring in countries situated between the Tropics of Cancer and Capricorn (Costa et al., 2015).

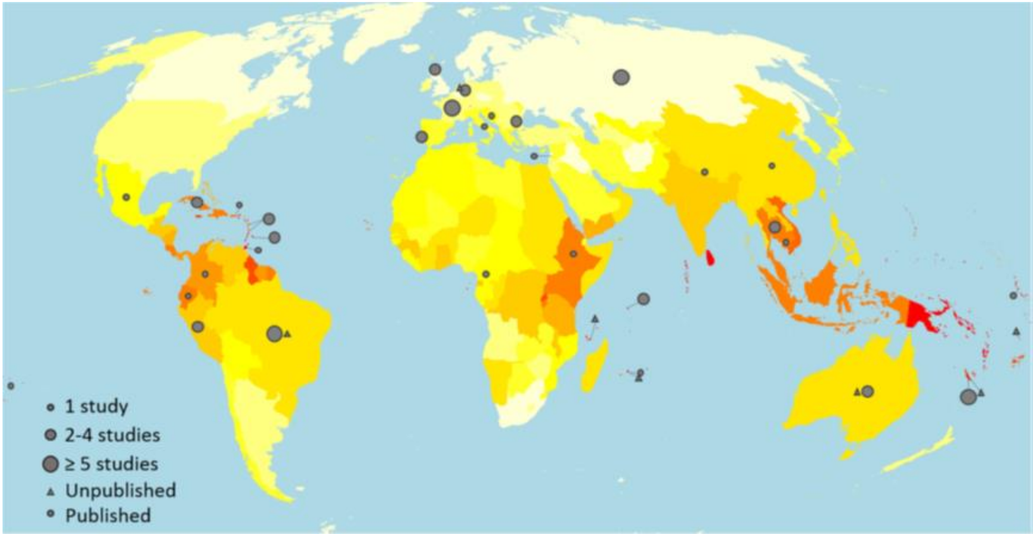

Figure 1. Leptospirosis incidence by country. The color represents annual cases per 100,000 population from white (0 – 3), yellow (7 – 10), orange (20 – 25) to red (over 100) (Costa et al., 2015).

The leptospirosis prevalence rates worldwide are underestimated (Sergio et al., 2012; Sharp et al., 2016) because the symptoms of this disease are similar to those of many diseases such as influenza, dengue fever, malaria or typhoid (Levett, 2001). In endemic areas, leptospirosis was sometimes diagnosed as dengue, rickettsioses (Q fever, typhus), malaria, pulmonary tuberculosis, viral hepatitis, bacterial or viral meningitis, influenza, brucellosis, ehrlichiosis, tularemia, syphilis, HIV, sepsis, yellow fever. In non-endemic areas, leptospirosis was diagnosed as pyelonephritis/urinary tract infection, overwhelming adenovirus infection, acute abdomen gastroenteritis and typical pneumonia (Plank and Dean, 2000). Because some patients antibody titers may not be present at the time of testing or could decrease to undetectable levels over time, the cut-off level above which titer is considered positive varies from lab to lab, and samples sent to a reference laboratory on another continent may be tested against serovars that do not represent those present in the community from which the sample originated (Rivera et al., 2012; Sethi et al., 2010). Moreover, the majority of infections caused by leptospires is either subclinical or of very mild severity, and patients will probably not seek medical attention (Costa et al., 2015; Levett, 2001). Leptospirosis is an emerging zoonotic disease worldwide but it is not included in the WHO list of neglected tropical diseases, although leptospirosis research area did not get attractive for funders and researchers (Goarant et al., 2019).

3. Taxonomy and Classification

Leptospirosis is a zoonotic bacterial disease (Bharti et al., 2003) which is caused by various species of *Leptospira*, a spirochete in the family Leptospiraceae, order Spirochaetales. Some *Leptospira* are harmless saprophytes that reside in the environment, while others are pathogenic. The basic unit of *Leptospira* taxonomy is based on serovar. Serovars consist of closely related isolates based on serological reactions to the organism's lipopolysaccharide. More than 250 pathogenic serovars, and at least 50 nonpathogenic serovars, have been identified. The genus *Leptospira* was originally divided into two species, *L. interrogans* which complex (later, *Leptospira interrogans* sensu lato) is comprising all pathogenic strains, and *L. biflexa* which complex (later, *Leptospira biflexa* sensu lato) is containing the saprophytic strains isolated from the environment (Bharti et al., 2003; Levett, 2001). The species classification of the genus *Leptospira* is now based on DNA relatedness. The genus defined as being at least 70% DNA-related and whose related DNA sequences contain at most 5% unpaired bases (divergence). More than 250 serovars arranged into 25 serogroups have been described under the species *L. interrogans.* The species *L. biflexa* has 65 serovars arranged in 38 serogroups (World Health Organization, 2007). The serogroups of *L. interrogans* and some common serovars are shown in Table 1.

Table 1. Serogroups and some serovars of *L. interrogans* sensu lato (Levett, 2001).

Serogroup	Serovar(s)
Icterohaemorrhagiae	Icterohaemorrhagiae, Copenhageni, Lai, Zimbabwe
Hebdomadis	Hebdomadis, Jules, Kremastos
Autumnalis	Autumnalis, Fortbragg, Bim, Weerasinghe
Pyrogenes	Pyrogenes
Bataviae	Bataviae
Grippotyphosa	Grippotyphosa, Canalzonae, Ratnapura
Canicola	Canicola
Australis	Australis, Bratislava, Lora
Pomona	Pomona
Javanica	Javanica
Sejroe	Sejroe, Saxkoebing, Hardjo
Panama	Panama, Mangus
Cynopteri	Cynopteri
Djasiman	Djasiman
Sarmin	Sarmin
Mini	Mini, Georgia
Tarassovi	Tarassovi
Ballum	Ballum, Aroborea
Celledoni	Celledoni
Louisiana	Louisiana, Lanka
Ranarum	Ranarum
Manhao	Manhao
Shermani	Shermani
Hurstbridge	Hurstbridge

Nowadays, 30 new *Leptospira* species were identified by using 16S phylogenetic analysis as shown in Figure 2.

Figure 2. Phylogenetic tree based *Leptospira* genus on the 16S rRNA and ppk sequences. The branches are colored according to their belonging to the four main subclades: *L. interrogans* strain L495 (red), *L. licerasiae* strain VAR010T (purple), S1: *L. biflexa* strain Patoc and new subclade (blue) (Vincent et al., 2019).

In Thailand, leptospires can be found in both humans and livestock. The most predominant leptospiral serovars in humans were Shermani, Bratislava, Panama, and Sejroe, Tarassovi were found in buffaloes, and Shermani and Ranarum were found in cattle and pigs. The most abundant serovar is Shermani across humans, buffaloes, cattle, pigs and in regions with a possible transmission pathway between humans and livestock (Chadsuthi et al., 2017).

4. Biology of Leptospires

Leptospires are flexible helical rods which are actively motile. The leptospiral motility is characterized by their rotation around their longitudinal axis and flexion and extension. The rotatory movement occurs in both directions alternately. Usually one or both ends are bent or hooked (World Health Organization, 2007). The genome of *leptospira* is both circular and larger than the genomes of other spirochetes. Leptospires share features of both Gram-positive and Gram-negative bacteria that are highly motile, obligate aerobic spirochetes. Therefore, *Leptospira* can live within diverse contexts: animal hosts and freely in the environment (Bharti et al., 2003). The sizes of leptospires are about 0.25 x 6 – 25 µm which can pass through 0.45 µM filters. Dark-field or phase-contrast microscopy of wet preparations is required for direct visualization of leptospires, since the bacteria stain poorly. Electron microscopy shows a cylindrical cell body (protoplasmic cylinder) wound helically around an axistyle (0.01 – 0.02 µm in diameter), which comprises two axial filaments (a spirochetal form of a modified flagellum) inserted subterminally at the extremities of the cell body, with their free ends directed towards the middle of the cell (Bharti et al., 2003; Levett, 2001). Newly isolated leptospires appear shorter on initial subculture with even higher translational and helical motility (Bharti et al., 2003). Leptospires have a typical double membrane structure as in other spirochetes, in which the cytoplasmic membrane and peptidoglycan cell wall are closely associated and are overlain by an outer membrane. Leptospires may be stained using carbol fuchsin counterstain (Levett, 2001). A large proportion of such proteins are lipoproteins with relative abundance on the cell surface: LipL32 > LipL21 > LipL41 (Adler and de la Peña Moctezuma, 2010). Leptospires can survive at pH 6.8 – 7.4 and temperature between 28°C and 30°C. They are catalase and oxidase positive. They can survive in undisturbed liquid culture for months, sometimes years (Bharti et al., 2003; Parker and Walker, 2011). Moreover, they can survive outside the host for up to six months in moist, warm conditions (Bharti et al., 2003). Leptospires survive approximately two weeks in the soil which was contaminated with urine from infected rodents. However, high temperatures (greater than 36°C), freezing, drying, or an acid or alkaline environment rapidly can kill them (Levett, 2001). Therefore, it explains why leptospirosis is usually found in tropical areas.

5. Life cycle of pathogenic Leptospires

Leptospira are excreted in the urine of the infected host and can survive in the soil and infect a susceptible host by penetration through a broken skin, mucosa, conjunctiva, or intact skin after prolonged immersion in water, and ingestion through water or food, droplet infection. Animals, including humans can be divided into maintenance host and accidental host (Budihal and Perwez, 2014). The spirochete lives in the blood outside the cellular elements and in various organs and tissues. The leptospires can be observed within phagocytic cells. However, they are mostly observed in the epithelial cells. The liver contains the largest number of spirochetes. In the kidneys, the spirochete occurs inside the interstitial tissues and also in the walls and lumen of the uriniferous tubules (O'Toole et al., 2015). The disease is maintained by chronic infection of the renal tubules of maintenance hosts. The leptospiral life cycle involves shedding in the urine, persistence in the ambient environment, acquisition of a new host, and hematogenous dissemination to the kidneys through the glomerulus or peritubular capillaries. Once leptospires gain access to the renal tubular lumen of the kidney, they colonize the brush border of the proximal renal tubular epithelium, from which urinary shedding can persist for long periods of time without significant ill effects on the reservoir host (Adler, 2015).

6. Sources of Infection

A wide variety of animal species are the leptospiral reservoir hosts. There are 5 main sources of human infection.

1) Small mammal species, notably feral and peridomestic rodents (rats, mice, voles, bandicoots, etc.) and insectivores (shrews and hedgehogs); (World Health Organization, 2003) bats, pinnipeds. Rodents are considered as the most important reservoirs worldwide (Shah, 2012).

2) Domestic animals such as cattle, pigs, dogs, cats, more rarely sheep, goats, horses and buffaloes (World Health Organization, 2003). Almost all mammals (including aquatic mammals) and marsupials worldwide have been shown to be carriers of leptospires (Adler and de la Peña Moctezuma, 2010).

3) Wild animals such as fur-bearing animals (silver foxes, mink and nutria) squirrels, raccoons grown in captivity for fur production (World Health Organization, 2003).

4) Human, human-to-human transmission is non-existent and the disease is regarded globally as a zoonosis. Humans almost never become chronic carriers, but suffer acute infections, sometimes with longer term sequelae (Adler and de la Peña Moctezuma, 2010).

5) Other animals such as reptiles and amphibians (Adler and de la Peña Moctezuma, 2010; World Health Organization, 2003).

Leptospirosis in humans is always acquired from an animal source and rodents are thought to be the most important reservoirs of leptospiral infection. Mammal species are leptospiral reservoirs more often than other species. Some species of insectivores, carnivores and ruminants may also act as a reservoir for a variety of serovars.

7. Human transmission

Human leptospiral infections include:

1) Direct transmission from animals to human. It occurs when human are in contact with urine, blood, or animal tissue of an infected animal. Direct transmission usually occurs in people having occupations which involve handling of animals or animal tissue such as butchers, veterinarians, cattle and pig farmers, rodent control workers (Kobayashi, 2001b; Levett, 2001; World Health Organization, 2007). Moreover, humans can get the disease by being bitten by infected animals (Bedard et al., 2014).

2) Indirect transmission occurs when a human being is exposed to leptospires excreted from infected animals in the environment (Kobayashi, 2001b; Picardeau, 2013). Occupations such as sewer workers, miners, soldiers, septic tank cleaners, fish farmers, gamekeepers, canal workers, rice field workers, taro farmers, banana farmers, and sugar cane cutters increase exposure to leptospirosis exposure by indirect transmission (Levett, 2001). Infection in animals is usually subclinical, and urinary shedding of leptospires from infected animals is the most important source of transmission. *Leptospira* enter the human body via cuts or abrasions in skin, through mucus membranes, lungs in the form of aerosol droplets, and conjunctival membranes

(Shah, 2012; World Health Organization, 2007). In addition, spirochetes are able to penetrate through a human skin that has been immersed in water for a long time (Kobayashi, 2001b). For example, experiment in guinea pigs found that spirochete was able to penetrate through a macroscopically healthy skin and cause leptospirosis in the guinea pig (87%) (Inada et al., 1916). Moreover, in experimental animals, leptospires can be detected in blood and tissues 10 min after intra-peritoneal, intra-dermal or intra-ocular inoculation. Adhesion to host tissues seems to be a prerequisite for successful infection and indeed both intact leptospiral cells and a plethora of leptospiral proteins have been shown in vitro to adhere to a range of host components (Adler, 2014).

Leptospires can circulate in the bloodstream and spread to other organs. The primary lesion is damaging the endothelial lining of small blood vessels, which results in ischemic damage to the concerned organs (e.g., the liver, kidneys, meninges, and muscles). The pathogenicity of *Leptospira* results from the enzymes, toxins, or metabolites elaborated by or released from the lysed organisms. In severe cases, petechiae and ecchymosis are seen in various internal organs at postmortem examination. Degenerative changes, with hypertrophy and hyperplasia of Kupffer cells in the liver, diffuse tubulo-interstitial inflammation and tubular necrosis in the kidneys, and congestion with focal hemorrhages in the lungs, are the main histopathological features (Tullu and Karande, 2009).

8. Risk groups

Humans have an increased chance to be exposed to *Leptospira* by contact via occupational, recreational and social activities. The main risk groups for leptospirosis infection are

1) Animal farmers such as cattle farmers, pig farmers can contact leptospires when handling animals, touching dead, aborted fetuses and other procreational products (World Health Organization, 2003). Livestock farming is a major occupational risk factor throughout the world. The highest risk is associated with dairy farming (Levett, 2001).

2) Crop farmers such as vegetable farmers, rice farmers, gardeners, taro farmers, banana farmers, sugar cane and pineapple field harvesters can be exposed to water contaminated by rodents or livestock for instance.

3) Fishermen and fish farmers can be in contact with leptospires from contaminated waters.

4) Indoor workers such as veterinarians, abattoir workers, butchers and laboratory staff can contact leptospires from infected or died animals.

5) Sewer workers can contact leptospires from sewage contaminated by rat urine.

6) Industrial workers such as miners can contact leptospires from water contaminated with rat urine.

7) People living in close contact with domestic animals can contact leptospires from infected animals. Dogs are a significant reservoir for human infection in many tropical countries.

8) Soldiers, hunters and hikers can contact leptospires from wading through contaminated surface waters or swamps, walking on or through contaminated soil, mud or wet vegetation, or by contact with animals (Levett, 2001).

9) Activities such as jungle trekking, caving, outrigger sailing, canoeing, scuba diving, mountain biking, water fishing (Haake et al., 2002) and swimming can favor contact with leptospires from water contaminated with rat urine (Friman et al., 2000).

10) Children can contact leptospires when playing in yards or swimming in the river.

11) People participating in leisure, recreational activities (swimming, sailing, canoeing, rafting, caving, canyoning, fishing, etc.) or involved in accidents (car accidents, boat accidents) and travelers can contract leptospires from contaminated surface waters, especially with prolonged (head under water) submersion.

12) People having a poor hygiene as those living in warren, can contract leptospires from rat-contaminated surroundings and get contaminated by consuming food or water (World Health Organization, 2003).

9. Clinical features of Leptospirosis

The clinical features of leptospirosis in human show extremely broad ranges in severity from a mild, self-limited febrile illness to a fulminant life-threatening illness.

The symptom depends on the organ systems may be involved, reflecting the systemic nature of the infection.

9.1 Incubation Phase

The incubation phase of leptospirosis averages from 7 to 12 days from exposure to *Leptospira*. However, it can be as short as three days or as long as a month (Adler, 2015). During this phase, the patient do not show any symptom.

9.2 Presentation

The signs and symptoms are nonspecific and also occur with other causes of acute febrile syndrome. Patients typically present with sudden onset of fever, chills, and headache (Adler, 2015). Sub clinical and mild infections are quite common. Only a small proportion of cases develop severe leptospirosis (World Health Organization, 2007). The clinical features in presentation phases are as follows.

1) Anicteric febrile illness

Most patients show subclinical sign of very mild severity, and they will probably not seek medical attention. They get ill abruptly with rapidly rising fever and other symptoms such as febrile illness, chills, headache, myalgia, abdominal pain, conjunctival suffusion (Levett, 2001). The symptoms are similar with febrile illnesses (Budihal and Perwez, 2014). This phase lasts for 4 - 7 days (World Health Organization, 2007).

2) Icteric leptospirosis (Weil's Disease)

About 5 to 10% of leptospirosis patients show icterus (Levett, 2001). Icteric leptospirosis is characterized by a combination of hepatic and renal impairment, hemorrhage, and vascular collapse (Budihal and Perwez, 2014; O'Toole et al., 2015). Some patients progress to renal failure which is the most common cause of death in icteric leptospirosis and involvement the most serious complication (Kobayashi, 2001a).

9.3 Complications of Leptospirosis

The majority of leptospirosis complications are myocarditis, hemorrhage complications, hypotension and uveitis. Myocarditis are usually mild and can revert to normal within 2 - 3 weeks. Moreover, hemorrhage complications are usually found and massive bleeding and may cause asphyxiation and death. Hypotension is an important complication noted in patients with severe leptospirosis. In addition, Uveitis is usually found in patients who have been sick for leptospirosis for more than 6 months (World Health Organization, 2007).

9.4 Recovery Phase

Most leptospirosis patients recover completely. However, many patients suffer from chronic post leptospirosis symptoms (fatigue, myalgia, malaise, headache) for months by, and weakness for more than a year (Adler, 2015). The patients reported in Japan showed that the patient got treatment in hospital before sixth days have more change to recover. Most fatal cases are found when people get treatment after sixth days. This difference of one day may be significant for prognosis. The majority of deaths occurred between the tenth and the fifteenth days of illness (Kobayashi, 2001a).

10. Prevention and control

World Health Organization recommended 3 main strategies for leptospirosis prevention and control, as follows:

1) Prevention and control at the source of infection.

Mammals are the main source of leptospirosis infection. The infected animals excreted leptospires from their urine to the environment. Moreover, infected animals transfer leptospires to their offsprings either in utero or during the neonatal period. These offsprings then transfer the infection to their own offsprings, and so on. In this way, a chain of infection is maintained by the maintenance host. Prevention and control at the source of infection are necessary as follows:

1. Isolate infected animals which can be slaughtered if necessary.
2. Treat infected animals with antibiotics to control leptospiral shedding.
3. Rodents (rats, mice) can be poisoned, trapped.
4. Deprive rodents and other feral sources of access to the human living environment by erecting fences, screens and rodent-proof buildings, stables.
5. Deprive rodents of access to food and drinking water, by building rodent-proof warehouses and other food/harvest depots, water reservoirs, stables, yards and pens, and by moving all spilled and waste food out of reach of pests.
6. Prevent rodents and other feral from living in areas of human habitation by keeping the surroundings scrupulously clean, removing rubble and litter, cutting

down tall grass and shrubs, and installing adequate sanitation, and in particular waste disposal with good sewers and toilets, and by providing clean water.

7. Use vaccines for the immunization of pets and farm animals.

8. Dispose excreta from domestic animals in such a way as to avoid contamination (World Health Organization, 2003).

2) Prevention and control of the transmission.

Transmission can be prevented by:

1. Wearing protective clothing such as boots, gloves, spectacles, aprons, masks, adequate warnings near water bodies.

2. Covering skin lesions with waterproof dressings.

3. Washing or showering after exposure to contaminated urine.

4. Washing and cleaning wounds.

5. Avoiding touching ill, urine or dead animals, fetuses, placentas, organs (kidneys, bladders) with bare hands.

6. Disinfecting contaminated areas.

7. Providing clean drinking water.

8. Mechanizing risk activities such as harvesting rice or cutting cane.

9. Introducing good herd management (World Health Organization, 2003).

3) Prevention and control at the level of the human host can be done by:

1. Raising awareness of the population.

2. Antibiotic prophylaxis in patients or other people at high-risk exposure. Doxycycline is reported to give some degree of protection to exposed individuals from non-endemic areas. However, even if it does not always prevent infection, it can reduce the severity of the disease and thus mortality and morbidity.

3. Giving vaccines against the serovars of *Leptospira*.

4. Giving health education to people (World Health Organization, 2003).

11. Factors contributing to leptospirosis infections

The previous researches showed that human leptospirosis infection in the world is often influenced by complex and multifactorial including: individual factors, environmental factors, population factor and livestock factors.

11.1 Individual factors

There are four factors related to the incidence of leptospirosis including: age, sex, occupational and behavioral.

1) Age

Most of leptospirosis patients were found in adult groups. In Thailand the highest incidence rate is found in people aged 55 - 64 years (Hinjoy, 2014). Similarly, in Argentina, leptospirosis patients were predominantly adults (Vanasco et al., 2008). In France, the mean age of leptospirosis patients was 45 ± 18 years (Abgueguen et al., 2008). Adults were at more risk of leptospirosis due to higher occupational and recreational exposure however, children lower than 15 years of age have been implicated in outbreaks due to contact with water (Shah, 2012).

2) Sex

Males tend to have a much higher incidence and prevalence of leptospirosis than females (Plank and Dean, 2000). Leptospirosis incidence is found in nine men among every woman (Abgueguen et al., 2008). Similarly in Thailand, leptospirosis ratio of male to female cases is 3.5/1 (Hinjoy, 2014).

3) Occupational

Farmers were found with the highest leptospirosis incidence in Thailand in terms of occupation (60.6% in Hinjoy, 2014). Similarly in Argentina, most of leptospirosis patients were associated with rural-based risk activities, such as agricultural work (Vanasco et al., 2008). There is a worldwide occupational association, especially in developed countries with agriculture and animal production (cropping, dairy farming, pig production, abattoirs) and a universal risk from rodent-carrier mediated infection, especially prevalent in tropical countries (Adler and de la Peña Moctezuma, 2010).

4) Behavior

In Thailand, walking through water, plucking paddy sprouts for replanting, plowing, fertilizing in wet fields are risk factors of leptospirosis (World Health Organization, 2007). Many leptospirosis patients in Thailand got infected from walking barefoot in damp conditions or gardening (Khomtang, 2001; Ratsameeyoongthong, 2001; Sudjanham, 2005). Moreover, agricultural activities (Odd ratios (OR) = 11.94), not wearing boots while performing agricultural activities (OR =

6.64), and having heavy mice infestation in the area of the participant's home (OR = 5.41) were statistically significantly associated with the occurrence of leptospirosis (Sudjanham, 2005). In addition, recreational, adventure tourism and travels are emerging as significant risk factors for leptospirosis in developed countries (Lau, Smythe, and Weinstein, 2010).

11.2 Environmental factors

Environmental factors, such as rainfall, flooding events, slope, contribute to the leptospirosis transmission and infection risk.

1) Rainfall

Leptospirosis incidence shows a strong seasonality with a high incidence during the wet season (Hinjoy, 2014). Leptospirosis outbreaks have been related to heavy rainfall (Plank and Dean, 2000; Shah, 2012) which is suitable for the development and survival of *Leptospira* species in the environment (Pappas et al., 2008; Victoriano et al., 2009). Rainfall threshold values are associated with leptospirosis outbreaks (Tassinari et al., 2008). Leptospirosis is notable to have seasonal occurrence with increased incidences observed with rainfall (Shah, 2012). In Thailand, rainfall was found to be correlated with leptospirosis cases. During the rainy season, the soil accumulates moisture, leading to small or large water pools. These facilitate *Leptospira* organisms' growth in water-soaked soils (Chadsuthi et al., 2012).

2) Flooding

Many studies consistently reported high risk from water-related *Leptospira* exposures. Floods can be considered as one of the main risk factors in tropical countries (Ledien et al., 2017; Mwachui et al., 2015). Contact with floods is the most important single risk for leptospirosis (OR = 4.49; 1.17 – 17.25) in the study of Vanasco et al. (2008). Flooding leads to an increase of water contamination from the urine of infected animals. In many tropical countries, heavy rains and/or floods increased the size of outbreaks, via indirect transmission from contaminated water after flooding (Chadsuthi et al., 2012; Hagan et al., 2016). Outbreaks of leptospirosis are often reported after flooding events (Amilasan et al., 2012; Dechet et al., 2012; Lau, Smythe, Craig, et al., 2010). However, Suwanpakdee et al. (2015) found that flooding seems less influential in leptospirosis transmission in Thailand.

3) Mean slope

The decrease of sloping and flat topography allow the formation of permanent puddles which is strongly associated with the formation of the flood and be an important source of transmission of leptospirosis (Sulistyawati et al., 2016). Households situated within 20 meters from the lowest point in the valley were found to be at positive risk of *Leptospira* infection by Reis et al. (2008). Rainwater and unpaved dirt can stay for a long time in the soil of low mean slope area which facilitates *Leptospira* survival in these conditions. Flooding may lead to a dilution of *Leptospira* which can reduce the levels of the infective dose (Suwanpakdee et al., 2015).

11.3 Population factors

Human population growth and increasing density are important independent predictors of leptospirosis infections (Coker et al., 2011). Population growth is typically associated with agricultural intensification, leading to increase in livestock numbers and occupational exposure which in turn leads to enhanced leptospirosis transmission (Lau et al., 2016).

11.4 Livestock factors

Domestic animals such as cattle, pigs, dogs, cats are significantly associated with human leptospirosis infection (Sugunan et al., 2009; World Health Organization, 2003). The most important maintenance hosts are small mammals, which may transfer infection to domestic farm animals, dogs, and humans (Plank and Dean, 2000). Exposure to animals could be a potential risk of human leptospirosis infection and rearing domestic animals at home was identified as a risk factor (OR = 1.21) (Kamath et al., 2014). Animal husbandry practices favor the shed of *Leptospira* into the environment. Moreover, grazing range characteristics are likely to play a role in the concentration *Leptospira* in the environment (Barragan et al., 2017). A recent study of Chadsuthi et al. (2017) showed a clear statistical association between human incidence and the prevalence of *Leptospira* serovars in livestock. Moreover, Shermani serovar is a cross infection in cattle to humans (Chadsuthi et al., 2017).

12. Behavioral Health

Health behavior is defined as the activity undertaken by people for the purpose of maintaining or enhancing their health, preventing health problems, or achieving a positive body image, intended to prevent sickness and injury, or to prolong their lives (Gibbs et al., 2015). World Health Organization (WHO) suggests prevention of human leptospirosis by avoiding risk of contact with *Leptospira* such as work in the farm without using boots, gloves, spectacles, aprons, masks..., and as not strictly maintain hygienic measures during care or handling all animals and avoiding contact with urine or other body fluids., etc (World Health Organization, 2003).

Individual or intra-personal factors include knowledge, attitudes, beliefs, motivation, self-concept, developmental history, past experience, and skills that have influence the behavior of individuals (U.S. Department of Health and Human Services et al., 2005). Many health practitioners and researchers try to establish strategies to develop health behavioral by one-on-one activities such as give health education (Mahasarakham Provincial Public Health Office, 2000), develop health education programs which apply health belief model and social support to improve leptospirosis prevention behavior (Chathongyot, 2001), or using participatory learning and social support to promote the leptospirosis preventive behavior (Buriwath, 2012; Nikratok, 2012). Individual behavior is the fundamental unit of group behavior (Glanz et al., 2008).

Understanding of individual knowledge (K), attitude (A) and practices (P) are essential to develop prevention and control policy implementation. KAP surveys can identify knowledge gaps, behavioral patterns that may facilitate understanding and action, as well as pose problems or create barriers for prevention and control of the disease. They can identify information that is commonly known and attitudes that are commonly held. To some extent, they can identify factors influencing behavior that are not known to most people, reasons for their attitudes, and how and why people have certain health behaviors (World Health Organization, 2008).

13. Human leptospirosis situation in Thailand

Leptospirosis is an important public health problem and was found in every region in Thailand. Indeed, Thailand is located in the tropical zone with an important soil moisture in some parts, with a climate producing high rainfall which is appropriate for *Leptospira* spreading. Over than 70,000 cases of leptospirosis were recorded in

Thailand since its emergence in the 2000s (Morand et al., 2018). Leptospirosis incidence in Thailand shows a strong seasonality with a high incidence during the rainy season (Hinjoy, 2014) and outbreaks of leptospirosis are often reported after flooding events (Amilasan et al., 2012; Dechet et al., 2012; Lau, Smythe, Craig, et al., 2010). The history of the report of leptospirosis and leptospiral research in Thailand closely followed that of the rest of the world.

In 1942, the first isolate of Leptospires from human patients in Thailand was reported by Chai Yunipan, M.D. in Siriraj hospital, Bangkok while there was a big flood in Bangkok. 2 patients survived but 2 patients died (Keatikun et al., 1974; Sukhothaithummatirat, 1994). After that event, patients suffering leptospirosis were found in every region. From 1972 to 1982, 10 to 20 leptospirosis cases were reported annually in Thailand (Department of Medical Service, 2007).

The second huge outbreak happened in 1983 with flooding in the south of Thailand. Between 1982 and 1994, the number of cases ranged from 55 to 272 cases per year and represented an annual incidence rate of approximately 0.3/100,000 population (Department of Medical Service, 2007). The disease showed a seasonal fluctuation with most of the cases occurring between June and December. The peak of incidences was observed in October (Tangkanakul et al., 2005).

After 1995, leptospirosis report increased dramatically from 143 cases in 1995 to 6,080 cases in 1999 and leptospirosis outbreak occurred in many provinces (Tangkanakul et al., 2005). From 2000, an intensive prevention and control campaign was implemented nationwide and cases of leptospirosis decreased to from 10,217 in 2001 to 4,500 - 5,000 cases annually since 2003, with an incidence rate of 5 - 9 per 100,000 population (Bureau of Epidemiology Department of Disease Control, 2000). From 2003 to 2012, 41,089 cases of leptospirosis were reported to the Bureau of Epidemiology, Ministry of Public Health, Thailand. The average annual incidence rate was 6.6 per 100,000 population. Northeastern region showed the highest incidence (12.5 per 100,000 population). There were 606 deaths during 2003 - 2012, with a case fatality rate of 1.5% (Hinjoy, 2014).

The temporal pattern analysis of leptospirosis in Thailand from 2000 to 2017 shows a global decrease of leptospirosis transmission the last years (Figure 3). There are seasonal variations of leptospirosis in relation to the monsoon. There is a significant temporal autocorrelation of 12 months as shown in Figure 4 (Morand et al., 2018).

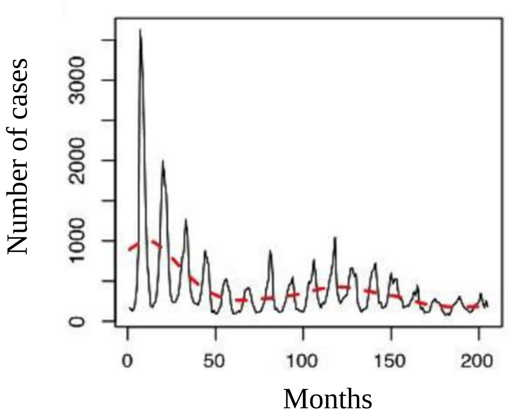

Figure 3. Leptospirosis temporal pattern in number of cases per month for 2000 – 2017 for all Thailand. The red curve represents the smoothed trend. (Morand et al., 2018).

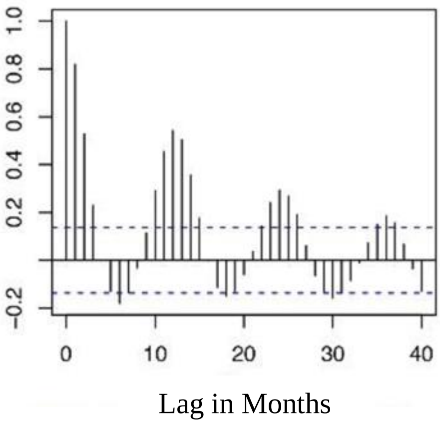

Figure 4. Temporal autocorrelation of number of cases of leptospirosis for 2000 - 2017 (Morand et al., 2018).

Spatial epidemiology of the total number of leptospirosis cases for 18 years as shown in Figure 5 found that North-eastern Thailand presents the highest leptospirosis incidence (Morand et al., 2018). It is confirmed with interpolative maps using kriging methods as shown in Figure 6

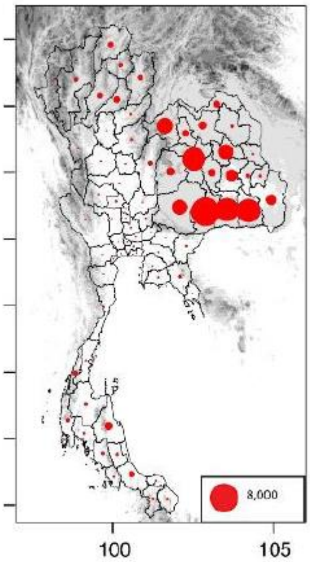

Figure 5. Spatial epidemiology of the total number of leptospirosis cases in Thailand by province for 2000 - 2017 (Morand et al., 2018).

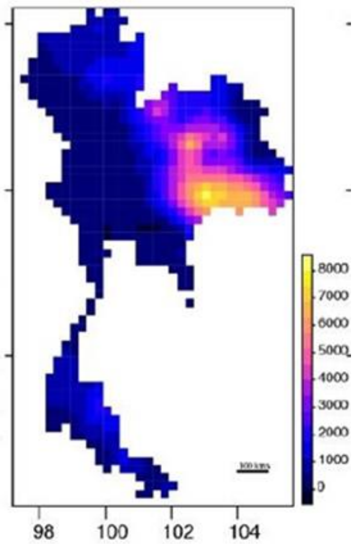

Figure 6. Interpolation of the map in figure 5 of leptospirosis by kriging methods (Morand et al., 2018).

14. Human leptospirosis situation in Mahasarakham Province

Mahasarakham province is located in the northeast of Thailand. This province covers 5,300 Km^2 lying within the 15°25 - 16°40”N and 102°50 - 103°30”E as shown in Figure 7. Mahasarakham province is divided into 13 districts, 133 subdistricts and 1,982 villages. Mahasarakham is in the middle of the Khorat plateau and it display a relatively flat landscape with elevation ranging from 130 to 230 meters. It corresponds mostly to a plain except in the northern and western parts where low hills occur; the south show the lowest elevation. The climate in Mahasarakham province is of savannah type with a rainy season spanning from May to November. Three main rivers are present with Chee, Seaw and Choo rivers (Department of Mineral Resources and Minister of Natural Resources and Environment, 2009). The population is estimated to reach 869,280 persons and 244,155 households in 2016 (Mahasarakham Provincial Public Health Office, 2016). Most citizens (43.92%) are living from agriculture (Mahasarakham Provincial Labor Office, 2017).

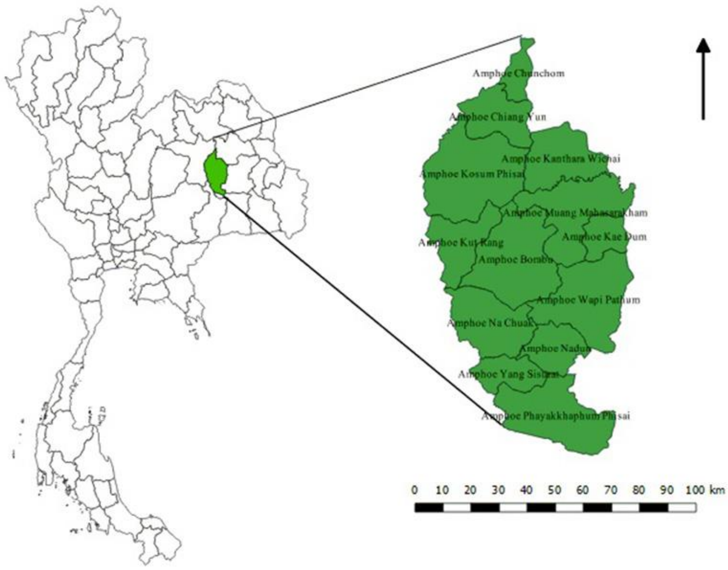

Figure 7. Mahasarakham map with its 13 districts on the right side, Thailand.

Leptospirosis is endemic in Mahasarakham Province. The prevalence of leptospirosis in the province is the 9th of Thailand and 5th of the Northeastern region of Thailand. The first leptospirosis patient was reported in 1996 which has known a total of 12 leptospirosis patients were reported in the province during the same year. Number of leptospirosis patients increased dramatically to 300 in 1997 (Mahasarakham Provincial Public Health Office, 2000). After 1997, report of leptospirosis patients occurred annually until now.

Between 2000 and 2003, the Ministry of Public Health has chosen Mahasarakham as a pilot province to develop and improve the implementation of leptospirosis prevention policy. Mahasarakham Provincial Public Health Office established many implementations measures such as employing people in the community to kill rats (Mahasarakham Provincial Public Health Office, 2000), giving health education for the people, establishing a surveillance system (Regional Health 5, 2000), a "war room" (Wibulpolprasert et al., 2007), setting the Surveillance and Rapid Response Team (SRRT) in every district (MoPH Bureau of Epidemiology Department of Disease Control, 2007), based on the District Strengthening Disease Control (Department of Disease control, 2016). However, leptospirosis prevalence was still high and still caused death.

15. One Health implementation in Thailand

"One Health is an approach to design and implement programs involving the collaboration of multiple sectors communicating and working together to achieve better public health outcomes" (The World Health Organization, 2017). Health issues at the human-animal-environment interface cannot be effectively addressed by the sole human health sector. Zoonotic diseases need collaboration across all sectors and disciplines at the human-animal-environment interface (World Health Organization et al., 2019). Implementing the One Health approach's can improve communication of risks and to help turn rhetoric into reality (Binot and Morand, 2015).

Thailand has encouraged cooperation between departments for prevention and control of epidemics before adopting the One Health concept. However, cooperation was informal and occurred when there was a specific mission or in case of disease outbreak. Some prevention and control activities did not take into account the question or did not fully consider the necessary linkages to plan comprehensive disease prevention activities (Sommanustweechai et al., 2016). However, after Thailand adopted the One Health concept, the departments had a better understanding of the importance of working together for prevention and control of epidemics. At present, the implementation of the One Health approach is based on the province's voluntary action. The collaboration between departments for prevention and disease control continues and improves from the past until the present.

In Thailand, the One Health approach was recorded for the first time in Thailand National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response (2013 - 2016). In 2014, One Health is a term understood only by the public health department, although there was cooperation in disease prevention and control between the public health department and the livestock department for more than a decade. For example, during the Avian Influenza (bird flu) outbreak in 2004, Thailand expanded cooperation between these departments. Thailand got the idea of One World One Health from abroad and for the first time, in March 2012, the One Health term was used in Thailand.

Using the "One Health" concept is a way to clarify the importance of multidisciplinary and intersectoral work to underline the interlinkages between human, animal and environmental health. It helps to develop collaboration between the existing agencies and motivation for continuing to get prepared for future outbreaks.

Phase 1: Before 2004, cooperation in controlling zoonosis diseases.

Collaboration between public health and livestock officers to control zoonoses started before the official use of the One Health concept. Collaboration between public health and livestock officers emphasized prevention and control of diseases such as rabies, anthrax, brucellosis, salmonellosis, trichinosis, encephalitis, leptospirosis, etc. The level of cooperation actually depends on the needs associated with a specific problem. Cooperation between public health and livestock officers includes the investigation of the diseases, conferences and exchange of information between departments. However, in the first period, the departments did not have the same understanding about disease prevention and control because and they had different roles, activities and duties. Moreover, there was no clear definition of the working scope area (Sommanustweechai et al., 2014).

Phase 2: Between 2004 and 2008, when the Strategic Plan to had to Prevent and Control Avian Influenza and to prepare for the influenza 1 outbreak issue 1 (2005 to 2007) and issue 2 (2008 to 2010).

In January 2004, an outbreak of bird flu in Thailand occurred. The impact of the Avian influenza epidemic has resulted in policy developments concerning people and organizations involved in the prevention and control of epidemics including:

1) Development of national policy and mechanisms for national order.

The Thai government paid attention to avian influenza which became a priority in the national agenda. The Prime Minister appointed the National Board of Directors which comprised the Deputy Prime Minister, the Ministry of Public Health and the Ministry of Agriculture. A coordinated system was developed with the cooperation of enterprises and the private sector. Moreover, a strategic plan for prevention and control of influenza outbreak issue was established (2005 to 2007).

2) Capacity development and personnel preparation for surveillance and investigation.

The Bureau of Epidemiology, the Public Health Ministry established the project "Field Epidemiology Training Program for Veterinarian: (FETP-V)" for training veterinarians in surveillance and investigation in epidemiology in 2005. In 2007, the Department of Livestock Development established a project "Field Epidemiology Training Program for Veterinarian: (FETP-V)" and signed a Memorandum of Understanding (MoU) between the Department of Livestock and the Bureau of Epidemiology for Development of Field Veterinarians which got support by Food and Agriculture Organization (FAO) of the United Nations. Moreover, this project expanded to an International Training Program for veterinarians in Asia in 2009.

3) From the Bureau of Influenza to the Bureau of Emerging Infectious Diseases.

The Bureau of Influenza developed into the Bureau of Emerging Infectious Diseases for prevention and control (Sommanustweechai et al., 2014).

Phase 3: Between 2009 and 2014, expansion of the concept of One Health in Thailand and establishment of the Thailand National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response 2013 - 2016.

In this phase, Thailand adopted the "One World One Health" concept after the International Ministerial Conference on Animal and Pandemic Influenza, in Hanoi in 2010. Moreover, the FAO, the Office International des Epizooties (OIE) and World Health Organization (WHO) published a concept paper about One Health for the member countries. Thailand convened a conference on the concept of One Health in 2009 called the "Zoonotic and One World One health in 2009", and established a 1st and 2nd forum in 2010 and 2012 for monitoring wildlife, exotic animals and migratory animals.

The outbreak of H1N1 Pandemic in 2009 Thailand further triggered resolutions regarding emerging diseases involving cooperation between organizations for the prevention and control of emerging diseases.

On 7 July 2011, the Ministry of Public Health, the Ministry of Agriculture and Cooperatives, the Ministry of Natural Resources and Environment, the Centers for Disease Control and Prevention of the United States (US-CDC), the United States Agency for International Development (USAID) were involved together in disease prevention and control. Educational institutions including Chulalongkorn University, Mahidol University, Thai One Health Network made a declaration of intent about one health including:

1) The awareness of the importance and necessity of the One Health approach and preparation for response against emerging infectious diseases.

2) Cooperation of organizations regarding the health of human, animals, wildlife and ecosystems among a One Health network aiming at promoting a healthy Thailand.

3) Collaboration of the network on the development of policy recommendations and long-term and short-term One Health plans.

4) Cooperation of the network with "One Health One World" network and provision of resources to work together in an effective and beneficial way.

Phase 4: 2015 - 2016

Thailand promulgated the new national Communicable Diseases Act in 2015. Within that frame, the Thai National Communicable Diseases Committee comprises members from: Minister of Health, Permanent Secretary for Foreign Affairs, Ministry of Transport, Secretary of the Interior, Permanent Secretary for Labor, Permanent Secretary for Education, Permanent Secretary for Public Health, Secretary General of the Council of State, Commander of the National Police, Director of the Department of Medical Services, Director of Public Relations Department, Director General of the Department of Livestock, Director General of the Department of Disaster Prevention and Mitigation, Director-General of the Department of Medical Sciences, Director-General of the Department of Local Administration, Director of the Department of Health, Director-General of the National Park, Wildlife and Plant Conservation Department.

The Thai national Communicable Diseases Committee is responsible for: 1) approving the action plans for surveillance, prevention and control of communicable diseases or epidemics, 2) submitting to the Cabinet for approval, monitoring, evaluation and monitoring of surveillance operations and disease prevention of state agencies and the Committee on Communicable Diseases.

The Thai National Communicable Diseases Act of 2015 has a clear role in setting board committee from various agencies for the prevention and control of diseases. In this way, it diverged from the new Thai National Communicable Diseases Act of 1980 which stated that disease control was the duty of the public health department (Law Center Department of Disease Control, 2015).

Phase 5: 2017 Until Now

The Thailand National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response (2017 - 2021) includes a One Health approach. The leader of the Department of Disease Control adopted the One Health concept in the second strategic framework for disease prevention and disease control. The objective of this plan consists of: 1) developing an integrated surveillance system to prevent, treat and control emerging infectious diseases in human health, animals, wildlife and the environment; 2) an Emerging Infectious Disease Surveillance System to detect emerging infectious diseases and to control the diffusion and spread of emerging infectious diseases at the early stages of the epidemic; 3) the involvement of laboratories for detecting the cause of emerging infectious diseases and 4) the certification of animal farms (poultry, pigs, cattle, sheep goats) as animal husbandry by the Department of Livestock; 5) the protection of wildlife sites and the control epidemics in this sites as defined by the Department of National Parks, and 6) effective control guidelines for humans, animals, wildlife (Bureau of Emerging Infectious Diseases Department of Disease Control, 2016).

The importance of outbreaks and of One Health implementation measures at the national and provincial levels is shown in Table 2.

Table 2. The importance outbreaks and related One Health measures in Thailand.

Before 2004	**2004 - 2007**	**2008-2010**	**2011-2012**	**2013-2015**	**2016 – recently**
Important outbreak in Thailand	Epidemic of avian influenza	Epidemic influenza (H1N1)	Hand-foot-and-mouth disease Big flooding in Thailand	High *Dengue hemorrhagic fever* epidemic DHF	Rabies Zika fewer
National level					
- Collaboration between public health and livestock officers with emphasis on cooperation in the prevention and control of diseases such as rabies, leptospirosis, etc.	- Ensuring the understanding of the One Health approach among officers in ministries - Establishing Field Epidemiology Training Program for Veterinarian: (FETP-V)” for training veterinarians in surveillance and investigation epidemiology in 2005.	- Developing a strategic plan for prevention and control of influenza pandemic (H1N1) (2008-2010).	- Declaration of the use of One Health approach in 2011. - Establishment of the Thailand National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response in 2012 (2013-2016) - Adopting the idea of One World One Health from abroad in 2012. - Support of the USAID for the establishment of the Thai One Health University Network	- MoU for the implementation of One Health signed between 4 ministries in 2013. - Developing One Health epidemiology teams in 14 provinces in 2015. - Announcing the Communicable Disease Act 2015.	- MoU for implementation one health between 7 ministries and 1 organized in 2016 - Developing One Health epidemiology teams in 19 provinces in 2016 - Encouraging the free rabies in human and animal by the wishes of Her Royal Highness Princess Chulabhorn (valayaluk)

Before 2004	2004 - 2007	2008-2010	2011-2012	2013-2015	2016 – recently
			Thai One Health University Network (THOHUN) - Establishment of an Epidemiological Development Project under the One Health concept in 5 provinces.		project 2017 – 2020.
Provincial level					
- Public health and livestock officers cooperate in the investigation disease such as rabies, leptospirosis, etc. - Public health department invites livestock department to attend the disease investigation in case of zoonosis outbreaks.	Same as 2004	Same as 2004	Same as 2004	- Mahasarakham get money support from the USA for One Health epidemiology teams. - Mahasarakham establishes a project by using the One Health concept in building the knowledge of human perception for rabies prevention in 2015. - Appointment of the Pivotal Action Plan for the	- Establishment of Mahasarakham Communicable Diseases (2016). - Planning the project of free rabies in human and animal by the wishes of Her Royal Highness Princess Chulabhorn (valayaluk) project 2017 – 2020.

Before 2004	2004 - 2007	2008-2010	2011-2012	2013-2015	2016 – recently
				Prevention and Elimination of Rabies (2015) by cooperation with 7 departments.	
Public health surveillance					
	Era of developing foundation of disease prevention. During 2004 to 2010, Mahasarakaham was following the guidelines of the Ministry of Public Health of Thailand which in establishing a rapid disease control, the "war room", and the "Special Response Team" to handle leptospirosis outbreak.		Era of participatory disease control. During 2011 to 2014, Mahasarakaham Province developed leptospirosis implementation policy by increasing the participation of the public health department, the livestock department, the agriculture department and the Tambon Administration Organization for the prevention and control of leptospirosis.		

Research objectives

Leptospirosis is an important zoonotic disease and is considered as the most widespread zoonosis in the world (World Health Organization, 2007). More than 70,000 cases of leptospirosis have been detected since its emergence in Thailand (Morand et al., 2018). In Mahasarakham Province, leptospirosis is considered as endemic, and as a significant public health issue. Although, for more than two decades, the Provincial Public Health Office, the Livestock Department, the Agriculture Department tried to control this disease by establishing actions such as employing people to exterminate rats in infected areas, providing health education for the people, establishing a surveillance system, a "war room", setting the Surveillance and Rapid Response Team or SRRT in every district (Bureau of Epidemiology Department of Disease Control, 2000) using the District Strengthening Disease Control. However, leptospirosis is still present and causing death.

The objective of this study is to understand the cause of leptospirosis epidemics and leptospirosis prevention and control policy implementation of Mahasarakham Province, Thailand to improve the prevention and control of this disease. I intend to address the following issues in the following sections:

1. To describe the health policy of surveillance and control of leptospirosis in Thailand and Mahasarakham province which has been chosen as a pilot province to develop and improve leptospirosis prevention policy.

It is necesssary to understand how Mahasarakham Province in Thailand improved previous national policies for leptospirosis prevention and control strategies by using a One Health perspective for detection and response to leptospirosis outbreaks. The research questions here comprise: What are the strategies in leptospirosis prevention and control of Mahasarakham, Thailand from 2004 to 2014? How did Mahasarakham improved previous national policies by using a One Health perspective responding to and preventing leptospirosis outbreaks? What are the problems in leptospirosis prevention and control in Mahasarakham province from 2004 – 2014?

I used a qualitative analysis by studying documentation reviews, individual in-depth interviews and structured interviews of public health officers, local government officers, livestock officers who developed policy implementation tools or had responsibility in leptospirosis prevention and control.

2. To investigate the role of seasonality, environment, agriculture, and the effect of the surveillance system on the epidemiological pattern.

In this part, the objective is to understand how environmental and societal driving factors are influencing occurrence of human leptospirosis in Mahasarakham Province on fine spatial and temporal scales. I analyzed data by GIS methods and statistics to answer research questions such as: How leptospirosis incidence are spatially distributed between 2004 and 2014? What are the temporal distributions of leptospirosis incidence between 2004 and 2014? What are the significant spatial clusters, temporal clusters, and spatiotemporal clusters of leptospirosis incidence? How agro-environmental factors explain the incidence at the level of sub-districts?

We used secondary data from 4 departments including: the public health department, the natural resources and environment department, the livestock department of Mahasarakham Province and the NASA to establish 15 variables and analyzed the causes of leptospirosis epidemics in Mahasarakham Province, Thailand.

3. To describe knowledge, attitude and practice (KAP) of people, public health volunteers, community leaders regarding the leptospirosis epidemiology and control.

I studied here the knowledge, attitude and practice of people, public health volunteers, community leaders regarding the leptospirosis epidemiology and control. The research questions addressed here are: What are the lacks of knowledge, and the problems of attitude and practice of patients, people, public health volunteers, community leaders in leptospirosis prevention and control? Are there differences in knowledge, attitude and practice between patients, people, public health volunteers, community leaders in leptospirosis prevention and control?

I used a cross-sectional study to study KAP. Data were collected thanks to structured interviews from patients, neighbors of patients, village health volunteers and community leaders. KAP were analyzed and compared to understand the KAP problem of each group.

4. To develop guidelines to improve cooperation among departments for leptospirosis prevention and control.

I took results of three issues above, to establish guidelines for the development of cooperation between departments for prevention and control leptospirosis of Mahasarakham Province, Thailand.

The appropriateness, comprehensiveness and consistency of these guidelines with the specific working context of the province have been checked by Mahasarakham Provincial Public Health Officers, network agent of Thailand One Health University Network and lecturers from the public health faculty, Mahasarakham University, Thailand.

Chapter 2

Evolution of public health prevention of leptospirosis in Mahasarakham Province (Thailand) in a One Health Perspective

Parts of this chapter were submitted in Asia Pacific Journal of Public Health under the title "Evolution of Public Health Prevention of Leptospirosis in Mahasarakham Province (Thailand) in a One Health Perspective" (see annex).

Summary

For more than two decades, the Ministry of Public Health and Mahasarakham Provincial Public Health Office established and developed policy implementation of leptospirosis prevention and control, but leptospirosis still shows a high incidence and is an endemic disease in the province. Collaboration between departments using the One Health approach may improve the effectiveness of prevention and control of the outbreak.

Qualitative design was used to study how Mahasarakham Province, Thailand transfer from the national level to the other administrative levels, its policy implementation mission regarding leptospirosis prevention and control, through a One Health perspective. We collected data from two sources: first, we collected data from reviewed primary documents obtained from the public health department: provincial reports, meeting reports, command documents, handbooks; and twenty secondary documents: journal articles, presentation handouts and internet information. Second, we collected data among officers from different administrative departments at various decision-making levels by using in-depth interviews from 26 persons (public health officers, local government officers, livestock officers) who developed policy implementation tools or have responsibility in leptospirosis prevention and control. We participated in three meetings relating to disease prevention and control in Mahasarakham Province and in one fieldwork in leptospirosis investigation.

The results show that Thailand has progressively developed leptospirosis prevention and control policy framework at the national level and transferred the responsibility of its implementation to the local level. Leptospirosis prevention and control have been the main priority under the responsibility of public health officers. Between 2011 and 2014 prevention and control of leptospirosis in Thailand was developed through policy and guidelines for cooperation between departments following "The District Strengthening Disease Control". At the level of the province, public health department and livestock department are cooperating for the prevention and control of the epidemic even before the promotion of the One Health concept. However, after Thailand supported and adopted the One Health approach, the various departments had a better understanding of the importance of cooperation for epidemic

prevention and control. Moreover, prevention and control disease are carried out by following the new national Communicable Diseases Act, 2015. The Communicable Diseases committee of the province gathers for allowing the various agencies in charge of awareness problems, solving issues and shared resources for prevention and control disease. However, there are weaknesses in leptospirosis prevention and control policy implementation in each level including: 1) at the national level, there are no plan and indicator between departments for prevention and control of leptospirosis, 2) at the provincial level, the Communicable Diseases Committee is not concerned by leptospirosis issues and the cooperation between departments is only occasional, 3) at the subdistrict level, there was no standard or clear role for cooperation between departments and leptospirosis prevention mainly concerns patients and is not continuously directed to the whole population.

There are gaps in linkages between departments to ensure comprehensive disease prevention activities. Acceptance of the One Health approach for leptospirosis prevention and control will improve impacts of prevention and control of leptospirosis. Mahasarakham Province needs to develop clearer concrete cooperation between departments and further study to establish realistic leptospirosis guidelines at the local level is a priority.

Introduction

Leptospirosis is an important zoonotic disease and is considered as the most widespread zoonosis in the world (World Health Organization, 2007). Leptospirosis is a zoonotic bacterial disease caused by spirochete species of the genus *Leptospira* (Bharti et al., 2003; Levett, 2001) which includes nine pathogenic species and at least five intermediate pathogenic ones (Adler, 2015). Leptospirosis patients can develop a more severe disease characterized by hepatic, renal or pulmonary dysfunction, or hemorrhagic manifestations which can be a cause of mortality (Guerra, 2013; World Health Organization, 2003).

High incidence of human leptospirosis occurs in tropical environments where conditions may favor the development of *Leptospira* in the environment (Pappas et al., 2008; Victoriano et al., 2009). The socio-economic factors (e.g. poverty), the influences of environmental factors, including climatic factors, flooding events related with leptospirosis incidence and animal reservoirs contributed to the disease incidence and infection risk (Morand et al., 2018).

Thailand is located in the tropical zone with important soil moisture in some parts, a tropical climate with high rainfall, which favors *Leptospira* spreading. *Leptospira* has been isolated for the first time from a human patient in 1942, during a big flood event that hit Bangkok (Keatikun et al., 1974). Leptospirosis has caused over than 70,000 cases since its emergence in Thailand. Leptospirosis incidence in the country shows a strong seasonality with a high incidence during the rainy season (Hinjoy, 2014). Outbreaks of leptospirosis are often reported after flooding events (Amilasan et al., 2012; Dechet et al., 2012).

Mahasarakham Province is located in the Isan part (North East) of Thailand with a high leptospirosis incidence (Morand et al., 2018). For more than two decades, the Ministry of Public Health and Mahasarakham Provincial Public Health Office established and developed policy implementation of leptospirosis prevention and control, but leptospirosis still shows a high incidence and is an endemic disease in the province.

The World Health Organization (WHO) has highlighted the importance of the One Health approach to design and implement programs, policies, legislation for the prevention and control of zoonosis (The World Health Organization, 2017). Collaboration between veterinarians dealing with livestock and wild animal populations and ecologists examining ecosystem biodiversity and public health experts can get more effective in prevention and control of the outbreak (Bidaisee and Macpherson, 2014).

Thailand integrated the One Health approach into the Thailand National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response (Bureau of Emerging Infectious Disease Department of Disease Control, 2016). Thailand has played an important role in promoting and encouraging the use of the One Health approach in ASEAN notably under South East Asia One Health University Network (SEAOHUN) to facilitate collaborative activities and projects among network members, with an emphasis on trans-disciplinary and trans-boundary partnerships (South East Asia One Health University Network, 2018) and driving the development of the One Health approach at the regional level.

Leptospirosis in Mahasarakham Province is an important health problem and there is a need to develop policy of leptospirosis prevention and control. Therefore, understand how Mahasarakham, Thailand transcended previous national policies for leptospirosis prevention and control strategies by using One Health perspective, can improve the effectively of detecting, responding, and preventing leptospirosis outbreaks.

Methods

1. Study design

Qualitative study was conducted, using documentation reviews, individual in-depth interviews, structured interviews, participant observations to understand the different phases of the implementation of leptospirosis prevention and control policy in a One Health perspective.

2. Study population

The study population included the leader of the department of disease control, the officer of the coordination unit for One Health, public health officers in Mahasarakham Province, livestock officers in Mahasarakham Province, local government officers, to identify the factors that have enabled or constrained the planning and implementation of policies regarding leptospirosis prevention and control. Initial findings were integrated back into the investigation, and were used to guide further exploration and analysis of key issues as they emerged. The study population is shown in Table 1.

Table 1. Presentation of study samples.

Groups of population	**Number of people interviewed**	**Data collection**	**Sampling**
Leader of the department of disease control	1	In depth interview	-
Officer of coordination unit for One Health	1	In depth interviews	-
Provincial Public health officers	3	In depth interviews	purposively selected
District Public health officers in Mahasarakham Province	3	In depth interviews	purposively selected
Subdistrict Public health officers in Mahasarakham Province	13	Interviews	Purposive sampling in subdistricts with the highest leptospirosis incidence within a district
Local government officers	3	In depth interviews	purposively selected
Livestock officers in Mahasarakham	2	In depth interviews	purposively selected
Total	26		

3. Data collection

Data collection consists of 2 steps:

First, we reviewed primary documents obtained from the public health department of Mahasarakham Province (province reports, meeting reports, command documents, handbooks) and twenty secondary documents (journal articles, presentation handouts and internet information). We selected all the documents using 2 criteria:

1) documents related to leptospirosis prevention and control in Mahasarakham, Thailand and ASEAN;

2) document relating to One Health in Mahasarakham Province, in Thailand (national level) and ASEAN (regional level).

Secondly, we collected data among officers from different administrative departments at various decision-making levels using individual in-depth interviews, and participant observations (during meetings and disease investigations).

<u>Interviews</u>

Structured interviews of 13 subdistrict public health officers in Mahasarakham Province, within the subdistricts where the prevalence was the highest. The interviews focused mainly on their practice regarding their mission of prevention and control of leptospirosis and the problems and barriers they meet.

<u>In-depth Interviews</u>

Thirteen in-depth interviews of the leader of the department of disease control, the Officer of the coordination unit for One Health, provincial public health officers, district public health officers in Mahasarakham Province, Local government officers and livestock officers in Mahasarakham Province were realized. Informants were purposively selected to provide insights for the identification of the factors that have enabled or constrained the leptospirosis policy implementation. In-depth interviews were conducted using flexible topic guides with open-ended questions that allowed them to express their views on leptospirosis policy implementation. Topic guides included questions about the way to implement leptospirosis prevention and control policy integrating the One Health approach.

<u>Participant Observation</u>

Participant observations were collected during three meetings relating to disease prevention and control in Mahasarakham Province and one fieldwork in leptospirosis investigation in 2017.

Observations were recorded in the form of field notes to provide a descriptive account of the highlights of the program's implementation. Analytical comments were added progressively as insights were gained throughout the dynamic of the discussions and the investigations. The field notes were dated, then transcribed in their entirety.

Ethical statement

Approval notices for interviews and for the use of human incidence recordings were given by the Ethics Committee of Public Health of Mahasarakham Province, Thailand (No. 5/2558 on 20 April 2015).

Results

1. Leptospirosis Outbreak Trends in Mahasarakham, Thailand.

Leptospirosis is an endemic disease in Mahasarakham Province. The first leptospirosis cases were reported in Mahasarakham Province (Northeastern Thailand) in 1996, and concerned 12 patients. In 1997, the number of diagnosed cases increased up to 300 (Mahasarakham Provincial Public Health Office, 2000). After 1997, leptospirosis cases were reported every year.

During the period between 2004 and 2014, 752 leptospirosis cases were reported with an average annual incidence rate of 7.97 cases per 100,000 persons in Mahasarakham Province. The largest leptospirosis outbreaks between 2009 and 2012 concerned 90 and 177 patients, respectively. The outbreak trend increased in 2004 – 2009 but slightly decreased in 2010 as shown in Figure 1. During 2010 to 2012, the number of leptospirosis patients reported increased dramatically. Leptospirosis incidence measured in 127 subdistricts for a total of 133 subdistricts in the province is shown in Figure 2.

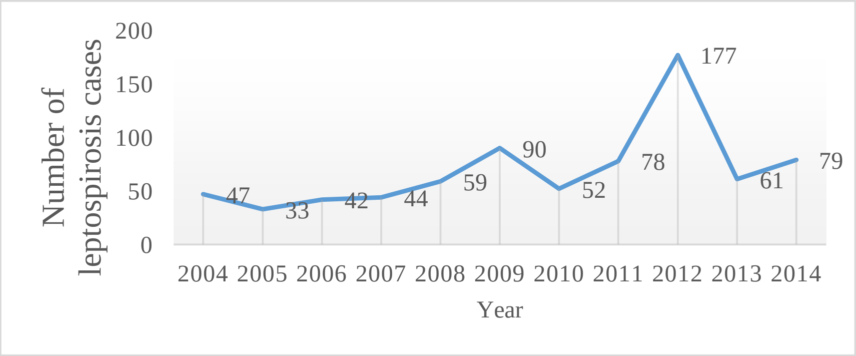

Figure 1. Annual incidence rate of leptospirosis in Mahasarakham Province, Thailand, 2004 - 2014.

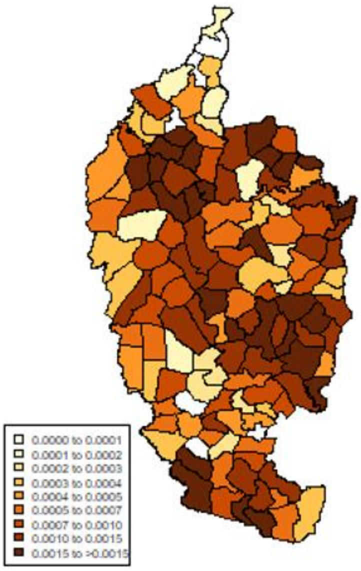

Figure 2. Incidence rate (number of cases relative to population) of leptospirosis in subdistricts of Mahasarakham Province, Thailand during 2004 – 2014

2. Evolution of Leptospirosis Prevention and Control Policy Implementation in Mahasarakham

2.1 Leptospirosis prevention and control policy implementation before 2000

The first leptospirosis patient was found in 1996 at a time when public health staff did not have enough knowledge about leptospirosis. Thus, the Ministry of Public Health decided to transfer knowledge to the regional Health Office. The Regional health Office passed on the knowledge to Mahasarakham Provincial Public Health Office which established a leptospirosis prevention and control policy emphasizing health education and cases report. Public health officers educated people in avoiding contact with water resources, consuming cooked and hot food, consuming boiled water and using sanitary toilet (Mahasarakham Provincial Public Health Office, 2000). Public health officers were the only persons in charge of leptospirosis prevention and control.

2.2 Leptospirosis prevention and control policy implementation 2000 to 2003

In 2000, Mahasarakham province was chosen by the Ministry of Public Health to be a pilot province for solving the outbreak of leptospirosis and thus for implementing a leptospirosis prevention policy. They got budget support from the Miyasawa project for conducting prevention and control leptospirosis activities. Mahasarakham Provincial Public Health Office set an academic conference to share knowledge about prevention, control, and treatment of leptospirosis among public health officers. Moreover, they set a big campaign for the prevention and control of leptospirosis in direction of the population. There were activities about health education, exhibitions about leptospirosis disease, contests to find new ways to catch and cook rats. These activities resulted in 34 innovative ways to catch rats and 79 menus for cooking rats as shown in Figure 3. In addition, Mahasarakham Provincial Public Health Office planned and forwarded a strategy to subdistrict public health officers for giving health education to people and promote campaigns to kill rats. The government allocated a budget for buying the rat tails from people (Mahasarakham Provincial Public Health Office, 2000).

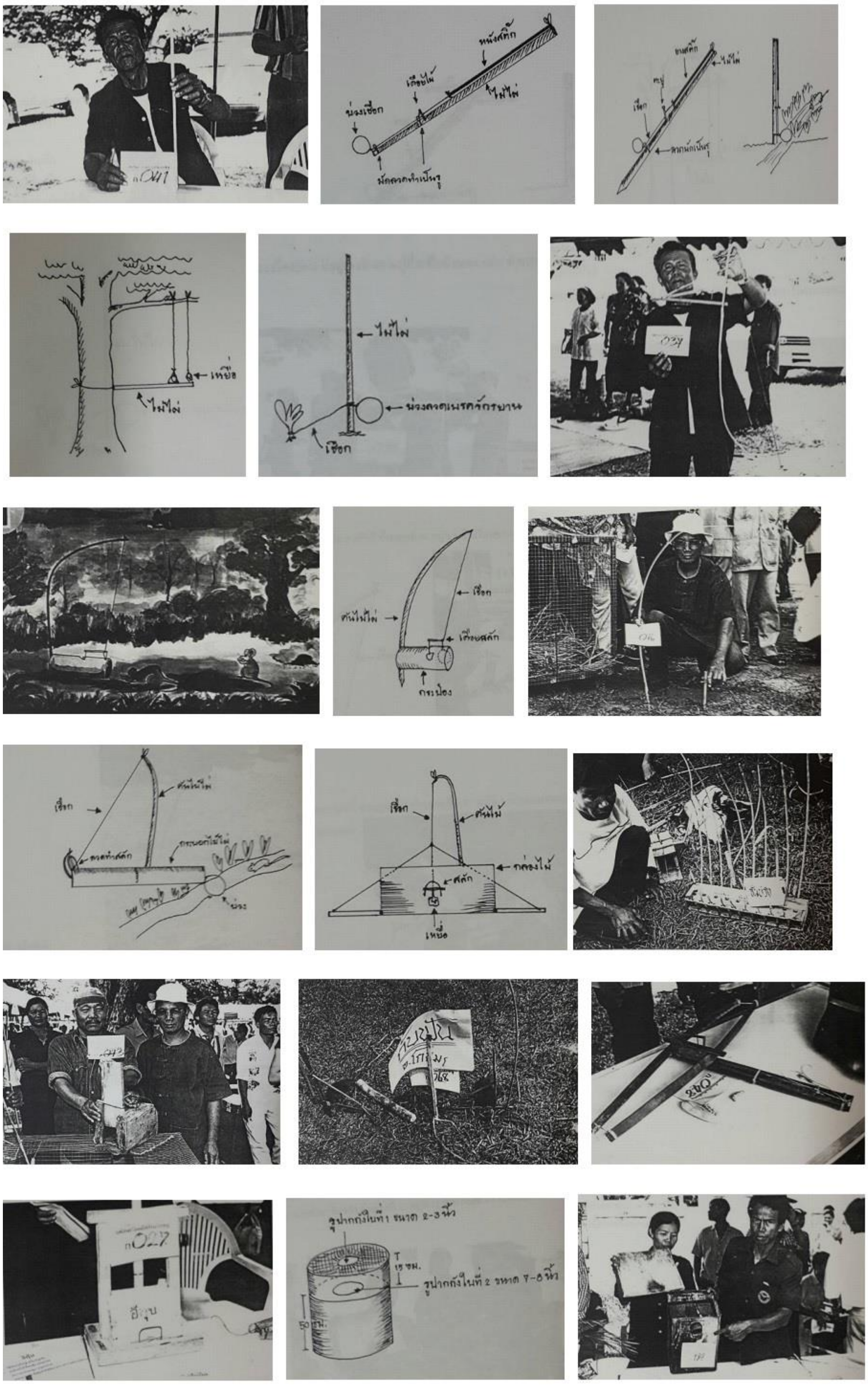

Figure 3. Rat traps, with the authorization of Mahasarakham Provincial Public Health Office (Mahasarakham Provincial Public Health Office, 2000).

From 2000 to 2003, the Ministry of Public Health supported various media such as handbooks, brochures, etc. for leptospirosis prevention and control in Mahasarakham

Province. Mahasarakham Provincial Public Health Office organized many activities to educate people, local government organizations, public health volunteers and students in schools. Moreover, there were disseminating to hospitals and public health centers leptospirosis handbooks about biology of leptospires, clinical features of leptospirosis, diagnostic methods, leptospirosis monitoring and investigation and method of rat eradication (Bureau of General Communicable Department of Disease Control, 2000). During this phase, the Ministry of Public Health and the Ministry of Education cooperated for the promotion of leptospirosis prevention and control. Teachers in the schools had responsibility in teaching students about leptospirosis prevention and control and public health officers had responsibility in supporting knowledge and evaluation. The evaluation was followed by the development of a "Strategy of supervision and school development for leptospirosis prevention and control handbook" (Department of Disease Control and Office of the Basic Education Commission, 2003). Moreover, a "war room" or "ad hoc operations center" was established to handle leptospirosis. The "Special Response Team" comprised of disease prevention officers, environmental officers and disease prevention agents of subdistrict were in charge to identify leptospirosis cases, source of transmission and risk factors, and environmental improvement (Bureau of General Communicable Department of Disease Control, 2000).

2.3 Leptospirosis prevention and control policy implementation from 2004 to 2010 (era of developing foundation of disease prevention)

After 2003, prevention and control leptospirosis became a routine job for public health officers. The Division of Epidemiology of the Ministry of Public Health has been reformed, upgraded as the Bureau of Epidemiology and transferred to the Department of Disease Control. At the provincial level, even though the Epidemiology Unit and the Disease Control Unit were put under the same section, the Technical Support Group, some epidemiology activities remained under the Planning and Strategy Section. This structural change placed the emphasis on surveillance for action, not only for making a budgetary request, which should be the right direction. However, the number of full-time disease surveillance personnel was too small, on average only one or two officials per province and there were no established positions in regional/ general or community hospitals (Wibulpolprasert et al., 2007). The Bureau of Epidemiology established policy for prevention and control diseases by using the Surveillance and Rapid Response Team or SRRT. SRRT was established in every district. In order for the SRRT operations to be efficient, the Ministry of Public Health has made efforts to develop four major elements as follows: 1) development of policies and strategies; 2) development of surveillance system; 3) personnel development and 4) promote personnel and information networks in-country and abroad.

Mahasarakham Province adopted prevention and control disease policy by using the SRRT and developed SRRT in every district. Prevention and control leptospirosis followed the implementation of the Ministry of Public Health called 4E2C as shown in Table 2.

Table 2. 4E2C.

Implementation	**Activities**	**Responsible person**
Early detection	Share outbreak information with healthcare providers	Patients Public health volunteers
Early diagnosis	Make a preliminary diagnosis from the patient's history and symptoms such as acute fever, headache, muscle pain following the leptospirosis diagnosis guidelines.	Healthcare providers
Early treatment	Give treatment to patients, following the leptospirosis diagnosis guideline.	Healthcare providers
Early control	Prevention and control of leptospirosis one week after receiving the leptospirosis report.	Surveillance and Rapid Response Team
Coordination	Investigate causes of leptospirosis cases and prepares advice for the people in the community. For example, advice about feeding animals, monitoring animal diseases and reporting leptospirosis cases.	Public health officers Livestock department

Implementation	Activities	Responsible person
Community involvement	Community participate in the prevention and control of leptospirosis. For example, warning about leptospirosis, establishing the leptospirosis prevention in the community, etc.	Community

SRRT comprise approximately five persons including field epidemiologists and public health officers. The responsibilities of SRRT are:

(1) Perform surveillance on outbreaks or unusual events that might put public health at risk.

(2) Conduct preliminary field investigation to verify the fact, and determine the cause and magnitude of the event in a rapid manner.

(3) Implement necessary containment response in an immediate fashion (Kumnuan Ungchusak et al., 2011).

For example, SRRT managed information about history and screening of exposure of patients, confirm clinical findings, collected water or soil for finding *Leptospira*, survey villages and identify exposure, finding leptospirosis cases and ensure surveillance of all household members, doing warning panel and educated villagers to avoid risk when leptospirosis cases were found.

Figure 4. Collecting water to find *Leptospira* from Mahasarakham Provincial Public Health Office.

Figure 5. Warning panels about area contamination by leptospirosis made by Mahasarakham Provincial Public Health Office.

Figure 6. Educating villagers for leptospirosis prevention by Mahasarakham Provincial Public Health Office.

2.4 Evolution of leptospirosis prevention and control policy implementation during 2011 to 2014 (era of participation of disease control)

In 2011, the Department of Disease Control of the Ministry of Public Health established the prevention disease standard “The District Strengthening Disease Control”. The Department of Disease Control designated districts as target areas for developing disease surveillance and preparing response when there is an outbreak in the district. Their role is to develop systems and mechanisms for the surveillance, prevention, and disease control. Moreover, it must ensure strong cooperation of Government departments, private organizations, and people in the community for the prevention and control of the disease. They use Sufficiency Economy philosophy model of His Majesty the King for creating unity and good governance in the health system, giving importance to the participation of all sectors of the society, creating health security and service delivery systems in a thorough and equitable manner and valuing the creation of good provider recipient relationships (Ministry of Public Health, 2012). The Ministry of Public Health monitors the District Strengthening Disease Control indicators.

Moreover, the Ministry of Public Health introduced the One Health concept as a fundamental principle in Thailand's National Strategic Plan for Emerging Infectious Diseases (2013 – 2016). This plan helped foster national capacity and broadened collaboration through the routine meetings of key stakeholders to discuss disease dynamics, share knowledge, conduct research, and train staff jointly (Sommanustweechai et al., 2016).

Leptospirosis prevention and control systems of Mahasarakham Province were implemented following the District Strengthening Disease Control which was the standard in prevention disease in the district. The District Strengthening Disease Control has been used from 2011 until present (2018). Leptospirosis prevention and control consist of 2 strategies via establishing the leptospirosis network participation and Surveillance and Rapid Response. Leptospirosis network participation is activated for leptospirosis prevention while Surveillance and Rapid Response team intervene when a leptospirosis case has been found. The establishment of a leptospirosis network participation encompasses 5 procedures shown in Figure 7.

Procedures for establishing leptospirosis network	**Responsible person**
- Appointment of the leptospirosis prevention and control committee of district. This committee consists of at least 4 departments including, public health, livestock department, agriculture and the Tambon Administration Organization. - Committee analyzes leptospirosis situation and defines at least two subdistricts that have leptospirosis problems.	Public health officer of district
↓	
Coordinate a community forum to establish prevention and control leptospirosis plan by following 4E2C.	The leptospirosis prevention and control committee
↓	
Organize activities to prevent disease control plan.	The Tambon Administration Organization
↓	
Follow up the leptospirosis activities.	- The prevention and control leptospirosis committee - Tambon Administration Organization
↓	
Sum up the results of the leptospirosis activity, analysis of the problem and any obstacles, and advice to develop the leptospirosis plan.	The Tambon Administration Organization

Figure 7. Procedures for establishing leptospirosis network.

Leptospirosis prevention and control system following 4E2C procedure established by the Ministry of public health (Bureau of Emerging Infectious Diseases Department of Disease Control, 2016).

At present, disease prevention and control measures are carried out by following the new national Communicable Diseases Act, 2015. The law does not detail the measure to be taken but one of the missions of government agencies in the province is to jointly plan the control and prevention of the disease. The Communicable Diseases committee of the province is meeting every 4 months for the planning and follow-up of their activities. The committee gathers for allowing the various agencies in charge of awareness problems, solving issues and shared resources for disease prevention and control. After the meeting, the relevant agencies will proceed to their operation plan for prevention and control disease.

3. Leptospirosis Prevention and Control in Mahasarakham Province, One Health Perspective

The One Health concept was applied for the first time to address practical health problems in Thailand in 2012. The One Health concept has been adopted as a key component of national health policy, in particular in the National Strategic Plan for Emerging Infectious Diseases (2013 - 2016) adopted in 2012 (Sommanustweechai et al., 2014) and in the National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response (2017 - 2021).

Moreover, in 2013, 4 ministries (the Ministry of Public Health, the Ministry of Agriculture and Cooperatives, the Ministry of Natural Resources and Environment and the Ministry of Education) signed the Memorandum of Understanding (MoU) on the implementation of the One Health Initiative for National Health Security. In addition, in 2016, the cooperation between Thai's ministries has been developed further with the signature of the Memorandum of Understanding on the Implementation of One Health Initiative for National Health Security jointly by 7 ministries and 1 organization: the Ministry of Agriculture and Cooperatives, the Ministry of Natural Resources and Environment, the Ministry of Interior, the Ministry of Social Development and Human Security, the Ministry of Labor, the Ministry of Public Health, and the Thai Red Cross Society. The purpose of those MoU is to address the threats coming from emerging infectious diseases (EIDs) and zoonotic diseases, which are closely intertwined and could potentially have significant socio-economic and environmental impacts. The parties to this One Health Collaboration Network are committed to collaborating actively on the areas of program coordination and management, technical cooperation, and resource mobilization and allocation so as to adopt an integrated approach towards implementing One Health work plans or One Health-related activities and encouraging the development of One Health work plans (Thailand, 2016).

Thailand has played an important role in publishing One Health in ASEAN under the South East Asia One Health University Network (SEAOHUN). SEAOHUN is organized to encourage and facilitate collaborative activities and projects among network members, with an emphasis on trans-disciplinary and trans-boundary partnerships. Programming includes, supporting student and staff exchange, curriculum development, strengthening and developing teaching methodologies, research capacity building and innovative projects that provide an evidence-based One Health advocacy with the government and other collaborating partner agencies. SEAOHUN was supported by the United States Agency for International Development's (USAID) One Health Workforce project. Governed by SEAOHUN by-laws and the laws of the Government of Thailand. In the present SEAOHUN is a consortium of 10 founding universities and 14 founding faculties in Indonesia, Malaysia, Thailand and Viet Nam that are collaborating to build One Health capacity and academic partnerships with governments, national and regional stakeholders in the Southeast Asian region (South East Asia One Health University Network, 2018).

In Thailand, the Thai One Health University Network has been established: THOHUN, which combines Mahidol University, Chumphon University, Khon Kaen University and Songkhla University, get support from The United States Agency for International Development (USAID).

In 2015, the Ministry of Public Health encouraged province prevention and control disease by using the One Health concept. They encouraged provinces by providing funding through research projects. This funding is an external funding from the United States of America. Provinces which join these projects designed healthcare solutions using the concept of One Health. Nowadays, the use of the One Health concept for the prevention and control of diseases depends on the willingness of the practitioners and on the specific health problems in each province. If a province detects emerging diseases, it must ensure prevention and control, following the plan of National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response. However, other infectious disease prevention and control measures decided at the district level should follow "The District Strengthening Disease Control".

Currently, although, there is a Communicable Diseases Committee of the province, it is not interested in the specific leptospirosis issue at the level of the province. There is no plan or action to foster cooperation between departments of the province for the prevention and control of leptospirosis. At the provincial level, leptospirosis is a priority only for the public health department but not for other departments such as livestock department or agriculture department.

Leptospirosis prevention and control in districts of Mahasarakham Province is the main priority and is under the responsibility of public health officers. There are guidelines for cooperation between departments following "The District Strengthening Disease Control" adopted before Thailand decided to the use of the One Health concept to prevent and control diseases. However, departments in districts cooperate together to develop plans to prevent and control leptospirosis. "The District Strengthening Disease Control" does not allow a complete approach of activities necessary to prevent and control leptospirosis. Therefore, there is a lack of linkages to ensure comprehensive disease prevention activities and other departments such as livestock department, agriculture and the Tambon Administration Organization do not have their own indicators in leptospirosis prevention and control.

4. The Mechanism in Public Health Implementation in Thailand

With the movement of decentralization in Thailand, the government decided that of each provincial governor would be chief executive officer (CEO) administering all activities within his/her jurisdiction in an integrated manner. The Ministry of Public Health establishes the main health policy and supports academic health knowledge to the public health officers in the province. The health activities in districts vary according to the district health plan. They analyze the main health policy and health problems in the district to devise a district health plan. The public health officers in the Tambon Health Promotion Hospital have an important role in encouraging health activities in the Tambon, which are assessed and controlled by the District Health Officer, the Provincial Public Health Office and the Regional Health Office. In addition, the department of public health cooperates with the Ministry of Interior in order to evaluate indicators and set a budget. The relations between public health departments in Thailand are shown in Figure 8.

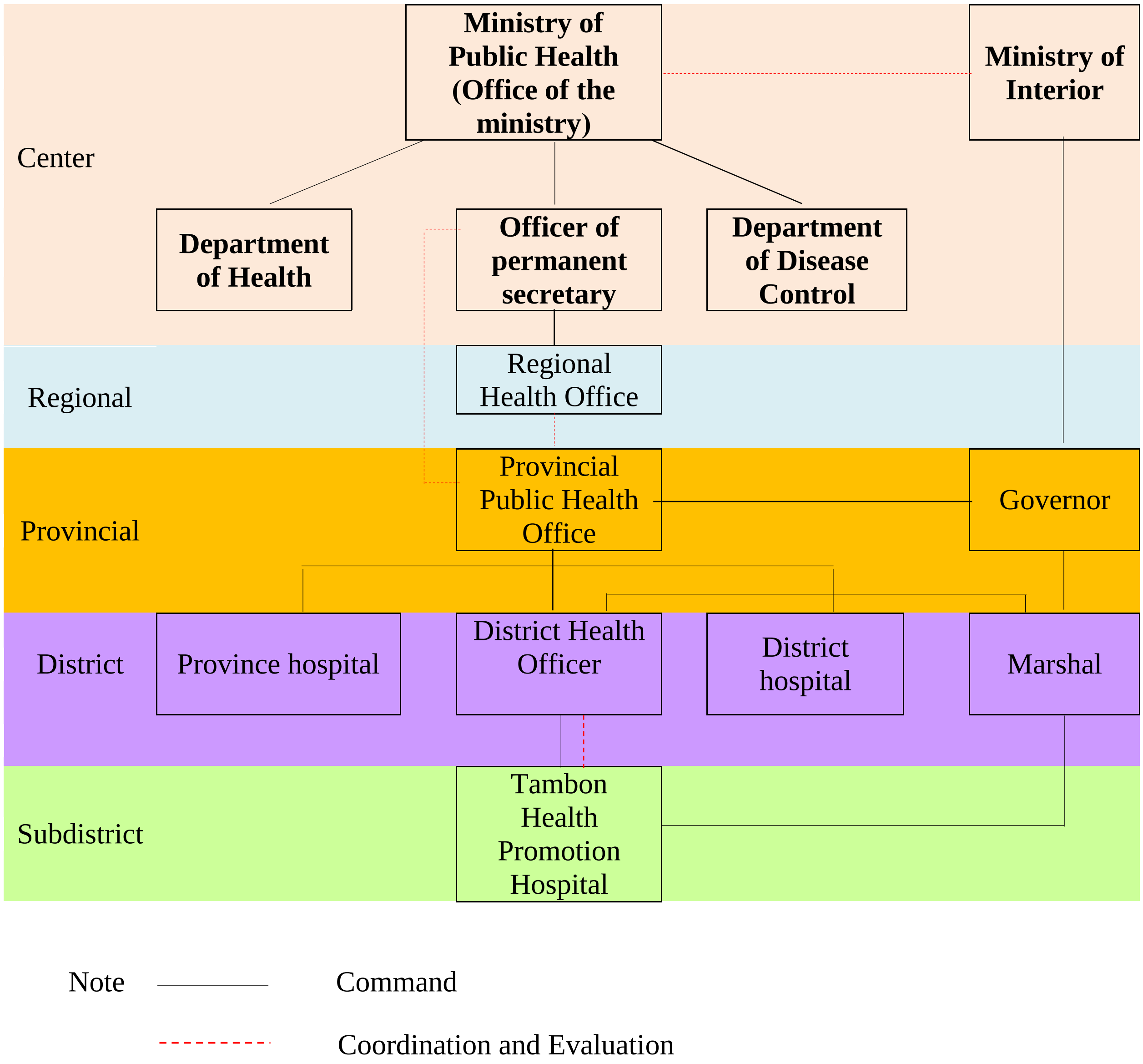

Figure 8. The relations between public health departments in Thailand at different administrative levels.

Discussion

Developing Leptospirosis Reporting

Leptospirosis is an important zoonotic disease of Mahasarakham Province and considered as the most widespread zoonosis in the world (World Health Organization, 2007). During 2004 – 2014 found the average annual incidence rate in Mahasarakham Province was 7.97 cases per 100,000 persons which is higher than the average annual incidence rate in Thailand, 6.6 per 100,000 persons (Hinjoy, 2014). Although the annual incidence rate in Mahasarakham Province was lower than the annual incidence rate worldwide with 14.77 cases per 100,000 persons (Costa et al., 2015), prevention and control of leptospirosis is an important responsibility of outbreak countries government to reduce the disease risk, the economic loss and the spread of the disease to their countries (Della Rossa et al., 2016; Kaufman et al., 2011). The highest number of leptospirosis cases was reported in Mahasarakham in 2012, a year after the Ministry of public health decided to improve leptospirosis prevention and control by giving responsibility to the districts for developing disease surveillance and preparing response within their territory. The development of public health campaigns in Thailand has decreased the overall leptospirosis incidence (Sakundarno et al., 2013) but at the same time the improvement of disease reporting will lead to an increase in reported cases over the long term. Similarly, a better reporting of non-communicable diseases in Thailand led to an increase in declared cases (Mohan and Chadee, 2011). Consequently, increase of leptospirosis cases reported could partly result from improvements in the quality of data collection and reporting on death rates and causes.

Evolution of Leptospirosis Prevention Policy Implementation

Thailand has progressively developed leptospirosis prevention and control policy framework at the national level and transferred the responsibility of its implementation to the local level. Leptospirosis prevention and control have been the main priority under the responsibility of public health officers.

Before 2000, the policy implementation in this phase was not clearly framed at the local level because the officer lacked understanding of the disease and did not have means to spread knowledge among people. The knowledge was also provided to small groups which could not cover the whole population.

Between 2000 and 2003, the Ministry of Public Health has chosen Mahasarakham Province as a pilot province to develop and improve leptospirosis prevention policy implementation. Thus, Mahasarakham Provincial Public Health Office supported public health officers in their responsibility to control the disease and gave them a clearer role in the prevention of the disease. A specific budget has been dedicated to prevention and control of the disease. Those measures improved the awareness of public health officers regarding their role in policy implementation. They had enough budget to provide health education. The Department of Public Health was the main organization to run prevention and control activities. It developed cooperation with the Department of Education for the education of students in the schools.

Between 2004 and 2010, leptospirosis prevention and control have been enhanced at the district level. The cooperation of between public health officers in the district is now clearly established and public health officers must share knowledge and resources between subdistricts within the district. However, leptospirosis prevention and control remained the main responsibility of public health officers. Although, a movement of decentralization in the Health Sector allocated a proportion of the central budget to the local government organizations (LGO). These LGOs play an important role to develop social services in several forms (roads, water supply, waste management…), in line with local administration laws. Nevertheless, there was no specific obligation to work on health issues and health and administrators of LGO were not interested in this sector. Moreover, public health department worked jointly with livestock department only in the case of an outbreak to investigate the disease.

Between 2011 and 2014, the leptospirosis prevention disease activities were designed by public health officers at the district level. The Committee of Communicable Diseases of the province created at that time became an important mechanism that makes all sectors aware of health issues and its role is to develop a comprehensive plan involving the different sectors. Moreover, it can help reduce redundancy in the operations driven by each unit. Local government is in charge to allocate the budget for disease prevention in subdistricts. Therefore, prevention and control disease activities are more comprehensive and can reduce the problem of budget sharing. At the level of the province, public health department and livestock department are cooperating for the prevention and control of the epidemic even before the promotion of the One Health concept. However, the cooperation stays informal at that time: for a specific mission in case of disease outbreaks, for example. Some prevention and control activities are under the sole responsibility of public health officers and thus there is a clear lack of linkages necessary for comprehensive disease prevention activities. However, after Thailand supported and adopted the One Health approach, the various departments had a better understanding of the importance of cooperation for epidemic prevention and control.

Lessons learnt for Leptospirosis Prevention Policy Implementation

Prevention and control of leptospirosis need to be supported by complex scientific knowledge and are constituting policy challenges. Social, cultural, and political norms and values are essential to address a successful control of leptospirosis (Rodríguez-

Vidigal et al., 2014). There are complex leptospirosis risk factors such as socio-economics (Mohan and Chadee, 2011; Topic et al., 2010), environment (Benacer et al., 2016; Sethi et al., 2010; Shah, 2012), livestock (Binot and Morand, 2015; Sugunan et al., 2009; Zinsstag and Tanner, 2015) and community involvement. Reducing leptospirosis transmission implies to focus on leptospirosis prevention or control programs to cut the chain of infection by avoiding direct contact or minimizing the risks of indirect contact with sources of infection (Rodríguez-Vidigal et al., 2014). Prevention and control of leptospirosis in Thailand were developed through policy and guidelines for cooperation between departments following "The District "Strengthening Disease Control". Departments in districts cooperate to develop plans to prevent and control leptospirosis but the range of common activities is not sufficient to be effective. However, there are some gaps at the local level in linkages between departments to ensure comprehensive disease prevention activities. For instance, other departments such as livestock department, agriculture and the Tambon Administration Organization do not have their own indicators in leptospirosis prevention and control. Strengths and weaknesses in leptospirosis prevention and control policy implementation are shown in table 3.

Table 3. Strengths and weaknesses in leptospirosis prevention and control policy implementation.

Strengths		
Nation level	**Province level**	**Subdistrict level**
- There is a National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response. - There are mechanisms for cooperation between departments via the Officer of the coordination unit for One Health.	- There is a Communicable Diseases Committee in the Province.	- There are guidelines for The District Strengthening Disease Control.
Weaknesses		
Nation level	**Province level**	**Subdistrict level**
- No plan and indicator between departments for prevention and control leptospirosis.	- The Communicable Diseases Committee is not concerned by leptospirosis issues. - The cooperation is only occasional. For example, public health and livestock officer join only to investigate leptospirosis disease punctually.	- No standard or clear role for cooperation between departments. - No indicator to work using the One Health approach. - Leptospirosis prevention mainly concerns patients and is not continuously directed to the whole population.

The One Health approach, employing disease surveillance, management, and eradication through collaboration between public health improving personal protection, veterinarians dealing with livestock and wild animal populations and ecologists examining ecosystem biodiversity and public health experts, to improve the prevention and control of the disease (Zinsstag and Tanner, 2015). One Health approach's implementation can enhance risk communication and help turn rhetoric into reality (Binot and Morand, 2015). National health policies and systems should allow a better cooperation between departments in accordance with One Health approach.

Conclusion

Leptospirosis outbreak in Mahasarakham Province, Thailand is still currently a health issue. Although the Ministry of public health developed and implemented leptospirosis prevention measures by increasing cooperation between ministries and by giving academic support to public health officers, there are gaps in linkages between departments to ensure comprehensive disease prevention activities. Acceptance of the One Health approach for leptospirosis prevention and control will improve impacts of prevention and control of leptospirosis. Mahasarakham Province needs to develop clearer concrete cooperation between departments and further study to establish realistic leptospirosis guidelines at the local level is a priority.

Chapter 3

Agro-environmental determinants of leptospirosis in Mahasarakham Province (Thailand), 2004 - 2014: a retrospective spatiotemporal analysis

All the contents of this chapter were used to establish manuscript 2.

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Summary

Leptospirosis is now considered as endemic in Mahasarakham Province, and a significant public health issue. The Mahasarakham Provincial Public Health Office, the Livestock Department, and the Agriculture Department have tried to control this disease. Because of the still occurring leptospirosis, the province has implemented new objectives in public health taking into account environmental and lifestyle changes as well as social development. The aim of the present study is to describe the spatiotemporal distribution of human leptospirosis cases in Mahasarakham Thailand from 2004 to 2014 in order to identify the potential agro-environmental determinants of disease incidence.

We analyzed human leptospirosis incidence between 2004 and 2014 in Mahasarakham Province in Northeastern Thailand, in order to identify the agronomical and environmental factors likely to explain the incidence at the level of 133 subdistricts of the province. I conducted several analyses: first (1), We investigated the spatial autocorrelation of leptospirosis incidence and performed spatial interpolation using kriging method; second (2), We analyzed the temporal incidence and the temporal autocorrelation of leptospirosis incidence; third (3), We described the spatiotemporal distribution of incidence using autocorrelation method and wavelet analysis and looked for correlation between leptospirosis incidence, rainfall and flood cover; fourth (4), We tested the effect of health policy and surveillance systems change in 2012 on the temporal dynamics; fifth (5) We explored the links between leptospirosis cases and incidence and the agro-environmental data set using general linear modeling (GLM and GLMM), with selection of best models based on AIC criteria; sixth (6), and finally, We used general additive modeling (GAM) to take into account the spatiotemporal dynamics obtained from (1), (2), (3) and (4) starting with the initial model that retained the potential explanatory factors of (5).

The result found that pooling human leptospirosis incidence for the whole-time sequence revealed a weak local spatial autocorrelation, not significant after 20 km. There was a strong seasonal pattern with a large number of leptospirosis cases during the rainy season (June to October) but that was decreasing in winter until the end of the

dry season. Leptospirosis cases, rainfall and flood cover, revealed a lag time that did not excess more than one month.

There was no significant decrease of incidence after 2010 when public health policies have changed by improving the health surveillance. The best GLM model showed that the number of leptospirosis cases per subdistrict was significantly associated with the population density, month, rainfall, average slope, flood cover, animal land cover, density of cattle, density of pigs, and public health. Moreover, the best GAM model confirmed the different results obtained above with a significant influence of geography (matrix of geographic coordinates of subdistricts).

The findings of our study give some evidence that environment, climate and livestock contribute to leptospirosis transmission to humans. Our results stress the importance of livestock favoring leptospirosis transmission to humans and suggest that prevention and control of leptospirosis need strong collaboration between the public health and livestock departments together with local communities in order to promote public and animal health educational activities. More generally, such collaboration would help for a better control of diseases in livestock promoting public health as encouraged by the One Health approach.

Introduction

Human leptospirosis is a neglected infectious disease (Goarant et al., 2019) with a high incidence in 34 countries (Costa et al., 2015). High prevalence of human leptospirosis occurs in tropical environments where conditions may favor the development of *Leptospira* in the environment (Pappas et al., 2008; Victoriano et al., 2009). Leptospirosis is a zoonotic bacterial disease caused by spirochete species of the genus *Leptospira* (Levett, 2001), which includes nine pathogenic species and at least five intermediate pathogenic ones (Adler, 2015). The clinical manifestations in humans are extremely broad. Leptospiral infection has often minimal manifestations, such as febrile illness. However, some patients may develop icteric leptospirosis, which is characterized by a combination of hepatic and renal impairment, hemorrhage, and vascular collapse (Plank and Dean, 2000; World Health Organization, 2003). Exposure to virulent leptospires may be direct, via contact with urine or tissues from infected animals, or indirect, via water contaminated with infected animals. Many animal species are thought to act as reservoirs (Adler, 2015) with an important role for livestock (Chadsuthi et al., 2017). Wild rodents have usually been considered as one of the main reservoirs for human leptospirosis (Cosson et al., 2014), although several studies have recently challenged their importance in rural environments compared to urban environments (Biscornet et al., 2017; Blasdell et al., 2019; Della Rossa et al., 2016).

Leptospirosis incidence in Thailand shows a strong seasonality with a high incidence during the wet season (Morand et al., 2018). Environmental factors, climate variability and extreme events resulting in flooding events may contribute to leptospirosis transmission and increased infection risk (Amilasan et al., 2012; Lau, Smythe, Craig, et al., 2010; Weinberger et al., 2014). Leptospirosis outbreaks have often been related to heavy rainfall, which conditions that may favor the development, the survival and dispersion of *Leptospira* species in the environment.

In Asia, leptospirosis incidences range from 0.1 to 10 cases per 100,000 persons but can reach over 50 per 100,000 per year during outbreaks (World Health Organization, 2009). The magnitude of the leptospirosis problem differs from country to country and depends on the awareness and attitude decision makers in terms of public health. In Asia, leptospirosis is a major health problem that has been related both to the monsoon and extreme events (Amilasan et al., 2012; Morand et al., 2018), exposure to moist soils (Ittyachen et al., 2007) and poor sanitary conditions (Picardeau, 2013).

In Thailand, the average annual incidence rate is 6.6 cases per 100,000 persons (Hinjoy, 2014). Leptospirosis was identified as a major problem as early as 1943, following a big flood event that hit Bangkok. In 1972, leptospirosis was included as one of the 58 reportable infectious diseases under the National Passive Surveillance System (Tangkanakul et al., 2005). Leptospirosis re-emerged in the mid-1990s with a major outbreak occurring in 2000. Outbreaks of leptospirosis were often reported after flooding events (Lau, Smythe, Craig, et al., 2010), although a retrospective study concluded to a lack of statistical association between the locations of leptospirosis cases and the flooded areas during the big flood event that hit Bangkok in 2012 (Suwanpakdee et al., 2015).

The first report in Mahasarakham Province (Northeastern Thailand) in 1996 reported 12 patients. In 1997, the number of diagnostic cases increased up to 300 (Mahasarakham Provincial Public Health Office, 2000). Leptospirosis is now considered as endemic in the province, and a significant public health issue. In that province, the Provincial Public Health Office, the livestock department, the agriculture department have tried to control this disease by employing people to eradicate rats in infected areas, by providing health education, by establishing a surveillance system and by setting the Surveillance and Rapid Response Team or SRRT in every district of the province under the District Strengthening Disease Control Program. Because of the still occurring leptospirosis, the province has implemented new objectives in public health taking into account environmental and lifestyle changes as well as social development.

The aim of the present study is to describe the spatiotemporal distribution of human leptospirosis cases in Mahasarakham Thailand from 2004 to 2014 in order to identify the potential agro-environmental determinants of disease incidence such as rainfall, flood cover or livestock.

Materials and methods

Study location

Mahasarakham Province is located in the Northeast of Thailand located in the middle of the Khorat plateau (Figure 1A). The climate is of savannah type with a rainy season spanning from May to November. There are 3 main rivers: Chee, Seaw, and Choo all tributes of the Mekong River (Department of Mineral Resources and Minister of Natural Resources and Environment, 2009). This province covers 5,300 square km lying within the 15°25 - 16°40 N and 102°50 - 103°30 E with low elevation variation (130 to 230 meters) (Figure 1B). The province is divided into 13 districts, 133 subdistricts comprising 1,982 villages. The last census of 2016 gave a total population of 869,280 persons and 244,155 households (Mahasarakham Provincial Public Health Office, 2016). Most citizens are living from agriculture (43.92%) (Mahasarakham Provincial Labor Office, 2017).

Leptospirosis Prevention and Control Implementation

Public health implementation for leptospirosis prevention and control in Mahasarakham can be separated in two parts during the analyzed time span. From 2004 to 2010, the province followed the guideline of the Minister of public health of Thailand which focused on rapid disease control with a "war room"and a Special Response Team established to handle leptospirosis outbreaks. From 2011 to 2014 Mahasarakham Province modified its prevention strategy by increasing the participation of the public health department, the livestock department, the agriculture department and the Tambon Administration Organization (Viroj et al., Un publish).

Data used in the study

Human leptospirosis incidence

Data on leptospirosis incidence were obtained for each of the 133 subdistricts and the 1,982 villages, for the years 2004 – 2014 from the public health department of Mahasarakham Province (Figure 1C). Patients were clinically diagnosed in hospitals, and only patients with severe symptoms were laboratory confirmed for leptospirosis. Leptospirosis cases are then symptomatic cases obtained through passive surveillance and may not reflect the real incidence due to the under-reporting of asymptomatic cases.

Land Use and Land Cover

Land use was obtained from the Ministry of Natural Resources and Environment, Thailand (Natural Resources and Environment, 2009). Five land cover types were used: building areas (i.e. villages, cities), agricultural areas (i.e. rice fields, mixed horticulture and orchards), water areas (ponds, lakes, rivers), forest areas and livestock areas (i.e. poultry farms, swine farms).

Seasonality and Rainfall

The climate of Mahasarakham is impacted by the monsoon and can be divided in 3 seasons: the summer occurring from February to May, the wet season from May to October and the winter from November to January. Monthly rainfall data (in millimeter) were obtained from the Thai Meteorological Department, Ministry of Information and Communication Technology.

Flood Cover

Flooding information was obtained using satellite remote sensing. We used MODIS TERRA MOD09A1 Surface-Reflectance Product, with a spatial resolution of 500 m and a temporal resolution of 10 days, from the Land Processes Distributed Active Archive Center of NASA (National Aeronautics and Space Administration). We used the Modified Normalized Difference Vegetation Index (MNDWI) to determine the flooded status of a 500m pixel as validated and used in previous works focusing on flood-driven leptospirosis in Cambodia (Ledien et al., 2017) and Thailand. The flood cover was estimated at the subdistrict level from the proportion of pixels (covering an area of 500m x 500m) having the flooded status in the subdistrict.

Livestock data

The number of cattle, buffaloes, and pigs per subdistrict were obtained from the livestock department of Mahasarakham (Figure 2).

Data integration

Data were obtained at different levels: incidence at village level, livestock at subdistrict level, rainfall at provincial level. We integrated all data at the subdistrict level. We therefore aggregated data obtained at the village level (human incidence); and replicated data obtained at the whole province for rainfall.

Statistical analyses

Statistical workflow

We conducted our analyses following this workflow: first (1), we investigated the spatial autocorrelation of leptospirosis incidence and performed spatial interpolation using kriging method; second (2), we analyzed the temporal incidence and the temporal autocorrelation of leptospirosis incidence; third (3), we described the spatiotemporal distribution of incidence using autocorrelation method and wavelet analysis and looked for correlation between leptospirosis incidence, rainfall and flood cover; fourth (4), we tested the effect change in 2012 on health policy and surveillance systems on the temporal dynamics; fifth (5) we explored the links between leptospirosis cases and incidence and the agro-environmental data set using general linear modeling (GLM and GLMM), with selection of best models based on AIC criteria; sixth (6), and finally, we used general additive modeling (GAM) to take into account the spatiotemporal dynamics obtained from (1), (2), (3) and (4) starting with the initial model that retained the potential explanatory factors of (5). All analyses were conducted using the R freeware (R Core Team, 2018).

Spatial Autocorrelation of Leptospirosis Cases

Correlogram analysis was used to identify spatial autocorrelations. Moran's I test was performed to test the significance of the correlations with spatialEco implemented in R (Evans, 2015). We also studied the autocorrelation by using subdistricts as units and using the lag in terms of neighboring with the spData package implemented R (Bivand, Nowosad, et al., 2018). We performed the analysis on the whole-time range and also for the three years showing the highest number of cases.

Semi-Variogram and Kriging Interpolation of Leptospirosis Cases

Kriging involves including a fixed number of nearest neighbor points within a fixed radius (De Smith et al., 2015) and relies on semi-variograms that quantify spatial autocorrelation among all pairs of data according to distance (Isaaks and Srivastava, 1989). Semi-variograms were estimated from survey data by calculating the squared difference of human incidence between all pairs of subdistrict centroids. Semi-variance values were grouped and averaged according to separation distance (lags). Semi-variogram model and kriging were obtained using the packages FRK and INLA implemented in R (Bivand et al., 2015; Brownrigg et al., 2015).

Temporal Analysis and Temporal Autocorrelation

We used time-series analysis to study the patterns of leptospirosis incidence during the study period. The exponential smoothing model was used to assess temporal trends in the overall rates of leptospirosis incidence using ncf implemented in R (Ottar N and Bjornstad, 2019). The time series included 132 months in total from January 2004 to December 2014. To determine the general form of the model to be fitted, the residual ACF (Autocorrelation Function) was examined. Considering the ACF graphs, different ARIMA models were identified for model selection. The series were then decomposed with a moving average taking into account a period of one year using the package stats, function decompose, implemented in R (Kendall and Stuart, 1983).

Similarly, we analyzed the temporal variations of rainfall and flood cover (as mean percentage computed over subdistricts) using the same methodology as above. The function ccf was used to compute the cross-correlation or cross-covariance between univariate series, i.e. rainfall and leptospirosis incidence, rainfall and flood cover and leptospirosis incidence.

We used wavelet analysis which decomposes a time series to reveal periodic signals at each time point in the series. The wavelet analysis coefficients showed magnitudes of correlation of the leptospirosis incidence for each year and period length and were displayed using a power spectrum over the full-time series. We used the packages biwavelet and WaveletComp (Gouhier et al., 2018; Roesch and Schmidbauer, 2015) implemented in R.

Association between Rainfall, Flood Cover and Leptospirosis Cases

We used the above time-series analysis to study the patterns of leptospirosis cases during the study period. Using ACF with investigated correlation lag and the correlation values at the best lag period (in months) among rainfall, flood cover and leptospirosis cases.

Causality of Public Health Change on the Temporal Dynamics

We investigated the causal effect of a designed intervention on a time series using the package CausalImpact implemented in R (Brodersen et al., 2015). Given a response time series, the method implemented in CausalImpact constructs a Bayesian structural time-series model that predicts how a response metric would have evolved after an intervention and if this intervention had never occurred (Brodersen et al., 2015).

Spatial Analysis

Mapping cases per capita and per year was used to show major trends and spatial match or mismatch with other spatially distributed variables. We started the year at the lowest level of incidence to potentially produce maps on which different outbreaks would not overlap. The incidence per capita was calculated by the division of the number of cases by the number of persons in a subdistrict. Moreover, the factors that could likely be in association with human leptospirosis cases or incidence including pig density, cattle density, buffalo density, population density, were mapped with a resolution at the subdistrict level. The rgdal and tmap packages (Bivand, Keitt, et al., 2018; Tennekes, 2018) implemented in R were used.

Association between Leptospirosis Incidence / Occurrence and Investigated Factors

The distribution of leptospirosis cases per subdistrict and per month was investigated using the package fitdistrplus (Delignette-Muller and Dutang, 2015) implemented in R. Leptospirosis incidence was computed by dividing the number of cases by the number of people for each subdistrict and for each month. We ran a GLM model on leptospirosis cases with all potential explanatory factors using a binomial link function and select the best model using a stepwise approach and Akaike Information Criteria (AIC) selection procedure. The package lme4 (Bates et al., 2015) was used to implement this model with the binomial family. Potential co-linearities were assessed using vif (variance inflated factors) implemented in R.

Confounding effects among Investigated Factors

Explanatory factors were evaluated as determinants of leptospirosis incidence at subdistrict level. Since these factors are potentially correlated and can lead to confounding effects, we used the following strategy (Skelly et al., 2012). We first identified all potential effects by running simple models with incidence as response and for each effect individually. We then started with the explanatory variable that was associated with the largest decrease in AIC. Confounding effects would occur when combining two significant individual effects would not decrease AIC. We followed that forward approach by appending variables that were further decreasing the AIC to establish the largest and most parsimonious model (see Supplementary Information).

We run three different families of models. We started with simple models using average data for all subdistricts and summing data on the whole sequence assuming no random effects. After that, models were made more complex with the inclusion of random effects for accommodating time variation.

The first simplest group of models corresponds to generalized linear models (GLM) with binomial distribution to analyze human leptospirosis incidence at the level of subdistrict pooling the month and years. The response was compared with the percentage of agricultural areas, percentage of animal areas, percentage of building areas, percentage of forest areas, percentage of water areas, population density, cattle density, buffalo density, chicken density, duck density, percentage of flooded areas and mean slope obtained from pixels covering 1 squared km. We followed the forward selection explained above to obtain a more complex model.

In a second group of models, we used all the data pooled and analyzed by year irrespective of months by using subdistrict as random effect and by including the variable change in leptospirosis prevention as explanatory variable subdistrict. In order to identify a possible general trend, year was used as a control fixed variable and the variance of the random effect (subdistrict) were computed for both the intercept and the implementation effect. In order to avoid pooling data corresponding to two consecutive outbreaks, the data corresponding to a year started in April (the month with the lowest occurrence rate) and finished in March. The function glmer of the package lme4 (Bates et al., 2015) was used to implement this model with the binomial family (see Supplementary Information).

The last model considered seasonal variation on pooled data by subdistrict and month irrespective of years. Month was treated as a category and as a fixed effect in the model, subdistrict as a random effect (acting on both intercept and month effect). The variance within subdistrict could depend on the month and each subdistrict may differ in average response (effect on the intercept).

Association between Leptospirosis Cases and Investigated Factors Using General Additive Modeling

General Additive Modeling (GAM) is an extension of the generalized linear models with the adaptability for non-normally distributed variables. The model assumes that the response variable, here leptospirosis cases per subdistrict and per month, is dependent on the univariate smooth terms of independent variables (Hastie and Tibshirani, 1990). All models were fitted using the MGCV package implemented in R (Wood and Simon, 2017). We used the function gam.check to choose the basis dimension for each predictor according to estimated degrees of freedom value in the main effect. Outputs of GAM models were obtained using the package gratia implemented in R (Simpson, 2019).

Model performance

Performance of models, GLMs and GAMs, on leptospirosis cases, incidence and occurrence were assessed using the package ROCR implemented in R (Sing et al., 2005).

Results

Human Leptospirosis Incidence

The total number of leptospirosis human cases recorded from 2004 – 2014 was 762, with the highest number (177) recorded in 2012 followed by year 2009 (90) and 2014 (79). The annual incidence rate was 7.97 cases per 100,000 and ranged from 3.80 to 20.36 cases per 100,000.

The largest number of cases were found in Wapi Pathum District (160), followed by Kosum Phisai District (123) which are all located in low elevation. Chuen Chom

District (North of the province) had the lowest number of cases over the considered period (3) and is located at higher elevation (Figure 1C).

Two areas showed nearly no cases, they corresponded to Chuen Chom District in the north and to the Eastern part of Na Chuak District; places with largest incidences were situated in the east (Wapi Pathum District, Kea Dum District), in the south (Phayakkhaphum Phisai District), in the west (Borabu District) and in the east of Kosum Phisai District.

Spatial Autocorrelation of Leptospirosis Incidence

Pooling human leptospirosis incidence for the whole-time sequence revealed a weak local spatial autocorrelation, not significant after 20 km (see Supplementary Information). Local autocorrelation nevertheless increased during two years of highest incidence (2012 and 2014), suggesting the existence of a pattern of spatial variation changing through time. During these two years, autocorrelation was significant until spatial lag ranging from 20 to 40 km (size of two adjacent subdistricts). This observation was not verified in 2009, a year characterized by its high incidence (see Supplementary Information). When analyzing data considering the order of the neighborhood between subdistricts, a positive autocorrelation was found at the first and second order while considering data during the whole-time study. In 2012 during highest number of cases, a similar but stronger pattern was found at the first and second order also. In 2009 during the second highest number of cases such autocorrelation was not observed. However, in 2014 during the third highest number of cases, a similar pattern was found at the first and second order (see Supplementary Information).

Semi-Variogram and Kriging of Incidence

The spatial distribution of the human incidence among subdistricts (Figure 1C) was analyzed using semi-variogram analysis with the best model function spherical. The kriging interpolation, using the results of the semi-variogram analysis, is represented in Figure 1D. A high spatialized interpolation of leptospirosis incidence corresponds to low elevation areas (Figure 1B).

Time Series Analysis of Leptospirosis Incidence

There was an increasing trend in leptospirosis cases from 2004 to 2012 (Figure 3A) with a sharp decrease at the end of 2012, followed by a slight increase in 2013 and 2014. There was a strong seasonal pattern with a large number of leptospirosis cases during the rainy season (June to October) but decrease in winter until the end of the dry season (Figure 3A). The ACF graph showed seasonality in leptospirosis cases. However, the wavelet analysis (Figure 4A) did not confirm a seasonal pattern at the exception of years 2009 - 2010.

Time Series Analysis of Rainfall and Flood Cover

Using a similar method as above, we found a strong seasonal pattern of rainfall and flood cover (Figure 3B & C). A strong decrease in both rainfall and flood cover occurred after 2012 suggesting that Mahasarakham was entering in a drought period.

Wavelet power spectrum (Figure 4B & C) confirmed the above observation by revealing significant 12-month periodicity over the entire time period. However, the seasonal autocorrelation disappeared from 2012 to 2014 for both flood cover (Figure 4B) and rainfall (Figure 4C), confirming the time series trends (Figure 3B & C).

Cross Temporal Correlation Analysis

Cross-correlation analysis among pairs of univariate series, leptospirosis cases, rainfall and flood cover, revealed a lag time of less than one month (Figure 5). Significant correlation among pairs of univariate series was observed with higher correlation between rainfall and flood cover ($R = 0.69$) than between rainfall and leptospirosis cases ($R = 0.17$) or between flood cover and incidence (0.36).

Impact of the Surveillance System

There was no significant decrease of incidence after 2010 when public health policies have changed by improving the health surveillance. Rather, an increase in the number of cases was observed (Figure 6).

A significant causal effect of the change in public health policies after the high incidence of 2010 (Figure 6) was noted (Bayesian one-sided tail-area probability $P = 0.03$ with a posterior probability of a causal effect: 96.967%). In relative terms, the number of leptospirosis cases showed an increase of 38%, however, with a large credible interval that was still crossing the 0 increase even when considering the entire post-intervention period after 2012 (i.e. 2012 - 2014).

GLMM and Confounding Factors

The best GLM model at the subdistrict level pooled over years included seven explanatory variables of leptospirosis incidence: the density of cattle per subdistrict, the density of buffaloes per subdistrict, the density of pigs per subdistrict, the percentage of livestock areas, the percentage of building areas, the population density and the mean slope of the subdistrict (see Supplementary information). However, there were some collinearity among the selected variables with a VIF value of 4.7 for the percentage of building areas. The AUC value of 0.57 confirmed the low prediction power of this best GLM model See Supplementary information.

The best GLMM model at the level of the subdistrict with leptospirosis prevention and control implementation and subdistrict as random effects showed significant association of human leptospirosis incidence with mean slope, population density, percentage of building area, density of pigs per subdistrict and leptospirosis prevention and control implementation. However, the percentage of building areas was confounded with the population density and only the following factors were significantly associated with human leptospirosis incidence: leptospirosis prevention and control implementation, year, mean slope of the subdistrict, population density and the density of pigs per subdistrict (see Supplementary Information). There was no collinearity among the selected explanatory factors with all VIF values < 1.7). The AUC value was 0.75 indicating a better performance prediction.

The best GLMM model at the subdistrict level and pooling month and subdistrict as random effects showed significant association between human leptospirosis incidence and percentage of agricultural areas, percentage of building area, density of cattle per subdistrict, density of pigs per subdistrict, month, slope mean and population density. However, taking into account confounding effects gave a final model that kept the explanatory factors: month, mean slope, population density and density of pigs per subdistrict (see Supplementary Information). There was no collinearity among the selected explanatory factors with all VIF values < 1.1). However, the AUC value was

0.73 indicating a lower performance than the precedent model. See Supplementary information.

Association between Leptospirosis Occurrence and Explanatory Factors Using General Additive Modeling

In order to design the GAM model, we first performed a GLM analysis on leptospirosis presence/absence (occurrence) using a negative binomial function. This distribution was chosen because there was a good fit of the response ($P < 0.001$), with a theta value of 0.267 (standard deviation = 0.037). Explanatory variables in the model were: number of people, percentage of agricultural areas per subdistrict, percentage of building areas per subdistrict, percentage of livestock areas per subdistrict, percentage of flooded areas per subdistrict, population number per district, mean slope of the subdistrict, cattle per subdistrict, pigs per subdistrict, month, and buffaloes per subdistrict, change in public health surveillance and month. The best model selected using stepwise procedure and AIC values showed that occurrence of leptospirosis is significantly associated with the number of people, month, rainfall, average slope, flood cover, animal land cover, number of cattle, number of pigs, and public health (Table 1).

Multicollinearity assessed using Variance Inflating Factor (VIF) showed VIF values inferior to 2.03 suggesting lack of collinearity.

We developed the following initial GAM model that took into account the spatiotemporal dynamics of leptospirosis occurrence and the temporal dynamics of rainfall and flood cover, and the potential explanatory variables using a negative binomial function (with theta estimated before). The best GAM model selected on the basis of AIC value (Table 2, Figure 7) was: gam(leptospirosis cases per subdistrict ~ s(longitude, latitude) + te(month, rainfall) + te(month, flood cover) +s(number of people in subdistrict)+s(pigs) + s(cattle) + s(average slope).

Discussion

We investigated the spatiotemporal distribution of leptospirosis in Mahasarakham province over 11 years and identified several factors associated with human leptospirosis incidence. Mahasarakham was chosen as a pilot province for the implementation of surveillance and control of leptospirosis (Viroj et al., Unpublished) and the present study contributes to the assessment of the public health policy.

The highest number of leptospirosis cases was reported in Mahasarakham Province in 2012, one year after Mahasarakham province has implemented a new leptospirosis prevention and control plan with the Surveillance and Rapid Response Team (SRRT) and the District Strengthening Disease Control. This new plan aimed at increasing collaboration between the public health department, the livestock department, the department of agriculture and the Tambon Administration Organization for better prevention and control leptospirosis (Department of Disease Control, 2016). This new implementation can improve the quality of data collection and reporting on death rates and causes, so the increase of the number of leptospirosis cases recorded in 2012 may partially be due to a better reporting in the province. In this study, we found that the new leptospirosis prevention and control plan on leptospirosis was associated with an increase of incidence, independently of environmental factors, although the significance of this impact on middle term necessitates more years of observation. This unexpected effect may result from a better documentation of cases, since the new leptospirosis prevention and control plan has increased participation, awareness and better communication towards the health officers, the district hospitals and the local communities.

Temporal Analysis of Leptospirosis

Leptospirosis cases dramatically increased in the wet season and had the highest rate at the end of the rainy season as shown by the time series analysis. This observation is similar with numerous studies showing that most leptospirosis cases occurred during the rainy season (Benacer et al., 2016; Morand et al., 2018; Topic et al., 2010). During the rainy season, the soil is moist and allows the bacterial leptospires to survive outside longer while water flushes and flooding might help their dispersion (Kloos and Berhane, 2006). In complement, the results of the time series analyses showed the likely association between rainfall, flood areas and leptospirosis cases, although flood cover explained better the number of leptospirosis cases than rainfall.

Spatial Analyses of Leptospirosis

The low local spatial autocorrelation, inferior to 20 km, is also in agreement with other studies on environmentally transmitted diseases such as leptospirosis. This result is similar to a study undergone in Netherlands where autocorrelation of leptospirosis incidence was about 12 km (Rood et al., 2017). Local autocorrelation nevertheless increased during the two years of highest incidence (2012 and 2009) but geographical patterns where different, suggesting that spatial variation exist but change through time. Positive autocorrelation was found at the first and second district neighborhood order while considering the whole time period showing that disease transmission commonly occurred among adjacent subdistricts as also observed using kriging interpolation.

Likely Agro-Environmental Determinants of Leptospirosis

The results of GLM conducted at the level of the subdistrict showed that human population size, pig density, cattle density, percentage of flooded areas, percentage of livestock areas, percentage of building areas, rainfall, change in public health surveillance, average slope and time (months) were significantly associated with leptospirosis incidence. GLMMs taking into account potential confounding effects and considering time and/or subdistricts as random effects consistently selected average slope, human population density and pig density as likely determinants.

Finally, GAM analysis allowed us to consider the spatiotemporal dynamics of the leptospirosis transmission revealed by the kriging and time series analyses. The best GAM model confirmed the different results obtained above with a significant influence of geography (matrix of geographic coordinates of subdistricts), rainfall, slope and flood cover, population size and number of cattle and pigs. The partial contribution of geography to the variable response (Figure 7A), i.e. leptospirosis occurrence, reflected the kriging map (Figure 1C), while the greatest effects of the partial contributions of rainfall and of flooded cover (controlling for time) occurred in 2012 or later.

The average slope of the district was negatively associated with human leptospirosis incidence. Flat topography allows the formation of permanent puddles, which is strongly associated with the formation of flooded areas favoring the transmission of leptospires through contaminated water (Gracie et al., 2014; Sulistyawati et al., 2016). However, some studies did not find a significant association between flooded areas and leptospirosis incidence such as in Thailand during the flooding event of 2012 (Suwanpakdee et al., 2015; Thaipadungpanit et al., 2013) hypothesized that long and intense flooding may lead to a dilution of leptospires reducing the risk of transmission during this long flooding event (Thaipadungpanit et al., 2013). Indeed, the GAM model showed that the effect of the partial contributions of flood cover (controlling for time) decreased for both low and large flooded areas (Figure7C).

Population size was positively and significantly associated with leptospirosis occurrence. A pattern commonly found for environmentally transmitted diseases (Antonovics, 2017). Human population growth and increasing population size are important drivers of infectious diseases in Southeast Asia (Coker et al., 2011). Moreover, population size and population growth are typically associated with agricultural intensification and increasing farming that may enhance leptospirosis transmission (Lau et al., 2016).

Our results showed a positive association between cattle density and leptospirosis occurrence. Cattle are well-known as carriers of leptospires (Adler and de la Peña Moctezuma, 2010; Chadsuthi et al., 2017) and a strong association between cattle density and leptospirosis transmission has already been reported (Mwachui et al., 2015). Free-ranging cattle systems can increase transmission of leptospirosis by exposing human to contaminated environment by cattle urine and leptospires (Rood et al., 2017). In low-income rural communities, cattle appear more important than rats for maintaining the transmission of leptospirosis (Barragan et al., 2017). Grazing range characteristics are likely to play a role in shedding the concentration of leptospires in the environment (Barragan et al., 2017; Suwancharoen et al., 2016). In Thailand, the dominant serovar Shermani observed in cattle was also observed in humans (Chadsuthi et al., 2017). The importance of cattle as a determinant of leptospirosis occurrence in Mahasarakham finds its confirmation by the fact that farmers are the main people infected by leptospirosis. Buffaloes could play a role as an important leptospirosis animal reservoir in Thailand. The serovars found in buffaloes, such as Shermani, Pomona, Sejroe, Bratislava and Bataviae can be pathogenic in humans (Chadsuthi et al., 2017). However, our results did not support a role for buffaloes in the transmission of the disease.

The large number of pigs and backyard piggeries that drainage of refuse downhill from piggeries has been implicated in leptospirosis transmission (Lau et al., 2012). However, our results consistently showed a negative association between the density of pigs and the occurrence of leptospirosis. As commonly observed in Northeast Thailand, most pig farming in Mahasarakham Province consist in small backyard stables, in which pigs are supposed to have low exposure to environmental pathogens contrary to cattle. But the negative effect of pig density on the leptospirosis transmission can be explained by the intensive and misuse of antibiotics in the backyard and small pig farming (Karnchanabanthoeng et al., unpublished). Our hypothesis is then that the release of antibiotics in the pig manure may contaminate the surrounding environment and may decrease the survival of environmental leptospires, ultimately leading to a decrease in their transmission.

The low explanatory power of our models with quite low AUC values, even though higher using GAM, stresses some missing factors in the understanding of the transmission dynamics of leptospirosis. The most important one is the human individual risk behavior which could not be integrated in the modeling framework used in this study, but nevertheless, human factors need to be considered in any strategic planning for disease prevention.

Implications for Leptospirosis Surveillance and Control

Leptospirosis incidence trend did not show any decrease in Mahasarakham province after the implementation of a new leptospirosis prevention and control plan. Leptospirosis prevention and control implementation require strong strategies to improve surveillance, health education, and good practices to avoid sources of contamination (Guerra, 2013; John, 2005). The findings of our study give some evidence that environment, climate and livestock contribute to leptospirosis transmission to humans. This retrospective analysis may help at targeting subdistrict presenting environmental and farming characteristics associated with a higher risk of leptospirosis transmission to humans for improvement of leptospirosis prevention and control in Mahasarakham Province, notably by using the One Health approach to improve multi-sectoral collaboration between public health, livestock department,

department of agriculture, district hospitals and local communities in order to promote public and animal health educational activities.

Conclusion

The factors associated with leptospirosis infection in Mahasarakham Province are complex and multifactorial, including human population density, livestock, rainfall, flood cover and physical geography, i.e. average slope. In order to gain in efficiency, leptospirosis prevention and control need enhanced collaboration between public health, livestock department with community involvement under the One Health approach. In particular, targeting areas prone at risk, i.e. with high livestock or in flooded areas, should be complemented by improving communication to people at risk, i.e. farmers.

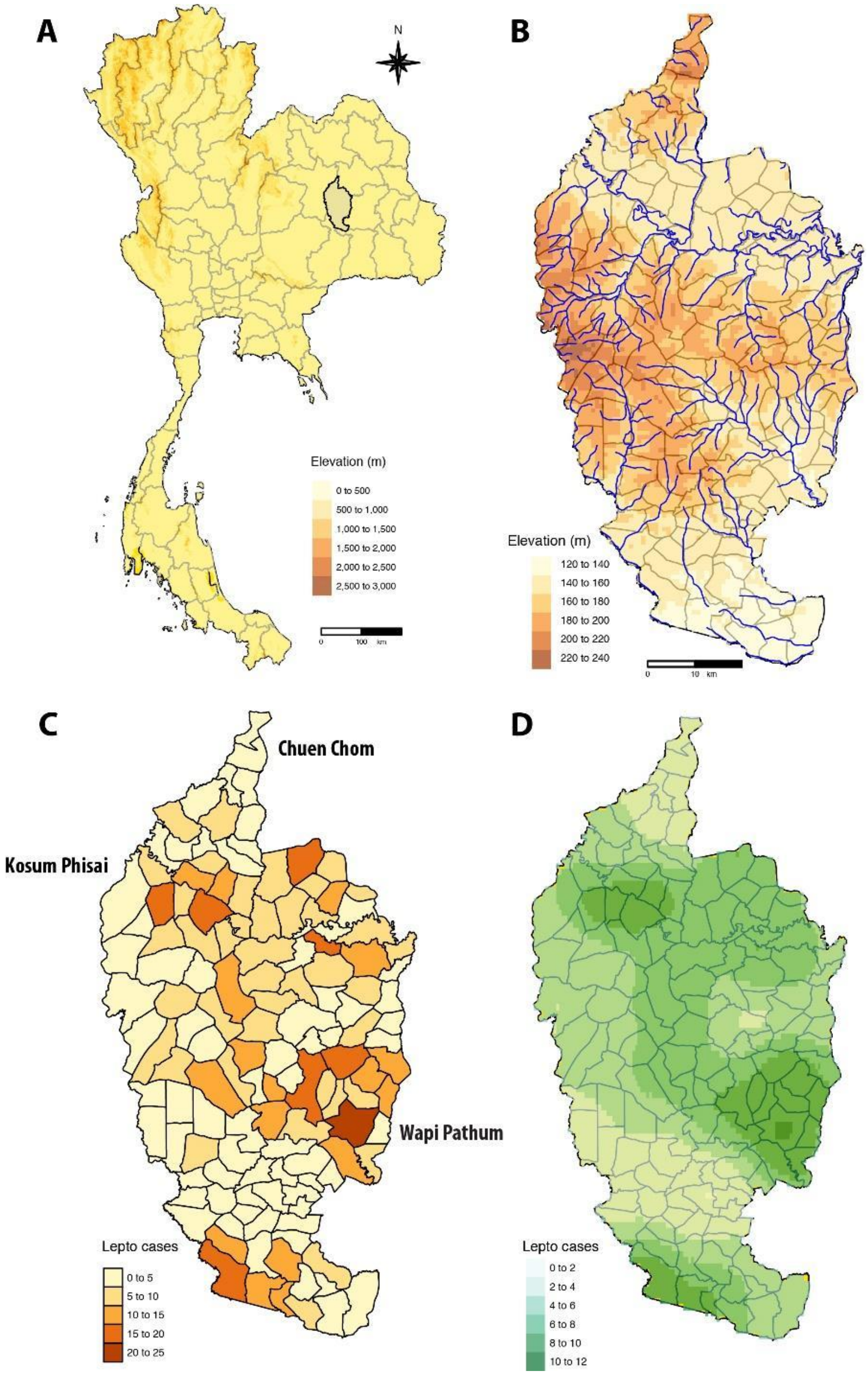

Figure 1. Mahasarakham Province with: (A) the location of the province in Thailand (in grey) (B) geography with elevation, main rivers and subdistrict boundaries; (C)

overall leptospirosis incidence cases over 2004 - 2014 period per subdistrict (with localization of Wapi Pathum District, Kosum Phisai District and Chuen Chom District, cited in the results section) (D) interpolation of leptospirosis cases at the level of subdistrict by kriging using semi-variogram based on the centroids of geographical coordinates of each subdistrict.

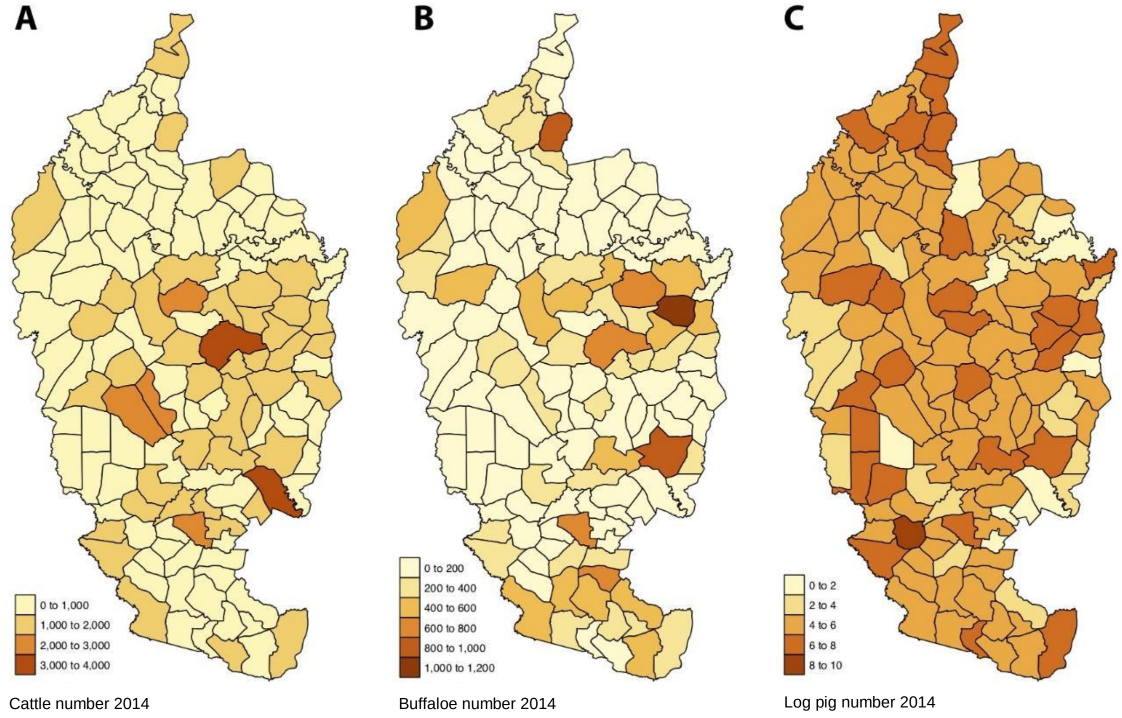

Figure 2. Mahasarakham Province with (A) Cattle number, (B) Buffalo number, (C) Pig number (in natural logarithm) per subdistrict in 2014.

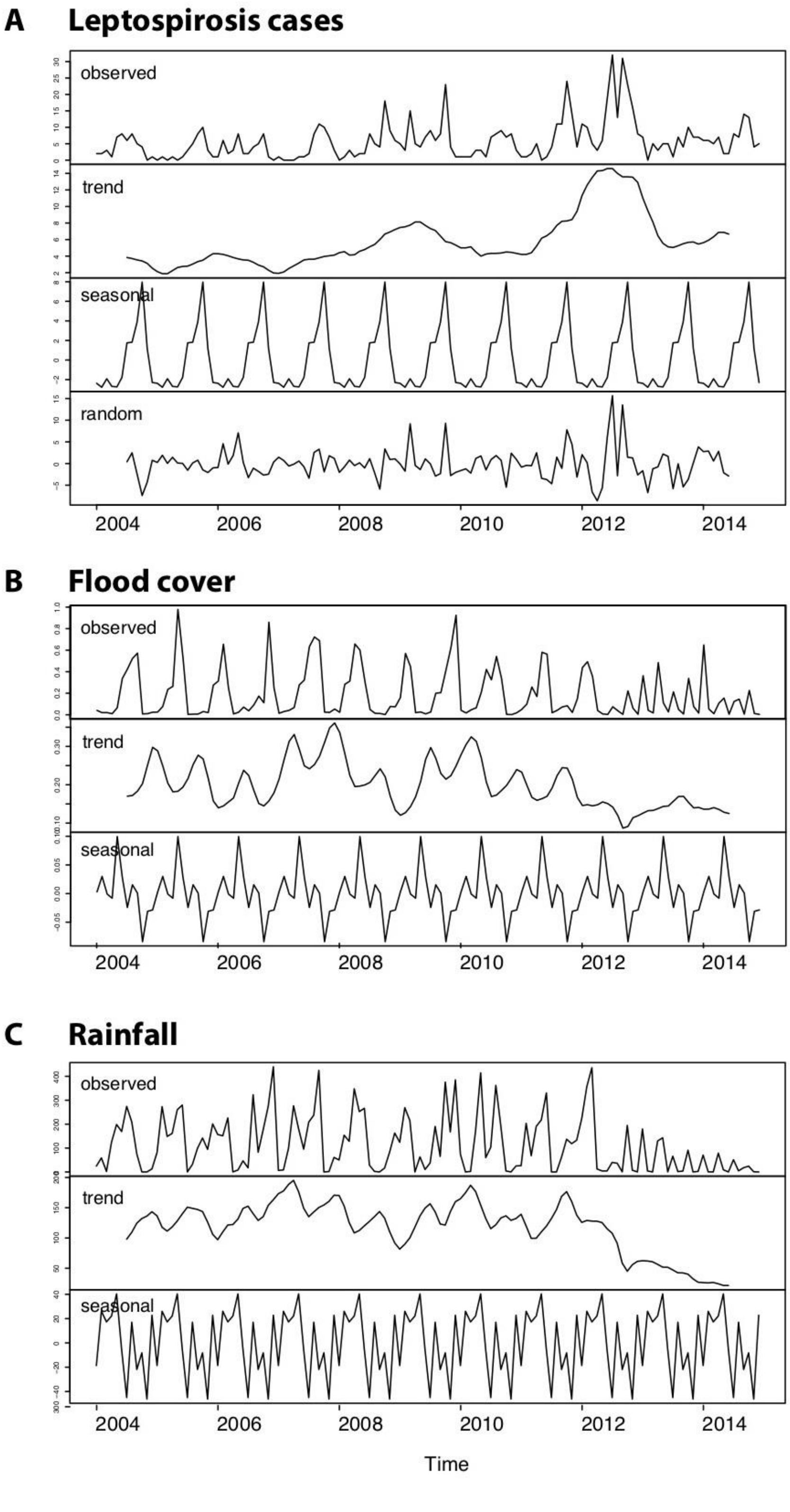

Figure 3. Temporal analysis over the period 2004 - 2014 by month. (A) Observed leptospirosis cases decomposed in smooth trends, seasonal and random effects; (B)

flood cover decomposed in smooth trends and seasonal effect; (C) rainfall decomposed in smooth trends and seasonal effect.

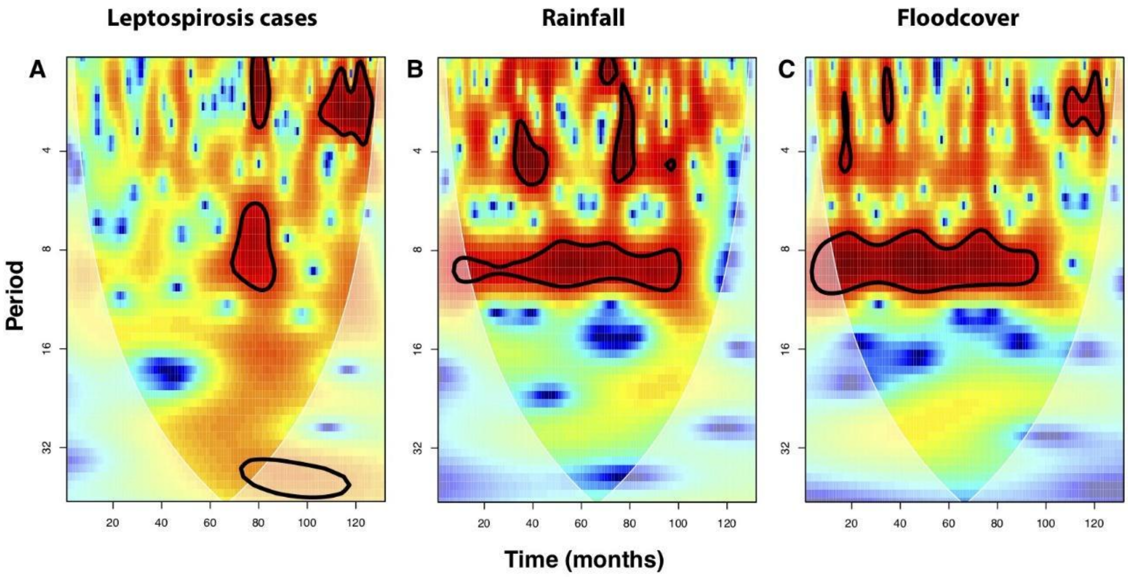

Figure 4. Wavelet power spectrum of (A) observed leptospirosis cases, (B) rainfall, (C) flood cover over 2004 - 2014 (132 months). Wavelet power values increased from blue to red, and black contour lines indicate the 5% significance level. In this example, the time-series shows a significant periodicity corresponding to 12 months over 2009 - 2010 observed leptospirosis cases and over for 2004 - 2012 for rainfall and flood cover.

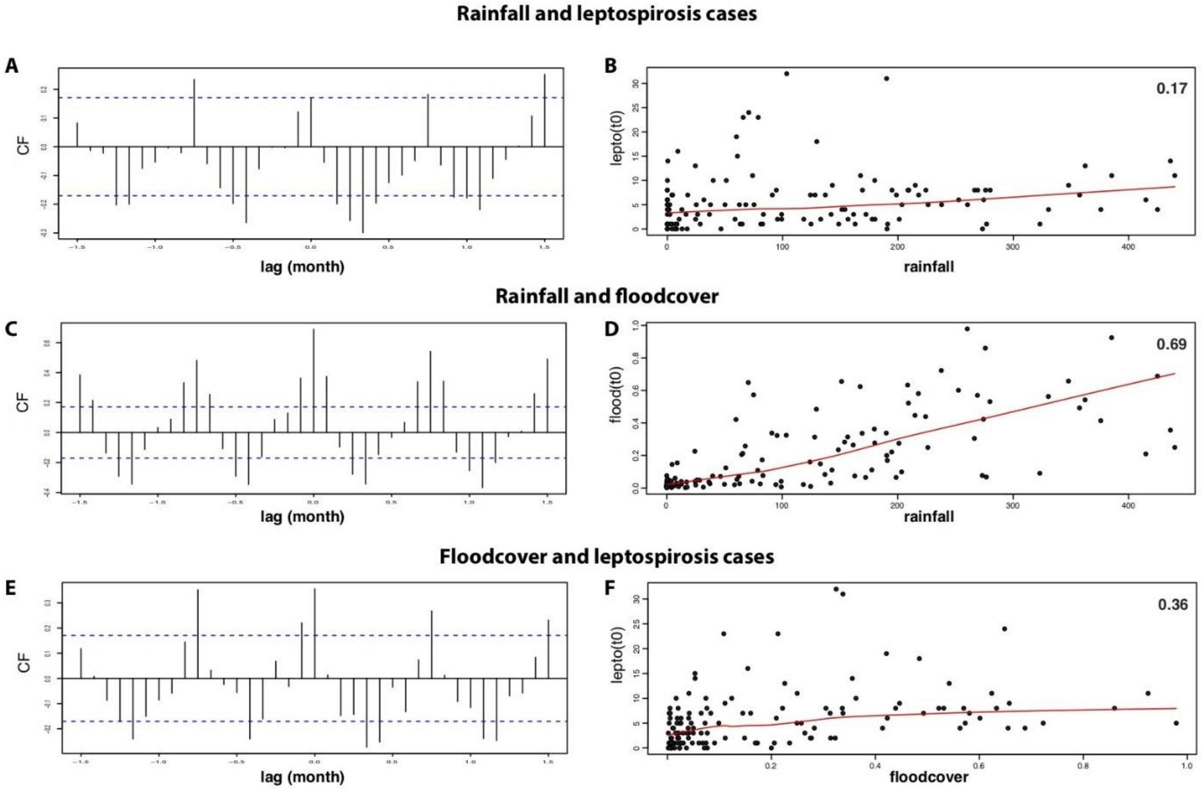

Figure 5. Temporal correlation over the period 2004 - 2014 between: (A & B) rainfall and leptospirosis cases with lag < 1 month (A) and R = 0.17 (B); (C & D) rainfall and flood cover with lag < 1 month (C) and R = 0.69 (D); (E & F) flood cover and leptospirosis cases with lag < 1 month (E) and R = 0.36 (F).

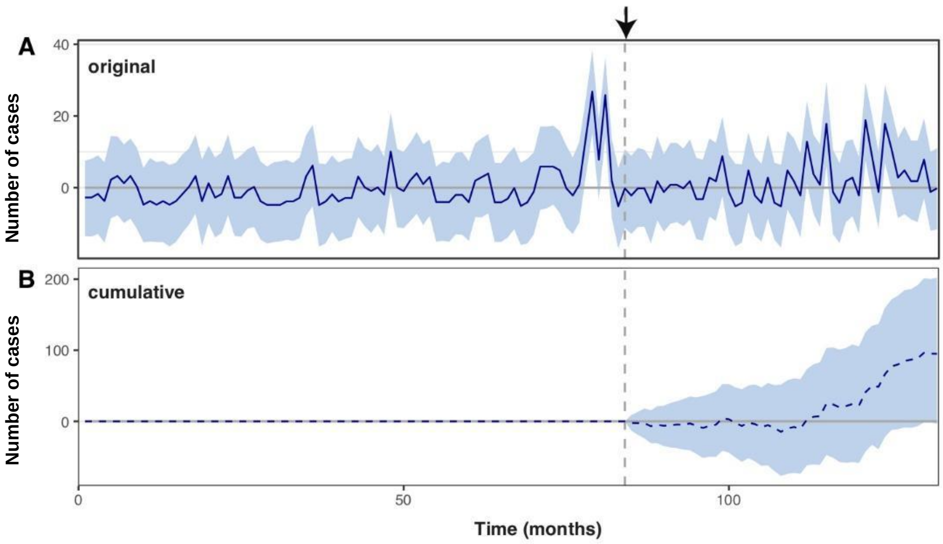

Figure 6. Causal effect of the change in the health surveillance system after 2010. Significant causal effect of the change in public health policies was assessed using Bayesian one-sided tail-area probability (P = 0.03). The relative number of leptospirosis cases showed an increase of 38%, however, the 95% credible interval on this increase overlapped the 0 [-1%, +81%] during the whole time observed after the change in the surveillance system (the arrow on the top of the dashed line indicates the change in health surveillance systems).

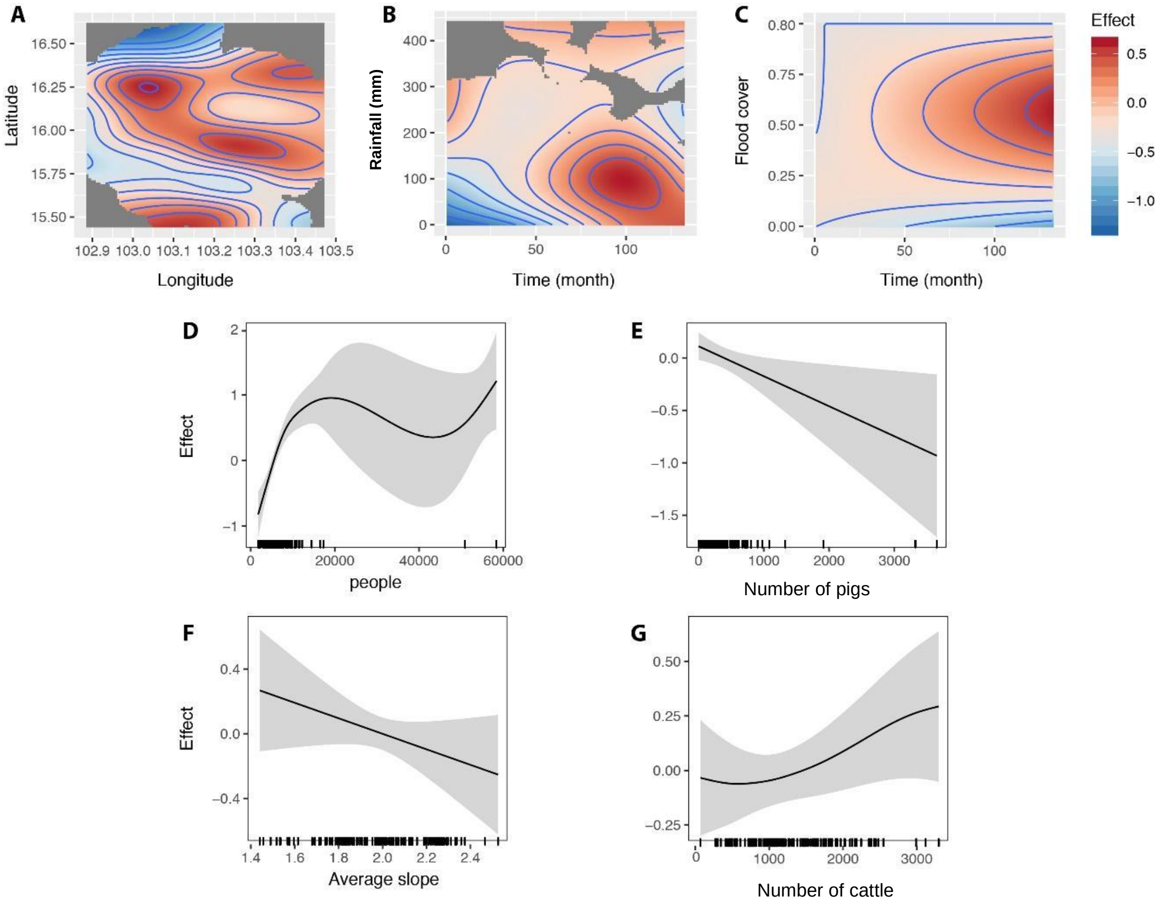

Figure 7. Results of the best General Additive Modeling explaining the number of cases of leptospirosis in Mahasarakham Province over 2004 - 2014 by subdistrict and by month, using a negative binomial link function (with theta = 0.267) (see Table 2). The smoothed variables selected in the best GAM were (A) the geographical distribution of subdistrict (given by longitude and latitude of the centroid), (B) rainfall inmm controlling for time (month); (C) flooded areas in percentage cover (of subdistrict) controlling for time (month) ; (D) population size per subdistrict; (E) pig number per subdistrict; (F) average slope of the subdistrict; (G) cattle number per subdistrict.

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Table 1. Results of the best global GLM (with negative binomial link function, with theta = 0.267 (with standard deviation = 0.037, $p < 0.001$), explaining the number of cases of leptospirosis in Mahasarakham Province over 2004 - 2014 by subdistrict and by month with estimate and standard deviation (SD) for each selected explanatory variables, P value, VIF (Variance Inflating Factor), and Log likelihood with degree of freedom (DF), R^2 estimated by maximum likelihood (R2ML) and AIC of this best model.

Explanatory variables	Estimate (SD)	*P* value	VIF*	Log likelihood (DF)	R2ML	AIC
Population size	$3.7\ 10^{-5}$ ($0.4\ 10^{-5}$)	< 0.0001	1.08			
Time (month)	$4\ 10^{-6}$ ($5\ 10^{-7}$)	< 0.0001	1.33			
Flood cover	1.05 (0.18)	< 0.0001	1.66			
Rainfall	0.001 (0.0004)	< 0.0001	2.03			
Animal land cover	3.90 (1.22)	0.0014	1.14			
Public health	0.63 (0.08)	< 0.0001	1.00			
Average slope	-0.69 (0.20)	< 0.0001	1.14			
Number of cattle per subdistrict	0.0004 (0.0006)	< 0.001	1.11			
Number of pig per subdistrict	$-2.5\ 10^{-4}$ ($1.2\ 10^{-4}$)	0.025	1.06	-2,979 (17,555)	0.083	5,978

(* value of VIF > 10 for continuous variable may indicate collinearity problem)

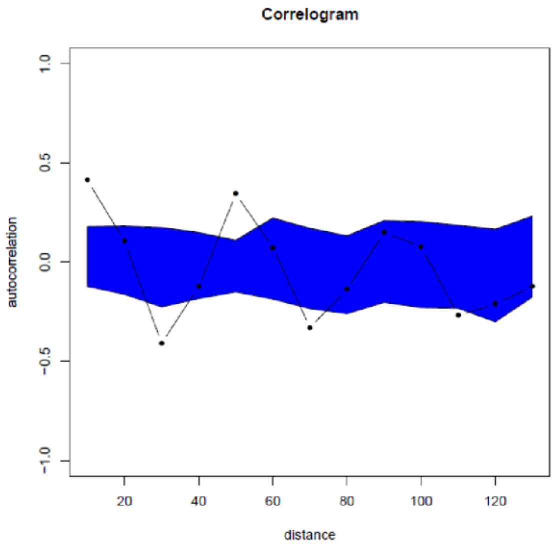
Table 2. Results of the general additive modeling (GAM) explaining the number of cases of leptospirosis per subdistrict in Mahasarakham Province using a negative binomial link (theta = 0.267, with approximate significance of smooth terms. Deviance explained = 14%, REML = 2950.7, AIC = 5,852 (see Figure 9).

Terms	edf	Ref.df	Chi square	p-value
s (longitude, latitude)	17.82	29	67.44	< 0.0001
te (month, rainfall)	12.28	24	94.43	< 0.0001
te (month, flood cover)	3.36	20	42.89	< 0.0001
s (population)	3.98	9	72.42	< 0.0001
s (pig number per subdistrict)	0.87	9	5.99	0.006
s (cow number per subdistrict)	1.26	9	3.44	0.037
s (average slope)	0.68	9	2.11	0.043

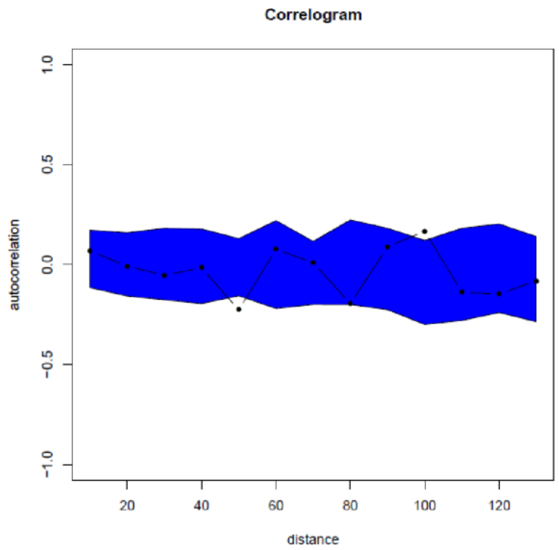
Supplementary information

Spatial autocorrelation of leptospirosis incidence.

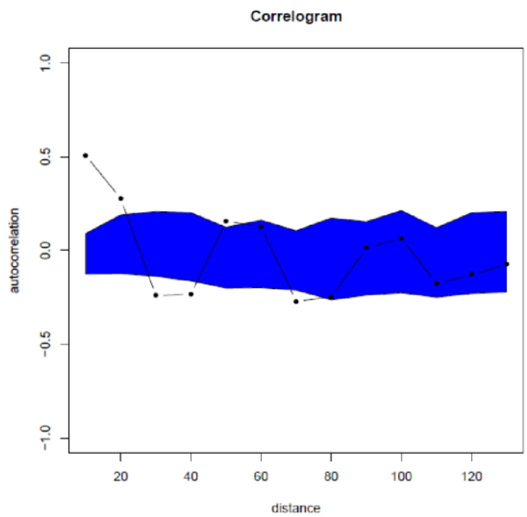
Correlograms were used to identify the spatial autocorrelation with lag distance and the Moran's I test can be used to test the significance of the correlations. Spatial autocorrelation range was determined by checking at the significance value (P = 0.05) of the individual bins of lag distance at every 20 km.



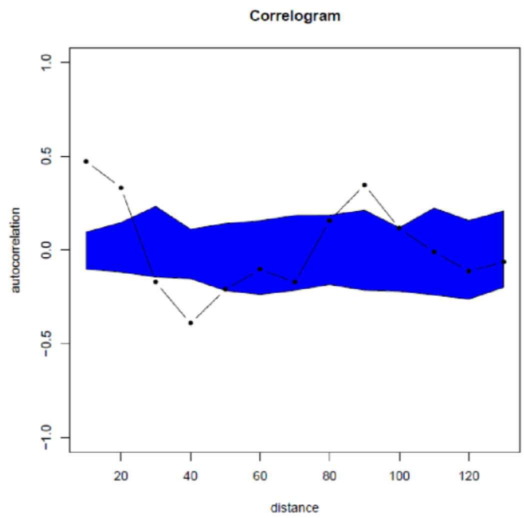
Auto correlation during 2004 – 2014



Auto correlation in 2009



Auto correlation in 2012



Auto correlation in 2014

Spatial autocorrelation analysis of neighbors of subdistrict showed autocorrelation in the first level ($P < 0.0001$) and the second level ($P = 0.004$) of subdistrict.

GLMM analyses: searching for confounding variables

Confounding variables.

model	confounding
mod.0<-glm(cbind(case, round(pop_tum)) ~ x1+x2, family="binomial", data=data5)	- Population density/ mean slope, percentage of agricultural areas, percent of forest areas, percent of livestock areas, buffaloes density - Percentage of building areas/ percentage of agricultural areas, percentage of forest areas, percent of livestock areas, buffaloes density - Mean slope / Buffaloes density - Cows density/ Buffaloes density - Percentage of agricultural areas/ Buffaloes density - Percentage of flooding/ Buffaloes density
mod.0<-glmer(cbind(case, round(pop_tum)) ~ year+ im+x1+x2 +((1+im)|Tumb), family="binomial", data=data3)	- Population density/ Percentage of building area
mod.0<-glmer(cbind(case, round(pop_tum)) ~ month+ x1+x2 +((1+month)|Tumb), family="binomial", data=data4)	- Percentage of building area/ Population density - Population density/ Percentage of building area

Final model of generalized linear models of human leptospirosis incidence (n = 133).

AIC = 751.19, Null deviance = 430.81, Residual deviance = 309.50

Variable	Coefficient (b)	Standard error	z-value	p-value
population density	-1.104e+03	2.431e+02	-4.540	5.63e-06
mean slope	-8.894e-01	1.750e-01	-5.082	3.73e-07
pig density	-1.518e+04	4.857e+03	-3.126	0.00177
cow density	1.219e+04	2.892e+03	4.216	2.48e-05
percentage of livestock area	3.212e+00	1.146e+00	2.804	0.00506
percentage of building area	2.722e+00	1.100e+00	2.474	0.01335
buffalo density	-1.665e+04	8.829e+03	-1.886	0.05932

Final model of generalized linear mixed models of human leptospirosis incidence with leptospirosis prevention and control implementation and subdistrict as random effects (n= 1,463).

AIC = 2780.7, BIC = 2828.3, deviance = 2762.7, df.resid = 1454

Variable	Coefficient (b)	Standard error	z-value	p-value
Public health implementation	3.110e-02	1.712e-01	0.182	0.856
year	5.279e-02	2.027e-02	2.604	0.009
mean slope	-6.697e-01	2.678e-01	-2.501	0.012
population density	-5.367e+02	2.213e+02	-2.425	0.015
pig density	-1.175e+04	5.941e+03	-1.978	0.048

Final model of generalized linear mixed models of human leptospirosis incidence by treated month and subdistrict as random effects.

AIC = 2746.5, BIC = 2746.5, deviance = 2560.5, df.resid = 1503

Variable	Coefficient (b)	Standard error	z-value	p-value
month2	-5.171e-01	2.992e-01	- 1.728	0.08394
month3	4.745e-01	2.541e-01	1.867	0.06186
month4	5.402e-02	2.731e-01	0.198	0.84318
month5	5.638e-02	2.847e-01	0.198	0.84298
month6	3.539e-01	2.700e-01	1.311	0.18994
month7	1.048e+00	2.242e-01	4.673	2.97e-06
month8	1.174e+00	2.404e-01	4.882	1.05e-06
month9	1.362e+00	2.140e-01	6.361	2.01e-10
month10	1.662e+00	2.208e-01	7.524	5.31e-14
month11	8.921e-01	2.259e-01	3.949	7.86e-05
month12	1.949e-01	2.789e-01	0.699	0.48465
mean slope	-7.294e-01	2.627e-01	-2.777	0.00549
population density	-4.995e+02	2.088e+02	-2.392	0.01678
pig density	-1.197e+04	6.136e+03	-1.950	0.05114

Chapter 4

Knowledge, attitudes and practices of patients, neighbors, village health volunteers and community leaders of leptospirosis prevention and control in Mahasarakham Province, Thailand

Parts of this chapter are in press in the Southeast Asian Journal of Tropical Medicine and Public Health under the name "Knowledge and Practices of Leptospirosis Patients, Their Neighbors, Village Health Volunteers and Community Leaders Regarding Leptospirosis Prevention and Control in Mahasarakham Province, Thailand" (see annex).

Summary

Outbreaks of leptospirosis in Mahasarakham Province are still a major health issue. Although the Ministry of public health and Mahasarakham Provincial Public Health Office developed and implemented leptospirosis prevention by increasing cooperation with the community, they lack awareness about the potential and ability of people within the community. The understanding of individual knowledge, attitude and practices (KAP) is important to better implement disease control and public health development.

A cross-sectional study was conducted to assess knowledge attitude and practice of patients, neighbors, village health volunteers and community leaders in leptospirosis prevention and control of Mahasarakham Province, Thailand. Data were collected by structured interviews from 167 patients, 325 neighbors of patients, 480 village health volunteers and 320 community leaders. Initial structured interviews were given to three public health experts for quality assessment and the reliability of the structured interviews was assessed using 30 interviews of each group. The Cronbach's Alpha coefficient of those interviews is more than 0.70. The structured interviews contained four sections: socio-demography, knowledge, attitude and practice. ANOVA, independent samples t-test, Tukey HSD and Chi-square test were used to compare knowledge, attitude and practice. Moreover, odd ratio was used to measure the association between variables.

The result found that most of the patients and community leaders were male (78.4% and 78.8%) but most of the neighbors and village health volunteers were female (66.5% and 77.1%). The majority of people sampled was between 41 and 60 years old. There were significant differences regarding the total knowledge of every group ($P < 0.001$).

Knowledge of patients was not significantly different from neighbors' knowledge. The community leaders group had a higher knowledge score than other groups. Every group had low knowledge level about leptospirosis in animals. Only 29.8% of patients, 34.0% of neighbors, 57.5% of village health volunteers and 52.2% of community leaders knew that chicken, dogs, cats and cattle could suffer from leptospirosis. There were significant differences of total attitude ($P < 0.001$). The majority of patients, neighbors and community leaders have an acceptable attitude but the majority of village health volunteers have an unacceptable attitude. The majority of patients and neighbors believed that only farmers must be concerned by leptospirosis at 52.7% and 48.6% respectively. 68.9% of the patients and 57.8% of the neighbors agree that *Leptospira* may be found in their community but only 21.5% of village health volunteers and 21.6% of community leaders agree. There were significant differences in the practice of patients and neighbors ($P < 0.001$). Neighbors have better practice than patients. The patients did not paddle or fish when they had wounds on the body (26.3%). The neighbors did not paddle or fish when they had wounds on the body (46.2%). The majority of village health volunteers did leptospirosis surveillance in the community (96.5%). However, only 74.8% of them collected data regarding cattle and pigs that died from leptospirosis and reported this information to the health center. Community leaders supported people by providing garbage disposal in the community at 99.4%. However, only 63.8% participated in meeting of summary the result of leptospirosis prevention and monitoring of community. There were significant differences regarding the knowledge and practice of village health volunteers in high and low incidence area groups. Village health volunteers in high incidence area have better knowledge than in low incidence area (OR = 1.84). Moreover, village health volunteers in high incidence area have less acceptable practice than in low incidence area (OR = 0.44). In addition, there were significant differences regarding the attitude of community leaders in high and low incidence area groups. Community leaders in high incidence areas have a more acceptable attitude than in low incidence area (OR = 2.00).

The majority of interviewed people did not follow leptospirosis prevention practices. They need better support given by scientific knowledge and improved awareness of leptospirosis risk from health scientists and practitioners. Moreover, leptospirosis prevention and control should integrate community engagement and involve local government in accordance with One Health approach.

Introduction

Leptospirosis is a zoonotic disease which is caused by spirochete species of the genus *Leptospira* (Bharti et al., 2003; Levett, 2001). Leptospires share features of both Gram-positive and Gram-negative bacteria that are highly motile, obligate aerobic spirochetes and live within diverse environments, animal hosts and freely in the environment (Bharti et al., 2003). Every year, more than 14.8 people per 100,000 suffer from leptospirosis (Costa et al., 2015). Leptospirosis patients can develop a more severe disease characterized by hepatic, renal or pulmonary dysfunction, or hemorrhagic manifestations which can be a cause of mortality (Guerra, 2013; World Health Organization, 2003). Leptospirosis is considered as the most widespread zoonosis in the world (World Health Organization, 2007).

High human leptospirosis incidence occurs in tropical environments where conditions may favor the development of leptospires in the environment (Pappas et al., 2008; Victoriano et al., 2009). Exposure to virulent leptospires may be direct, via contact with urine or tissues from infected animals, or indirect, via water contaminated with infected animal urine. Numerous animal species can act as reservoirs, but wild rodents are usually considered to be the main reservoirs for human leptospirosis, although several studies challenged the epidemiological importance of rodents (Biscornet et al., 2017; Della Rossa et al., 2016). Moreover leptospirosis incidence relates to socio-economic factors (e.g. poverty) and environmental factors, including climatic factors or flooding event. Animal reservoirs contributed to the disease incidence and infection risk (Morand et al., 2018).

The understanding of individual knowledge, attitude and practices (KAP) is important to better implement disease control and public health development (U.S. Department of Health and Human Services et al., 2005). KAP study can identify knowledge gaps, behavioral patterns that may facilitate understanding and action, as well as identifying problems that create barriers for prevention and disease control (World Health Organization, 2008). Moreover, such study may compare different groups of people that have different ways to interact with a disease, such as patients, lay people, health volunteers or community leaders. For example, studies are investigating KAP of leptospirosis among people community (Kamsopa, 2014) to identify risks factors that could be taken into account for the prevention and control of leptospirosis. Here, we performed a comparable study in a province of Thailand.

Thailand is located in the tropical zone with important soil moisture in some parts, a tropical climate with high rainfall. Over than 70,000 cases of leptospirosis were recorded in Thailand since its emergence in the 2000s (Morand et al., 2018). Leptospirosis incidence in Thailand shows a strong seasonality with a high incidence during the rainy season (Hinjoy, 2014) and outbreaks of leptospirosis are often reported after flooding events (Amilasan et al., 2012; Dechet et al., 2012; Lau, Smythe, and Weinstein, 2010).

Domestic animals such as cattle, pigs, dogs, cats are significantly associated with human leptospirosis infection (Sugunan et al., 2009; World Health Organization, 2003). A recent study of Chadsuthi et al. 2017 showed a clear statistical association between human incidence and the prevalence of *Leptospira serovars* in livestock. *Shermani serovar* is a cross infection in cattle to humans (Chadsuthi et al., 2017). Knowledge of risk in animals should be a special concern to consider when a majority of people have numerous domestic animals and livestock.

Mahasarakham Province is located in the North East of Thailand with a high leptospirosis incidence. For more than two decades, the Ministry of Public Health and Mahasarakham Provincial Public Health Office established and developed the implementation of leptospirosis prevention and control policy (Mahasarakham Provincial Public Health Office, 2000). Outbreaks of leptospirosis in Mahasarakham Province, Thailand are still a major health issue. Although the Ministry of public health and Mahasarakham Provincial Public Health Office developed and implemented leptospirosis prevention by increasing cooperation with the community, they lack awareness about the potential and ability of people within the community.

Community leaders and village health volunteers got a more important role in prevention and control disease after decentralization in the health sector in 1999 (Wibulpolprasert et al., 2007). They are participating in disease surveillance and they follow the implementation of the disease prevention and control policy in the community (Department of Disease Control, 2016). Moreover, they are close to people in the community, which allow them to encourage the effectiveness of disease detection and control. Community leaders and village health volunteers are important persons to support, encourage and facilitate health practices in the local communities.

Then the study of knowledge, attitude and practice of people, village health volunteers and community leaders is a first important step to get baseline information in the community for the development of an effective leptospirosis prevention and control policy implementation, which is both sustainable and consistent and relevant with community needs.

MATERIALS AND METHODS

Research Design and Study Area

The research utilized a cross-sectional study design in Mahasarakham Province. This province is divided into 13 districts, 133 subdistricts and 1,982 villages, with a population of 869,280 individuals and 244,155 households in 2016 (Mahasarakham Provincial Public Health Office, 2016) as shown in Figure1. Most citizens are living from agriculture 43.9% (Mahasarakham Provincial Labor Office, 2017). During 2004 to 2014, the total number of leptospirosis cases recorded reached 762.

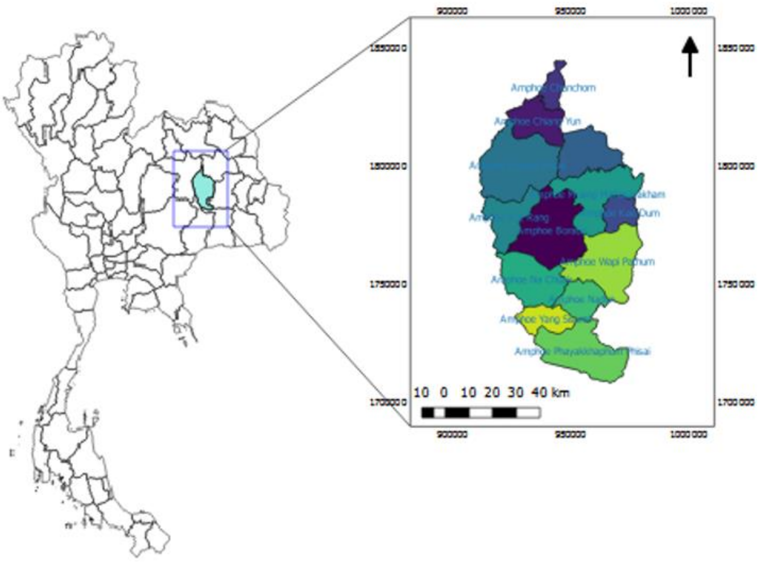


Figure 1. Map showing Mahasarakham province in Thailand, with its13 districts.

Sampling procedure and sample size

This research collected data in four sample groups including patients, neighbors, village health volunteers and community leaders were shown in Table 2.

Patients were the Mahasarakham people who got sick from leptospirosis during 2004 to 2014. They were clinically diagnosed in hospitals, and only patients with severe symptoms were laboratory confirmed for leptospirosis. Those leptospirosis cases were reported in the epidemic database of public health departments of Mahasarakham Province. During the period 2004 – 2014, leptospirosis cases were recorded in 127 subdistricts from a total of 133 subdistricts in the province. We conducted interviews in every subdistrict which has reported at least one leptospirosis case. Only one patient was selected randomly for interviews when leptospirosis incidence was less than five cases. When leptospirosis incidence was higher than five cases, then two patients were selected randomly for interviews. A total of 167 patients were interviewed in the 127 subdistricts presenting leptospirosis cases.

Neighbors were selected from closest households of reported patients. We interviewed two neighbors for each patient, with nearly the same age and occupation as the patient.

The sampling strategy for interviews of community leaders was as follows. We selected the subdistrict with the highest leptospirosis incidence for each of the 13 districts of the province. The selected subdistricts comprised 160 villages. We then selected community leaders of every village for interviews. Community leaders are village leaders (i.e. head of the village) and members of the subdistrict administration. Village leaders are elected by the villagers. They have duties in the governance of the village, such as supporting, encouraging and facilitating the activities of the different government agencies (public health, veterinary health, agriculture, etc.) (Thailand, 1914). Members of the subdistrict administration are elected by villagers. They have a role in the governance of the subdistrict (such as approval of the budget) (Thailand, 1999). For each village, we interviewed the village leader and one member of the subdistrict administration. We did a total of 320 interviews with the village leader and one member of the subdistrict administration for the 160 villages belonging to the 13 subdistricts.

We selected village health volunteers for interviews at the level of the 13 subdistricts (as above previously selected). The number of health volunteers depends on the population size of each district. We selected 480 health volunteers from a total of 1,495 health volunteers in the 13 subdistricts using sample size with continuous data procedures (Cochran, 2007). Village health volunteers assist the village leaders and the communities in health development. Village health volunteers were trained for a total of 45 hours in primary health care, public health system, laws related to village health volunteers, communication, planning and projects, management and community resolutions. In 2014, they got a performance compensation of 600 Baht per month, medical expenses help from the government and quotas for study in educational institution depending of the Ministry of Public Health (Department of Health Service Support, 2011). Village health volunteers have a role in the implementation of the policy of the Ministry of Public Health. They are involved in prevention and health promotion activities, development of appropriate health behaviors and coordinated health activities between government agencies and local communities (Thailand, 2001) as shown in Table 1.

Table 1. Distribution of surveys and sampling method of 4 sample groups.

Group of population	**Number of people interviewed**	**Sampling**
Community leaders	320	Stratified sampling of each village belonging to the subdistrict with the highest leptospirosis cases in each of the 13 districts of the province.
Village health volunteers	480	Stratified sampling in each subdistrict with the highest leptospirosis incidence
Patients	167	One or two patients from all subdistricts with leptospirosis cases, with lottery sampling when incidence is higher than two cases
Neighbors	325	Purposively selected, from households in the vicinity of each interviewed patient
Total	1,292	

Survey Instrument

Initial structured interviews were given to three public health experts for quality assessment. These public health experts, public health lecturers and the public health officer are responsible in leptospirosis prevention and control of Mahasarakham Provincial Public Health Office.

The structured interviews contained four sections: socio-demography, knowledge, attitude and practice. The sociodemographic section was composed of questions concerning age, gender, profession, education, animals.

The knowledge section comprised 42 questions which cover origin of disease, ways of transmission, symptoms of the disease, prevention of infection and leptospirosis in animals. Answers to each question was categorized as 'correct', 'wrong' and 'do not know'. A score of 1 was given for the correct answer and 0 for the wrong and do not know answers. Participants with knowledge score higher than 60% of the maximum total scores were defined as having a good knowledge (respectively those with knowledge score lower than 60% were defined as having a low knowledge) following the classification of Nozmi et al. (2018).

The attitude section comprised 13 questions which cover leptospirosis risk, leptospirosis prevention, leptospirosis reservoirs and leptospirosis dangerousness. The attitude answered using a Likert scale which 3, 2 and 1 corresponded to 'completely agree', 'mostly agree' and 'slightly agree'. As for the negative statements, the scales were reversely arranged and recorded. Participants with attitude scores higher than 80% of the maximum total scores were defined as having an acceptable attitude (respectively those with attitude score lower than 80% were defined as having an unacceptable attitude following the classification of Nozmi et al. (2018).

The last section comprised different questions related to practice. These questions differed among groups according to their role and responsibility in prevention and control of leptospirosis. In patients and neighbors, 12 questions which answer as usually, sometimes and never practice were collected and scored as 3, 2 and 1 respectively. Moreover, 18 and 11 questions were asked respectively to village health volunteers and community leaders: they had the choice to answer 'do' and 'do not', scored respectively as 1 and 0. Participants with practice scores higher than 80% of the maximum total scores were defined as having an acceptable practice (respectively those with practice score lower than 80% were defined as having an unacceptable practice following the classification of Nozmi, et al. (2018).

The reliability of the structured interviews was assessed using 30 interviews of each group which involved village health volunteers, community leaders and members of the neighboring of Kalasin Province. For that, we used the Cronbach's Alpha which measures consistency between different items of the same construct. If items have internal consistency, the respondents rate them in a similar manner (Bhattacherjee, 2012). Those interviewed have high reliability. The Cronbach's Alpha coefficient of those interviews were shown in table 2.

Table 2. The Cronbach's Alpha coefficient of interviews (30 people from Kalasin Province).

Reliability	**Interviews**		
	Community members	**Village health volunteers**	**community leaders**
knowledge	0.86	0.75	0.83
attitude	0.75	0.81	0.78
practice	0.70	0.93	0.89

Leptospirosis incidence

Leptospirosis incidence rate was computed by district between 2004 and 2014. The mean leptospirosis incidence per district is 0.00075 cases per total people. We grouped the 13 districts into two groups, the ones with high incidence and the other ones with low incidence, using the mean leptospirosis incidence per district as cutting point.

Ethical statement

Approval notices for interviews were given by the Ethics Committee of Public Health of the Mahasarakham Province (Institutional Review Board) reference number 5/2558, delivered on 20 April 2015.

Data processing and statistical Analysis

Data processing entailed editing of the accomplished data collection forms, coding, encoding. All statistical analyses were carried out using the R statistical programming language (R Core Team, 2018), statistical tests were two-sided and P-values with less than 0.05 were considered statistically significant. ANOVA, independent-samples t-test, Tukey HSD and Chi-square test were used to compare knowledge, attitude and practice. Moreover, odd ratio was used to measure the association between variables.

RESULTS

Socio-demographic characteristics or Demographic characteristics of respondents

Most of patients and community leaders are male (78.4% and 78.8%) but most of the neighbors and village health volunteers are female (66.5% and 77.1%). The majority of people sampled was between 41 and 60 years old. Community leaders had higher education (with 46.6 % that had completed high school) than patients, neighbors and village health volunteers who had completed elementary school (79.6%, 78.2% and 44.2% respectively). About 70% of people in each group fed animals. 24% of the patients had a family member suffering from leptospirosis which is more than other groups as shown in Table 3.

Table 3. Socio-demographic characteristics of interviewees in Mahasarakham Province (n = 1,292).

General questions	**Patients n (%)**	**Neighbors n (%)**	**Village health volunteers n (%)**	**Community leaders n (%)**
Gender				
male	131 (78.4)	109 (33.5)	110 (22.9)	252 (78.8)
female	36 (21.6)	216 (66.5)	370 (77.1)	68 (21.2)
Age (years)				
15-20	4 (2.4)	1 (0.3)	-	-
21 - 40	21 (12.6)	36 (11.1)	117 (24.4)	44 (13.7)
41 - 60	93 (55.7)	196 (60.3)	323 (67.3)	254 (79.4)

General questions	Patients n (%)	Neighbors n (%)	Village health volunteers n (%)	Community leaders n (%)
> 60	49 (29.3)	92 (28.3)	40 (8.3)	22 (6.9)
Mean(SD)	53.6 (14.0)	53.4 (12.4)	47.1 (9.2)	49.7 (7.9)
Education level				
No education	1 (0.6)	3 (0.9)	6 (1.3)	-
Elementary	133 (79.6)	254 (78.2)	212 (44.2)	53 (16.5)
Secondary	18 (10.8)	17 (5.2)	120 (25.0)	86 (26.9)
High school	12 (7.2)	42 (12.9)	129 (26.9)	149 (46.6)
Bachelor's degree	3 (1.8)	9 (2.8)	12 (2.6)	32 (10.0)
Animals in the household				
No	39 (23.4)	97 (29.8)	121 (25.2)	86 (26.9)
Yes	128 (76.6)	228 (70.2)	359 (74.8)	234 (73.1)
Family member who got leptospirosis				
Yes	40 (24.0)	16 (4.9)	40 (8.3)	19 (5.9)
No	127 (76.0)	309 (95.1)	440 (91.7)	301 (94.1)

Knowledge

Knowledge questions were about the origin of the disease, way of transmission, symptoms of the disease, prevention of infection and leptospirosis in animals (Table 4).

The community leaders group has a higher knowledge score than other groups. Every group has low knowledge level about leptospirosis in animals. Only 29.8% of patients, 34.0% of neighbors, 57.5% of village health volunteers and 52.2% of community leaders who knew that chicken, dogs, cats and cattle could suffer from leptospirosis. Moreover, they know less about leptospirosis symptoms while 66.5% of patients, 65.5% of neighbors, 80.2% of village health volunteers and 68.5% of community leaders can answer correctly in leptospirosis symptoms. Less than 24% of every group know that severe leptospirosis does not affect the heart. In addition, less than 56% of neighbors and patients know that symptoms of *Leptospira* show about 10 days after exposure. Similarly, about 70% of every group has correct knowledge about the origin of leptospirosis disease. Only about 30% of every group know that *Leptospira* cannot be found in saliva of animals. About 30% of patients and neighbors know that cattle can carry the leptospirosis disease. Less than 36% of each group know that human can get infected from leptospirosis during the dry season.

However, every group has high knowledge about leptospirosis transmission. About 90% of every group know that they can get leptospirosis in rice fields and get infected from leptospirosis in rainy season. Moreover, about 95% of every group answered correctly about the fact that rubber boots can protect humans from leptospirosis.

Table 4. The knowledge of interviewees of causes, ways of contraction, symptoms, prevention and risk in animals of leptospirosis in Mahasarakham province with correct answers (n = 1,292).

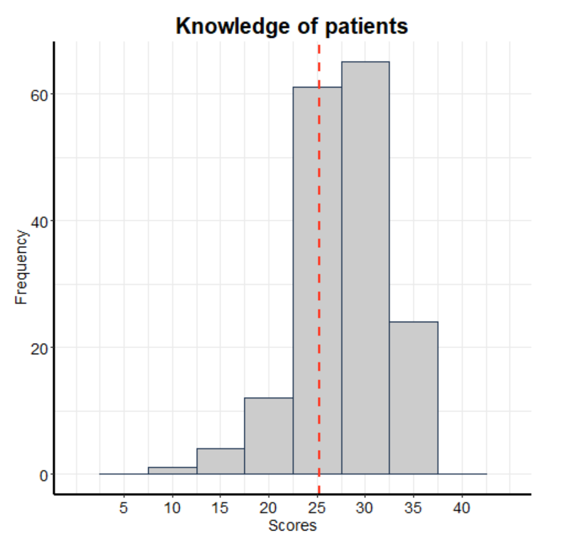
Question	**Correct answer n (%)**			
	Patients	**Neighbors**	**Village health volunteers**	**Community leaders**
Origin of disease	**58.1%**	**60.0%**	**78.4%**	**70.8%**
Leptospira cannot be found in saliva of animals.	49 (29.3)	86 (26.5)	180 (37.5)	113 (35.3)
Leptospira can be found in animal urine.	118 (70.7)	255 (78.5)	431 (89.8)	289 (90.3)
Leptospira can live in water for 6 months.	60 (35.9)	146 (44.9)	271 (56.5)	198 (61.9)
Cattles can carry *Leptospira*.	51 (30.5)	123 (37.8)	265 (55.2)	207 (64.7)
Mosquitoes cannot carry the *Leptospira*.	108 (64.7)	206 (63.4)	333 (69.4)	252 (78.8)
Leptospira can be transmitted from animals to humans.	149 (89.2)	287 (88.3)	424 (88.3)	300 (93.8)
Every occupation is risky regarding leptospirosis.	144 (86.2)	262 (80.6)	355 (74.0)	228 (71.3)
Way of transmission	**80.6%**	**80.1%**	**88.3%**	**75.9%**
People cannot contract *Leptospira* on foot cracks and heels.	133 (79.6)	252 (77.5)	389 (81.0)	273 (85.3)
If the pond has *Leptospira*, and people soaked a part of their body in the water for	141 (84.4)	284 (87.4)	403 (84.0)	282 (88.1)

Question	Correct answer n (%)			
	Patients	**Neighbors**	**Village health volunteers**	**Community leaders**
a period of time, they contracted *Leptospira*.				
You can get leptospirosis from a pond.	155 (92.8)	299 (92.0)	378 (78.8)	260 (81.3)
You can get leptospirosis from the river.	148 (88.6)	289 (88.9)	376 (78.3)	251 (78.4)
You can get leptospirosis from rice fields.	165 (98.8)	312 (96.0)	426 (88.8)	303 (94.7)
You can get leptospirosis from the forest.	150 (89.8)	276 (84.9)	349 (72.7)	208 (65.0)
You can get leptospirosis from the house.	123 (73.7)	233 (71.7)	328 (68.3)	206 (64.4)
You can get leptospirosis from flooded lands.	145 (86.8)	294 (90.5)	415 (86.5)	300 (93.8)
You can get infected in dry season.	60 (35.9)	117 (36.0)	125 (26.0)	88 (27.5)
You can get infected in rainy season.	156 (93.4)	306 (94.2)	441 (91.9)	311 (97.2)
You can get infected in winter season.	104 (62.3)	201 (61.8)	309 (64.4)	188 (58.8)
Symptoms of the disease	**66.5%**	**65.5%**	**80.2%**	**68.5%**
Symptoms of leptospirosis show about 10 days after exposure.	87 (52.1)	179 (55.1)	320 (66.7)	251 (78.4)
The major symptoms of leptospirosis are high fever, headache and muscle pain.	165 (98.8)	302 (92.9)	415 (86.5)	281 (87.8)
Severe leptospirosis does not affect the heart.	28 (16.8)	58 (17.8)	112 (23.3)	64 (20.0)
Severe leptospirosis does affect the liver.	101 (60.5)	181 (55.7)	302 (62.9)	191 (59.7)
Severe leptospirosis does affect the kidney.	119 (71.3)	213 (65.5)	284 (59.2)	189 (59.1)
Patients can contract the disease more than once.	118 (70.7)	253 (77.8)	410 (85.4)	255 (79.7)
Late received treatment may cause death from leptospirosis.	160 (95.8)	304 (93.5)	446 (92.9)	304 (95.0)
Prevention of infection	**70.5%**	**68.6%**	**82.7%**	**72.4%**
You cannot protect yourself from a patient	107 (64.1)	187 (57.5)	337 (70.2)	230 (71.9)

Question	Correct answer n (%)			
	Patients	Neighbors	Village health volunteers	Community leaders
with leptospirosis by avoiding talking with the patient.				
You cannot protect yourself from a patient with leptospirosis by avoiding contact with the patient body.	99 (59.3)	177 (54.5)	273 (56.9)	205 (64.1)
You can protect yourself from a patient with leptospirosis by avoiding contact with the patient blood and saliva.	72 (43.1)	154 (47.4)	259 (54.0)	135 (42.2)
House cleaning can prevent the spread of leptospirosis.	147 (88.0)	272 (83.7)	382 (79.6)	263 (82.2)
The spread of leptospirosis cannot be prevented by giving medication to animals.	27 (16.2)	69 (21.2)	167 (34.8)	98 (30.6)
Eating fresh vegetable from the pond can increase risk contact to *Leptospira*.	135 (80.8)	256 (78.8)	369 (76.9)	235 (73.4)
Drinking water from the pond can increase risk contact to *Leptospira*.	144 (86.2)	278 (85.5)	392 (81.7)	256 (80.0)
Mask cannot protect you from leptospirosis.	74 (44.3)	135 (41.5)	274 (57.1)	202 (63.1)
Rubber boots can protect you from leptospirosis.	159 (95.2)	311 (95.7)	456 (95.0)	307 (95.9)
Checking boots for leaks before wearing can protect you from leptospirosis.	156 (93.4)	288 (88.6)	438 (91.3)	298 (93.1)
Leptospirosis spread in rainy season to winter.	153 (91.6)	287 (88.3)	343 (71.5)	293 (91.6)
Farmers can protect themselves from leptospirosis by controlling the rat population.	139 (83.2)	261 (80.3)	384 (80.0)	257 (80.3)
Leptospirosis in animals	**33. 9%**	**38.4%**	**63.9%**	**58.3%**
Rats can suffer from leptospirosis.	84 (50.3)	182 (56.0)	358 (74.6)	264 (82.5)

Question	Correct answer n (%)			
	Patients	**Neighbors**	**Village health volunteers**	**Community leaders**
Chicken can suffer from leptospirosis.	47 (28.1)	99 (30.5)	194 (40.4)	120 (37.5)
Dogs can suffer from leptospirosis.	49 (29.3)	107 (32.9)	221 (46.0)	163 (50.9)
Cats can suffer from leptospirosis.	49 (29.3)	107 (32.9)	214 (44.6)	164 (51.3)
Cattle can suffer from leptospirosis.	54 (32.3)	129 (39.7)	313 (65.2)	221 (69.1)

There were significant differences regarding the total knowledge of every group ($P < 0.001$). Knowledge of patients was not significantly different from neighbors' knowledge but significantly lower than community leaders' knowledge, as shown in Figure 2.



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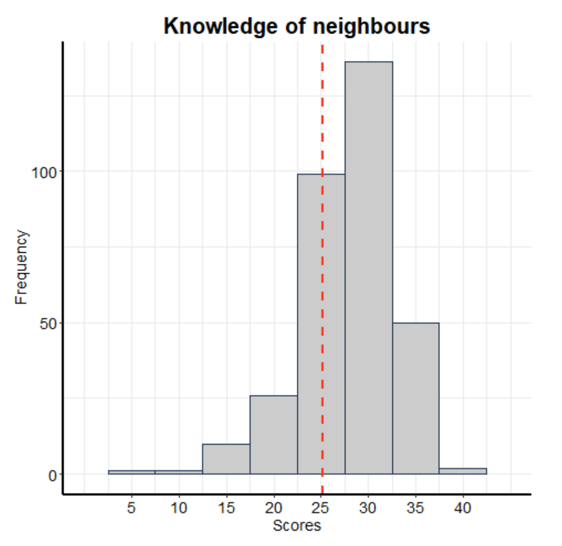

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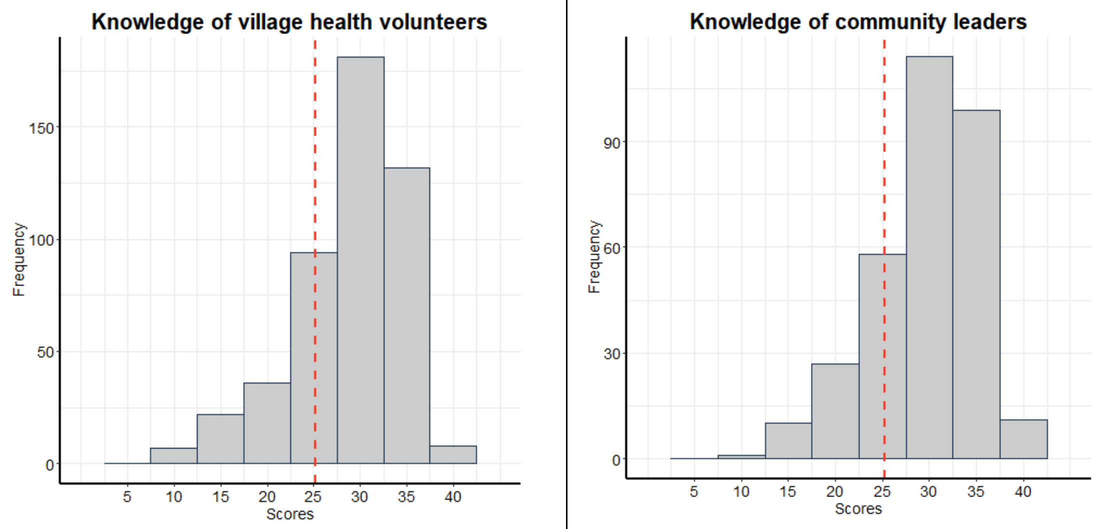


2C 2D

Figure 2 Level of leptospirosis knowledge of (2A) patients (n = 167), (2B) neighbors (n = 325), (2C) village health volunteers and (n = 480), (2D) community leaders in Mahasarakham Province (n = 320). Scores represent the correct responses regarding knowledge of leptospirosis (see Material and Methods) (cutting at 60% is represented by the dashed red lines) comparison among groups: Anova: F-value = 8.969, $P < 0.001$). Leptospirosis knowledge of community leaders significantly higher than patients ($P < 0.001$). Leptospirosis knowledge of neighbors significantly higher than village health volunteers ($P = 0.018$) and community leaders ($P < 0.001$).

The total of leptospirosis knowledge of patients, neighbors, community leaders and village health volunteers were significantly different. Moreover, there were significant differences in leptospirosis knowledge of origin of leptospirosis, way of transmission and leptospirosis in animals as shown in Table 5.

Table 5. Comparison in knowledge about leptospirosis in patients, neighbors, village health volunteers and community leaders in Mahasarakham Province using Chi-square test.

Knowledge	Patients		Neighbors		Village health volunteers		Community leaders		Chi-square (p-value)
	n	%	n	%	n	%	n	%	
Origin of disease									93.32 (< 0.001)
good	61	36.5	128	39.4	301	62.7	222	69.4	
low	106	63.5	197	60.6	179	37.3	98	30.6	
Way of transmission									25.616 (< 0.001)
good	155	92.8	296	91.1	393	81.8	259	80.9	
low	12	7.2	29	8.9	87	18.2	61	19.1	
Symptoms of the disease									3.068 (0.381)
good	105	62.9	183	56.3	293	61.0	198	61.9	
low	62	37.1	142	43.7	187	39.0	122	38.1	
Prevention of infection									7.222 (0.065)
good	127	76.1	235	72.3	367	76.5	260	81.3	
low	40	23.9	90	27.7	113	23.5	60	18.7	
Leptospirosis in animals									50.238 (< 0.001)
good	40	23.9	84	25.9	186	38.8	157	49.1	
low	127	76.1	241	74.1	294	61.2	163	50.9	
Total knowledge									8.454 (0.038)
good	121	72.5	230	70.7	378	78.8	249	77.8	
low	46	27.5	95	29.3	102	21.2	71	22.2	

Attitude

Attitude questions were about leptospirosis risk, leptospirosis prevention, leptospirosis reservoirs and leptospirosis dangerousness (Table 6).

Questions concerning attitude regarding leptospirosis risk found that majority of patients and neighbors believed that only farmers must be concerned by leptospirosis at 52.7% and 48.6% respectively. 68.9% of the patients and 57.8% of the neighbors agree with that *Leptospira* may be found in their community but only 21.5% of village health volunteers and 21.6% of community leaders agree. The answer to each section is detailed here after.

Attitude regarding leptospirosis prevention: the answers show that most groups agree that eating cooked food can prevent leptospirosis. More than 70% in every group agree that wearing boots can prevent from leptospirosis and taking a bath or body wash immediately after walking through water and mud can prevent leptospirosis. However, less than 55% in every group agrees that wearing pants and long sleeves can protect against leptospirosis.

Attitude regarding leptospirosis reservoirs: 53.3% of patients, 56.9% of neighbors and 50.6% of leaded community agree that rats in the house can carry leptospirosis. Moreover, the majority of patients, neighbors and community leaders agrees that leptospirosis prevention is not complicated because they think they can eradicate rats, but only 22.3% of village health volunteers agree with that.

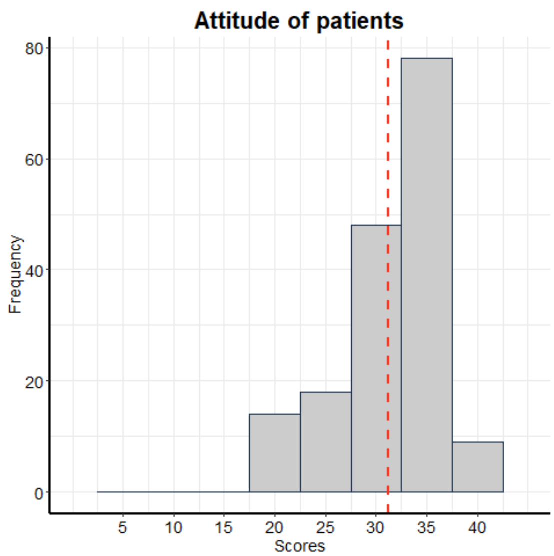
Attitude regarding leptospirosis dangerousness: the majority of every group agree that getting leptospirosis health education is useful and that leptospirosis is a dangerous disease which is a cause of death.

Table 6. The attitude of interviewees about risk, prevention, vectors and dangerousness of leptospirosis in Mahasarakham Province.

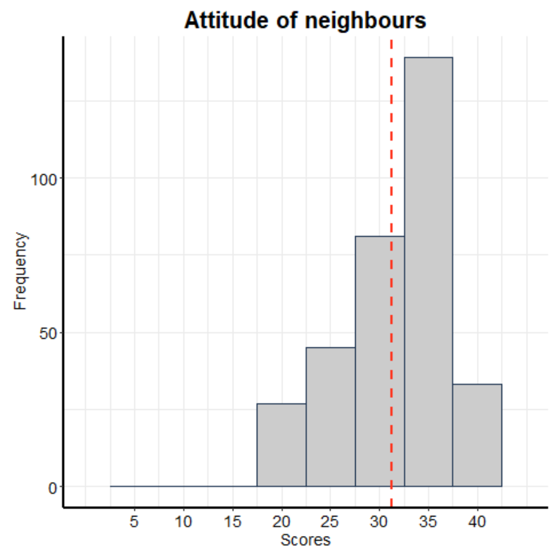
Attitude	Patients (n = 167)			Neighbors (n = 325)			Village health volunteers (n = 480)			Community leaders (n = 320)		
	Most	Medium	Least	Most	Medium	Least	Most	Medium	Least	Most	Medium	Least
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Leptospirosis risk												
Not only farmers must prevent against leptospirosis.	43 (25.7)	36 (21.6)	88 (52.7)	86 (26.5)	81 (24.9)	158 (48.6)	208 (43.3)	154 (32.1)	118 (24.6)	210 (65.6)	77 (24.1)	33 (10.3)
The people who have been farmers for a long time did not develop leptospirosis immunity.	82 (49.1)	33 (19.8)	52 (31.1)	160 (49.2)	86 (26.5)	79 (24.3)	232 (48.3)	167 (34.8)	81 (16.9)	222 (69.4)	71 (22.2)	27 (8.4)
Leptospira may be found in your community.	115 (68.9)	30 (18.0)	22 (13.1)	188 (57.8)	72 (22.2)	65 (20.0)	103 (21.5)	220 (45.8)	157 (32.7)	69 (21.6)	151 (47.2)	100 (31.2)
Using bared hands to shovel animal manure can cause leptospirosis.	95 (56.9)	39 (23.3)	33 (19.8)	191 (58.8)	71 (21.8)	63 (19.4)	176 (36.7)	184 (38.3)	120 (25.0)	147 (45.9)	119 (37.2)	54 (16.9)
Washing your hands in the pond can cause leptospirosis.	98 (58.7)	34 (20.3)	35 (21.0)	189 (58.2)	84 (25.8)	52 (16.0)	185 (38.5)	173 (36.1)	122 (25.4)	152 (47.5)	115 (35.9)	53 (16.6)
Leptospirosis prevention												
Eating cooked food can prevent leptospirosis.	146 (87.4)	15 (9.0)	6 (3.6)	279 (85.8)	33 (10.2)	13 (4.0)	332 (69.2)	107 (22.3)	41 (8.5)	204 (63.8)	92 (28.8)	24 (7.4)

Attitude	Patients (n = 167)			Neighbors (n = 325)			Village health volunteers (n = 480)			Community leaders (n = 320)		
	Most	**Medium**	**Least**	**Most**	**Medium**	**Least**	**Most**	**Medium**	**Least**	**Most**	**Medium**	**Least**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Wearing boots can prevent from leptospirosis.	121 (72.5)	29 (17.3)	17 (10.2)	237 (72.9)	58 (17.9)	30 (9.2)	372 (77.5)	88 (18.3)	20 (4.2)	284 (88.8)	33 (10.3)	3 (0.9)
Wearing pants and long sleeves can protect against leptospirosis.	77 (46.1)	42 (25.2)	48 (28.7)	143 (44.0)	104 (32.0)	78 (24.0)	165 (34.4)	191 (39.8)	124 (25.8)	175 (54.7)	100 (31.2)	45 (14.1)
Taking a bath or body wash immediately after walking through water and mud can prevent leptospirosis.	138 (82.6)	23 (13.8)	6 (3.6)	259 (79.7)	55 (16.9)	11 (3.4)	356 (74.2)	97 (20.2)	27 (5.6)	277 (86.6)	30 (9.3)	13 (4.1)
Leptospirosis reservoirs												
Rats in the house can carry leptospirosis.	89 (53.3)	35 (21.0)	43 (25.7)	185 (56.9)	81 (24.9)	59 (18.2)	196 (40.8)	180 (37.5)	104 (21.7)	162 (50.6)	73 (22.8)	85 (26.6)
Prevention leptospirosis is not complicated because we can eradicate rats.	106 (63.5)	34 (20.3)	27 (16.2)	184 (56.6)	90 (27.7)	51 (15.7)	107 (22.3)	236 (49.2)	137 (28.5)	143 (44.7)	143 (44.7)	34 (10.6)
Leptospirosis dangerousness												
Getting health education about leptospirosis is useful.	122 (73.1)	19 (11.4)	26 (15.5)	229 (70.5)	49 (15.0)	47 (14.5)	258 (53.8)	138 (28.7)	84 (17.5)	212 (66.3)	83 (25.9)	25 (7.8)
Leptospirosis is a dangerous disease which can cause of death.	128 (76.6)	24 (14.4)	15 (9.0)	247 (76.0)	45 (13.8)	33 (10.2)	368 (76.7)	88 (18.3)	24 (5.0)	265 (82.8)	43 (13.4)	12 (3.8)

There were significant differences of total attitude ($P < 0.001$). The majority of patients, neighbors and community leaders have an acceptable attitude but the majority of village health volunteers have an unacceptable attitude as shown in Figure 3.



3A



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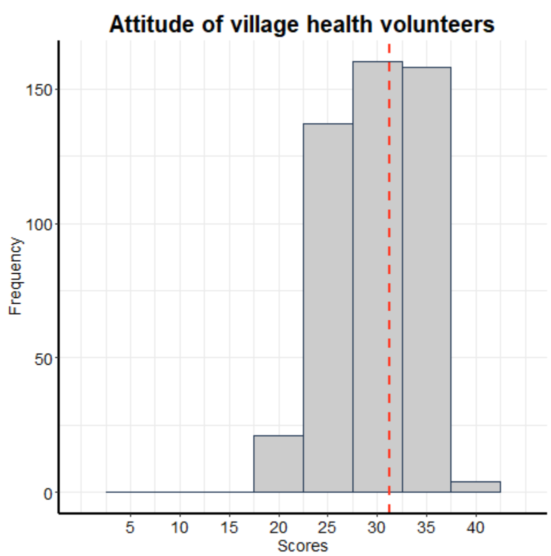

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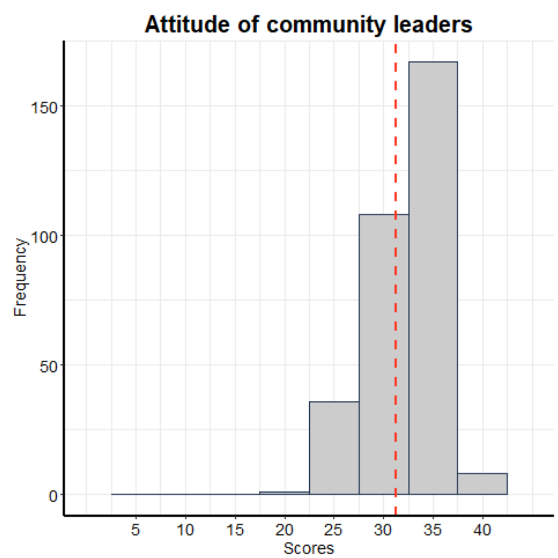

3D

Figure 3 Level of leptospirosis attitude of (3A) patients (n = 67), (3B) neighbors (n = 325), (3C) village health volunteers and (n = 480), (3D) community leaders in Mahasarakham Province (n = 320). Scores represent the responses regarding attitude in regard to leptospirosis (see Material and Methods) (cutting at 80% is represented by the dashed red lines) comparison among groups: Anova: F-value = 19.93, P < 0.001). Leptospirosis attitude of village health volunteers significantly lower than patients (P < 0.001), neighbors (P < 0.001) and community leaders (P < 0.001).

Leptospirosis attitudes, whether they concern attitude in leptospirosis risk, leptospirosis prevention, leptospirosis reservoirs and leptospirosis dangerousness were significantly different for each group as shown in Table 7.

Table 7. Comparison of attitudes regarding leptospirosis in patients, neighbors, village health volunteers and community leaders in Mahasarakham Province using Chi-square tests.

Attitude	**Patients (n = 167)**		**Neighbors (n = 325)**		**Village health volunteers (n = 480)**		**Community leaders (n = 320)**		**Chi-square (p_value)**
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	
Leptospirosis risk									9.7874 (0.021)
acceptable	57	34.1	122	37.5	143	29.8	127	39.7	
unacceptable	110	65.9	203	62.5	337	70.2	193	60.3	
Leptospirosis prevention									18.926 (< 0.001)
acceptable	125	74.9	245	75.4	343	71.5	271	84.7	
unacceptable	42	25.1	80	24.6	137	28.5	49	15.3	
Leptospirosis reservoirs									48.121 (< 0.001)
acceptable	95	56.9	190	58.5	177	36.9	175	54.7	
unacceptable	72	43.1	135	41.5	303	63.1	145	45.3	

Attitude	Patients (n = 167)		Neighbors (n = 325)		Village health volunteers (n = 480)		Community leaders (n = 320)		Chi-square (p_value)
	n	%	n	%	n	%	n	%	
Leptospirosis dangerousness									11.578 (0.009)
acceptable	125	74.9	241	74.2	334	69.6	257	80.3	
unacceptable	42	25.1	84	25.8	146	30.4	63	19.7	
Total attitude									34.711 (< 0.001)
acceptable	100	59.9	184	56.6	205	42.7	197	61.6	
unacceptable	67	40.1	141	43.4	275	57.3	123	38.4	

Practice

Regarding the patients, the majority of them usually washed their hand before having a meal (85.0%), cooked rats before eating them (79.6%) and cleaned fresh vegetables before consumption (74.3%). Only 26.3% did not paddle or fish when they had wounds on the body and only 27.5% wore boots when they worked in flooding area. 29.3% of them only wore boots when they went to the farm.

Similarly, neighbors usually washed their hand before having a meal (84%), cleaned fresh vegetables before consumption (82.5%) and kept clean the work area (76.6%). 33.5 % did not keep the waste on the ground beside your house and 46.2% did not paddle or fish when they had wounds on the body. 48% of them did not walk barefoot on earthen dykes as shown in Table 8.

Table 8. Practice about prevention and control of leptospirosis disease in patients and neighbors.

Practice	Patients (n = 167)			Neighbors (n = 325)		
	Usually	**Sometimes**	**Never**	**Usually**	**Sometimes**	**Never**
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
You washed your hands before having meal.	142 (85.0)	19 (11.4)	6 (3.6)	273 (84.0)	49 (15.1)	3 (0.9)
You cooked rat before eating them.	133 (79.6)	15 (9.0)	19 (11.4)	235 (72.3)	37 (11.4)	53 (16.3)
You cleaned fresh vegetables before consumption.	124 (74.3)	27 (16.1)	16 (9.6)	268 (82.5)	33 (10.1)	24 (7.4)
You kept clean the work area.	104 (62.3)	60 (35.9)	3 (1.8)	249 (76.6)	71 (21.9)	5 (1.5)
You controlled rats population in your house.	93 (55.7)	67 (40.1)	7 (4.2)	192 (59.1)	107 (32.9)	26 (8.0)
You did not have overnight food which was not kept in a hermetically closed container.	76 (45.5)	67 (40.1)	24 (14.4)	218 (67.1)	79 (24.3)	28 (8.6)
You took a bath immediately after coming out from the pond.	65 (38.9)	75 (44.9)	27 (16.2)	183 (56.3)	112 (34.5)	30 (9.2)
You checked boot leaks before wearing them.	61 (36.5)	66 (39.5)	40 (24.0)	176 (54.2)	97 (29.8)	52 (16.0)
You did not keep the waste on the ground beside your house.	53 (31.8)	50 (29.9)	64 (38.3)	109 (33.5)	84 (25.9)	132 (40.6)
You did not walk barefoot on earthen dykes.	52 (31.1)	76 (45.5)	39 (23.4)	156 (48.0)	118 (36.3)	51 (15.7)
You wore boots when you went to the farm.	49 (29.3)	77 (46.1)	41 (24.6)	169 (52.0)	120 (36.9)	36 (11.1)
You wore boots when you work in flooding area.	46 (27.5)	78 (46.8)	43 (25.7)	170 (52.3)	116 (35.7)	39 (12.0)

Practice	Patients (n = 167)			Neighbors (n = 325)		
	Usually	Sometimes	Never	Usually	Sometimes	Never
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
You did not paddle or fish when you had wounds on the body.	44 (26.3)	87 (52.1)	36 (21.6)	150 (46.2)	129 (39.6)	46 (14.2)

Neighbors had better practice than patients (P < 0.001), as shown in Figure 4.

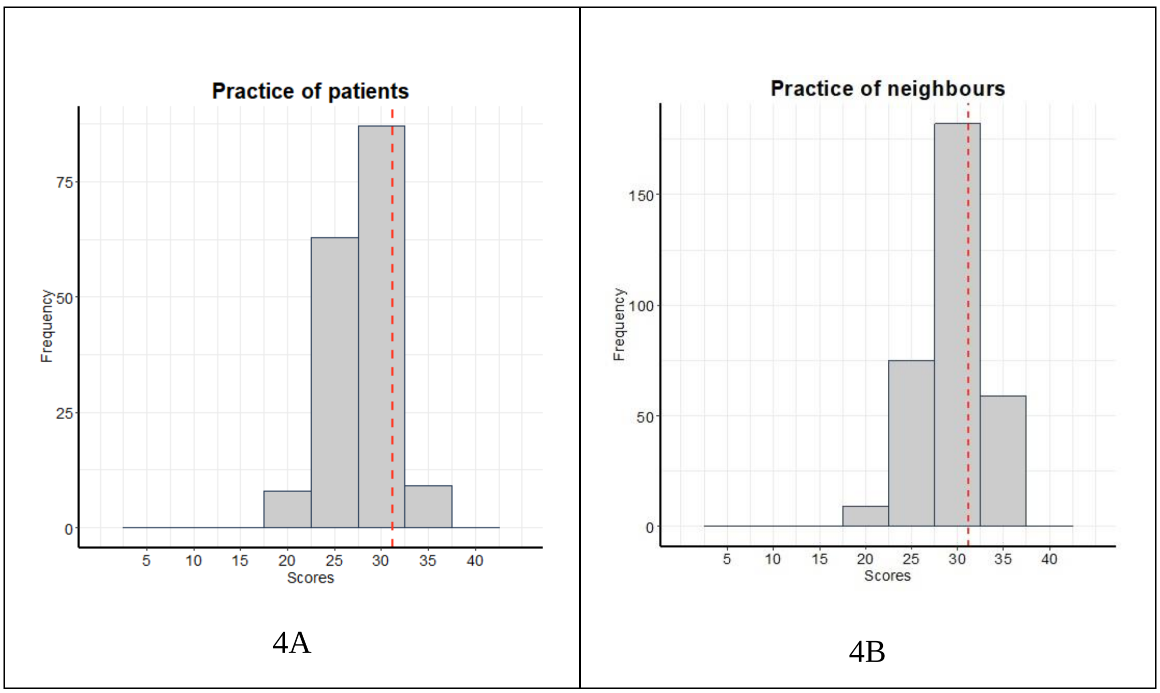

Figure 4. Level of leptospirosis practice of (4A) patients (n = 167) and (4B) neighbors (n = 325). Score represent the responses regarding practice of leptospirosis (see Material and Methods) (cutting at 80% is represented by the dashed red lines) comparison between groups: t-test: t = -5.272, P < 0.001)

The majority of village health volunteers did leptospirosis surveillance in the community (96.5%). 96% warned about leptospirosis problem when they found a leptospirosis case in their community and 95.6% exchanged information about leptospirosis prevention and control for coordinating people and public health officer. Furthermore, they are the good model for leptospirosis prevention: e.g by wearing boots when they worked in flooding area (95.6%). However, only 74.8% of them collected data regarding cattle and pigs that died from leptospirosis and reported this information to the health center. Only 76.7% set an agreement about human and animal water resource. 84.6% showed poster about leptospirosis prevention to the population. These results are shown in Table 9.

Table 9. Practice about prevention and control of leptospirosis disease in village health volunteers (n = 480).

Leptospirosis practice	**Do**	
	n	**(%)**
You did leptospirosis surveillance leptospirosis in your community.	463	(96.5)
You wore leptospirosis problem when there were leptospirosis patients in your community.	461	(96.0)
You coordinated for exchanged information about prevention and control leptospirosis between people and public health officer.	459	(95.6)
You were yourself, a good model about leptospirosis protection leptospirosis for instance wearing boots when you work in a flooding area.	459	(95.6)
You suggested people to wear boots for leptospirosis protection.	449	(93.5)
You suggested people to meet a doctor when they had high fever, headache and muscle pain.	448	(93.3)

Leptospirosis practice	**Do**	
	n	**(%)**
You suggested people to eat cook food and wash vegetables before eating.	447	(93.1)
You sent the name of a person who could have contracted leptospirosis to a public health officer.	446	(92.9)
You organized a rat eradication campaign.	436	(90.8)
You supported people about garbage disposal in the community for destroy disease habitat source.	432	(90.0)
You disseminated knowledge about leptospirosis prevention and control via broadcast tower.	428	(89.2)
You suggested people to keep food in containers by covering or sealing.	419	(87.3)
You learnt to increase your leptospirosis knowledge.	410	(85.4)
You and your team collected the corral and pig data and show it to the health center.	409	(85.2)
You and your team determined leptospirosis risk area, such as the pond.	408	(85.0)
You showed posters about prevention leptospirosis.	406	(84.6)
You set an agreement about using water resource which separated water resource for human and animal consumption and use.	368	(76.7)
You and your team collected data about the death corral and pig death from disease and show at the health center.	359	(74.8)

The majority of village health volunteers have acceptable practice (72.8%). The mean score of total practice was 15.98 and standard deviation was 2.48, as shown in Figure 5.

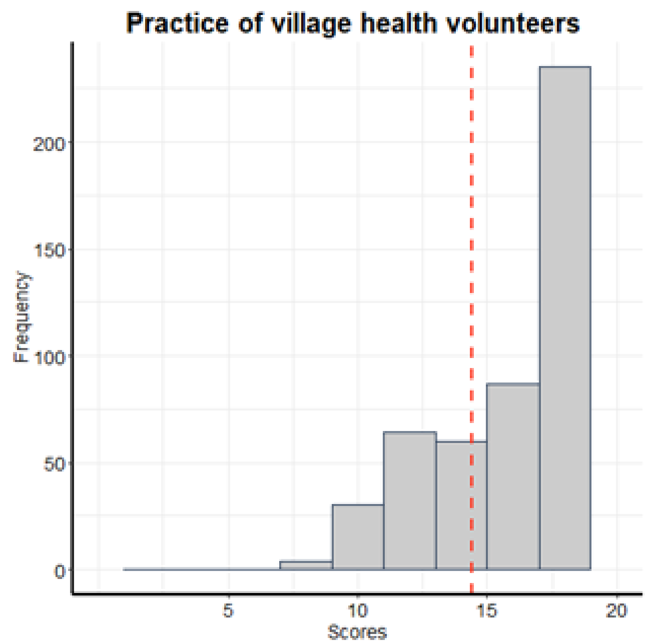

Figure 5. Practice of leptospirosis of village health volunteers.

Community leaders supported people about garbage disposal in the community at 99.4%, mobilized people in the community to clean the house and to destroy rat habitat at 97.8% and supported water clean conservation at 93.8%. However, 63.8% participated in meeting of summary the result of leptospirosis prevention and monitoring of community and 74.7% participated in the evaluation of leptospirosis prevention activity in community and participated in making budget plans for leptospirosis prevention in the community. 78.8% participated in the follow-up of leptospirosis prevention plan in the community. Results are shown in Table 10.

Table 10. Practice about prevention and control of leptospirosis disease of the community leaders (n = 320).

Leptospirosis practice	Do	
	n	**(%)**
You supported people about garbage disposal in the community to destroy disease habitat sources.	318	(99.4)
You mobilized people in the community to clean the house and to destroy rat habitat.	313	(97.8)
You campaigned for pond or river cleanliness.	300	(93.8)
You advised people to keep their corral dry to protect it against leptospirosis.	285	(89.1)
You coordinated between governmental organisms and people in your community about leptospirosis prevention.	283	(88.4)
You publicized about prevention leptospirosis project or activity or monitoring in the community.	274	(85.6)
You participated in making district annual development plan about prevention and control leptospirosis in your community.	256	(80.0)
You participated in the follow-up of leptospirosis prevention plan in the community.	252	(78.8)
You participated in the evaluation of leptospirosis prevention activity in the community.	239	(74.7)
You participated in making budget plans for leptospirosis prevention in the community.	239	(74.7)
You participated in meeting about summary the result of leptospirosis prevention and monitoring of the community.	204	(63.8)

The majority of community leaders have acceptable practice (70.0%). The mean score of total practice is 9.26 and standard deviation is 2.40 as shown in Figure 6.

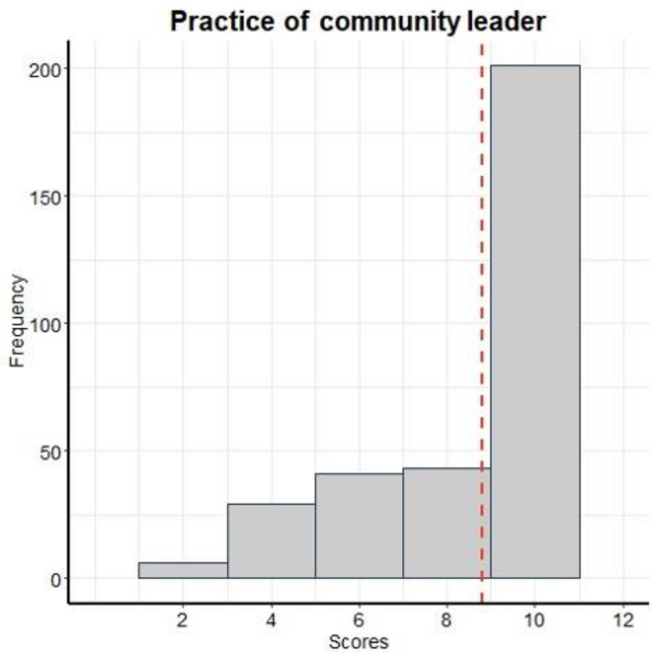

Figure 6. Practice score concerning leptospirosis control and prevention for community leaders.

Leptospirosis Incidence of Mahasarakham, Thailand between 2004 and 2014

Mahasarakham province is divided into 13 districts. During the period between 2004 to 2014, 762 leptospirosis cases were reported with an average incidence rate per district of 7.5 cases per a 100,000 population. The highest leptospirosis incidence is in Wapi Pathum District with an incidence rate of 15.73 per a 100,000 population. However, the lowest leptospirosis incidence is in Chunchom District with an incidence rate of 1.41 for 100,000 people. 5 districts among the 13 districts had a leptospirosis incidence higher than the average incidence as shown in Table 11.

Table 11. Leptospirosis case and incidence in districts of Mahasarakham Province, Thailand during 2004 - 2014.

District	case	Incidence per 10,000
Wapi Pathum	160	15.73
Phayakkhaphum Phisai	101	12.26
Kosum Phisai	123	11.65
Borabu	104	11.06
Kae Dum	20	8.32
Kanthara Wichai	78	7.35
Kut Rang	22	6.93
Muang Mahasarakham	77	5.53
Nadun	17	5.33
Na Chuak	21	4.36
Yang Sisurat	13	4.28
Chiang Yun	23	3.94
Chunchom	3	1.41
Total	762	

Comparison in knowledge, attitude and practice in high incidence district area and low incidence district area.

There were significant differences regarding the knowledge and practice of village health volunteers in high and low incidence area groups (Table 12). Village health volunteers in high incidence area have better knowledge than in low incidence area (OR =1.84). Moreover, village health volunteers in high incidence area have less acceptable practice than in low incidence area (OR = 0.44).

In addition, there were significant differences regarding the attitude of community leaders in high and low incidence area groups. Community leaders in high incidence area have a more acceptable attitude than in low incidence area (OR = 2.00), see in table 12.

Table 12. Comparison of knowledge, attitude and practice between high incidence area and low incidence area in Mahasarakham Province.

Group	Low incidence	High incidence	OR (95%CI)	Chi-square (p-value)
Patients				
Knowledge			0.82 (0.41:1.65)	0.137 (0.711)
good	53	68		
low	18	28		
Attitude			1.17 (0.62: 2.19)	0.105 (0.746)
acceptable	41	59		
unacceptable	30	37		
Practice			0.50 (0.18:1.30)	1.426 (0.233)
acceptable	11	8		
unacceptable	60	88		
Neighbors				
Knowledge			0.83 (0.51: 1.35)	0.395 (0.529)
good	100	130		
low	37	58		
Attitude			1.20 (0.77: 1.88)	0.482 (0.488)
acceptable	74	110		
unacceptable	63	78		
Practice			1.02 (0.62:1.68)	<0.001 (1)
acceptable	36	50		
unacceptable	101	138		
Village health volunteers				
Knowledge			1.84 (1.15: 3.01)	0.694 (0.017)
good	223	155		
low	74	28		
Attitude			1.03 (0.71:1.50)	0.004 (0.948)
acceptable	126	79		
unacceptable	171	104		
Practice				
acceptable	237	116	0.44 (0.29: 0.66)	14.839 (<0.0001)
unacceptable	60	67		
Community leaders				
Knowledge			0.80 (0.47: 1.38)	0.454 (0.501)
good	157	92		
low	41	30		
Attitude			2.00 (1.23: 3.25)	7.268 (0.007)
acceptable	110	87		
unacceptable	88	35		
Practice			0.76 (0.47: 1.24)	0.960 (0.327)
acceptable	143	81		
unacceptable	55	41		

Discussion

This study aimed to explore the gaps in leptospirosis knowledge, attitude and practice in patients and their neighbors, as well as in village health volunteers and community leaders, in Mahasarakham Province in relation to leptospirosis incidence.

Gap in Leptospirosis Knowledge

We found that the majority of patients, neighbors, village health volunteers and community leaders have a good knowledge level (around 70 %). Their knowledge has improved when we compare with a survey conducted in rural villages in a highly endemic area of Thailand in 2006, which found that only 20% of participants had good leptospirosis knowledge (Wiwanitkit, 2006). In addition, the knowledge level of people in Mahasarakham appeared higher than in a rural community in Hulu Langat District, Malaysia, where 43% of the population have good leptospirosis knowledge (Nozmi et al., 2018). In 2000, Mahasarakham Province was chosen by the Ministry of Public Health to be a pilot province for solving the outbreak of leptospirosis by setting a big campaign in the whole province for the prevention and control of leptospirosis in direction of the population (Mahasarakham Provincial Public Health Office, 2000). Mahasarakham Province used various media such as handbooks, brochures, etc. for leptospirosis prevention and control to inform people (Bureau of General Communicable Department of Disease Control, 2000). The leptospirosis campaign aimed at improving the implementation of leptospirosis prevention policy and developing knowledge of people.

More than 50% of all groups considered that rodents are important in the leptospirosis transmission, which shows the success of the big campaign targeting rodents as reservoirs of leptospirosis. However, there were only 29.8% of patients, 34.0% of neighbors, 57.5% of village health volunteers and 52.2% of community leaders who knew that chicken, dogs, cats and cattle could suffer from leptospirosis. The results are similar to a study in a community of residents of riverside settlements in Santa Fe, Argentina, which showed a low percentage of respondents recognizing dogs (12.8%) and cattle/pigs (5.4%) as animal sources of leptospirosis (Ricardo et al., 2018). The recent study of

Chadsuthi et al. 2017 showed a clear statistical association between human incidence and the prevalence of *Leptosira serovars* in livestock. *Shermani serovar* is across infection in cattle to humans (Chadsuthi et al., 2017). However, health media started a campaign in Mahasarakham did not cover knowledge about leptospirosis in animals.

Knowledge of leptospirosis symptoms was not really good in all groups. We found that only 60% of respondents could correctly answer questions about leptospirosis symptoms. Most of them lacked knowledge about the incubation period of leptospires. Moreover, only around 30% of every group knew that leptospires cannot be found in saliva of animals and cattle that can carry the leptospirosis disease. Similarly in a study conducted in Ubon Ratchathani Province, Thailand, only 36.5% of people knew incubation period of leptospirosis (Wongbutdee et al., 2016). Understanding symptoms and cause of leptospirosis can help a patient to meet a doctor early and can reduce the morbidity and death rate of the infection. Patients who meets a doctor after sixth days of infection by *Leptospira* have greater chances to develop a fatal disease (Kobayashi, 2001a).

Comparing the total knowledge score of every group, we found that the community leaders have significantly higher leptospirosis knowledge than other groups. Accordingly, community leaders have higher education than other groups. The majority of community leaders get a high school education level while other groups just reach the primary school education level. Village health volunteers who have an important role in sharing leptospirosis information to healthcare providers during outbreaks (Department of Disease Control, 2016) and for their involvement in prevention and health promotion activities (Thailand, 2001) , did not have a complete knowledge on leptospirosis. The results showed some important gaps in their knowledge, which might be crucial for early detection of leptospirosis outbreaks.

Gap in Leptospirosis Attitude

The majority of patients, neighbors and community leaders group have an acceptable attitude but the majority village health volunteers have an unacceptable attitude. More than half of patients and neighbors agreed that only farmers must prevent themselves against leptospirosis. Only 21.5% of village health volunteers and 21.6% agreed that leptospires may be found in their community. The results of this study are similar with people attitude observed in Ubon Ratchathani Province, which found that people agreed that leptospirosis can only infect farmers 48.1% (Wongbutdee et al., 2016). These results can be explained by the fact that, the majority of patients (72.5%) in Thailand were farmers (Hinjoy, 2014) and leptospirosis cases did not occur every year in a given community; which might influence wrong attitudes toward leptospirosis.

Moreover, half of the patients, neighbors and community leaders agreed that rats in the house can carry leptospirosis and 28.5% of village health volunteers agreed that prevention leptospirosis is complicated. It is similar to people in Hulu Langat District, Selangor, Malaysia where the majority did not care about the presence of rat in their house or in its surroundings (Nozmi et al., 2018).

Gap in Leptospirosis Practice of Patients and Neighbors

Interestingly in our study leptospirosis practice of patients is significantly lower ($P < 0.001$) than neighbors. Most of the patients showed high risk behavior of contracting leptospirosis than their neighbors. For example, 46.2% of neighbors were not fishing in the water when had wounds on the body, but 26.3% of patients did those activities. Moreover, 52.3% of neighbors wore boots when working in flooding areas but only 27.5% of patients did those activities. Like people in northeastern Malaysia, most of them were categorized as having unsatisfactory practice which low percentage of them wearing boots (51%), rubber gloves (43%) and masks (20%) while working (Azfar et al., 2018). Other studies have found that protective gear is often not used (Shin-ichi, 2016) due to the difficulty in acquiring it or because people feel that it is uncomfortable (Samarakoon and Gunawardena, 2013). Finally, another problem is that the patients who experienced leptospirosis have shown that they are not able to improve their health behaviors.

Gap in Leptospirosis Practice of Village Health Volunteers

This study found that nearly 100% of village health volunteers did leptospirosis surveillance in the community and warned about leptospirosis issues when they found leptospirosis patients in their community. There were only some activities that they could not complete such as collected data regarding cattle and pigs that died from leptospirosis and reported this information to the health center (74.8 %). It seems therefore that the role for village health volunteers is not well defined regarding the implementation of the surveillance policy decided by the Ministry of Public Health.

Gap in Leptospirosis Practice of Community Leaders

This study found that, 63.8% of community leaders participated in meeting of summary the result of leptospirosis prevention and monitoring of community and 74.7% participated in the evaluation of leptospirosis prevention activity in community and participated in making budget plans for leptospirosis prevention in the community. 78.8% participated in the follow-up of leptospirosis prevention plan in the community. Community leaders have an important role in organizing activities to prevent disease and set a control plan as well as taking care of the budget allocation for health activities in community (Department of Disease Control, 2016). However, the role of community leaders in the prevention and control of leptospirosis was not clearly defined. Their cooperation with local department depends on requests from local authorities in case of leptospirosis outbreak.

Implications and Recommendations

Developing leptospirosis prevention and control in the community should focus on people, community leaders and village health volunteers. In this study, we found gaps of prevention and control of the leptospirosis in the community. Further implementation of leptospirosis prevention should be developed:

1. The patients should be the first targeted group of people in the community for the development of their prevention practices skill. Indeed, the patients had experience of

leptospirosis disease but most of them have less personal skill in regarding the prevention of the disease. The leptospirosis practice of patients can also reflect that health prevention activities of public health departments should improve health education activities, increase the participation of people in the community and encourage local organization in sharing resources and experience to improve the implementation of the leptospirosis prevention and control policy.

2. The gap in knowledge concerning the role of domestic animals and livestock in leptospirosis in the communities of Mahasarakham should be taken into account to encourage collaboration between departments of public health and animal health in accordance with the One Health approach.

3. These results showed big gaps of leptospirosis attitude towards the control of leptospirosis vector. Public health officers should encourage and raise awareness in the control of leptospirosis vector among people, community leaders and village health volunteers.

4. The results showed some important gaps in knowledge of village health volunteers, which might be crucial for early detection of leptospirosis outbreaks.

5. The responsibility of village health volunteers in the community depends on subdistrict guidelines. Then the health sector should establish a handbook containing the main knowledge about leptospirosis and resolutions for the prevention and control of the disease in direction of village health volunteers.

6. Community leaders have an important role in organizing activities to prevent the disease thanks to a control plan and in considering the budget allocation for health activities in the community; therefore, they should develop their skill in disease surveillance and develop knowledge regarding prevention and control.

Limits of Our Study

This study follows the methodology of KAP agreements found in previous studies about leptospirosis. They were all taking the knowledge of experts as the reference. Nevertheless, the example of rat eradication in the present study shows the limit of the exercise. Indeed, rat eradication is considered as easy and important by the public health experts, and not by the respondents. We must underline that mammalogists recognize the impossibility to eradicate commensal animals. This shows that the knowledge of the experts can be biased, which may have consequences in the interpretation of the knowledge the respondents and thus be crucial in the interpretation of their attitudes and practices.

Conclusion

In Mahasarakham, Thailand, there is a gap of knowledge regarding leptospirosis in animals and leptospirosis symptoms: only one third of patients knew that animals can suffer from leptospirosis and only three fifths of patients knew leptospirosis symptoms. More than half of the patients agreed on the fact that only farmers should prevent themselves against leptospirosis. Prevention practice of leptospirosis is also deficient. Less than one third of the patients avoided paddling or fishing when they had wounds on the body and wore boots when working in flooding areas. Similarly to neighbors, a majority of village health volunteers and community leaders lack knowledge about leptospirosis risk in animal and leptospirosis symptoms. Attitude of village health volunteers is weak and only one fifth of village health volunteers agreed that *Leptospira* may be found in their community. We found the same results with community leaders. Neighbors had better leptospirosis practice than patients. More than half of them paddled or fished when they had wounds on the body and they did not wear boots when working in flooding areas. Village health volunteers did not complete some prevention leptospirosis activities such as collecting corral data and number of pigs dead from leptospirosis. Community leaders organized less participatory meetings to present leptospirosis prevention measures, evaluation and follow-up of the leptospirosis prevention plan in the community. Each group did not have enough knowledge, attitude and prevention practice regarding the disease. They need to improve their knowledge by having access to complex scientific knowledge, improve awareness about leptospirosis and should increase the participation in leptospirosis prevention and control with various departments and sectors in accordance with the One Health approach.

Chapter 5

Discussion

General Discussion and Perspective

Leptospirosis is an important zoonotic disease in Mahasarakham Province. During the period 2004 – 2014 the average annual incidence rate in Mahasarakham Province was 7.97 cases per 100,000 persons which is higher than the average annual incidence rate in Thailand, 6.6 per 100,000 persons (Hinjoy, 2014). Although the annual incidence rate in Mahasarakham Province was lower than the annual incidence rate worldwide with 14.77 cases per 100,000 persons (Costa et al., 2015), prevention and control of leptospirosis is an important responsibility for governments to reduce the disease risk, spead of epidemies, and the economic loss due to the disease in their countries (Guerra, 2013; World Health Organization, 2003). I studied three aspects of the disease in the province: the evolution of public health prevention of leptospirosis, the agro-environmental determinants of leptospirosis, and the attitudes, knowledge and practice of the population towards leptospirosis.

Evolution of Leptospirosis prevention policy implementation in Mahasarakham Province (Thailand) in a One Health Perspective)

For two decades, Thailand has progressively developed a leptospirosis prevention and control policy framework at the national level and transferred the responsibility of its implementation to the local level.

At the national level, prevention and control of leptospirosis approaches were developed to have clearer guidelines regarding the implementation in the field of Public health. Thailand promulgated the new National Communicable Diseases Act and designated various Ministries and departments as members of the Thai national Communicable Diseases Committee. However, leptospirosis prevention and control remained the main responsibility of public health officers. Indicators were produced only for evaluating the work done by the public health department. Consequently, I suggest that the National Communicable Diseases Act should develop cooperation guidelines between Ministries and define indicators for each Ministry regarding the prevention and control leptospirosis or other zoonosic diseases, using the One Health approach. Thailand should establish a specific organization to coordinate and develop cooperation between departments at the national level for zoonosis prevention and control.

At the provincial level, the Committee of Communicable Diseases of the province became an important mechanism that makes all sectors aware of health issues. However, the Provincial Communicable Diseases Committee is not concerned by leptospirosis issue and the cooperation is only occasional. There is no indicators and guidelines for corporation in leptospirosis prevention and control between departments. Consequently, the Provincial Governor should encourage the development of knowledge and skills of government officers to favor interoperability between departments for the leptospirosis prevention and control. The committee of Communicable Diseases of province should favor the participation of departments for establishing leptospirosis cooperation guidelines, policy, performance indicators, specify work operation for the leptospirosis prevention and control.

At the level of the sub district, leptospirosis prevention and control was developed only by public health officers to strengthen participation between departments in the sub district under the guidelines for the District Strengthening Disease Control. However, the District Strengthening Disease Control does not allow a complete approach of activities necessary to prevent and control leptospirosis. Therefore, there is a lack of linkages to ensure comprehensive disease prevention activities with other departments. Government officers in sub district should develop knowledge and skills to favor interoperability between departments for the leptospirosis prevention and control. Moreover, population in the community such as village health volunteers, livestock volunteers and leader community should participate in leptospirosis prevention and control. They should develop skills in leptospirosis surveillance of humans and animals. Nowadays, leptospirosis prevention and control is active when a leptospirosis case is reported. Leptospirosis prevention mainly concerns patients and is not continuously directed to the whole population. Developing health prevention behaviors can protect leptospirosis infection in human (World Health Organization, 2003). Therefore, department at the sub district level should enhance knowledge, attitude and practice among people using multidisciplinary and participatory methods.

Agro-environmental determinants of leptospirosis in Mahasarakham Province (Thailand), 2004 -2014: a retrospective spatiotemporal analysis

Leptospirosis cases dramatically increased in the wet season and had the highest rate at the end of the rainy season. This observation is similar with numerous studies showing that most leptospirosis cases occurred during the rainy season (Benacer et al., 2016; Morand et al., 2018; Topic et al., 2010). In the beginning of every rainy season, public health officers should give or recall health education programs about the origin of leptospirosis, way of transmission, symptoms of leptospirosis, prevention of infection and leptospirosis in animals, etc.

The low local spatial autocorrelation, inferior to 20 km, is also in agreement with other studies on environmentally transmitted diseases such as leptospirosis. Local autocorrelation nevertheless increased during the two years of highest incidence (2012 and 2009), suggesting that patterns of spatial variation exist but change through time. Positive autocorrelation was found at the first and second district neighborhood order while considering the whole time period showing that disease transmission commonly occurred among adjacent districts as also observed using kriging interpolation. The Ministry of public health should develop disease data base of disease outbreak that could be manageable for public health officers at the subdistrict level. When a leptospirosis case is reported in a subdistrict, an alert about potential outbreak should be sent to subdistrict neighborhood. Therefore, subdistrict neighborhood can prepare surveillance leptospirosis in their subdistrict.

Leptospirosis incidence trend did not show any decrease in Mahasarakham Province after the implementation of a new leptospirosis prevention and control plan. Leptospirosis prevention and control implementation require strong strategies to improve surveillance, health education, and good practices to avoid sources of contamination (Guerra, 2013; John, 2005). The findings of my study give also some evidence that environment, climate and livestock contribute to leptospirosis transmission to humans. My retrospective analysis may help at targeting subdistricts presenting environmental and farming characteristics associated with a higher risk of leptospirosis transmission to humans for the improvement of leptospirosis prevention and control in Mahasarakham Province, notably by using the One Health approach to foster multi-sectoral collaboration between public health, livestock department, department of agriculture, district hospitals and local communities in order to promote public and animal health educational activities.

Knowledge, Attitudes and Practices of Patients, Neighbors, Village health volunteers and Community leaders of Leptospirosis Prevention and Control in Mahasarakham Province, Thailand

Leptospirosis patients and their neighbors are risk groups of leptospirosis. Moreover, community leaders and village health volunteers have an important role in disease prevention and control (Wibulpolprasert et al., 2007), they participate in disease surveillance and they follow the implementation of the disease prevention and control policy in the community (Department of Disease Control, 2016). There was a several gaps in leptospirosis knowledge and attitude in the different public analysed. The majority of interviewed people did not follow leptospirosis prevention practices.

More than 50% of all groups considered that rodents are important in the leptospirosis transmission, which show the success of the big campaign targeting rodents as reservoirs of leptospirosis. However, public health department in Mahasarakham started a campaign but it did not covered knowledge about leptospirosis in animals and complete knowledge about symptoms of leptospirosis. The Ministry of public health and Mahasarakham Provincial Public Health Office should produce new media about leptospirosis which cover necessary knowledge such as the origin of leptospirosis, way of transmission, symptoms of leptospirosis, prevention of infection and leptospirosis in animals. The gap in knowledge concerning the role of domestic animals and livestock in leptospirosis in the communities of Mahasarakham should be taken into account to encourage collaboration between departments of public health and animal health in accordance with the One Health approach.

Comparing the total knowledge score of every group, I found that the community leaders have significantly a higher leptospirosis knowledge than the other groups. However, village health volunteers who have an important role in sharing leptospirosis information to healthcare providers during outbreaks (Department of Disease Control, 2016) and for their involvement in prevention and health promotion activities (Thailand, 2001), did not have a complete knowledge on leptospirosis. The results showed some important gaps in their knowledge, which might be crucial for early detection of leptospirosis outbreaks.

Interestingly, leptospirosis practice of patients is significantly lower ($P < 0.001$) than neighbors. Most of the patients showed high risk behavior of contracting leptospirosis than their neighbors. The patients who experienced leptospirosis have shown that they are not able to improve their health behaviors. The patients should be the first targeted group of people in the community for the development of their skills concernning prevention practices. Moreover, the leptospirosis practice of patients can reflect that health prevention activities of public health department should offer improved health education activities, increase the participation of people in the community and encourage local organization in sharing resources and experience to improve the implementation of the leptospirosis prevention and control policy.

Nearly 100% of village health volunteers did leptospirosis surveillance in the community and warned about leptospirosis issue when they found leptospirosis patients in their community. However, there were only some activities that they could not complete such as collecting coral data and number of pig death from leptospirosis. Therefore, there were not complete and clear role for village health volunteers regarding the implementation of the surveillance policy decided by the Ministry of Public Health. The responsibility of village health volunteers in the community depends on subdistrict guidelines. Then the health sector should establish a handbook containing the main knowledge about leptospirosis and resolutions for the prevention and control of the disease in direction of village health volunteers.

Community leaders organized less participated in meeting of summary the result of leptospirosis prevention and monitoring of community 63.8% and participation in the evaluation of leptospirosis prevention activity in the community 74.7%. Community leaders have an important role in organizing activities to prevent disease and set a control plan as well as taking care of the budget allocation for health activities in community (Department of Disease Control, 2016). However, the role of community leaders in the prevention and control of leptospirosis was not clearly defined. Their cooperation with local department depends on requests from local authorities in case of leptospirosis outbreak. Moreover, community leaders should develop their skill in disease surveillance and develop knowledge regarding prevention and control.

Conclusions, critics and general recommendations.

Leptospirosis is still not under control in Mahasarakham Province despite more than 20 years of prevention with the public health department of Mahasarakham that has developed leptospirosis prevention and control employing people to eradicate rats in infected areas, providing health education (Mahasarakham Provincial Public Health Office, 2000), establishing a surveillance system and setting the Surveillance and Rapid Response Team or SRRT (Department of Disease Control, 2016), etc.

There are gaps in linkages between departments to ensure comprehensive disease prevention activities. There are also gap in knowledge, practice and attitude at all level as well. For instance, the officers at the provincial and local level such as livestock department, agriculture and the Tambon Administration Organization need a better understanding about the transmission of leptospirosis from animals to humans. They know that *Leptospira* coming from rats can be transmitted to humans but do not consider enough the other vectors, in particular the one living close to humans such as the cattle. As a result, leptospirosis prevention often only focuses on rats eradication while the cattle is likely to be a more important source of infection in the province. Stronger evidences to find causes and mechanisms of leptospirosis transmission from animals to humans are needed to develop appropriate leptospirosis prevention and control programs to target potential and major sources of infections.

The factors associated with leptospirosis infection in Mahasarakham Province are complex and multifactorial, including human population density, livestock, rainfall, flood cover and physical geography, i.e. average slope. Moreover, patients, neighbors, village health volunteers and community leaders did not have enough knowledge, attitude and prevention practice regarding the disease. The different public I interviewed need to improve their knowledge by having access to the often complex and up-to-date scientific knowledge about leptospirosis. In order to gain in efficiency, I suggest that leptospirosis prevention and control need enhanced collaboration between public health and livestock departments with community involvement under for leptospirosis prevention and control the One Health approach. Leptospirosis prevention and control should consist in three important components: management, coordination and evaluation. Those components will promote cooperation in disease prevention and control in people, animals and the environment. This cooperation can ensure a better coordination and will improve and operations of prevention and control.

Nowadays, leptospirosis prevention and control in Mahasarakham becomes active when a case of leptospirosis is reported. Most of the campaigns focus on educating people in wearing boots and eradicating rats. I suggest that the Communicable Diseases Committee in the province should establish leptospirosis prevention and control plan in a participatory way before the outbreaks. Translate research in order to develop adaptive guidelines requires to consider strategies, regulations and laws of the country. Moreover, it necessitates the participation of the relevant departments to establish a concrete leptospirosis prevention and control with a consistent approach to the local context, as well as a good knowledge of socio-economic and environmental factors affecting the epidemiology of the disease.

In order to improve cooperation between the different stakeholders, I established guidelines to improve leptospirosis prevention and control in this work.

Human leptospirosis surveillance in Mahasarakham has been successful in better detecting leptospirosis cases in humans. Mahasarakham developed leptospirosis surveillance from the “Special Response Team” to “Surveillance and Rapid Response Team (SRRT)” in 2010 and “The District “Strengthening Disease Control” in 2011. I found that this change in policies was associated with an increase of the number of case reported and that these new implementation measures improved the quality of data collection. There is, however, still a lack of cooperation between public health, livestock department, agriculture and Tambon Administration Organization in leptospirosis promotion at the community level. Therefore, a clearer cooperation between departments should be defined as suggested in the guidelines elaborated jointly with different actors of leptospirosis prevention and control. Thailand needs to develop cooperation between departments at the national level by establishing a national policy and related indicators for each department involved in leptospirosis prevention and control.

Currently, leptospirosis prevention and control policy implementation targets only leptospirosis in humans. Nowadays, Thailand do not have surveillance system for leptospirosis in animals. Prevention and control of leptospirosis in animals consists in using antibiotics or separate infected animals from the herd (Chompoochan et al., 1996). This study found a positive association between cattle density and leptospirosis occurrence. Thailand needs to establish a leptospirosis surveillance system in animals. Livestock department should screen leptospirosis in cattle and treat sick animals with antibiotics. Moreover, the livestock department should be involved to find way to reduce leptospirosis in animals, via vaccination animals or euthanasia. An animal vaccination can break the cycle of leptospirosis infection as it is done in New Zealand (New Zealand government, 2019). My study showed that people lack knowledge regarding leptospirosis in animals. Public health department, livestock department an LGO should cooperate and share multidisciplinary knowledge in leptospirosis surveillance in human and animal. They should cooperate to develop surveillance knowledge and potential of village health volunteers, livestock volunteers. In the subdistrict, where people are raising cattle, the livestock department must randomly examine leptospirosis in cattle and provide education on sanitation in cattle to animal farmers. Public health department and livestock department should cooperate in developing campaigns to educate the population in leptospirosis prevention and control in human and animal.

Climate change and extreme weather events have impacts on pathogens, hosts/vectors, disease transmission (Wu et al., 2016) and the distribution of infectious diseases (Dennis and Fisher, 2018). The effects of climate on leptospirosis spread vary depending on the locally-specific control and intervention strategies regarding leptospiral infection (Dhewantara et al., 2019). At the national and international level, we need to better forecast the impact of climate change and demographic change on disease to improve and adapt prevention and control strategies. This concerns leptospirosis but also many infectious disease that are transmitted by the environment. In this respect, I think it could be interesting to further develop models to get accurate forecast of leptospirosis to guide government policies and recommend health behaviors.

Annex

Glossary

Term	Meaning
Accuracy	The degree to which repeated measurements under unchanged conditions show the same results.
Agricultural areas	Area of rice fields, mixed horticulture field, area for planting trees obtained from Minister of Natural Resources and Environment, Thailand and extracted data by using QGIs program.
Akaike Information Criteria (AIC)	An estimator based on in-sample fit to estimate the likelihood of a model to predict/estimate the future values.
Analysis of variance (ANOVA)	A statistical technique used to analyze differences between the means of more two groups.
Animal areas	Area of pasture and farm house obtained from Minister of Natural Resources and Environment, Thailand and extracted data by using QGIs program.
Area Under The Curve (AUC)	The degree or measure to explain the model performances.
Attitudes	A psychological construct, a mental and emotional entity that inheres in, or characterizes a person
Autocorrelation	A statistical technique helping finding repeating patterns.
Bayesian probability	A statistical technique which determines a level of certainty relating to a potential event.
Binomial distribution	The discrete probability distribution of the number of successes or failure outcomes in a survey.
Building areas	Area of villages, cities, place built by humans obtained from Minister of Natural Resources and Environment, Thailand and extracted data by using QGIs program.

Term	Meaning
Chi-square test	A statistical technique which determine whether there is a difference between the expected frequencies and the observed frequencies in one or more categories.
Co-linearity	A phenomenon in which some of the independent variables are highly correlated with a substantial degree of accuracy.
Community leaders	People who are village leaders (i.e. head of the village) or members of the subdistrict administration.
Confounder	A variable which influences both the dependent variable and independent variable.
Correlogram	An image of correlation statistics.
Correlogram analysis	In time series analysis, is an autocorrelation plot which plot of the sample autocorrelations r_h versus h (the time lags).
Cronbach's Alpha	A statistical technique which measures consistency between different items of the same construct. If items have internal consistency, the respondents rate them in a similar manner.
Decentralization	The process by which the activities of an organization, particularly those regarding planning and decision-making, are distributed or delegated away from a central authority to local authorities.
Disease outbreaks	A disease situation is the occurrence of cases of disease in excess of what would normally be expected in a defined community, geographical area or season.
Disease surveillance	An epidemiological practice which the monitoring spread of disease and practice of disease case reporting.
Emerging infectious diseases (EIDs)	An infectious disease which has newly appeared in a population or that has been known for some time but is rapidly increasing in incidence.

Term	Meaning
Endemic	An infection is constantly maintained at a baseline level in a geographic area without external inputs.
Fixed effect factors	The variables which values of interest are all represented in the data file.
Flooding data	The data which obtained from MODIS TERRA MOD09A1 Surface-Reflectance Product, resolution 500m), from the Land Processes Distributed Active Archive Center of NASA.
Forest areas	Areas of forest obtained from Minister of Natural Resources and Environment, Thailand and extracted data by using QGIs program.
General additive modeling (GAM)	A statistical technique which the linear predictor depends linearly on unknown smooth functions of some predictor variables, and interest focuses on inference about these smooth functions.
Generalized linear models (GLM)	A flexible statistical technique to describe linear relationship between predictor terms and a response variable.
Incidence	The number of individuals who develop disease during a time period.
Independent-samples t-test	A statistical technique which determines whether there is a difference between the means in two unrelated groups.
In-depth interviews	A qualitative data collection method used to conduct intensive individual interviews where the number of respondents is small.
Interpolation	The process of using points with known values or sample points to estimate values at other unknown points.
Knowledge	A familiarity, awareness, or understanding of something.
Kriging	A method of interpolation for which the interpolated values are modeled by a Gaussian process governed by prior covariances.

Term	Meaning
Land cover	The physical material at the surface of the earth.
Land use	The areas which management and modification of natural environment or wilderness into built environment.
Leptospira	The zoonotic organisms with a worldwide distribution that infect a variety of mammals, including mice, rats, carnivores, and ruminants.
Leptospirosis	Zoonotic bacterial disease caused by various species of the bacterial genus *Leptospira*.
Local government organizations (LGO)	Department in Thailand which divided into provincial administrative organization, municipalities, sanitary districts, the Bangkok Metropolitan Administration (BMA), and the City of Pattaya.
Lottery sampling	A method to select samples by which every person has an equal chance of being selected in the sample. A researcher randomly picks numbers, with each number corresponding to a subject.
Members of the subdistrict administration	People who are elected by villagers and have a role in the governance of the subdistrict (such as approval of the budget).
Memorandum of Understanding (MOU)	A formal document describing the broad outlines of an agreement that two or more parties have reached through negotiations.
Moran's I test	A statistical technique which measure of characterized by a correlation in a signal among nearby locations in space.
Negative binomial distribution	A discrete probability distribution of the number of successes in a sequence of independent and identically distributed Bernoulli trials before a specified (non-random) number of failures occur.
Neighbors	People who stay closest households of reported patients.

Term	Meaning
One Health concept	An approach to designing and implementing programs, policies, legislation and research in which multiple sectors communicate and work together to achieve better public health outcomes.
Participant observations	A qualitative data collection method which researcher engages in the activities of the research participants.
Pathogenic	A medical term that describes viruses, bacteria, and other types of germs that can cause some kind of disease.
Patients	People who got sick from leptospirosis during 2004 to 2014 and were recorded in Database of Mahasarakham Provincial Public Health Office.
Primary documents	Documents such as reports, meeting reports, command documents and handbooks.
Purposive sampling	A non-probability sampling techniques which the units that are investigated are based on the judgment of the researcher.
Qualitative study	A study which used to gain an understanding of underlying reasons, opinions, and motivations.
Quantitative study	A study which used to quantify the problem by way of generating numerical data or data that can be transformed into numerical values.
Random effects factor	The variables which values in the data file can be considered a random sample from a larger population of values and explaining excess variability in the dependent variable.
Receiver Operating Characteristic Curve (ROC)	A probability curve to explain how good the model can distinguish between two things.

Term	Meaning
Reliability	The degree of consistency of a measure. A test will be reliable when it gives the same repeated result under the same conditions.
Retrospective study	Study performed a posteriori, using information on events that have taken place in the past.
Secondary documents	Documents such as journal articles, presentation handouts and internet information.
Semi-variogram	A graph to describe the degree of dissimilarity between observations as a function of distance.
Socio-economic variable	The variables which indicate a person's status within a community.
Southeast Asia One Health University Network (SEAOHUN)	An organized to encourage and facilitate collaborative activities and projects among network members, innovative projects that provide an evidence-based One Health advocacy with government and other collaborating partner agencies in Southeast Asia.
Spatial analysis	A statistical technique which describes patterns of a situation through their spatial locations and their relationships in space.
Spatiotemporal analysis	A statistical technique which describes a spatial and temporal phenomenon.
Stepwise selection	The method of fitting models in which the choice of predictive variables is carried out by an automatic procedure with addition or subtraction of explanatory variables from a set of explanatory variables.
Stratified sampling	A method of sampling from a population which can divide the entire population into different subgroups or strata, then randomly selects the final subjects proportionally from the different strata.

Term	Meaning
Structured interviews	The fixed format interview in which all questions are prepared beforehand and are put in the same order to each interviewee.
Surveillance and Rapid Response Team or SRRT	Policy for prevention and control diseases which established by Bureau of Epidemiology, Ministry of Public Health, Thailand.
Temporal analysis	A statistical technique which describes patterns of a situation based on time.
Thai One Health University Network (THOHUN)	An organized which comprise with Thai University for build, develop, and expand One Health University Network of Thailand.
The District Strengthening Disease Control	Policy for disease surveillance and preparing response outbreak in the district which established by Bureau of Epidemiology, Ministry of Public Health, Thailand.
Time-series	A set of observation x, each one being recorded at a specified time.
Time-series analysis	A statistical technique deals with time series data, or trend analysis.
Tropical zone	The areas on the Earth where the Sun contacts a point directly overhead at least once during the solar year and a climate is warm to hot and moist year-round.
Tukey HSD	A statistical technique which determines means different from each other.
United States Agency for International Development's (USAID)	An agency of the United States federal government that works to end extreme global poverty and enable resilient, democratic societies to realize their potential.

Term	Meaning
Village health volunteers	People who are volunteers for assist communities in health development.
Village leaders	People who are elected by the villagers and have duties in the governance of the village, such as supporting, encouraging and facilitating the activities of the different government agencies (public health, veterinary health, agriculture, etc.).
Water areas	Area of natural water, reservoir (built-up) which obtained from Minister of Natural Resources and Environment, Thailand and extracted data by using QGIs program.
Wavelet analysis	A statistical technique which decomposes a signal into multiple lower resolution levels by controlling the scaling and shifting factors of a single wavelet function called "mother wavelet"
Zoonosis	A disease that can be transmitted from animals to people or, more specifically, a disease that normally exists in animals but that can infect humans.

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Evolution of Public Health prevention of leptospirosis in Mahasarakham Province (Thailand) in a One Health perspective

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Authorship

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Abstract

Leptospirosis is an endemic disease with moderate to high incidence in Mahasarakham Province, Thailand. The present study was designed to assess the policy implementation mission regarding leptospirosis prevention and control from the national level to the local administrative levels, through a One Health perspective. Qualitative study was conducted, using documentation reviews, individual in-depth interviews and structured interviews in public health officers, local government officers, livestock officers who developed policy implementation tools or have responsibilities in leptospirosis prevention and control. The results show that Thailand has progressively developed a leptospirosis prevention and control policy framework at the national level, transferring the responsibility of its implementation to the local level. The province of Mahasarakham has decided to foster cooperation in leptospirosis prevention and control at the local level. However, some linkage gaps between provincial departments and leptospirosis prevention were identified, concerning mainly patients and the whole population.

Keywords: leptospirosis, One Health, prevention and control, Thailand, policy implementation

Background

Leptospirosis is an important zoonotic disease and is considered as one of the most widespread zoonoses in the world.[1] The disease is caused by several spirochete species of the genus *Leptospira*.[2] Infected patients can develop severe symptoms characterized by hepatic, renal or pulmonary dysfunction, or hemorrhagic manifestations which can be a cause of mortality.[3,4] High incidence of human leptospirosis occurs in tropical environments where conditions may favor the development and survival of *Leptospira* species in the environment.[5,6]

Thailand is located in the tropical zone with important soil moisture and high rainfalls during the wet season, which favors letospire transmission. More than 70,000 cases have been recorded since the emergence of this disease in Thailand.[7] Leptospirosis incidence shows a strong seasonality with a high incidence during the wet season.[8] Moreover, outbreaks of leptospirosis are often reported after flooding events.[9,10]

The province of Mahasarakham is situated in the Isan part (North East) of Thailand characterized by a moderate to high leptospirosis incidence. For more than two decades, the Ministry of Public Health and the Mahasarakham Provincial Public Health Office have established and developed policy implementation of leptospirosis prevention and control. However, despite some success, leptospirosis is still an endemic disease in the province.

The World Health Organization (WHO) has highlighted the importance of the One Health approach to design and implement programs, policies, legislation for prevention and control of zoonoses.[11] Collaboration between veterinarians dealing with livestock and wild animal populations, ecologists and public health experts enhances prevention and control.[12]

Thailand has integrated the One Health approach into the Thailand National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response.[13] Thailand has also played an important role in promoting and encouraging the use of the One Health approach within the Association of South-East Nations (ASEAN) notably under the South East Asia One Health University Network (SEAOHUN)[14] and in driving the development of the One Health approach at the regional level.

Leptospirosis is still an important health issue in the province of Mahasarakham and there is a need to improve the policy of leptospirosis prevention and control. Therefore, understand how Mahasarakham, Thailand improved previous national policies for leptospirosis prevention and control strategies by using a One Health perspective can help to enhance the efficiency of the prevention, detection and response to leptospirosis outbreaks previous national policies for leptospirosis prevention and control strategies by using One Health perspective, can improve the effectively of detecting, responding, and prevention leptospirosis outbreaks.

Methods

1. Study design

Qualitative study was conducted, using documentation reviews, individual in-depth interviews, structured interviews, participant observations in order to describe the different phases of the implementation of leptospirosis prevention and control policy in a One Health perspective.

2. Study population

The study population included the head of the Department of Disease Control, the officer of Coordination Unit for One Health, public health officers, livestock officer and local government officers of Mahasarakham, to identify the factors that have enabled or constrained the planning and implementation of policies regarding leptospirosis prevention and control. Initial findings were integrated back into the investigation, and were used to guide further exploration and analysis of key issues as they emerged.

3. Data collection

Data collection consists of two steps:

First, we reviewed primary documents obtained from the public health department (provincial reports, meeting reports, command documents, handbooks). Access to those non publicly available documents was granted by the Deputy Head of the Department of Disease Control of Mahasarakham Provincial Public Health Office. We also used eighteen secondary documents: journal articles, presentation handouts and internet information. All the documents were selected following two criteria:

i) documents related to leptospirosis prevention and control in Mahasarakham, Thailand and ASEAN,

ii) documents relating to One Health implementation in Mahasarakham, in Thailand (national level) and ASEAN (regional level).

Secondly, we collected data among officers from different administrative departments at various decision-making levels using individual in-depth interviews, and participant observations (during meetings and disease investigations).

Interviews

Structured interviews of 13 subdistrict public health officers in Mahasarakham, within the subdistricts characterized by high leptospirosis incidence. The interviews focused on their practice regarding their mission of prevention and control of leptospirosis and the difficulties and barriers they may meet.

In-depth Interviews

Thirteen in-depth interviews of the head of the Department of Disease Control, the Officer of the Coordination Unit for One Health, Provincial Public Health officers, District Public Health officers, local government officers and District Livestock officers were realized. Informants were purposively selected to provide insights on the identification of the factors that have enabled or constrained the leptospirosis policy implementation. In-depth interviews were conducted using flexible topic guides with open-ended questions that allowed participants to express their views on leptospirosis policy implementation. Topic guides included questions on the way to implement leptospirosis prevention and control policy integrating the One Health approach.

Participant observation

The research was conducted by collecting participant observations during three meetings relating to disease prevention and control in the province of Mahasarakham and one fieldwork in leptospirosis investigation in 2017.

Observations were recorded in the form of field notes to provide a descriptive account of the highlights of the program implementation. Analytical comments were added progressively as insights were gained throughout the dynamic of the discussions and the investigations. The field notes were dated, then entirely transcribed.

Ethical statement

Approval notices for interviews were given by the Ethics Committee of Public Health of the Mahasarakham Province (Institutional Review Board) reference number 5/2558, delivered on 20 April 2015.

Results

1. Evolution of Leptospirosis Prevention and Control Policy Implementation in Mahasarakham

1.1 Leptospirosis prevention and control policy implementation before 2000

In 1996, the first leptospirosis patient was reported at a time when public health staff did not have knowledge on leptospirosis. Thus, the Ministry of Public Health decided to improve the knowledge on the disease at the Regional Public Health Office. The Regional Health Office was then charged to the formation of the Provincial Public Health Office.[15] Public health officers were the only persons in charge of leptospirosis prevention and control.

1.2 Leptospirosis prevention and control policy implementation 2000 to 2003

In 2000, the province of Mahasarakham was chosen by the Ministry of Public Health as a pilot province for a better control of the outbreak of leptospirosis and thus for implementing a leptospirosis prevention policy. The province got budget support from the Miyasawa project for conducting prevention and control leptospirosis activities. Mahasarakham Provincial Public Health Office set a big campaign for the prevention and control of leptospirosis in direction of the population. The government allocated a budget for buying rat tails from people.[15]

From 2000 to 2003, the Ministry of Public Health supported various media for leptospirosis prevention and control in the province.[16] During this phase, the Ministry of Public Health and the Ministry of Education cooperated for the promotion of leptospirosis prevention and control.[17] Moreover, a “war room” or “ad hoc operations center” was established to handle leptospirosis.[18]

1.3 Leptospirosis prevention and control policy implementation from 2004 to 2010

After 2003, prevention and control leptospirosis became a routine activity for public health officers. The Bureau of Epidemiology established policy for prevention and disease control by creating the Surveillance and Rapid Response Team (SRRT).

Mahasarakham province adopted prevention and control diseases policy by developing and implementing SRRT in every district. Prevention and control leptospirosis followed the implementation from Ministry of public health called 4E2C as shown in Table 1.

Table 1. 4E2C.

Implementation	Activities	Responsible person
Early detection	Share outbreak information with healthcare providers.	Patients Public health volunteers
Early diagnosis	Make a preliminary diagnosis from the patient's history and symptoms such as acute fever, headache, muscle pain following the leptospirosis diagnosis guideline.	Healthcare providers
Early treatment	Give treatment to patient, following the leptospirosis diagnosis guideline.	Healthcare providers
Early control	Prevention and control of leptospirosis one week after receiving the leptospirosis report.	Surveillance and Rapid Response Team
Coordination	Investigate causes of leptospirosis cases and prepares advice for the people in the community. For example, advise about feeding animal, monitoring animal diseases and reporting leptospirosis cases.	Public health officers Livestock department
Community involvement	Community participate in the prevention and control of leptospirosis. For example warning about leptospirosis, establishing the leptospirosis prevention in the community etc.	Community

In 2006, the Thai government decided a decentralization reform in the health sector and allocated 24.1% of the central budget dedicated to public health to the Local Government Organizations of the whole country.

1.4 Leptospirosis prevention and control policy implementation during 2011 to 2014

In 2011, the Department of Disease Control of the Ministry of Public Health established the prevention disease standard “The District Strengthening Disease Control”. The Department of Disease Control designated districts as target areas for developing disease surveillance and preparing response when there is an outbreak in the district.

Leptospirosis prevention and control of Mahasarakham Province was implemented following the District Strengthening Disease Control which was the standard in prevention disease in the district. The District Strengthening Disease Control has been used from 2011 until present (2018). Leptospirosis prevention and control consist of two strategies via establishing the leptospirosis network participation and Surveillance and Rapid Response. Leptospirosis network participation is activated for leptospirosis prevention while Surveillance and Rapid Response team intervene when a leptospirosis case has been reported. The establishment of a leptospirosis network participation consists of 5 procedures shown in Figure 1.

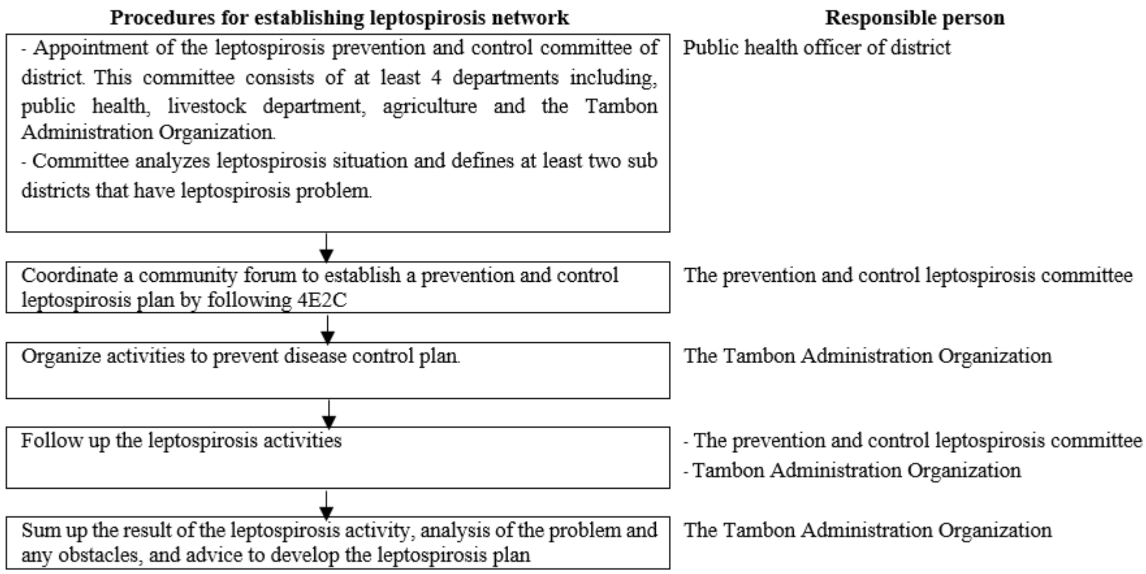

Figure 1. Procedures for establishing leptospirosis network.

Prevention and control of leptospirosis following 4E2C procedure established by the Ministry of public health.[13]

At present, prevention and control disease are carried out by following the new national Communicable Diseases Law, 2015. The law does not detail the measures to be taken but one of the missions of the government agencies in the province is to jointly plan control and prevention of the disease. The Communicable Diseases Committee of the province meets every four months for the planning and the follow-up of their activities. After the meeting, the relevant agencies proceed to their operation plan for prevention and control disease.

2. Leptospirosis Prevention and Control in Mahasarakham Province, One Health Perspective

The One Health concept was applied for the first time in 2012 in Thailand to address practical health problems. The One Health concept has been adopted as a key component of the national health policy, in particular the National Strategic Plan for Emerging

Infectious Diseases (2013 - 2016) adopted in 2012[19] and the National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response (2017 - 2021).

In 2013, four ministries signed a Memorandum of Understanding (MoU) on the implementation of One Health Initiative for National Health Security. In addition, in 2016, the cooperation between ministries has been developed further with the signature of a MoU on the Implementation of One Health Initiative for National Health Security jointly by seven ministries and one organization.[20]

In 2015, the Ministry of Public Health encouraged province prevention and control disease by using the One Health concept. They encouraged the provinces by providing funding through research projects. Nowadays, the use of the One Health approach for the prevention and control of diseases depends on the willingness of the practitioners and on the specific health problems in each province. If a province detects emerging diseases, it must ensure prevention and control, following the plan of National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response. However, other infectious disease prevention and control measures decided at the district level should follow "The District Strengthening Disease Control".

Currently, although, there is a Communicable Diseases committee of the province, the committee is not specifically interested in leptospirosis issues at the level of the province. There is no plan or action to foster cooperation between departments of the province for the prevention and control of leptospirosis. At the provincial level, leptospirosis is a priority only for the public health department but not for other departments such as livestock department or agriculture department.

Leptospirosis prevention and control in districts of Mahasarakham are under the responsibility of public health officers. There are guidelines for cooperation between departments following "The District Strengthening Disease Control" adopted before Thailand decided to use the One Health approach. However, departments in districts cooperate together to develop plans to prevent and control leptospirosis. The District "Strengthening Disease Control does not allow a complete approach of activities necessary to prevent and control leptospirosis. Therefore, there is a lack of linkages to ensure comprehensive disease prevention activities with other departments such as livestock department, agriculture. Moreover, the Tambon Administration Organization does not have its own indicators for leptospirosis prevention and control.

3. The Mechanism of Public Health Implementation in Thailand

With the movement of decentralization in Thailand, the Government decided that each provincial governor would be Chief Executive Officer (CEO) administering all activities within his/her jurisdiction in an integrated manner. The Ministry of Public Health establishes the main health policy and supports academic health knowledge to the public health officers in the province. The health activities in districts vary according to the district health plan. They analyze the main health policy and health problems in the district to devise a district health plan. The public health officers in the Tambon Health Promotion Hospital have an important role in encouraging health activities in the Tambon, i.e. subdistrict, which are assessed and controlled by the District Health Officer, the Provincial Public Health Office and the Regional Health Office. In addition, the Department of Public Health cooperates with the Ministry of Interior in order to evaluate indicators and set a budget.

Discussion

Evolution of Leptospirosis Prevention Policy Implementation

Thailand has progressively developed leptospirosis prevention and control policy framework at the national level and transferred the responsibility of its implementation to the local level. Leptospirosis prevention and control is under the responsibility of public health officers.

Before 2000, the policy implementation in this phase was not clearly framed at the local level because the officers lacked understanding of the disease and did not have means to disseminate knowledge among people. The knowledge was also provided to small groups which could not cover the whole population.

Between 2000 and 2003, the Ministry of Public Health has chosen Mahasarakham as a pilot province to develop and improved leptospirosis prevention policy implementation. Thus, Mahasarakham Provincial Public Health Office supported public health officers in their responsibility to control the disease and gave them a clearer role in the prevention of the disease. A specific budget has been dedicated to prevention and control of the disease. The department of public health was the main organization to run prevention and control activities. It developed cooperation with the Department of Education for the education of students in the schools.

Between 2004 and 2010, leptospirosis prevention and control policy has been enhanced at the district level. The cooperation between public health officers in the district is now clearly established and public health officers must share knowledge and resources among subdistricts (tambon) within their district. Although, a movement of decentralization in the Health Sector allocated a proportion of the central budget to the LGO. These LGOs play an important role to develop social services in several forms (roads, water supply, waste management…), in line with local administration laws. Nevertheless, there was no specific obligation to work on health issues and administrators of LGO were not interested in this sector. Moreover, public health department worked jointly with livestock department only in the case of an outbreak to investigate the disease.

Between 2011 and 2014, the leptospirosis prevention disease activities were designed by public health officers at the district level. The Committee of Communicable Diseases of the province created at that time became an important mechanism making all sectors aware of health issues by developing a comprehensive plan involving the different sectors. Moreover, the committee helped reducing redundancy in the operations driven by each unit. Local government was in charge to allocate the budget for disease prevention in subdistricts. Therefore, prevention and control disease activities were more comprehensive and could contribute to reducing the problem of budget sharing. At the level of the province, public health department and livestock department were cooperating for the prevention and control of the epidemic even before the promotion of the One Health concept. However, the cooperation stayed informal at that time: for a specific mission in case of zoonotic disease outbreaks, for example. Some prevention and control activities were under the sole responsibility of public health officers and thus there was a clear lack of linkages necessary for comprehensive disease prevention activities. However, after Thailand supported and adopted the One Health approach, the various departments had a better understanding of the importance of cooperation for epidemic prevention and control.

Lessons Learnt for Leptospirosis Prevention Policy Implementation

Prevention and control of leptospirosis needs to be supported by complex scientific knowledge and health policy development. Social, cultural, political norms and values are essential to address a successful control of leptospirosis.[21] There are complex leptospirosis risk factors such as socio-economics[22,23], environment[24], livestock[3,25] and community involvement. Reducing leptospirosis transmission implies to focus on leptospirosis prevention or control programs to break the chain of infection by avoiding direct contact or minimizing the risks of indirect contact with sources of infection.[21] Departments in districts cooperate to develop plans to prevent and control leptospirosis but there is a lack of continuity in these activities and they do not cover the whole population. However, there are insufficient linkages between departments to ensure comprehensive disease prevention activities at the local level. Strengths and weaknesses in leptospirosis prevention and control policy implementation are shown in Table 2.

Table 2. Strengths and weaknesses in leptospirosis prevention and control policy implementation.

Strengths		
Nation level	**Province level**	**Subdistrict level**
- There is a National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response. - There are mechanisms for cooperation between departments via Officer of coordination unit for One Health.	- There is a Communicable Diseases Committee in the Province.	- There are guidelines for The District Strengthening Disease Control.
Weaknesses		
Nation level	**Province level**	**Subdistrict level**
- No plan and indicator between departments for prevention and control leptospirosis.	- The Communicable Diseases Committee is not concerned by leptospirosis issue. - The cooperation is only occasional. For example, public health and livestock officer join only to investigate leptospirosis disease punctually.	- No standard or clear role for cooperation between department. - No indicator to work using the One Health approach. - Leptospirosis prevention mainly concerns patients and is not continuously directed to the whole population.

The One Health approach, thanks to disease surveillance, management, and eradication through collaboration between public health improving personal protection, veterinarians dealing with livestock and wild animal populations, ecologists and public health experts can improve the prevention and control of the disease.[26] The implementation of the One Health approach can enhance communication on risk and help turn rhetoric into reality.[27] National health policies and systems should allow a better cooperation between departments in accordance with the One Health approach. Moreover, at the local level, a standard joint action should be developed to prevent and control the zoonosis with the participation of local departments and people. This would help to clarify the role of each department for a comprehensive disease prevention and control, consistent with the issues encountered in the local context.

Conclusion

Leptospirosis outbreak in Mahasarakham is still a health issue. There are gaps in linkages between departments to ensure comprehensive disease prevention activities, but acceptance of the One Health approach for leptospirosis prevention and control will improve impacts of prevention and control of leptospirosis, which needs to develop clearer concrete cooperation between provincial departments and further to establish realistic leptospirosis guidelines at the local level.

References

1. World Health Organization. Leptospirosis laboratory manual. India: World Health Organization; 2007.
2. Levett PN. Leptospirosis. Clin Microbiol Rev. 2001;14.
3. World Health Organization. Human leptospirosis: guidance for diagnosis, surveillance and control. World Health Organization; 2003.
4. Guerra MA. Leptospirosis: Public health perspectives. Biologicals. 2013;41(5):295-297.
5. Pappas G, Papadimitriou P, Siozopoulou V, Christou L, Akritidis N. The globalization of leptospirosis: worldwide incidence trends. International Journal of Infectious Diseases. 2008;12(4):351-357.
6. Victoriano AFB, Smythe LD, Gloriani-Barzaga N, et al. Leptospirosis in the Asia Pacific region. BMC Infectious Diseases. 2009;9(1):147.
7. Morand S, Chaisiri K, Karnchanabanthoeng A, Hinjoy S. Environment and health in Thailand: investigating epidemiological trends of three infectious diseases to infer scenarios. In:Trisurat Y., Shrestha R.P., Hamovller P, editors.Environmental Resources and Related Policy and Social. New York: Nova Science Publishers (in press); 2018.

8. Soawapak Hinjoy. Epidemiology of leptospirosis from Thai National Disease Surveillance System, 2003-2012. Outbreak, surveillance and investigation reports. 2014;7(2):1-5.
9. Dechet AM, Parsons M, Rambaran M, et al. Leptospirosis outbreak following severe flooding: A rapid assessment and mass prophylaxis campaign; Guyana, January-February 2005. PLoS ONE. 2012;7(7):1-6.
10. Amilasan A-sT, Ujiie M, Suzuki M, et al. Outbreak of leptospirosis after flood, the Philippines, 2009. Emerging Infectious Diseases. 2012;18(1):91-94.
11. The World Health Organization. One Health. http://www.who.int/features/qa/one-health/en/. Published 2017. Accessed 21 February, 2018.
12. Bidaisee S, Macpherson CN. Zoonoses and one health: a review of the literature. Journal of parasitology research. 2014;2014.
13. Bureau of Emerging Infectious Diseases Department of Disease Control MoPH. Thailand National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response (2017-2021). Thailand: Office of Printing The Veterans Administration under the Royal Patronage; 2016.
14. South East Asia One Health University Network. What we do 2018. Available from: http://seaohun.org/index.php?option=com_content&view=article&id=155&Itemid=667. Published 2018. Accessed 16 February, 2018.
15. Mahasarakham Provincial Public Health Office. Method of catching and cooking rats by folk wisdom. Mahasarakham, Thailand: Mahasarakham Provincial Public Health Office; 2000.
16. Bureau of General Communicable Department of Disease Control MoPH. Academic leptosporosis handbook. Bangkok, Thailand: Community Cooperative Thailand Corporation; 2000.
17. Department of Disease Control: Ministry of Public Health and Office of the Basic Education Commission: Ministry of Education. Strategy of supervision and school development for leptospirosis prevention and controlling Bangkok, Thailand: The War Veterans Organization of Thailand; 2003.

18. Wibulpolprasert S, Sirilak S, Ekachampaka P, Wattanamano N, Taverat R. Thailand health profile report 2005 – 2007. Bureau of Policy and Strategy, Ministry of Public Health, Thailand. 2007.
19. Sommanustweechai A, Patcharanarumol W, Iamsirithaworn S, Kalpravidh W, Ratanakorn P, Tangcharoensathien V. Evolution of collaborations under the ”One Health” concept in Thailand. Journal of Health Systems Research. 2014;8(3):292-305.
20. Thailand. Memorandum of Understanding
on the implementation of One Health initiative for National Health Security
Published 2016. Accessed 21 February, 2018.
21. Sakundarno M, Bertolatti D, Maycock B, Spickett J, Dhaliwal S. Risk factors for leptospirosis infection in humans and implications for public health intervention in Indonesia and the Asia-Pacific region. Asia Pacific Journal of Public Health. 2014;26(1):15-32.
22. Mohan ARM, Chadee DD. Knowledge, attitudes and practices of Trinidadian households regarding leptospirosis and related matters. International Health. 2011;3(2):131-137.
23. Rodríguez-Vidigal FF, Vera-Tomé A, Nogales-Muñoz N, Muñoz-García-Borruel M, Muñoz-Sanz A. Leptospirosis in South-western Spain. Revista Clínica Española (English Edition). 2014;214(5):247-252.
24. Benacer D, Thong KL, Min NC, et al. Epidemiology of human leptospirosis in Malaysia, 2004–2012. Acta Tropica. 2016;157:162-168.
25. Shah I. Leptospirosis. Pediatric Infectious Disease. 2012;4(1):4-8.
26. Zinsstag J, Tanner M. Summary and outlook for practical use of One Health. In: Zinsstag J, Schelling E, Waltner-Toews D, Whittaker M, Tanner M, editors. One Health: the theory and practice of integrated health approaches. CABI; 2015. p. 427-34.
27. Binot A, Morand S. Implementation of the One Health strategy: Lessons learnt from community-based natural resource programs for communities' empowerment and

equity within an ecoHealth Approach. In: Morand S, Dujardin J-P, Lefait-Robin R, Apiwathnasorn C, editors. Socio-ecological dimensions of infectious diseases in Southeast Asia. Springer; 2015. p.325-35.

Manuscript 3:
Knowledge and practices of leptospirosis patients, their neighbors, village health volunteers and community leaders regarding leptospirosis prevention and control in Mahasarakham Province, Thailand

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KNOWLEDGE AND PRACTICES OF LEPTOSPIROSIS PATIENTS, THEIR NEIGHBORS, VILLAGE HEALTH VOLUNTEERS AND COMMUNITY LEADERS REGARDING LEPTOSPIROSIS PREVENTION AND CONTROL IN MAHASARAKHAM PROVINCE, THAILAND

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Abstract. Little is known about leptospirosis prevention at the community level in Thailand. In this study we aimed to investigate knowledge and practices of leptospirosis patients, their neighbors, village health volunteers and community leaders regarding leptospirosis prevention and control in Mahasarakham Province, Thailand, in order to inform a leptospirosis prevention and control program in the study province. Study subjects were chosen purposely by selecting one leptospirosis patient per subdistrict for subdistricts with fewer than 5 leptospirosis cases per subdistrict and 2 leptospirosis patients per subdistrict for subdistricts with more than 5 leptospirosis cases per subdistrict for this study conducted during 2004 - 2014. We attempted to interview 2 neighbors of each leptospirosis patient who were the same age and had the same occupation as the patient. We selected a community leader from each study subdistrict, a village leader from each study subdistrict, a member of each study subdistrict administrative team and a village health volunteer from each study subdistrict for interview. Each subject was interviewed following a structured form asking about knowledge and leptospirosis prevention practices. The results of interviews were then summarized and compared using ANOVA and independent-samples t-tests. A total of 167 patients, 325 neighbors, 320 community leaders and 480 village health volunteers were included in the study. The percentages of patients, neighbors, community leaders and village health volunteers who were male were 78.4%, 33.5%, 78.8% and 22.9%, respectively. The mean (±standard deviation, (SD)) ages of leptospirosis patients, neighbors, village health volunteers and community leaders were 53.6 (±14.0), 53.4 (±12.4), 49.7 (±7.9) and 47.1 (±9.2) years, respectively. The mean (±SD) of knowledge regarding leptospirosis of community leaders were the highest 30.3 (±5.7) points. 32.3% of patients and 39.7% of neighbors knew that cattle can get leptospirosis. 16.8% of patients, 17.8% of neighbors, 23.3% of village health volunteers and 20% of community leaders knew that severe leptospirosis does not affect the heart. Neighbors had better practice about leptospirosis prevention than leptospirosis patients ($P < 0.001$) whose mean (±SD) practice about leptospirosis prevention of neighbors and patients were 29.4 (±3.0) and 27.8 (±3.2) points respectively. 72.5% of patients and 49.2% of neighbors declared not to wear boots when they cleaned stable or worked in flooding areas. 63.8% of community leaders gave the results of leptospirosis prevention and monitoring campaigns to the community

There is a need for education regarding leptospirosis and its prevention for all the gaps in our study. Further study are needed to determine the best methods to accomplish this.

Keywords: leptospirosis, knowledge, practices, prevention, communities, public health, Thailand

INTRODUCTION

Leptospirosis is a neglected zoonotic disease caused by a spirochete species of the genus Leptospira (Bharti et al., 2003; Levett, 2001). About 14.8 per 100,000 people worldwide contract leptospirosis each year (Costa et al., 2015). Leptospirosis occurs more commonly in the tropics where conditions favor development of leptospires (Pappas et al., 2008). Leptospirosis incidence is associated with socio-economic factors, such as poverty (Sugunan et al., 2009) and environmental factors, such as climate and flooding (Amilasan et al., 2012). Animal reservoirs also contribute to leptospirosis incidence and infection risk (Morand et al., 2018).

Understanding knowledge and practices about a disease can inform effective disease control programs (Health and Services, 2005). It can help identify knowledge gaps and behavioral patterns that contribute to disease transmission and create barriers for disease control and prevention programs (Organization, 2008).

Thailand is a tropical country with a large amount of rainfall. More than 70,000 cases of leptospirosis have been recorded in Thailand since its emergence in the 2000s (Morand et al., 2018). Mahasarakham Province, in northeastern Thailand, has a moderate to high leptospirosis incidence (Morand et al., 2018). The Ministry of Public Health, Thailand and the Mahasarakham Provincial Public Health Office have developed and implemented a leptospirosis prevention program (Department of Disease Control, 2016). However there remains a lack of knowledge about this disease among the residents of this province. Community leaders and village health volunteers participate in the surveillance of leptospirosis (Department of Disease Control, 2016).

The aim of this study was to assess the knowledge and practices of leptospirosis patients, their neighbors, village health volunteers and community leaders regarding leptospirosis prevention and control in Mahasarakham Province, Thailand in order to inform leptospirosis prevention and control programs in that province.

MATERIALS AND METHODS

Study Design and Area

We conducted a cross-sectional survey in Mahasarakham Province regarding knowledge and practices of subjects regarding leptospirosis prevention and control. Mahasarakham Province had 13 districts, 133 subdistricts, 1,982 villages, 244,155 households and 869,280 individuals in 2016 (Mahasarakham Provincial Public Health Office, 2016). 43.9% of the population in Mahasarakham Province works in agriculture (Mahasarakham Provincial Labor Office, 2017).

Sample size and procedure

Study subjects were divided into 4 groups: leptospirosis patients, their neighbors, village health volunteers and community leaders.

Leptospirosis patients were those who contracted leptospirosis during 2004 to 2014. Leptospirosis cases are reported to the Mahasarakham Provincial Public Health Office. Leptospirosis patients were clinically diagnosed at a hospital. Patients with symptoms were diagnosed as having leptospirosis by the Leptocheck-WB, indirect immunofluorescent antibody test (IFA), microcapsule agglutination test (MCAT) or microagglutination test (MAT). For each subdistrict and outbreaks with fewer than 5 leptospirosis cases reported, 1 subject was asked to participate in this study and to be interviewed. For subdistricts with more than 5 cases of leptospirosis, 2 subjects were asked to participate. Among 127 subdistricts, 167 leptospirosis patients were involved in this study.

We also selected 2 neighbors for each patient to interview, selecting those of a similar age and occupation as the leptospirosis patient. We interviewed a total 325 neighbors. We then selected a community leader from each village in each subdistrict with the largest numbers of leptospirosis cases. The community leaders from each village have the responsibility to govern the village, including supporting government programs, such as the leptospirosis prevention and control program (Thailand, 1914). We also interviewed one member of the subdistrict administration from each subdistrict studied. Members of the subdistrict administration have the responsibility to manage the budget for the subdistrict (Thailand, 1999). We interviewed a total of 320 community leaders.

The numbers of village health volunteers vary by subdistrict. We interviewed a total of 480 village health volunteers out of a total of 1,495 health volunteers in the study area (Cochran, 2007). Village health volunteers participate in disease prevention and control programs conducted by the Thai government (Thailand, 2001).

Study Instrument

Each interview was conducted following a structured questionnaire reviewed by 3 experts. These were a public health expert, a public health lecturer and a public health officer responsible for leptospirosis prevention and control at the Mahasarakham Provincial Public Health Office.

The questionnaire was divided into demographics, knowledge (comprised of 42 questions) and practices (comprised of 12, 12, 18 and 11 questions for leptospirosis patients, their neighbors, village health volunteers and community leaders, respectively).

The knowledge section was scored as 1 point for each correct response and 0 points for each wrong or “do not know” response.

The practices section of the questionnaire for the leptospirosis patients and their neighbors was scored using a 3 – point Likert scale where 3 is “usually”, 2 is “sometimes” and 1 is “never”. The practices section of the questionnaire for the village health volunteers and community leaders was scored with 1 point if they do a specific activity and 0 points if they did not dot that activity.

The questionnaire was pilot tested among 30 subjects from each of the 4 groups from the neighboring Kalasin Province. The Cronbach’s Alpha coefficient for this pilot test these was > 0.70.

Ethical approval

This study was approved by the Ethics Committee for Public Health from the Mahasarakham Province (reference number: 5 / 2558).

Statistical analyses

Statistical analyses were carried out using the R statistical program (R Core Team, 2018, R Foundation for Statistical Computing, Vienna, Austria). A p-value < 0.05 was considered statistically significant. An ANOVA, an independent-samples t-test and a Tukey HSD were used to compare knowledge and practices.

RESULTS

Socio-demographic characteristics of the study subjects

78.4% of leptospirosis patients and 78.8% of community leaders were male; 33.5% of neighbors and 22.9% of village health volunteers were male. The mean (± standard deviation (SD)) ages of patients, neighbors, village health volunteers and community leaders were: 53.6 (±14.0), 53.4 (±12.4), 49.7 (±7.9) and 47.1 (±9.2), respectively. 46.6% of community leaders had a high school education level; 79.6% of leptospirosis patients, 78.2% of neighbors and 44.2% of village health volunteers had a primary school education level. About 70% of people in each group fed animals at their homes. Twenty-four percent of leptospirosis patients, 4.9% of neighbors, 5.9% of community leaders and 8.3% of village health volunteers had a history of a family member with leptospirosis.

Knowledge about Leptospirosis

The mean knowledge score among community leaders (30.3 points) was higher than the knowledge scores among patients (28.5 points), neighbors (28.6 points) and village health volunteers (29.5 points). There were significant differences regarding the total knowledge of leptospirosis by group ($p < 0.001$) as shown in Table 1. The result of multiple comparisons by Tukey HSD found that leptospirosis knowledge of community leaders was significantly higher than patients ($p < 0.001$). Leptospirosis knowledge of their neighbors was significantly lower than the leptospirosis knowledge of village health volunteers ($p = 0.018$) and community leaders ($p < 0.001$).

Table 1

Comparison of total knowledge point (n = 1,292).

Group	Knowledge point		F-test	p-value
	Mean	SD		
Leptospirosis patients	28.5	4.6	6.38	<0.001
Their neighbors	28.6	5.0		
Village health volunteers	29.2	6.0		
Community leaders	30.3	5.7		

29.8% of patients, 34.0% of neighbors, 57.5% of village health volunteers and 52.2% of community leaders knew that chickens, dogs, cats and cattle can get leptospirosis. 66.5% of patients, 65.5% of neighbors, 80.2% of village health volunteers and 68.5% of community leaders knew some leptospirosis symptoms. 16.8% of patients, 17.8% of neighbors, 23.3% of village health volunteers and 20.0% of community leaders knew severe leptospirosis does not affect the heart. 52.1% of patients and 55.1% of neighbors knew the incubation period of leptospirosis is about 10 days (Table 2).

Table 2

The knowledge of study subject about leptospirosis (n = 1,292).

Questions	Correct answers			
	Patients n (%)	Neighbors n (%)	Village health volunteers n (%)	Community leaders n (%)
Origin of disease	58.1%	60.0%	78.4%	70.8%
Leptospira is not found in the saliva of animals.	49 (29.3)	86 (26.5)	180 (37.5)	113 (35.3)
Leptospira is found in animal urine.	118 (70.7)	255 (78.5)	431 (89.8)	289 (90.3)
Leptospira can live in water for 6 months.	60 (35.9)	146 (44.9)	271 (56.5)	198 (61.9)
Cattle can carry *Leptospira*.	51 (30.5)	123 (37.8)	265 (55.2)	207 (64.7)
Mosquitoes cannot carry *Leptospira*.	108 (64.7)	206 (63.4)	333 (69.4)	252 (78.8)
Leptospira can be transmitted from animals to humans.	149 (89.2)	287 (88.3)	424 (88.3)	300 (93.8)
All occupations are at risk for getting leptospirosis.	144 (86.2)	262 (80.6)	355 (74.0)	228 (71.3)
Transmission route	80.6%	80.1%	88.3%	75.9%

Questions	Correct answers			
	Patients n (%)	Neighbors n (%)	Village health volunteers n (%)	Community leaders n (%)
People cannot contract *Leptospira* by splits in the skin of the feet.	133 (79.6)	252 (77.5)	389 (81.0)	273 (85.3)
People can contract leptospirosis by immersing in contaminated water.	141 (84.4)	284 (87.4)	403 (84.0)	282 (88.1)
You can get leptospirosis from a pond.	155 (92.8)	299 (92.0)	378 (78.8)	260 (81.3)
You can get leptospirosis from a river.	148 (88.6)	289 (88.9)	376 (78.3)	251 (78.4)
You can get leptospirosis from rice fields.	165 (98.8)	312 (96.0)	426 (88.8)	303 (94.7)
You can get leptospirosis from the forest.	150 (89.8)	276 (84.9)	349 (72.7)	208 (65.0)
You can get leptospirosis at home.	123 (73.7)	233 (71.7)	328 (68.3)	206 (64.4)
You can get leptospirosis from flooded areas.	145 (86.8)	294 (90.5)	415 (86.5)	300 (93.8)
You can get leptospirosis during the dry season.	60 (35.9)	117 (36.0)	125 (26.0)	88 (27.5)
You can get leptospirosis during the rainy season.	156 (93.4)	306 (94.2)	441 (91.9)	311 (97.2)

Questions	Correct answers			
	Patients n (%)	Neighbors n (%)	Village health volunteers n (%)	Community leaders n (%)
You can get leptospirosis during the winter season.	104 (62.3)	201 (61.8)	309 (64.4)	188 (58.8)
Leptospirosis symptoms	66.5%	65.5%	80.2%	68.5%
The incubation period of leptospirosis is 10 days.	87 (52.1)	179 (55.1)	320 (66.7)	251 (78.4)
The most common leptospirosis symptoms are high fever, headaches and muscle pain.	165 (98.8)	302 (92.9)	415 (86.5)	281 (87.8)
Severe leptospirosis does not affect the heart.	28 (16.8)	58 (17.8)	112 (23.3)	64 (20.0)
Severe leptospirosis affects the liver.	101 (60.5)	181 (55.7)	302 (62.9)	191 (59.7)
Severe leptospirosis affects the kidneys.	119 (71.3)	213 (65.5)	284 (59.2)	189 (59.1)
Leptospirosis can be contracted more than once.	118 (70.7)	253 (77.8)	410 (85.4)	255 (79.7)
Delayed treatment of leptospirosis can result in death.	160 (95.8)	304 (93.5)	446 (92.9)	304 (95.0)
Prevention of infection	70.5%	68.6%	82.7%	72.4%

Questions	Correct answers			
	Patients n (%)	Neighbors n (%)	Village health volunteers n (%)	Community leaders n (%)
You cannot avoid leptospirosis by avoiding an infected patient.	107 (64.1)	187 (57.5)	337 (70.2)	230 (71.9)
You cannot avoid leptospirosis by avoiding contact with a patient's body.	99 (59.3)	177 (54.5)	273 (56.9)	205 (64.1)
You can avoid leptospirosis by avoiding contact with a patient's blood and saliva.	72 (43.1)	154 (47.4)	259 (54.0)	135 (42.2)
House cleaning can prevent leptospirosis.	147 (88.0)	272 (83.7)	382 (79.6)	263 (82.2)
Leptospirosis spread cannot be prevented by giving medication to animals.	27 (16.2)	69 (21.2)	167 (34.8)	98 (30.6)
Eating fresh vegetables from a pond can increase the risk of leptospirosis.	135 (80.8)	256 (78.8)	369 (76.9)	235 (73.4)
Drinking pond water can increase the risk of contracting leptospirosis.	144 (86.2)	278 (85.5)	392 (81.7)	256 (80.0)

Questions	Correct answers Patients n (%)	Neighbors n (%)	Village health volunteers n (%)	Community leaders n (%)
Masks cannot protect you from leptospirosis.	74 (44.3)	135 (41.5)	274 (57.1)	202 (63.1)
Rubber boots can protect from leptospirosis.	159 (95.2)	311 (95.7)	456 (95.0)	307 (95.9)
Checking boots for leaks before wearing them can protect you from leptospirosis.	156 (93.4)	288 (88.6)	438 (91.3)	298 (93.1)
Leptospirosis is spread during the rainy season up to the winter.	153 (91.6)	287 (88.3)	343 (71.5)	293 (91.6)
Farmers can protect themselves from leptospirosis by controlling the rat population.	139 (83.2)	261 (80.3)	384 (80.0)	257 (80.3)
Leptospirosis in animals	33. 9%	38.4%	63.9%	58.3%
Rats can get leptospirosis.	84 (50.3)	182 (56.0)	358 (74.6)	264 (82.5)
Chickens can get leptospirosis.	47 (28.1)	99 (30.5)	194 (40.4)	120 (37.5)
Dogs can get leptospirosis.	49 (29.3)	107 (32.9)	221 (46.0)	163 (50.9)
Cats can get leptospirosis.	49 (29.3)	107 (32.9)	214 (44.6)	164 (51.3)
Cattle can get leptospirosis.	54 (32.3)	129 (39.7)	313 (65.2)	221 (69.1)

Practices

26.3% of patients avoiding paddling and fishing when they had wounds on the body and 27.5% of patients wore boots when they worked in flooded areas. 33.5% neighbors did not pick up trash from the ground around their houses and 46.2% did not paddle or fish when they had wounds on the body. 72.5% of patients and 49.2% of neighbors declared not to wear boots when they cleaned stable or worked in flooding areas.

Neighbors had significantly better practices about leptospirosis prevention than leptospirosis patients ($p < 0.001$) whose mean (±SD) practice about leptospirosis prevention of neighbors and patients were 29.4 (±3.0) and 27.8 (±3.2) points respectively.

96.5% of village health volunteers did leptospirosis surveillance in the community. 74.8% of village health volunteers collected data regarding cattle and pigs that died from leptospirosis and reported this information to the health center.

99.4% of community leaders started they encourage people to dispose of garbage correctly in the community; 97.8% stated they encouraged people in the community to clean their houses and destroy rat habitats. 63.8% of community leaders participated in meeting of summary the result of leptospirosis prevention and monitoring of community and 74.7% told the community about prevention activities in the community.

DISCUSSION

This study aimed to explore the leptospirosis knowledge and practices among leptospirosis patients and their neighbors, village health volunteers and community leaders, in Mahasarakham Province, Thailand.

Leptospirosis knowledge among study subjects

We found that 83.2% and 80.3% of leptospirosis patients and their neighbors knew that farmers can protect themselves from leptospirosis by controlling the rat population, which shows some success in the leptospirosis prevention campaign. However, only 29.8% of patients, 34.0% of neighbors, 57.5% of village health volunteers and 52.2% of community leaders knew chicken, dogs, cats and cattle can also get leptospirosis. Our results are similar to a study from Argentina, which showed only 12.8% of subjects knew dogs can get leptospirosis and only 5.4% of subjects knew cattle and pigs can get leptospirosis (Ricardo et al., 2018).

In our study, community leaders had significantly greater leptospirosis knowledge than other groups. Community leaders also had a higher education level than other groups. The majority of community leaders had a high school education level while the other groups had a primary school education level.

Village health volunteers have an important role in reporting leptospirosis information to healthcare providers during outbreaks (Department of Disease Control, 2016) and an important role in prevention and health promotion activities (Thailand, 2001), but in our study, they had an incomplete knowledge of leptospirosis. This may result in a delay in recognizing and reporting a leptospirosis outbreaks

Leptospirosis practices among patients and their neighbors

In our study, most patients had higher risk behavior for contracting leptospirosis than their neighbors. For example, 52.3% of neighbors wore boots when working in flooded areas but only 27.5% of patients did. A similar study from northeastern Malaysia, also found only 51% of subjects wore boots in flooded area (Azfar et al., 2018). Another study from the Philippines reported protective gear is often not used (Shin-ichi, 2016). Unfortunately, the patients in our study continued to have poor prevention behavior in spite of having previously contracted leptospirosis, suggesting the medical practitioners in the study area also may share part of the blame for not educating their patients about prevention behavior or they may not know about prevention behavior.

Leptospirosis practices among Village Health Volunteers

In this study, nearly all the village health volunteers conducted leptospirosis surveillance in the community but only 74.8% reported cases of cattle and pigs that died of leptospirosis. This suggests they need to be educated about their responsibilities by the Ministry of Public Health, which may not be informing the volunteers.

Leptospirosis practices among community leaders

In our study, 63.8% of community leaders participated in meeting of summary the result of leptospirosis prevention and monitoring of community and 74.7% of community leader participated in the evaluation of leptospirosis prevention activities in the community. This suggests community leaders may not be aware of those duties in the prevention and control of leptospirosis and must be informed of them by the appropriate control government authorities.

Implications and Recommendations

Leptospirosis prevention and control in the community should focus on patients, community leaders and village health volunteers. Leptospirosis prevention programs need to be developed and implemented in the study area.

The public health department should improve health education activities, increase the participation of people in the community and encourage local organizations to share resources and experiences to improve the implementation of the leptospirosis prevention and control programs.

Lack of knowledge regarding the role of domestic animals and livestock in leptospirosis in the communities of Mahasarakham needs to be corrected through collaboration between departments of public health and animal health in accordance with the government policies.

Village health volunteers also need to be educated to detect leptospirosis outbreaks earlier.

The responsibilities of village health volunteers depend on subdistrict guidelines. Then guidelines need to be updated and include information regarding leptospirosis and its prevention and control.

Community leaders need to better develop disease surveillance practices and have a better knowledge about leptospirosis and its prevention and control. Community leaders can improve prevention activities by allocating an adequate budget for public health in the community.

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REFERENCES

Amilasan A-sT, Ujiie M, Suzuki M, et al. Outbreak of Leptospirosis after Flood, the Philippines, 2009. Emerging Infectious Diseases 2012; 18: 91-4.

Azfar ZM, Nazri SM, Rusli AM, et al. Knowledge, attitude and practice about leptospirosis prevention among town service workers in northeastern Malaysia: a cross-sectional study. Journal of Preventive Medicine and Hygiene 2018; 59: E92-E8.

Bharti AR, Nally JE, Ricaldi JN, et al. Leptospirosis: a zoonotic disease of global importance. The Lancet Infectious Diseases 2003; 3: 757-71.

Cochran WG. Sampling techniques: John Wiley & Sons, 2007.

Costa F, Hagan JE, Calcagno J, et al. Global Morbidity and Mortality of Leptospirosis: A Systematic Review. PLoS Neglected Tropical Diseases 2015; 9: 1-19.

Department of Disease Control. District health system disease control handbook. Mahasarakham, Thailand: Mahasarakham Provincial Public Health Office, 2016.

Levett PN. Leptospirosis. American Society for Microbiology 2001; 14: 296-326.

Mahasarakham Provincial Labour Office. (2017). Mahasarakham statistic 1st Quarter 2017. Mahasarakham.

Mahasarakham Provincial Public Health Office. (2016). Population information. Mahasarakham, Thailand: Mahasarakham Provincial Public Health Office.

Morand S, Chaisiri K, Karnchanabanthoeng A, Hinjoy S. Environment and health in Thailand: investigating epidemiological trends of three infectious diseases to infer scenarios. In Y Trisurat, RP Shrestha & P Havmoller (Eds.), Environmental Management (161-79). New York: Nova Science Publishers, 2018.

Pappas G, Papadimitriou P, Siozopoulou V, Christou L, Akritidis N. The globalization of leptospirosis: worldwide incidence trends. International Journal of Infectious Diseases 2008; 12: 351-7.

R Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna. 2018 [Cited 2019 Jan 12]. Available from: https://www.R-project.org

Ricardo T, Bergero LC, Bulgarella EP, Previtali MA. Knowledge, attitudes and practices (KAP) regarding leptospirosis among residents of riverside settlements of Santa Fe, Argentina. PLoS Neglected Tropical Diseases 2018; 12: e0006470.

Shin-ichi Y. Knowledge, attitudes and practices of the community residents concerning the prevention and control of leptospirosis in the National Capital Region (NCR), Philippines. Acta Medica Philippina 2016; 50: 129-35.

Sugunan A, Vijayachari P, Sharma S, et al. Risk factors associated with leptospirosis during an outbreak in Middle Andaman, India. 2009.

Thailand. Act of Local administration in 1914(Revised to current). 1914 [Cited 2018 13 July]. Available from: http://pab.dopa.go.th/main/law/pab2457_12.pdf

Thailand. Act of District Council and Subdistrict Administrative Organization in 1994 (And revised to version 3, 1999). 1999 [Cited 2018 Jul 14]. Available from: http://www.local.moi.go.th/law28.htm

Thailand. Government gazette of regularity of village health volunteers in 2001. 2001 [Cited 2018 Jul 14]. Available from: http://www.klongchanak.go.th/2011/upfile/law/rulehealt54.pdf

U.S. Department of Health and Human Services, National Institutes of Health, National Cancer Institute. Theory at a glance: A guide for health promotion practice. 2005 [Cited 2018 Jul 20]. Available from: https://cancercontrol.cancer.gov/brp/research/theories_project/theory.pdf

World Health Organization. Advocacy, communication and social mobilization for TB control: a guide to developing knowledge, attitude and practice surveys. Switzerland: WHO Library Cataloguing-in-Publication Data, 2008.

Guidelines for improving cooperation among departments for leptospirosis prevention and control (English version)

The “Guidelines for improving cooperation among departments for leptospirosis prevention and control” is a translation from Thai to English. This guideline was elaborated by three groups of academics including: lecturers from the Public Health Faculty, Mahasarakham University, the network agent of Thailand One Health University Network (THOHUN) and Mahasarakham provincial public health officers. The list of people who have participated in the development of the guidelines is given below:

Mahasarakham Provincial Public Health Office

Name Surname	Position
1. Mr. Pornsit Thuainan	Deputy Public Health Doctor of Mahasarakham Province
2. Mr. Krit Phosi	Head of Communicable Disease Control
3. Mr. Chayanon Sukuna	Responsible of epidemiology
4. Ms. Palichad Pakilana	Responsible of epidemiology
5. Ms. Ketsirin Chailap	Responsible of zoonosis

Thailand One Health University Network (THOHUN)

Name Surname	Position
1.Assistant Professor Dr. Niruwan Ternblow	Network agent of THOHUN, North east of Thailand, Lecturer of the Public Health Faculty, Mahasarakham University

Public health faculty, Mahasarakham University

Name Surname	Position
1. Dr. Terdsak Promaruk	Lecturer of the Public Health Faculty, Mahasarakham University
2. Ms. Suwairin Sriwichai	Lecturer of the Public Health Faculty, Mahasarakham University

The process of establishing the guidelines with each group had to follow that procedure:

1. Make an appointment with each agency by requesting permission from the head of the department.
2. Conduct meetings to present my research results to authorities of the department to facilitate the understanding of leptospirosis situation and relative problems. A draft was established and was improved by exchanging opinions and discussion. When necessary, several meetings were scheduled in agreement until developing final guidelines.
3. I finally sent the final guidelines to Mahasarakham Provincial Public Health Office.

Figure 1. Meeting to develop guidelines with lecturers of Public Health Faculty, Mahasarakham University.

Figure 2. Meeting to develop guidelines with network agent of Thailand One Health University Network (THOHUN).

Figure 3. Meeting to develop guidelines with Mahasarakham provincial public health officers.

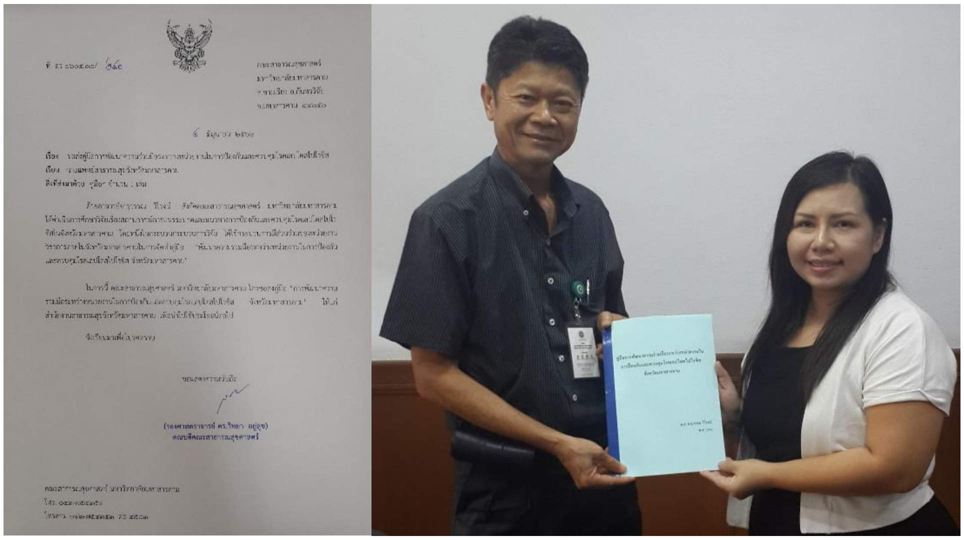


Figure 4. Final guidelines delivered to the Mahasarakham Provincial Public Health Office.

During this process, there was important factors to take into account as follow.

1. Involvement of department heads in the establishment of guidelines

In 2000, the Ministry of Public Health has chosen Mahasarakham as a pilot province to develop and improve leptospirosis prevention policy. In Thailand, board and head of the department is key personal to impel and encourage staff operations. For example, the board of Mahasarakham Provincial Public Health Office order and assign his staff to participate to research activities.

2. Collecting knowledge in multidisciplinary settings to develop leptospirosis prevention and control.

Nowadays, leptospirosis prevention and control policy in Mahasarakham is the main responsibility of public health officer. There is a controversy between internal departments and external agencies about causes of leptospirosis of this province. Therefore, collecting knowledge from various disciplines to study leptospirosis can promote the efficiency of leptospirosis prevention and control. Moreover, it allows establishing a concrete and consistent approach to the local context.

Implementation of guidelines

Mahasarakham Provincial Public Health Office will use the guidelines and support resources for implementing them in Borabu District as a pilot district, where, in addition high leptospirosis incidence an related death cases were found.

1. Concepts and principles of the guidelines for improving cooperation among departments for leptospirosis prevention and control of Mahasarakham Province, Thailand.

These guidelines are developed by taking into account the implementation of leptospirosis prevention and control measures adopted nationally and internationally. It integrates national strategy and regulations documents, international guides and the One Health Approach.

1) Thailand's National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response 2017 - 2021

The national plan aims to develop an effective, up-to-date strategy of surveillance, prevention, control of emerging infectious diseases and emergency public health scheme in Thailand following the One Health approach. Moreover, the plan encourages strengthening international cooperation for a better efficiency in surveillance prevention and control of emerging infectious diseases and public health emergency (Bureau of Emerging Infectious Disease Department of Disease Control, 2016).

2) Communicable diseases act B.E. 2558

The Communicable Diseases Act defines the competencies of government officers in disease surveillance and guidelines for prevention and control of communicable diseases. The Communicable Diseases Act aims to manage health problems in real time, to establish systems able to get prepared to deal with dangerous diseases and emerging infectious diseases and to reduce losses from illness and economic impacts. Moreover, the Communicable Diseases Act ambitions to create a Thai people's health security (Law Center Department of Disease Control, 2015).

3) One Health approach

One Health approach recognizes that the health of people is connected to the health of animals and of the environment. One Health is defined as a collaborative, multisectoral, and transdisciplinary approach working at the local, regional, national, and global levels with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment (The World Health Organization, 2017).

4) A Tripartite Guide to Addressing Zoonotic Diseases in Countries

The Tripartite Guide addresses urgent, ongoing, or potential health threats at the human-animal-environment interface at subnational, national, global, and regional levels. By promoting collaboration, multidisciplinary, and multisectoral approach the Tripartite Guide emphasizes balance and equity among all the relevant sectors and disciplines (World Health Organization et al., 2019).

5) District Health System (DHS)

The District Health System is a guide for disease prevention and control at the district level. The DHS was established by the Department of Disease Control, Ministry of Public Health, Thailand). Districts are target areas for developing disease surveillance and preparing response following a disease outbreak. The role of districts is to develop systems and mechanisms for the surveillance, prevention, and disease control. Moreover, districts must ensure strong cooperation among government departments, private organizations, and local communities for the prevention and control of diseases (Department of Disease Control, 2016).

6) World Health Organization (WHO): Human leptospirosis - guidance for diagnosis, surveillance and control.

The WHO guidance is directed towards health workers: clinicians, laboratory technicians, microbiologists, public health workers, veterinarians and biologists with an interest in zoonoses, etc., in relation to leptospirosis surveillance, prevention and control (World Health Organization, 2003).

2. Process of development of the guidelines for improving cooperation among departments for leptospirosis prevention and control of Mahasarakham Province, Thailand.

The guidelines have been established by considering strategies, regulations and laws of Thailand as well as documents and guides on leptospirosis prevention and control. The appropriateness, comprehensiveness and consistency of the guidelines with the specific working context of the province have been checked by Mahasarakham provincial public health officers, network agent of Thailand One Health University Network (THOHUN) and lecturers from the Public Health Faculty of Mahasarakham University. The guidelines have been developed following six steps as shown in Figure 5.

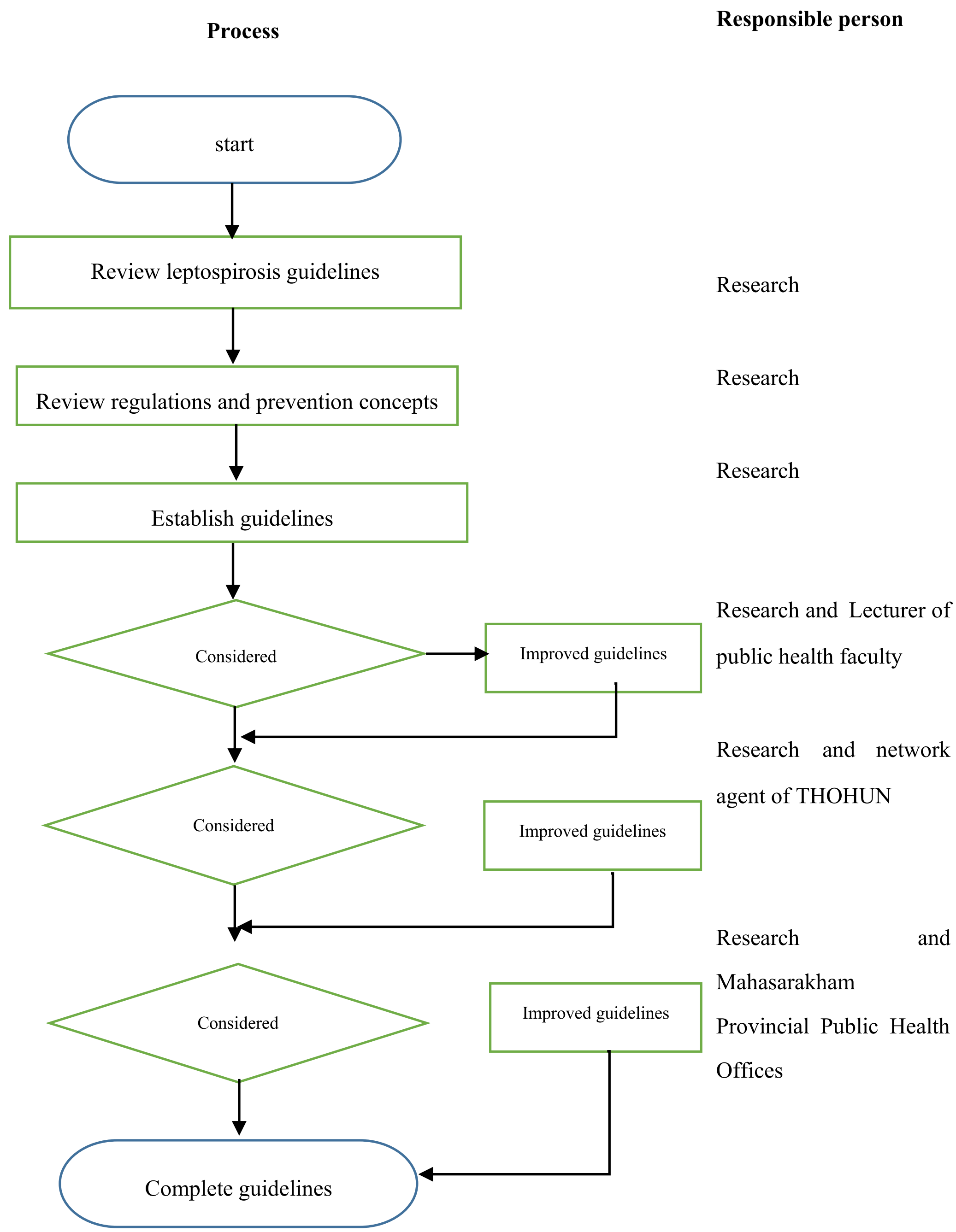
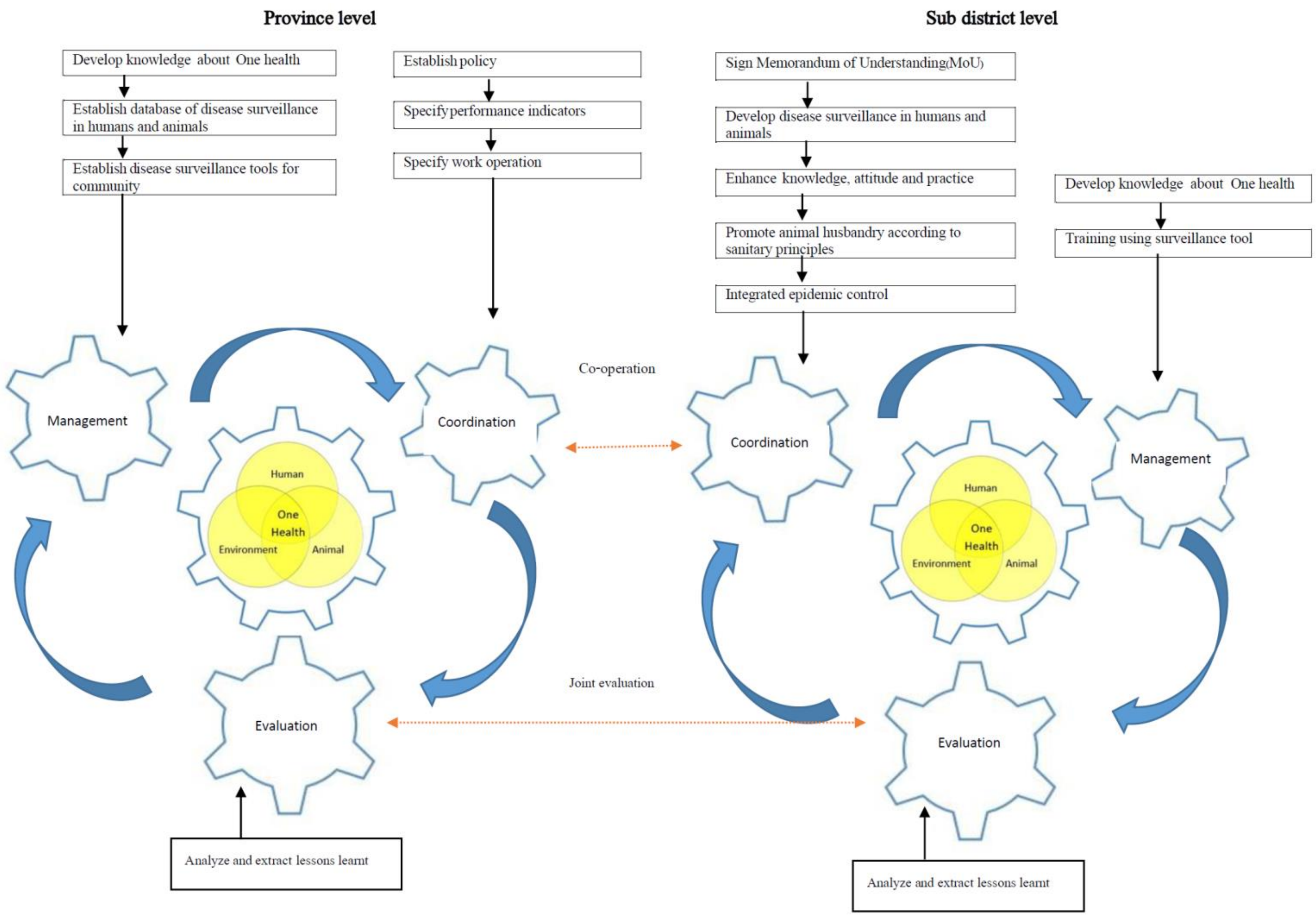


Figure 5. The process of development of the guidelines for improving cooperation among departments for leptospirosis prevention and control of Mahasarakham Province, Thailand.

3. Mechanisms of leptospirosis prevention



The mechanism for leptospirosis prevention and control using the One Health approach consists in three important components: management, coordination and evaluation. Those components will promote cooperation in disease prevention and control in people, animals and the environment. This cooperation will drive the mechanism to coordinate and operate prevention and control effectively.

The implementation of the driving mechanism at the provincial level will enhance the implementation of relevant mechanisms at the district level. Coordination and assessment of operations constitute the coordinating activities at provincial and subdistrict levels. The established connection will drive collaboration within and among administrative levels in order to improve leptospirosis prevention and control.

4. Summary of the guidelines of prevention and control under the One Health approach at the provincial level

	Operation guidelines	Responsible person
Management	1. Develop knowledge and skills of government officers to favor interoperability between departments for the prevention of communicable diseases at the provincial level. - training, participatory meeting	Provincial Governor
	2. Establish a database of disease surveillance in humans and animals. This database can link data between departments and can report epidemic between departments.	Communicable Diseases Committee of the Province
	3. Establish disease surveillance tools for the community level.	Provincial Public Health and Provincial Livestock officers
Coordination	1. Encourage all sectors at the provincial level to have a role in disease prevention and control by establishing policy, performance indicators and specify work operation for the prevention and control of outbreaks.	Provincial Public Health and Provincial Livestock officers
Evaluation	1. Follow and further develop guidelines of leptospirosis prevention and control.	Provincial public health and provincial livestock officers

5. Summary of the guidelines of prevention and control under the One Health approach at the subdistrict level.

	Operation guidelines	Responsible person
Management	1. Develop knowledge and skills of government officers to favor interoperability between departments for the prevention of communicable diseases at the subdistrict level. by the way of - e-learning	Provincial Governor
	2. Train village health volunteers, livestock volunteers to use surveillance tool by the way of - e-learning	Provincial Governor
Coordination	1. Sign Memorandum of Understanding (MoU) in the community	Public Health and Livestock officers, LGO
	2. Develop public participation, especially of village health volunteers and community leaders in diseases surveillance of humans and animals.	Public health and livestock officers
	3. Enhance knowledge, attitude and practice among people using multidisciplinary and participatory methods	Public health and livestock officers
	4. Promoting animal husbandry according to sanitary principles	Livestock officer
	5. Integrated epidemic control.	Public Health and Livestock officers
Evaluation	1. Follow and develop guidelines of leptospirosis prevention and control of diseases	Public health and livestock officers , LGO

6. Guidelines for developing cooperation among departments for prevention and control leptospirosis at the provincial level.

At the level of the province, disease prevention and cooperation activity between departments is organized by the Provincial Committee of Communicable Diseases. The Committee comprises the Governor, the public health department, the livestock department, the Provincial Public Relations Department, the Local Government, the Public Relations of the province and the Head of the Provincial Disaster Prevention and Mitigation Office. The role of the Committee is to plan surveillance, report disease situation, prevent, support, promote, follow and evaluate the control of communicable diseases in the province. Developing mechanisms for supporting coordination and collaboration among the various agencies will improve the efficiency and effective prevention of diseases. The mechanism consists in three important components: management, coordination and evaluation.

6.1 Management

Good management will enable to support preparation for leptospirosis prevention and control. The operation guidelines consist of the following:

6.1.1 Develop knowledge and understanding of interoperability between departments about disease prevention and control by government officials at the provincial level.

6.1.1.1 Educating government officials about the One health approach at the provincial level for developing their understanding and recognizing the importance of cooperation between departments.

6.1.1.2 Improving knowledge about leptospirosis prevention and control in health personals, livestock officers, local administrative organization's officers, public relations of the province officers, disaster prevention and mitigation officers.

Main responsibility

- **Provincial Governor**

Support for training of officers in the province.

6.1.2 Establish a database of disease surveillance in humans and animals.

6.1.2.1 Provincial public health and provincial livestock cooperation meeting for defining surveillance information such as animal surveillance, human surveillance, human behavioral surveillance, etc.

6.1.2.2 Establish a database of disease surveillance in humans and animals. This database can link department data and can report epidemic between departments.

Main responsibility

- **Provincial Governor**

  Established database of disease surveillance in humans and animals.

- **Provincial public health**

  Determine surveillance information.

- **Provincial livestock**

  Determine surveillance information.

- **Provincial Administrative Organizations (PAO)**

  Determine surveillance information.

6.1.3 Establish disease surveillance tools for community level.

6.1.3.1 Establish leptospirosis surveillance tools of humans and animals such as animal surveillance, human surveillance, human behavioral surveillance, etc.

6.1.3.2 Establish leptospirosis surveillance tools which can quickly report by using information technology. This tool should have the capacity to show the progress of surveillance. The person responsible of the surveillance in the province, district and subdistricts can access surveillance information.

Main responsibility

- **Provincial Governor**

  Control and supervise the establishment of surveillance tools at the community level.

- **Provincial public health**

  Jointly establish surveillance tools at the community level.

- **Provincial livestock**

  Jointly establish surveillance tools at the community level.

- **Provincial Administrative Organizations (PAO)**

  Jointly establish surveillance tools at the community level.

6.2 Coordination

The mechanism of coordination between departments is considered as essential to promote prevention and control of diseases of humans, animals and the environment. Establishing a mechanism for coordination between provincial agencies should follow the suggested steps;

6.2.1 Integration of prevention and control of leptospirosis at all levels in the same direction.

6.2.1.1 Establish a policy to prevent and control leptospirosis by enhancing cooperation between departments.

6.2.1.2 Establish a committee and determine the clear role of each department for leptospirosis prevention and control at the provincial, district and subdistrict level.

6.2.1.3 Assign indicators for leptospirosis prevention and control at the provincial, district and subdistrict level.

6.2.1.4 Every department participating in the development of leptospirosis project plan and action plan should coordinate its action with the other departments in order to work in the same direction.

Main responsibility

- **Provincial Governor**

  Organize a forum of cooperation to establish policy, performance indicators, guidelines for participatory prevention and control diseases.

- **Provincial public health**

  Jointly develop and implement the plan for surveillance, prevention and control of the disease.

- **Provincial livestock**

  Jointly develop and implement the plan for surveillance, prevention and control of the disease.

- **Provincial Administrative Organizations (PAO)**

  Jointly develop and implement the plan for surveillance, prevention and control of the disease.

- **Provincial Disaster Prevention and Mitigation**

  Jointly plan and implement the plan for surveillance, prevention and control of the disease.

- **Provincial Agriculture and Cooperatives**

  Jointly develop and implement the plan for surveillance, prevention and control of the disease.

- **Provincial Public Relations Department**

  Jointly develop and implement the plan for surveillance, prevention and control of the disease.

- **Provincial Natural resources and environment**

  Jointly develop and implement the plan for surveillance, prevention and control of the disease.

- **Provincial Education Officer**

  Jointly develop and implement the plan for surveillance, prevention and control of the disease.

6.2.2 Integrate using resources to prevent and control leptospirosis.

6.2.2.1 Integration of the resources of each department in the mechanism of leptospirosis prevention and control.

Main responsibility

- **Provincial Governor**

  Facilitate the use of resources for disease prevention of departments in the province.

- **Provincial public health**

  Participate in considering the use of resources for disease prevention in the province.

- **Provincial livestock**

  Participate in considering the use of resources for disease prevention in the province.

- **Provincial Administrative Organizations (PAO)**

  Participate in considering the use of resources for disease prevention in the province.

- **Provincial Disaster Prevention and Mitigation**

  Participate in considering the use of resources for disease prevention in the province.

- **Provincial Agriculture and Cooperatives**

  Participate in considering the use of resources for disease prevention in the province.

- **Provincial Public Relations Department**

  Participate in considering the use of resources for disease prevention in the province.

- **Provincial Natural resources and environment**

  Participate in considering the use of resources for disease prevention in the province.

- **Provincial Education Officer**

  Participate in considering the use of resources for disease prevention in the province.

6.3 Evaluation

Operational evaluation helps the person in charge to monitor epidemic situations and prepare the appropriate disease prevention and control measures. Evaluation mechanism consists of the following steps:

6.3.1 Determining roles and situations that need to report surveillance result.

6.3.1.1 Define the main responsibility for supervising the disease database in humans and animals. This staff has responsibility in monitoring leptospirosis outbreak database in humans and animals.

6.3.1.2 Determine the situation in which it is necessary to report leptospirosis epidemic to Provincial Communicable Disease Committee. For example, the supervisor of the disease database must report leptospirosis epidemic to the Provincial Communicable Disease Committee when leptospirosis incidence in human or animal is increasing.

6.3.1.3 Feedback about leptospirosis surveillance to departments in subdistricts for the development of leptospirosis prevention and control.

Main responsibility

- **Provincial Governor**

  Participate in selecting the main responsibilities in supervising the disease database in humans and animals.

- **Provincial public health**

  Participate in determining in which situation a leptospirosis epidemic should be reported.

- **Provincial livestock**

  Participate in determining in which situation a leptospirosis epidemic should be reported.

- **Provincial Administrative Organizations (PAO)**

  Participate in determining in which situation a leptospirosis epidemic should be reported.

- **Provincial Disaster Prevention and Mitigation**

  Participate in determining in which situation a leptospirosis epidemic should be reported.

- **Provincial Agriculture and Cooperatives**

Participate in determining in which situation a leptospirosis epidemic should be reported.

- **Provincial Public Relations Department**

Participate in determining in which situation a leptospirosis epidemic should be reported.

- **Provincial Natural resources and environment**

Participate in determining in which situation a leptospirosis epidemic should be reported.

- **Provincial Education Officer**

Participate in determining in which situation a leptospirosis epidemic should be reported.

6.3.2 Analyzing the lessons learnt among departments to summarize the issues and prepare leptospirosis following year plan.

6.3.2.1 Meeting to analyze the lessons learnt among departments in the Province about leptospirosis prevention and control.

6.3.2.2 Improving leptospirosis policy implementation.

Main responsibility

- **Provincial Governor**

Follow the leptospirosis policy implementation.

- **Provincial public health**

Participate in the follow-up and development of the leptospirosis policy implementation.

- **Provincial livestock**

Participate in the follow-up and development the of leptospirosis policy implementation.

- **Provincial Administrative Organizations (PAO)**

Participate in the follow-up and development the of leptospirosis policy implementation.

- **Provincial Disaster Prevention and Mitigation**

Participate in the follow-up and development the of leptospirosis policy implementation.

- **Provincial Agriculture and Cooperatives**

Participate in the follow-up and development the of leptospirosis policy implementation.

- **Provincial Public Relations Department**

Participate in the follow-up and development the of leptospirosis policy implementation.

- **Provincial Natural resources and environment**

Participate in the follow-up and development the of leptospirosis policy implementation.

- **Provincial Education Officer**

Participate in the follow-up and development of the leptospirosis policy implementation.

- **Leader community and Village volunteer**

Participate in the follow-up and development of the leptospirosis policy implementation.

7. Guidelines for developing cooperation among departments for leptospirosis prevention and control at the subdistrict level.

At the subdistrict level, several departments need to cooperate in leptospirosis prevention and control. They should consider the context of each local community. The leptospirosis surveillance and control policy implementation in a subdistrict should consider three important steps: management, coordination and evaluation.

7.1 Management

Good management will allow to support the preparation for leptospirosis prevention and control. The operation guidelines consist of the following:

7.1.1 Develop knowledge and understanding of interoperability between departments about disease prevention and control among government officials at the subdistrict level.

7.1.1.1 Educating government officials at the subdistrict level about the One Health approach to develop their understanding and recognizing the necessity of a tight cooperation between departments by e-learning system. This educating system should be able to follow the participants. Moreover, there is a requirement to study within this system and it constitutes an indicator of the officer self-development. The participants should get a certificate after finishing their learning period in the e-learning system.

7.1.1.2 Improving knowledge about leptospirosis prevention and control to health personnel, livestock officers, Subdistrict Administration Organization officers.

Main responsibility

- **Provincial Governor**

  Support for training of subdistrict officers.

- **Public health officers of subdistrict**

  Attending the training.

- **Livestock officers of subdistrict**

  Attending the training.

- **Subdistrict Administration Organization (SAO)**

  Attending the training.

7.1.2 Training of village health volunteers, livestock volunteers to use leptospirosis surveillance tools.

7.1.2.1 Conducting surveillance knowledge, using surveillance tools and surveillance reports to village health volunteers, livestock volunteers by using e-learning system.

Main responsibility

- **Provincial Governor**

  Control and ensure the follow-up of the development of knowledge following the leptospirosis surveillance tool within village health volunteers, livestock volunteers.

- **Public health officers of subdistrict**

  Use the educating system of leptospirosis surveillance.

- **Livestock officers of subdistrict**

  Use the educating system of leptospirosis surveillance.

- **Subdistrict Administration Organization (SAO)**

  Use the educating system of leptospirosis surveillance.

7.2 Coordination

Establishing a mechanism for cooperation between subdistricts according to the following:

7.2.1 Establish a Memorandum of Understanding (MoU) between departments in the subdistrict. Determine the roles of departments in preventing and controlling leptospirosis.

Main responsibility

- **Provincial Governor**

  Supporting the establishment of a memorandum of understanding (MoU)

- **Public health officers of subdistrict**

  Consider and establish guidelines for a tight cooperation between departments regarding leptospirosis prevention and control.

- **Livestock officers of subdistrict**

  Consider and establish guidelines for a tight cooperation between departments regarding leptospirosis prevention and control.

- **Subdistrict Administration Organization (SAO)**

  Consider and establish guidelines for a tight cooperation between departments regarding leptospirosis prevention and control.

- **Leader community and Village volunteer**

  Consider and establish guidelines for a tight cooperation between departments regarding leptospirosis prevention and control.

7.2.2 Promote participation and develop potential of village health volunteers, community leaders, network of farmers and animal husbandries in prevention and control of leptospirosis in the community.

7.2.2.1 Development of public participation, village health volunteers, community leaders.

Promote the participation of the public, village health volunteers, community leaders in leptospirosis prevention and control.

1) Define clear roles for village health volunteers, community leaders in leptospirosis prevention and control. Guidelines of leptospirosis surveillance and control policy implementation for village health volunteers and community leaders should be established.

2) Establish leptospirosis prevention and control plan with the participation of people in the community.

3) Develop a mentor system to support prevention and control of leptospirosis with village health volunteers and community leaders in the community.

7.2.2.2 Develop the potential of village health volunteers in leptospirosis prevention and control in the community

1) Training about leptospirosis causes, symptoms, prevention, control and surveillance to village health volunteers, community leaders.

2) Promote knowledge and advise attitude regarding leptospirosis prevention and control within village health volunteers, community leaders. For example, promote attitude about control vectors of leptospirosis.

3) Organize a forum to exchange knowledge within a community network about leptospirosis prevention and control.

4) Motivation to be morale to implement a network.

7.2.2.3 Support integration of farmers, herdsmen for exchange of experiences and new knowledge.

Main responsibility

- **Provincial Governor**

  Support development of the public network.

- **Public health officers of subdistrict**

  Develop the public network in human surveillance.

- **Livestock officers of subdistrict**

  * Develop the public network in animals surveillance.
  * Supporting the participation of groups working in agriculture and animal husbandry.
  * Develop knowledge and cooperation in disease prevention.

- **Subdistrict Administration Organization (SAO)**

  Develop the public network and support resources for network development.

- **Leader community and Village volunteer**

Join the disease surveillance network, disseminate knowledge and promote news within the network to prevent disease.

7.2.3 Enhance knowledge attitude and practice in prevention and control leptospirosis among people.

7.2.3.1 Production and development of knowledge media to transfer and disseminate knowledge about leptospirosis to networks and people.

7.2.3.2. Transfer of knowledge and encourage healthy behaviors to prevent and control leptospirosis among people.

1) Campaign to prevent disease in targeted group: people who got leptospirosis, farmers and animal husbandry.

2) Publicize knowledge using the news towers.

7.2.3.3 Follow up and evaluate the acknowledgement of leptospirosis prevention and control news in the public.

Main responsibility

- **Provincial Governor**

Follow up to enhance knowledge, attitude and practice in preventing leptospirosis control in the people.

- **Public health officers of subdistrict**

* Production of media in providing the appropriate attitude and practices for leptospirosis prevention and control to people.

* Conduct a health behavior assessment to prevent and control leptospirosis in the public.

* Campaign about leptospirosis prevention and control for the population.

- **Livestock officers of subdistrict**

Join the campaign about leptospirosis prevention and control in direction to people.

- **Subdistrict Administration Organization (SAO)**

Support resources regarding the campaign about leptospirosis prevention and control in direction to people.

- **Leader community and Village volunteer**

Cooperate in the performance of government departments and publicize the news to educate people.

7.2.4 Promoting animal husbandry according to sanitary principles.

7.2.4.1 Improve the preparation of guidelines and recommendations for animal husbandry according to sanitary principles.

7.2.4.2 Convey and promote animal husbandry according to sanitary principles.

1) Training and promotion of animal farmers to raise disease-free animals and reduce the risk of disease according to sanitary principles.

2) Training and support for the management of animal sanitation. Moreover, control the dereliction of waste caused by raising animals into water sources.

3) Development of water resources.

4) Advising people to protect themselves from leptospirosis in raising animals near water sources with low slope.

7.2.4.3 Establish animal database.

7.2.4.4 Educate farmers and livestock entrepreneurs.

Educate farmers and livestock entrepreneurs about causes, symptoms, prevention, control of leptospirosis in animals.

1) Production and development of knowledge media about causes, symptoms, prevention, control of leptospirosis in animals to farmers and livestock entrepreneurs.

2) Transfer of knowledge about causes, symptoms, prevention, control of leptospirosis in animals to farmers and livestock entrepreneurs.

7.2.4.5 Develop policy and measures for sanitary and standardized animal husbandry.

1) Consider relevant laws and policies and establish measures in the community for animal husbandry to be sanitary and standardized and to reduce the effects of disease transmission from animals to humans and animals to environment.

2) Determine water sources for humans and animals. Water sources should clearly be separated according to their use.

3) Set measures to control the disposal of waste from animal husbandry into public water sources. Establish understanding and knowledge about these measures to animal husbandry and control of animal husbandry to follow the prescribed measures.

Main responsibility

- **Provincial Governor**

  Control if animals are raised in accordance with the sanitation principles.

- **Public health officers of subdistrict**

  Gather other departments in the promotion of animal husbandry in accordance with the prescribed measures.

- **Livestock officers of subdistrict**

  * Establish media to provide knowledge on leptospirosis prevention and control in animals.
  * Provide knowledge about leptospirosis prevention and control in animals.
  * Improve and develop animal husbandry patterns.

- **Subdistrict Administration Organization (SAO)**

  * Establish measures with communities about the use of water sources for people and animals.
  * Control the implementation of the measures agreed with the community in using water sources for humans and animals.
  * Join other departments in promoting animal husbandry in accordance with the prescribed measures.

- **Leader community and Village volunteer**

  Support the operation of government departments and jointly control the animal husbandry system.

7.2.5 Integration of control leptospirosis epidemic in humans and animals.

7.2.5.1 Control leptospirosis epidemic in humans.

When a leptospirosis case is reported in human, leptospirosis prevention and control scheme follows the implementation mechanism called 4E2C including:

1) Early detection: if a patient or the public health volunteer find a change in a patient indicating that he is getting sick from leptospirosis, the patient must meet the healthcare providers.

2) Early diagnosis: healthcare providers or doctors make a preliminary diagnosis from the patient’s history and symptoms such as acute fever, headache, muscle pain following the leptospirosis diagnosis guidelines.

3) Early treatment: the patient is given treatment by healthcare providers or doctors following the leptospirosis diagnosis guidelines.

4) Early control: prevention and control of leptospirosis by the Surveillance and Rapid Response Team (SRRT) within a week of receiving the leptospirosis report.

5) Coordination: the Public health officer coordinates with the livestock department to investigate the leptospirosis cause and prepares advice for people in the community. Moreover, He may establish a leptospirosis prevention program by giving information about animal feeding, monitoring animal disease and reporting leptospirosis cases.

6) Community involvement: people in the community participate in the prevention and control of leptospirosis by, for example issuing a leptospirosis warning and establishing leptospirosis prevention in the community (Department of Disease Control, 2016)

7.2.5.2 Control leptospirosis epidemic in animals

When a leptospirosis case is reported in animals, leptospirosis prevention and control measures include:

1) Infected animals (cattle/pigs) can be isolated and if necessary slaughtered.

2) Infected animals can be treated with antibiotics to control Leptospiral shedding.

3) Vaccines can be used for the immunization of pets and farm animals.

4) Excreta from domestic animals should be disposed of in such a way as to avoid contamination (World Health Organization, 2003).

7.2.5.3 Warning signs for places constituting a disease source. For example, when investigating the history of leptospirosis in a patient it is found that he got infection from water sources, show warning signs to avoid using water sources, etc.

7.2.5.4 Establish a center to solve the epidemic problems.

In the case of severe epidemic trends, provide a command system, analysis of situations and prescribing important measures to solve problems between departments in a subdistrict.

7.2.5.5 Publicize the epidemic problem to people.

1) Publicize the epidemic problem.

2) Campaigning for people to reduce exposure to risk factors for disease. Moreover, develop knowledge and skills for prevention leptospirosis prevention among people.

Main responsibility

- **Provincial Governor**

  Monitoring the epidemic problem in humans and animals.

- **Public health officers of subdistrict**
  - Control the epidemic of leptospirosis in humans.
  - Develop knowledge and skills for leptospirosis prevention.

- **Livestock officers of subdistrict**
  - Control the epidemic of leptospirosis in animals.
  - Give immunity to prevent leptospirosis in animals.

- **Subdistrict Administration Organization (SAO)**

  * Supporting resources to control leptospirosis outbreaks.

  * Campaigning to reduce exposure to risk factors coming from the environment and prepare warning signs to avoid using water sources.

- **Leader community and Village volunteer**

Support the operation of government departments and jointly control leptospirosis outbreaks

7.3 Evaluation

Operational evaluation helps the person responsible in monitoring epidemic situation and can prepare the appropriate disease prevention and control. Evaluation mechanism consists of the following steps:

7.3.1 Determining roles and situations that need to report surveillance results.

7.3.1.1 Define the main responsibility in supervising surveillance database of a subdistrict.

1) Public health officials check the accuracy of the information when receiving surveillance information related to humans. After that importing information into the database.

2) Livestock officials check the accuracy of the information when receiving surveillance information related to animals and import information into the database.

Main responsibility

- **Provincial Governor**

Participate in selecting main responsibilities in supervising the disease database in humans and animals.

- **Public health officers of subdistrict**

Participate in determining the situation in which leptospirosis epidemic should be reported.

- **Livestock officers of subdistrict**

  Participate in determining the situation in which leptospirosis epidemic should be reported.

- **Subdistrict Administration Organization (SAO)**

  Participate in determining the situation in which leptospirosis epidemic should be reported.

- **Leader community and Village volunteer**

  Participate in determining the situation in which leptospirosis epidemic should be reported.

7.3.2 Analyze and lessons learning between departments for summarize the issues and prepare leptospirosis next year plan.

7.3.2.1 Meeting to analyze the lessons learnt between departments in subdistricts about leptospirosis prevention and control.

7.3.2.2 Develop leptospirosis surveillance and control policy implementation for improving the implementation the following year.

Main responsibility

- **Provincial Governor**

  Follow the surveillance and control policy implementation.

- **Public health officers of subdistrict**

  Follow the surveillance and control policy implementation.

- **Livestock officers of subdistrict**

  Follow the surveillance and control policy implementation.

- **Subdistrict Administration Organization (SAO)**

  Follow the surveillance and control policy implementation.

- **Leader community and Village volunteer**

  Follow the surveillance and control policy implementation.

Guidelines for improving cooperation among departments for leptospirosis prevention and control (Thai version)

คู่มือการพัฒนาความร่วมมือระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส จังหวัดมหาสารคาม

คู่มือการพัฒนาความร่วมมือระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส จังหวัดมหาสารคามฉบับนี้ จัดทำขึ้นโดยอาศัยกระบวนการมีส่วนร่วมของสาธารณสุขจังหวัดมหาสารคาม ตัวแทนเครือข่าย one health ในระดับมหาวิทยาลัยในภาคตะวันออกเฉียงเหนือ และคณาจารย์คณะสาธารณสุขศาสตร์ มหาวิทยาลัยมหาสารคาม โดยรายชื่อผู้ที่เข้ามามีส่วนร่วมในการพัฒนาคู่มือฉบับนี้ ได้แก่

สาธารณสุขจังหวัดมหาสารคาม

ชื่อ-สกุล	ตำแหน่ง
1. นายพรสิทธิ์ ทวยนันท์	รองนายแพทย์สาธารณสุขจังหวัด
2. นายกฤษณฎ์ โพธิ์ศรี	หัวหน้ากลุ่มงานควบคุมโรคติดต่อ
3. นายชยานนท์ สุคุณา	งานระบาดวิทยา
4. นางเกษศิรินทร์ ไชยลาภ	งาน zoonosis
5. นางปาริชาต ปกิรณ	งานระบาดวิทยา

เครือข่ายมหาวิทยาลัยไทยเพื่อสุขภาพหนึ่งเดียว (THOHUN)

ชื่อ-สกุล	ตำแหน่ง
1. ผศ.ดร.นิรุวรรณ เทิร์นโบล์	ตัวแทนเครือข่าย THOHUN ภาคตะวันออกเฉียงเหนือ, อาจารย์คณะสาธารณสุขศาสตร์

คณะสาธารณสุขศาสตร์ มหาวิทยาลัยมหาสารคาม

ชื่อ-สกุล	ตำแหน่ง
1. อาจารย์ ดร.เทอดศักดิ์ พรหมอารักษ์	อาจารย์คณะสาธารณสุขศาสตร์
2. อาจารย์ สุไวรินทร์ ศรีชัย	อาจารย์คณะสาธารณสุขศาสตร์

กระบวนการการสร้างคู่มือกับหน่วยงานต่างๆ ประกอบด้วยขั้นตอนดังต่อไปนี้

1. นักวิจัยทำการนัดหมายหน่วยงานที่เกี่ยวข้องเพื่อให้เข้าร่วมการประชุม นักวิจัยได้จัดทำเป็นบันทึกข้อความเพื่อเชิญเจ้าหน้าที่ในหน่วยงานเข้าร่วมประชุมเพื่อดำเนินการพัฒนา “คู่มือการพัฒนาความร่วมมือระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส จังหวัดมหาสารคาม”

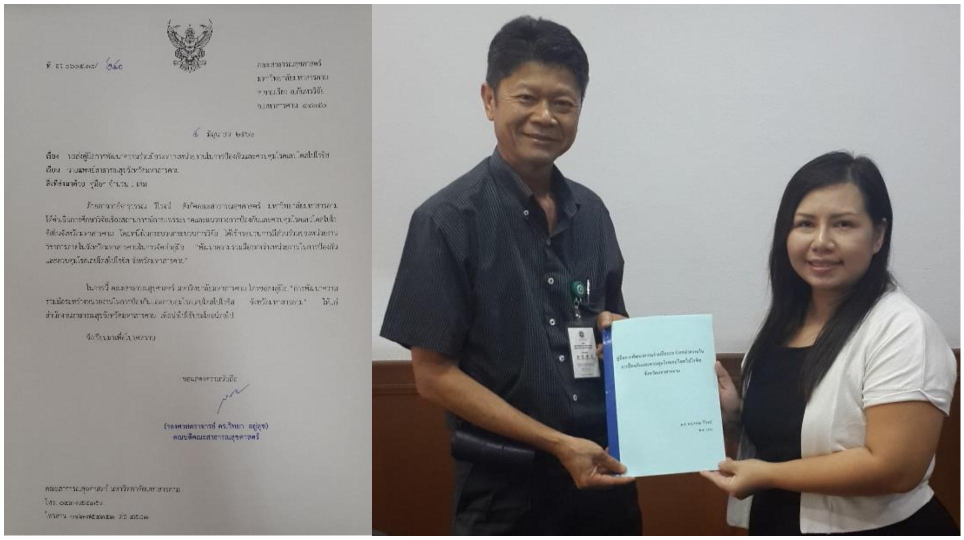
2. นักวิจัยทำการจัดการประชุม และนำเสนอผลการศึกษาวิจัยให้กับผู้ที่เข้าร่วมประชุม เพื่อให้ผู้เข้าร่วมประชุมมีความเข้าใจสถานการณ์ และสภาพปัญหาในการดำเนินการป้องกันโรคเลปโตสไปโรซิสของจังหวัดมหาสารคาม ภายหลังจากนั้นนักวิจัยได้เป็นผู้นำเพื่อให้ผู้เข้าร่วมประชุมได้แสดงความคิดเห็นและแลกเปลี่ยนแนวคิดเพื่อพัฒนาคู่มือฯ และได้มีการนัดหมายประชุมในคราวถัดไปจนสามารถพัฒนาคู่มือฉบับสมบูรณ์

3. นักวิจัยได้ทำการส่งมอบคู่มือฉบับสมบูรณ์แก่สำนักงานสาธารณสุขจังหวัดมหาสารคาม เพื่อให้สำนักงานสาธารณสุขจังหวัดมหาสารคามนำไปใช้ประโยชน์ต่อไป

ภาพ 1 การพัฒนาคู่มือร่วมกับคณาจารย์คณะสาธารณสุขศาสตร์ มหาวิทยาลัยมหาสารคาม

ภาพ 2 การพัฒนาคู่มือร่วมกับตัวแทนเครือข่ายมหาวิทยาลัยไทยเพื่อสุขภาพหนึ่งเดียว (THOHUN)

ภาพ 3 การพัฒนาคู่มือร่วมเจ้าหน้าที่ของสำนักงานสาธารณสุขจังหวัดมหาสารคาม



ภาพ 4 การมอบคู่มือการพัฒนาความร่วมมือระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิสแก่ผู้บริหารของสำนักงานสาธารณสุขจังหวัดมหาสารคาม

ปัจจัยสำคัญในการนำหน่วยงานที่เกี่ยวข้องเข้ามามีส่วนร่วมของหน่วยงานในการดำเนินการวิจัยประกอบด้วยดังนี้

1. ความสนใจของหัวหน้าหน่วยงาน

ตลอดระยะเวลา 4 ปีที่ทำการศึกษาวิจัยและดำเนินกิจกรรมเกี่ยวโรคเลปโตสไปโรซิสในจังหวัดมหาสารคาม นักวิจัยพบว่าการให้การสนับสนุนจากผู้บริหารในระดับจังหวัดเป็นเรื่องที่สำคัญ ผู้บริหารของสำนักงานสาธารณสุขจังหวัดให้เห็นความสำคัญของโรคเลปโตสไปโรซิส และนำไปสู่การให้ความร่วมมือของบุคลากรต่างๆ ของหน่วยงานในการดำเนินกิจกรรมต่างๆ ตัวอย่างเช่น ผู้บริหารสำนักงานสาธารณสุขจังหวัดมหาสารคามได้สั่งการให้เจ้าหน้าที่ในสาธารณสุขจังหวัดเข้ามามีส่วนร่วมในการประชุมเพื่อพัฒนาคู่มือฯ จากการสั่งการดังกล่าวทำให้เจ้าหน้าที่สาธารณสุขเกิดความกระตือรือร้นและให้ความร่วมมือในการดำเนินกิจกรรมการวิจัย นอกจากนี้ผู้บริหารของสำนักงานสาธารณสุขจังหวัดมหาสารคามได้ให้การสนับสนุนทรัพยากร และบุคลากรในการดำเนินการวิจัยในครั้งนี้ เป็นต้น

2. การใช้ความรู้สหสาขาวิชาในการพัฒนาแนวทางการป้องกันและควบคุมโรคเลปโตสไปโรซิส

ปัจจุบันการดำเนินการป้องกันและควบคุมโรคเลปโตสไปโรซิสของจังหวัดมหาสารคาม เป็นหน้าที่รับผิดชอบหลักของเจ้าหน้าที่สาธารณสุข และยังมีข้อถกเถียงภายในหน่วยงานและภายนอกหน่วยงานถึงสาเหตุของการเกิดโรคเลปโตสไปโรซิสภายในจังหวัด ดังนั้นการระดมความรู้จากสหสาขาวิชาในการพัฒนาแนวทางการป้องกันโรค จะสามารถนำไปสู่แนวทางการปฏิบัติที่เป็นรูปธรรมและสามารถสอดคล้องกับบริบทของชุมชน

การนำแนวทางในคู่มือฯ ไปสู่การปฏิบัติ

สำนักงานสาธารณสุขจังหวัดมหาสารคามจะนำแนวทางปฏิบัติที่สร้างขึ้นไปทดลองใช้ในการป้องกันโรคเลปโตสไปโรซิสในอำเภอบรบือ ซึ่งเป็นอำเภอที่มีอัตราการป่วยด้วยโรคเลปโตสไปโรซิสสูง และพบการป่วยตายด้วยโรคดังกล่าว ในการณ์นี้สำนักงานสาธารณสุขจังหวัดมหาสารคามจะให้การสนับสนุนทรัพยากรในการดำเนินการณ์ดังกล่าว

1. แนวคิดและหลักการในการพัฒนาคู่มือการพัฒนาความร่วมมือระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส จังหวัดมหาสารคาม

แนวคิดและหลักการการจัดทำคู่มือการพัฒนาความร่วมมือระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส จังหวัดมหาสารคาม พัฒนาขึ้นโดยอ้างอิงให้สอดคล้องกับกรอบการดำเนินงานป้องกันและควบคุมโรคในระดับประเทศและนานาชาติ เพื่อให้ทันต่อสถานการณ์และปัจจัยแวดล้อมในปัจจุบัน โดยการพัฒนาคู่มือดังกล่าวได้ยึดตามกฎหมายหลักจำนวน 2 ฉบับ แนวคิดด้านสุขภาพจำนวน 2 ฉบับ และคำแนะนำในการป้องกันและควบคุมโรคเลปโตสไปโรซิสจำนวน 2 ฉบับ ดังต่อไปนี้

1) แผนยุทธศาสตร์เตรียมความพร้อม ป้องกัน และแก้ไขปัญหา โรคติดต่ออุบัติใหม่แห่งชาติ (พ.ศ. 2560 - 2564)

เป็นแนวทางในการเตรียมความพร้อม เฝ้าระวัง ป้องกัน ควบคุมโรคติดต่ออุบัติใหม่ และภัยพิบัติฉุกเฉินด้านสาธารณสุขของประเทศไทย ภายใต้แนวคิดสุขภาพหนึ่งเดียว ให้มีประสิทธิภาพ ทันต่อสถานการณ์ และเป็นที่ยอมรับของนานาชาติ รวมทั้งเสริมสร้างความร่วมมือระหว่างประเทศเพื่อเพิ่มประสิทธิภาพการเตรียมความพร้อม เฝ้าระวัง ป้องกัน ควบคุมโรคติดต่ออุบัติใหม่ และภัยพิบัติฉุกเฉินด้านสาธารณสุข (Bureau of Emerging Infectious Disease Department of Disease Control, 2016)

2) พระราชบัญญัติโรคติดต่อ พ.ศ. 2548

เป็นกฎหมายที่กำหนดบทบาทหน้าที่ของเจ้าหน้าที่ การดำเนินการเฝ้าระวังโรค แนวทางในการป้องกันและควบคุมโรคติดต่อ รวมทั้งบทกำหนดโทษ เพื่อให้สามารถจัดการภัยสุขภาพได้ทันการณ์ สร้างระบบเตรียมพร้อมรับมือกับโรคติดต่ออันตราย โรคติดต่ออุบัติใหม่ของโลก เพื่อลดความสูญเสียจากการเจ็บป่วยและผลกระทบด้านเศรษฐกิจ รวมทั้งเป็นการสร้างความมั่นคงทางสุขภาพของคนไทย (Law Center Department of Disease Control, 2015)

3) แนวคิดสุขภาพหนึ่งเดียว (One Health)

เป็นระบบสุขภาพที่บูรณาการ ทั้งสุขภาพคน สุขภาพสัตว์ สุขภาพสัตว์ป่า ภายใต้ระบบนิเวศที่เอื้อต่อการมีสุขภาพที่ดี สนับสนุนโดยองค์การระหว่างประเทศ ประกอบด้วย องค์การอาหารและเกษตรแห่งสหประชาชาติ (UN Food and Agriculture Organization) องค์การโรคระบาดสัตว์ ระหว่างประเทศ (World Organization for Animal Health) และองค์การอนามัยโลก (World Health Organization) เป็นแนวความคิดในการทำงานร่วมกันระหว่างสหสาขาวิชาชีพที่เกี่ยวข้อง อันจะส่งเสริมให้เกิดการทำงานอย่างเป็นเอกภาพ เพื่อประโยชน์สาธารณะและสุขภาพที่ดีของทุกชีวิต (The World Health Organization, 2017)

4) คู่มือไตรภาคีเพื่อจัดการกับปัญหาโรคติดต่อจากสัตว์ในประเทศต่างๆ

เป็นแนวทางในทำงานร่วมกันแบบสหสาขาวิชาชีพและหลากหลายสาขาที่สามารถจัดการกับภัยคุกคามทางสุขภาพอย่างเร่งด่วนต่อเนื่อง เพื่อให้เกิดประสิทธิภาพในการแก้ไขปัญหาสิ่งคุกคามด้านสุขภาพที่มีสาเหตุมาจาก คน สัตว์ สิ่งแวดล้อม ในระดับภูมิภาค ระดับประเทศ และระดับโลก โดยการสร้างความสมดุลและความเสมอภาคในทุกภาคส่วน และสาขาที่เกี่ยวข้องในการดำเนินการป้องกันโรคติดต่อ (World Health Organization et al., 2019)

5) แนวทางการวินิจฉัย เฝ้าระวัง และควบคุมโรคเลปโตสไปโรซิสขององค์การอนามัยโลก

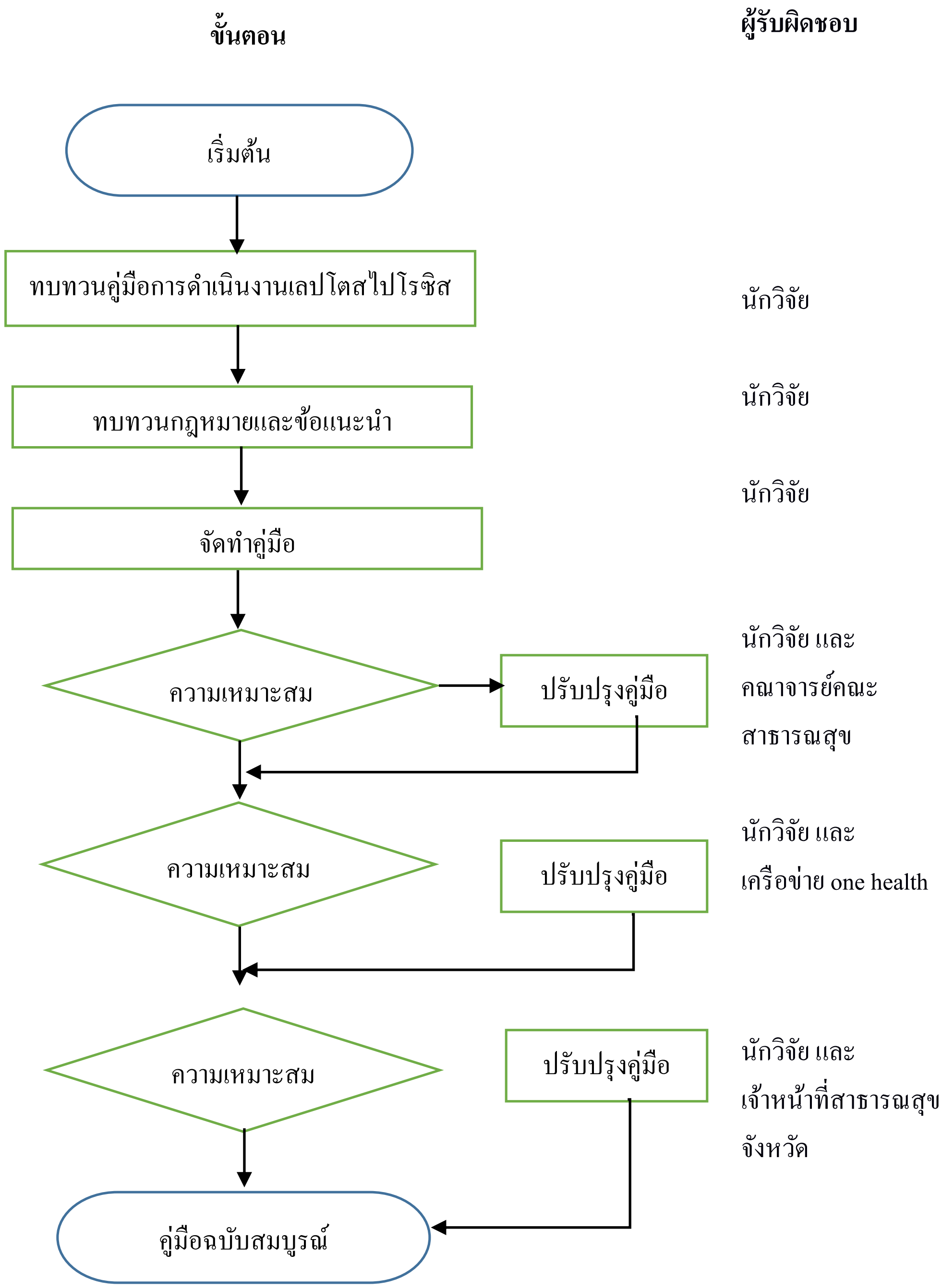
เป็นคู่มือที่องค์การอนามัยโรคได้ให้แนวทางปฏิบัติแก่บุคลากรด้านสาธารณสุข เช่น แพทย์ เจ้าหน้าเทคนิคการแพทย์ เจ้าหน้าที่สาธารณสุข สัตวแพทย์ ในการวินิจฉัย เฝ้าระวังและควบคุมการแพร่ระบาดของโรคเลปโตสไปโรซิส (World Health Organization, 2003)

6) ระบบสุขภาพอำเภอ (District Health System: DHS)

เป็นนโยบายการทำงานสุขภาพในระดับ อำเภอของกระทรวงสาธารณสุข ที่ใช้อำเภอเป็นฐานมองทุกส่วนในอำเภอเป็นเนื้อเดียวกัน ทั้งสาธารณสุข ส่วนราชการ องค์การบริหารส่วนท้องถิ่นและภาคประชาชน โดยขับเคลื่อนการดูแลสุขภาพผสมผสานทั้งงาน ส่งเสริม ป้องกัน รักษา ฟื้นฟู โดยมีเป้าหมายให้เกิด “อำเภอสุขภาวะ” คือ สถานะสุขภาพของประชาชนดีขึ้น ประชาชนดูแลตนเองได้ และทีมสุขภาพมีความเข้มแข็ง มีการดำเนินงานผ่านโครงการเพื่อจัดการประเด็น สุขภาพร่วมระดับอำเภอ (One District One Project: ODOP) (Department of Disease Control, 2016)

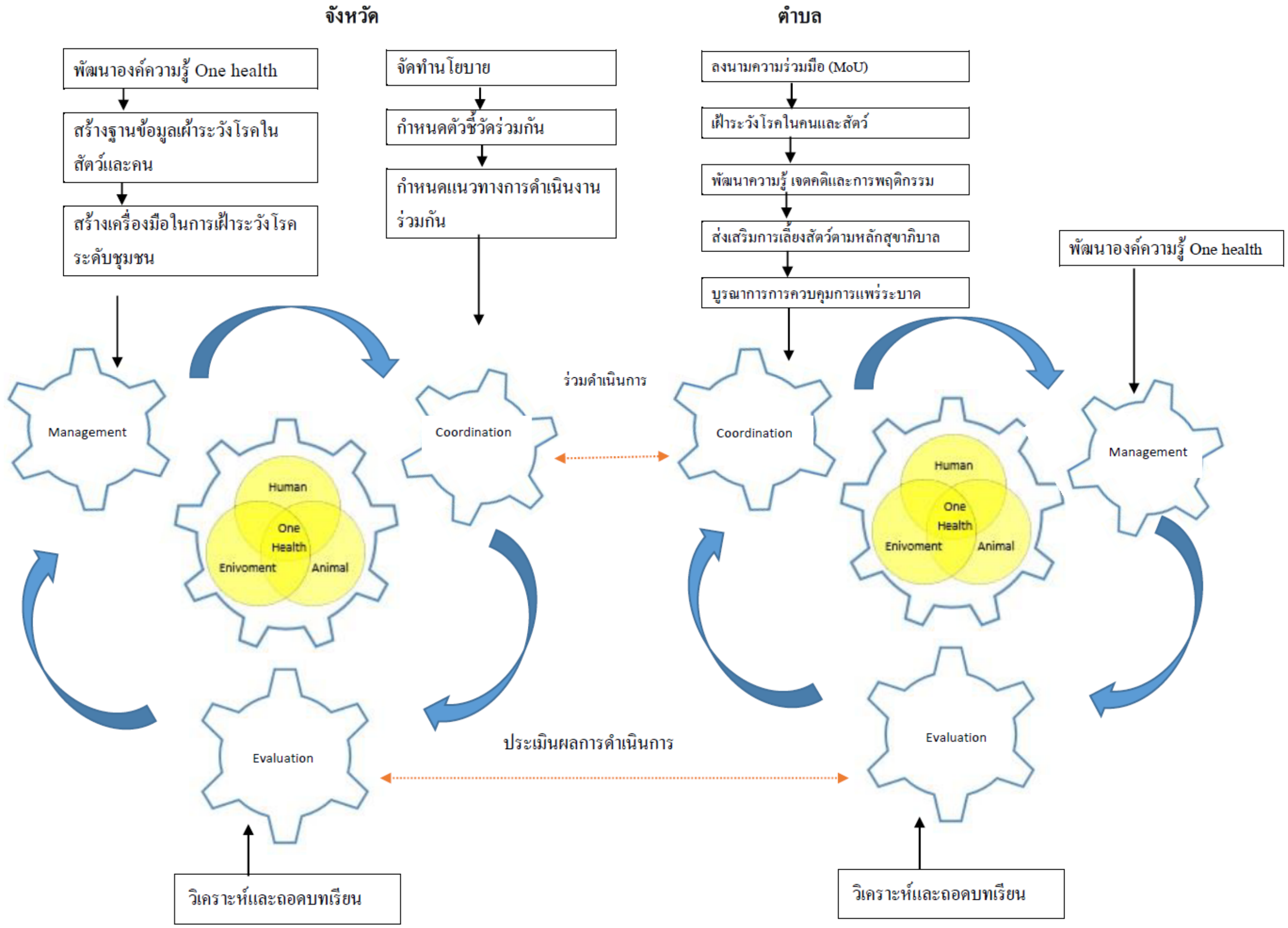
2. แนวทางการพัฒนาคู่มือการป้องกันและควบคุมโรคเลปโตสไปโรซิส

คู่มือการพัฒนาความร่วมมือระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส ฉบับนี้ จัดทำขึ้นโดยพิจารณาถึงกฎหมายและแนวคิดต่างๆ ที่เกี่ยวข้องกับการควบคุมโรคและป้องกันโรคติดต่อ ภายหลังที่คู่มือนี้จัดทำขึ้น ผู้วิจัยได้นำคู่มือที่สร้างขึ้นนำไปขอคำแนะนำและความคิดเห็นจากเจ้าหน้าที่สาธารณสุขจังหวัดมหาสารคาม ตัวแทนเครือข่าย one health ในระดับมหาวิทยาลัยในภาคตะวันออกเฉียงเหนือ และคณาจารย์คณะสาธารณสุขศาสตร์ มหาวิทยาลัยมหาสารคาม และทำการพัฒนาคู่มือเพื่อให้เกิดความเหมาะสม ความคลอบคลุม และความสอดคล้องกับบริบทในการทำงาน โดยมีขั้นตอนการพัฒนาคู่มือมีดังต่อไปนี้



ภาพ 5 ขั้นตอนการพัฒนาคู่มือการพัฒนาความร่วมมือระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส จังหวัดมหาสารคาม

3 . กลไกในการป้องกันและควบคุมโรคเลปโตสไปโรซิสภายใต้แนวคิด One health



กลไกที่สำคัญในการป้องกันและควบคุมโรคเลปโตสไปโรซิสโดยอาศัยแนวคิด One health ประกอบด้วยกลไกที่สำคัญ 3 ส่วน ได้แก่ กลไกในการจัดการ (Management) กลไกในการประสานความร่วมมือระหว่างหน่วยงาน (Coordination) และกลไกในการประเมิน (Evaluation) โดยกลไกดังกล่าวจะช่วยส่งเสริมให้เกิดความร่วมมือในการการป้องกันโรคในคน สัตว์ และสิ่งแวดล้อม โดยความร่วมมือดังกล่าวจะผลักดันให้กลไกสามารถประสานและดำเนินการได้อย่างมีประสิทธิ

เมื่อมีการขับเคลื่อนกลไกในการทำงานระดับจังหวัด จะทำให้เกิดการขับเคลื่อนกลไกการทำงานระดับตำบล โดยกลไกในแต่ระดับจะมีการทำงานและเชื่อมต่อกันในสองส่วน คือ การประสานการทำงานระหว่างจังหวัดและตำบล และการประเมินการดำเนินงาน กลไกดังกล่าวจะผลักดันให้เกิดการการทำงานร่วมกันในแต่ละระดับ และสามารถพัฒนาและขับเคลื่อนกลไกในการป้องกันและควบคุมโรคเลปโตสไปโรซิส

4. สรุปแนวทางการการพัฒนาความร่วมมือระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิสในระดับจังหวัด

การจัดการ

แนวทาง	ผู้รับผิดชอบ
1. พัฒนาองค์ความรู้และความเข้าใจในการทำงานร่วมกันระหว่างหน่วยงานในการป้องกันโรคในระดับ จังหวัด ได้แก่ สาธารณสุข ปศุสัตว์ อปท. - การอบรม, จัดประชุมแบบมีส่วนร่วม	**ผู้ว่าราชการจังหวัด**
2. สร้างฐานข้อมูลในการเฝ้าระวังโรคในสัตว์และในคน โดยฐานข้อมูลดังกล่าวต้องเชื่อมโยงกัน และแจ้งผลการเกิดโรคให้แต่ละหน่วยงานทราบร่วมกัน โดยอาจจะเชื่อมโยงฐานข้อมูลที่อยู่ของแต่ละหน่วยงานเข้าด้วยกันให้เป็นฐานข้อมูลกลาง	**คณะกรรมการโรคติดต่อระดับจังหวัด**
3. สร้างเครื่องมือในการเฝ้าระวังโรคระดับชุมชน	**สาธารณสุขจังหวัดและปศุสัตว์จังหวัด**

การดำเนินงานร่วมกัน

แนวทาง	ผู้รับผิดชอบ
1. ผลักดันให้ทุกภาคส่วนในระดับจังหวัดมีบทบาทในการป้องกันและควบคุมโรค โดยร่วมกัน กำหนดนโยบาย, ตัวชี้วัดในการทำงาน, แนวทางการดำเนินการป้องกันและควบคุมโรคเมื่อเกิดการระบาด	**สาธารณสุขจังหวัดและปศุสัตว์จังหวัด**

ติดตามและประเมินผล

แนวทาง	ผู้รับผิดชอบ
1. การบูรณาการติดตามการดำเนินงานและพัฒนาแนวทางการป้องกันและควบคุมโรค	**สาธารณสุขจังหวัดและปศุสัตว์จังหวัด**

5. สรุปแนวทางการการพัฒนาความร่วมมือระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิสในระดับตำบล

การจัดการ

แนวทาง	ผู้รับผิดชอบ
1. พัฒนาองค์ความรู้และความเข้าใจในการทำงานร่วมกันระหว่างหน่วยงานในการป้องกันโรคติดต่อระหว่างสัตว์สู่คน zoonosis ในระดับตำบล ได้แก่ สาธารณสุข ปศุสัตว์ อบต. - ระบบ e-learning	ผู้ว่าราชการจังหวัด
2. พัฒนาองค์ความรู้บุคลากรสาธารณสุขระดับตำบล อาสาสมัครสาธารณสุข อาสาสมัครปศุสัตว์ ในการใช้เครื่องมือในการเฝ้าระวัง - ระบบ e-learning /อบรม	ผู้ว่าราชการจังหวัด

การดำเนินงานร่วมกัน

แนวทาง	ผู้รับผิดชอบ
1. จัดลงนามความร่วมมือระหว่างหน่วยงานในชุมชน	สาธารณสุข, ปศุสัตว์, อบต
2. พัฒนาการส่วนร่วมของภาคประชาชน อาสาสมัครสาธารณสุข ผู้นำชุมชน ในการเฝ้าระวังโรคในคนและสัตว์	สาธารณสุข, ปศุสัตว์
3. เสริมสร้างความรู้ ทักษะและการปรับเปลี่ยนพฤติกรรมการป้องกันควบคุมโรคเลปโตสไปโรซิสในประชาชน โดยอาศัยองค์ความรู้จากหน่วยงานต่างๆ	สาธารณสุข, ปศุสัตว์
4. ส่งเสริมการเลี้ยงสัตว์ตามหลักสุขาภิบาล	ปศุสัตว์
5. บูรณาการการควบคุมการแพร่ระบาดของโรคในคนและสัตว์	สาธารณสุข, ปศุสัตว์

การติดตามและประเมินผล

แนวทาง	ผู้รับผิดชอบ
1. ประเมินผล และพัฒนาแนวทางป้องกันและควบคุมโรคร่วมกัน	สาธารณสุข, ปศุสัตว์, ท้องถิ่น

6. แนวทางปฏิบัติในการป้องกันและควบคุมโรคในระดับจังหวัด

การทำงานร่วมกันระหว่างหน่วยงานราชการในป้องกันและควบคุมโรคในระดับจังหวัดในปัจจุบันเป็นในรูปแบบการดำเนินการโดยคณะกรรมการโรคติดต่อระดับจังหวัด ซึ่งประกอบหน่วยราชการในระดับจังหวัด ได้แก่ ผู้ว่าราชการจังหวัด สาธารณสุขจังหวัด ปศุสัตว์จังหวัด ประชาสัมพันธ์จังหวัด หัวหน้าสำนักงานป้องกันและบรรเทาสาธารณภัยจังหวัด ตัวแทนจากท้องถิ่น คณะกรรมการดังกล่าวมีบทบาทหน้าที่ จัดทำแผนปฏิบัติการเฝ้าระวัง รายงานสถานการณ์โรคติดต่อ ป้องกัน สนับสนุน ส่งเสริม ติดตาม และประเมินผลการควบคุมโรคติดต่อ อันตราย โรคติดต่อที่ต้องเฝ้าระวัง หรือโรคระบาดในเขตพื้นที่จังหวัด การพัฒนากลไกเพื่อให้หน่วยงานต่างๆ สามารถประสานงานความร่วมมือและร่วมกันทำงานได้อย่างแท้จริง จะทำให้การป้องกันโรคมีประสิทธิภาพและประสิทธิผลเพิ่มมากขึ้น โดยกลไกดังกล่าวประกอบด้วยแนวทางดังต่อไปนี้

6.1 การสร้างกลไกในการจัดการ (Management)

การสร้างกลไกในการจัดการที่ดี จะเป็นการสร้างปัจจัยส่งเสริมที่สำคัญเพื่อเตรียมความพร้อมในการป้องกันและแก้ไขการแพร่ระบาดของโรคเลปโตสไปโรซิส โดยมีแนวทางการดำเนินการดังต่อไปนี้

6.1.1 พัฒนาองค์ความรู้และความเข้าใจในการทำงานร่วมกันระหว่างหน่วยงานในการป้องกันโรคติดต่อแก่เจ้าหน้าที่ของรัฐในระดับจังหวัด

6.1.1.1 ทำการอบรมให้ความรู้เกี่ยวกับแนวคิดของ One health เพื่อให้เกิดความเข้าใจและเล็งเห็นความสำคัญของการดำเนินงานร่วมกันของ เจ้าหน้าที่สาธารณสุข เจ้าหน้าที่ปศุสัตว์ และเจ้าหน้าที่องค์กรปกครองส่วนท้องถิ่น

6.1.1.2 ฟื้นฟูองค์ความรู้เรื่องโรคเลปโตสไปโรซิสในการป้องกันควบคุมโรคเลปโตสไปโรซิส ให้กับบุคลากรสาธารณสุข ปศุสัตว์ องค์กรปกครองส่วนท้องถิ่น ประชาสัมพันธ์จังหวัด ป้องกันและบรรเทาสาธารณภัย และหน่วยงานที่เกี่ยวข้อง

หน่วยงานหลักรับผิดชอบ

- **ผู้ว่าราชการส่วนจังหวัด**

สนับสนุนให้เกิดการอบรมแก่ผู้ปฏิบัติของหน่วยงานที่เกี่ยวข้องภายในจังหวัด

6.1.2 สร้างฐานข้อมูลในการเฝ้าระวังโรคในคนและในสัตว์

6.1.2.1 สาธารณสุขจังหวัดและปศุสัตว์จังหวัดทำการประชุมร่วมกัน เพื่อกำหนดข้อมูลที่ต้องทำการเฝ้าระวัง เช่น การเฝ้าระวังโรคในสัตว์ป่วย การเฝ้าระวังโรคในคน และการเฝ้าระวังพฤติกรรมการป่องกันตนเองในประชาชน เป็นต้น

6.1.2.2 สร้างฐานข้อมูลที่มีศักยภาพในการเชื่อมฐานข้อมูลในการเฝ้าระวังในคนและสัตว์ และสามารถรายงานผลการเฝ้าระวังให้หน่วยที่เกี่ยวข้องทราบ ทั้งนี้ฐานข้อมูลดังกล่าวต้องสามารถเชื่อมโยงฐานข้อมูลที่อยู่ของแต่ละหน่วยงานเข้าด้วยกันให้เป็นฐานข้อมูลกลาง

หน่วยงานหลักรับผิดชอบ

- **ผู้ว่าราชการส่วนจังหวัด**
  จัดทำฐานข้อมูล
- **สาธารณสุข**
  ร่วมจัดกำหนดข้อมูลในการเฝ้าระวัง
- **ปศุสัตว์**
  ร่วมจัดกำหนดข้อมูลในการเฝ้าระวัง
- **องค์การบริหารส่วนจังหวัด (อบจ.)**
  ร่วมจัดกำหนดข้อมูลในการเฝ้าระวัง

6.1.3. สร้างเครื่องมือในการเฝ้าระวังโรคระดับชุมชน

6.1.3.1 สร้างเครื่องมือในการเฝ้าระวังโรคเลปโตสไปโรซิสในคน และในสัตว์ เช่น เครื่องมือในการป้องกันพฤติกรรมการป้องกันโรคเลปโตสไปโรซิสในคน เป็นต้น

6.1.3.2 เครื่องมือมีความสามารถในการรายผลการเฝ้าระวังได้อย่าฉับไว โดยมีการนำเทคโนโลยีสารสนเทศมาใช้ในการสร้างเครื่องมือ เพื่อให้ผู้รับผิดชอบการเฝ้าระวังระดับจังหวัด อำเภอ และตำบลสามารถเข้าไปตรวจสอบความก้าวหน้าในการเฝ้าระวัง และสามารถนำผลการเฝ้าระวังไปใช้ได้

หน่วยงานหลักรับผิดชอบ

- **ผู้ว่าราชการส่วนจังหวัด**
  ควบคุม และกำกับการสร้างเครื่องมือในการเฝ้าระวังโรคระดับชุมชน
- **สาธารณสุข**
  ร่วมจัดทำเครื่องมือในการเฝ้าระวังโรคระดับชุมชน

- **ปศุสัตว์**

  ร่วมจัดทำเครื่องมือในการเฝ้าระวังโรคระดับชุมชน

- **องค์การบริหารส่วนจังหวัด (อบจ.)**

  ร่วมจัดทำเครื่องมือในการเฝ้าระวังโรคระดับชุมชน

6.2. กลไกในการประสานความร่วมมือระหว่างหน่วยงาน (Coordination)

ความร่วมมือระหว่างหน่วยงานนับว่าเป็นหัวใจสำคัญในที่จะช่วยส่งเสริมให้เกิดประสิทธิภาพในการควบคุม และป้องกันการแพร่ระบาดของโรคที่จะเกิดขึ้นในคน สัตว์ และสิ่งแวดล้อม การสร้างกลไกในการประสานความร่วมมือระหว่างหน่วยงานระดับจังหวัดมีแนวทางการดำเนินการดังต่อไปนี้

6.2.1. บูรณาการการดำเนินงานป้องกันและควบคุมโรคเลปโตสไปโรซิสในทุกระดับ ให้เป็นไปในทิศทาง เดียวกัน

6.2.1.1 จัดทำนโยบายในการป้องกันและควบคุมโรคเลปโตสไปโรซิสโดยการทำงานร่วมกันระหว่างหน่วยงาน

6.2.1.2 จัดตั้งคณะกรรมการ คณะทำงาน กำหนดบทบาทหน้าในการทำงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิสในระดับจังหวัด อำเภอ ตำบลของแต่ละหน่วยงานอย่างชัดเจน

6.2.1.3 กำหนดตัวชี้วัดในการป้องกันและควบคุมโรคเลปโตสไปโรซิสในการทำงานในระดับจังหวัด อำเภอ ตำบลของแต่ละหน่วยงานอย่างชัดเจน

6.2.1.4 ทุกภาคส่วนร่วมกันจัดทำแผนงานโครงการและแผนปฏิบัติการในการป้องกันโรคเลปโตสไปโรซิสให้เป็นทิศทางเดียวกัน

หน่วยงานหลักรับผิดชอบ

- **ผู้ว่าราชการส่วนจังหวัด**

  จัดเวทีเพื่อให้เกิดความร่วมมือกันในการจัดโยบาย, ตัวชี้วัดในการทำงาน, แนวทางการดำเนินการป้องกันและควบคุมโรคแบบมีส่วนร่วม

- **สาธารณสุข**

  ร่วมจัดทำแผน และดำเนินการตามแผนในการเฝ้าระวัง ป้องกัน และควบคุมโรค

- **ปศุสัตว์**

  ร่วมจัดทำแผน และดำเนินการตามแผนในการเฝ้าระวัง ป้องกัน และควบคุมโรค

- **องค์การบริหารส่วนจังหวัด (อบจ.)**

  ร่วมจัดทำแผน และดำเนินการตามแผนในการเฝ้าระวัง ป้องกัน และควบคุมโรค

- **สำนักงานป้องกันและบรรเทาสาธารณภัยจังหวัด**

  ร่วมจัดทำแผน และดำเนินการตามแผนในการเฝ้าระวัง ป้องกัน และควบคุมโรค

- **เกษตรและสหกรณ์จังหวัด**

  ร่วมจัดทำแผน และดำเนินการตามแผนในการเฝ้าระวัง ป้องกัน และควบคุมโรค

- **ประชาสัมพันธ์จังหวัด**

  ร่วมจัดทำแผน และดำเนินการตามแผนในการเฝ้าระวัง ป้องกัน และควบคุมโรค

- **ทรัพยากรธรรมชาติและสิ่งแวดล้อม**

  ร่วมจัดทำแผน และดำเนินการตามแผนในการเฝ้าระวัง ป้องกัน และควบคุมโรค

- **ศึกษาธิการ**

  ร่วมจัดทำแผน และดำเนินการตามแผนในการเฝ้าระวัง ป้องกัน และควบคุมโรค

6.2.2. บูรณาการการใช้ทรัพยากรในการป้องกันและควบคุมโรคเลปโตสไปโรซิส

6.2.2.1 บูรณาการใช้ทรัพยากรที่มีอยู่ในแต่ละหน่วยงานในการดำเนินงานป้องกันและควบคุมโรคเลปโตสไปโรซิสร่วมกัน

หน่วยงานหลักรับผิดชอบ

- **ผู้ว่าราชการส่วนจังหวัด**

  อำนวยการให้เกิดการใช้ทรัพยากรในการป้องกันโรคในหน่วยงานระดับจังหวัด

- **สาธารณสุข**

  ร่วมพิจารณาการใช้ทรัพยากรในการป้องกันโรคในหน่วยงานระดับจังหวัด

- **ปศุสัตว์**

  ร่วมพิจารณาการใช้ทรัพยากรในการป้องกันโรคในหน่วยงานระดับจังหวัด

- **องค์การบริหารส่วนจังหวัด (อบจ.)**

  ร่วมพิจารณาการใช้ทรัพยากรในการป้องกันโรคในหน่วยงานระดับจังหวัด

- **สำนักงานป้องกันและบรรเทาสาธารณภัยจังหวัด**

  ร่วมพิจารณาการใช้ทรัพยากรในการป้องกันโรคในหน่วยงานระดับจังหวัด

- **เกษตรและสหกรณ์**

  ร่วมพิจารณาการใช้ทรัพยากรในการป้องกันโรคในหน่วยงานระดับจังหวัด

- **ประชาสัมพันธ์จังหวัด**

  ร่วมพิจารณาการใช้ทรัพยากรในการป้องกันโรคในหน่วยงานระดับจังหวัด

- **ทรัพยากรธรรมชาติและสิ่งแวดล้อม**

  ร่วมพิจารณาการใช้ทรัพยากรในการป้องกันโรคในหน่วยงานระดับจังหวัด

- **ศึกษาธิการ**

  ร่วมพิจารณาการใช้ทรัพยากรในการป้องกันโรคในหน่วยงานระดับจังหวัด

6.3 กลไกในการประเมิน (Evaluation)

การประเมินการดำเนินงานจะช่วยให้ผู้ปฏิบัติงานสามารถติดตามสถานการณ์ของโรค และสามารถกำหนดแนวทางการป้องกันโรคได้อย่างเหมาะสม การสร้างกลไกการประเมิน ประกอบด้วยขั้นตอนดังต่อไปนี้

6.3.1 กำหนดบทบาทหน้าที่และสถานการณ์ที่ต้องรายงานผลการเฝ้าระวังแก่คณะกรรมการโรคติดต่อระดับจังหวัด

6.3.1.1 กำหนดหน้าที่ผู้รับผิดชอบหลักในการดูแลฐานข้อมูลโรคในคนและในสัตว์ โดยเจ้าหน้าที่ดังกล่าวมีหน้าที่ในการติดตามสถานการณ์การระบาดของโรคเลปโตสไปโรซิสจากฐานข้อมูลการเฝ้าระวังโรคในคนและในสัตว์

6.3.1.2 กำหนดสถานการณ์ที่ต้องดำเนินการรายงานการแพร่ระบาดของโรคเลปโตสไปโรซิสแก่คณะกรรมการโรคติดต่อระดับจังหวัด กรณีที่ต้องมีการรายงาน เช่น พบว่ามีอัตราการป่วยในสัตว์ หรือ คน เพิ่มขึ้น หรือเกิดการแพร่กระจายโรคครั้งใหม่

6.3.1.3 ส่งผลการวิเคราะห์กลับคืนหน่วยงานต่างๆ ในระดับตำบล เพื่อพัฒนาแนวทางการป้องกันและควบคุมโรคเลปโตสไปโรซิสระดับตำบล

หน่วยงานรับผิดชอบหลัก

- **ผู้ว่าราชการจังหวัด**

  ร่วมพิจารณาเลือกตัวบุคคลในการดูแลฐานข้อมูลโรคในคนและในสัตว์ระดับจังหวัด

- **สาธารณสุข**

  ร่วมกำหนดสถานการณ์ที่ต้องมีการรายงานการแพร่ระบาดของโรคเลปโตสไปโรซิส

- **ปศุสัตว์**

  ร่วมกำหนดสถานการณ์ที่ต้องมีการรายงานการแพร่ระบาดของโรคเลปโตสไปโรซิส

- **องค์การบริหารส่วนจังหวัด (อบจ.)**

  ร่วมกำหนดสถานการณ์ที่ต้องมีการรายงานการแพร่ระบาดของโรคเลปโตสไปโรซิส

- **สำนักงานป้องกันและบรรเทาสาธารณภัยจังหวัด**

  ร่วมกำหนดสถานการณ์ที่ต้องมีการรายงานการแพร่ระบาดของโรคเลปโตสไปโรซิส

- **เกษตรและสหกรณ์**

  ร่วมกำหนดสถานการณ์ที่ต้องมีการรายงานการแพร่ระบาดของโรคเลปโตสไปโรซิส

- **ประชาสัมพันธ์จังหวัด**

  ร่วมกำหนดสถานการณ์ที่ต้องมีการรายงานการแพร่ระบาดของโรคเลปโตสไปโรซิส

- **ทรัพยากรธรรมชาติและสิ่งแวดล้อม**

  ร่วมกำหนดสถานการณ์ที่ต้องมีการรายงานการแพร่ระบาดของโรคเลปโตสไปโรซิส

- **ศึกษาธิการ**

  ร่วมกำหนดสถานการณ์ที่ต้องมีการรายงานการแพร่ระบาดของโรคเลปโตสไปโรซิส

- **ชุมชน ผู้นำชุมชน รวมทั้งอาสาสมัครชุมชน**

  ร่วมกำหนดสถานการณ์ที่ต้องมีการรายงานการแพร่ระบาดของโรคเลปโตสไปโรซิส

6.3.2 วิเคราะห์และถอดบทเรียน ระหว่างหน่วยงาน เพื่อสรุปประเด็นปัญหาและเตรียมการแก้ไขปัญหาในปีต่อๆ ไป

6.3.2.1 ประชุมเพื่อวิเคราะห์และถอดบทเรียนการดำเนินการป้องกันและควบคุมโรคเลปโตสไปโรซิสของแต่ละหน่วยงานในระดับจังหวัด

6.3.2.2 พัฒนาแนวทางการป้องกันและควบคุมโรคเลปโตสไปโรซิส เพื่อใช้ในการจัดทำแผนในการป้องกันและควบคุมโรคในปีต่อไป

หน่วยงานรับผิดชอบหลัก

- **ผู้ว่าราชการจังหวัด**

  ติดตามการติดตามการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **สาธารณสุข**

  ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **ปศุสัตว์**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **องค์การบริหารส่วนจังหวัด (อบจ.)**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **สำนักงานป้องกันและบรรเทาสาธารณภัยจังหวัด**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **เกษตรและสหกรณ์**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **ประชาสัมพันธ์จังหวัด**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **ทรัพยากรธรรมชาติและสิ่งแวดล้อม**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **ศึกษาธิการ**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **ชุมชน ผู้นำชุมชน รวมทั้งอาสาสมัครชุมชน**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

7. แนวทางปฏิบัติในการป้องกันและควบคุมโรคในระดับตำบล

การป้องกันโรคระดับตำบลนับว่าเป็นหน่วยการปฏิบัติที่สำคัญ เพราะมีความใกล้ชิดกับภาคประชาชน ในระดับตำบลประกอบกอบหน่วยงานราชการต่างๆ จำเป็นต้องมีความร่วมมือซึ่งกันและกันในแต่ละหน่วยงาน เพื่อให้สามารถดำเนินการป้องกันและควบคุมโรคได้อย่างเหมาะสม และสอดคล้องกับบริบทของแต่ละชุมชน โดยแนวทางการดำเนินงาน เพื่อให้หน่วยงานต่างๆ ระดับตำบลสามารถดำเนินการป้องกันและควบคุมร่วมกันได้อย่างมีประสิทธิภาพ การดำเนินการป้องกันและควบคุมโรคเลปโตสไปโรซิส จำเป็นที่ต้องจัดให้มีกลไกที่สำคัญ 3 ส่วน ได้แก่ กลไกในการจัดการ (Management) กลไกในการประสานความร่วมมือระหว่างหน่วยงาน (Coordination) และกลไกในการประเมิน (Evaluation)

7.1. การสร้างกลไกในการจัดการ (Management)

7.1.1 พัฒนาองค์ความรู้และความเข้าใจในการทำงานร่วมกันระหว่างหน่วยงานในการป้องกันโรคในระดับตำบล ได้แก่ หน่วยงานด้านสาธารณสุข ปศุสัตว์ และองค์กรปกครองส่วนท้องถิ่น

7.1.1.1 ทำการอบรมให้ความรู้เกี่ยวกับแนวคิดของ One health เพื่อให้เกิดความเข้าใจและเล็งเห็นความสำคัญของการดำเนินงานร่วมกันแก่เจ้าหน้าที่ระดับตำบล รูปแบบการให้ความรู้อาจจะใช้การให้ความรู้แบบ e-learning โดยออกแบบให้ระบบมีความสามารถในการติดตามผู้ที่เข้าไปศึกษา และกำหนดให้การเข้าไปศึกษาระบบเป็นคะแนนตัวชี้วัดในการพัฒนาตนเองของผู้ปฏิบัติงาน และมีระบบที่มอบหลักฐานการเข้าไปอบรมให้กับผู้ที่เข้าไปศึกษา

7.1.1.2 ฟื้นฟูองค์ความรู้เรื่องโรคเลปโตสไปโรซิสให้กับบุคลากรสาธารณสุข ปศุสัตว์ องค์กรปกครองส่วนท้องถิ่น และหน่วยงานที่เกี่ยวข้อง เพื่อพัฒนาศักยภาพเจ้าหน้าในการป้องกันควบคุมโรคเลปโตสไปโรซิส

หน่วยงานหลักรับผิดชอบ

- **ผู้ว่าราชการส่วนจังหวัด**

  สนับสนุนให้เกิดการอบรมแก่ผู้ปฏิบัติของหน่วยงานที่เกี่ยวข้องภายในตำบล

- **สาธารณสุข**

  เข้าร่วมการอบรม

- **ปศุสัตว์**

  เข้าร่วมการอบรม

- **องค์กรปกครองส่วนท้องถิ่น**

  เข้าร่วมการอบรม

7.1.2 อบรมให้ความรู้ในการใช้เครื่องมือในการเฝ้าระวังโรคเลปโตสไปโรซิส แก่อาสาสมัครสาธารณสุข อาสาสมัครปศุสัตว์

7.1.2.1 ดำเนินการให้ความรู้ในการดำเนินการเฝ้าระวัง การใช้เครื่องมือในการเฝ้าระวังโรคเลปโตสไปโรซิส และแนวทางการรายงานผลการเฝ้าระวัง แก่อาสาสมัครสาธารณสุข อาสาสมัครปศุสัตว์ ซึ่งอาจจะใช้ให้ความรู้แบบ e-learning

หน่วยงานหลักรับผิดชอบ

- **ผู้ว่าราชการส่วนจังหวัด**

  ควบคุม และติดตามผลการพัฒนาองค์ความรู้แก่ อาสาสมัครสาธารณสุข อาสาสมัครปศุสัตว์ในการใช้เครื่องมือในการเฝ้าระวังโรคเลปโตสไปโรซิส

- **สาธารณสุข**

  ร่วมให้ความรู้ในการเฝ้าระวังโรคเลปโตสไปโรซิส

- **ปศุสัตว์**

  ร่วมให้ความรู้ในการเฝ้าระวังโรคเลปโตสไปโรซิส

- **องค์กรปกครองส่วนท้องถิ่น**

  ร่วมให้ความรู้ในการเฝ้าระวังโรคเลปโตสไปโรซิส

7.2 กลไกในการประสานความร่วมมือระหว่างหน่วยงาน (Coordination)

การสร้างกลไกในการประสานความร่วมมือระหว่างหน่วยงานระดับตำบลมีแนวทางการดำเนินการดังต่อไปนี้

7.2.1 จัดลงนามความร่วมมือระหว่างหน่วยงานในระดับตำบลในการป้องกันและควบคุมโรคเลปโตสไปโรซิส

7.2.1.1 จัดลงนามความร่วมมือ (MoU) ระหว่างหน่วยงานในระดับตำบล โดยกำหนดบทบาทของแต่ละหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส

หน่วยงานหลักรับผิดชอบ

- **ผู้ว่าราชการส่วนจังหวัด**

  สนับสนุนให้เกิดการลงนามความร่วมมือ

- **สาธารณสุข**

ร่วมพิจารณาและกำหนดแนวทางในการร่วมมือกันระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **ปศุสัตว์**

ร่วมพิจารณาและกำหนดแนวทางในการร่วมมือกันระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **องค์กรปกครองส่วนท้องถิ่น**

ร่วมพิจารณาและกำหนดแนวทางในการร่วมมือกันระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **ชุมชน ผู้นำชุมชน รวมทั้งอาสาสมัครชุมชน**

ร่วมพิจารณาและกำหนดแนวทางในการร่วมมือกันระหว่างหน่วยงานในการป้องกันและควบคุมโรคเลปโตสไปโรซิส

7.2.2 ส่งเสริมการมีส่วนร่วม และพัฒนาศักยภาพ อาสาสมัครในชุมชน ผู้นำในชุมชน เครือข่ายเกษตรกร ผู้เลี้ยงสัตว์ในการป้องกันควบคุมโรคเลปโตสไปโรซิสในระดับท้องถิ่น

7.2.2.1 พัฒนาการส่วนร่วมของภาคประชาชน อาสาสมัครสาธารณสุข ผู้นำชุมชน ส่งเสริมบทบาทของภาคประชาชน อาสาสมัครสาธารณสุข ผู้นำชุมชนให้เข้ามามีส่วนร่วมในการป้องกัน ควบคุม และเฝ้าระวังโรคเลปโตสไปโรซิสในชุมชน

1) กำหนดบทบาทหน้าที่ที่ชัดเจนของอาสาสมัครในชุมชน ผู้นำชุมชน ในการป้องกัน ควบคุม และเฝ้าระวังโรคเลปโตสไปโรซิส ซึ่งควรมีการจัดทำคู่มือการปฏิบัติงานที่ความชัดเจนในบทบาทหน้าที่ของ อาสาสมัครในชุมชน ผู้นำชุมชนในการดำเนินการป้องกัน ควบคุม และเฝ้าระวังโรคเลปโตสไปโรซิส

2) จัดทำแผนงานโครงการแก้ไขปัญหาโรคเลปโตสไปโรซิสโดยให้ภาคประชาชนเข้ามามีส่วนร่วม

3) พัฒนาระบบพี่เลี้ยงเพื่อสนับสนุนการดำเนินงานอาสาสมัครในชุมชนและผู้นำชุมชน ในการเฝ้าระวังป้องกันและควบคุมโรคเลปโตสไปโรซิส

7.2.2.2 พัฒนาศักยภาพอาสาสมัครสาธารณสุขในการดำเนินกิจกรรมป้องกันควบคุมโรคเลปโตสไปโรซิสในชุมชน

1) อบรมให้ความรู้แก่ อาสาสมัครสาธารณสุขและผู้นำชุมชนในการเกี่ยวกับสาเหตุการเกิดโรค อาการ การป้องกัน การควบคุม และการเฝ้าระวังโรคเลปโตสไปโรซิส

2) ส่งเสริมเจตคติในการป้องกันและควบคุมโรคเลปโตสไปโรซิสแก่อาสาสมัครสาธารณสุขและผู้นำชุมชน เช่น ส่งเสริมให้เกิดความตระหนักในการควบคุมสัตว์นำโรคในชุมชน เป็นต้น

3) จัดเวทีแลกเปลี่ยนเรียนรู้ของเครือข่ายในชุมชนเพื่อแลกเปลี่ยนแนวทางการการป้องกัน ควบคุม และเฝ้าระวังโรคเลปโตสไปโรซิส

4) เสริมสร้างแรงจูงใจเพื่อเป็นขวัญกำลังใจในการดำเนินการของเครือข่าย

7.2.2.3 สนับสนุนการรวมกลุ่มของเกษตรกร ผู้เลี้ยงสัตว์ เพื่อความเข้มแข็งของเกษตรกร ตลอดจนการแลกเปลี่ยนประสบการณ์และความรู้วิทยาการใหม่ๆ

หน่วยงานหลักรับผิดชอบ

- **ผู้ว่าราชการส่วนจังหวัด**

  สนับสนุนการพัฒนาเครือข่ายภาคประชาชน

- **สาธารณสุข**

  พัฒนาเครือข่ายภาคประชาชนในการเฝ้าระวังโรคในคน

- **ปศุสัตว์**

  * พัฒนาเครือข่ายภาคประชาชนในการเฝ้าระวังโรคสัตว์
  * สนับสนุนการร่วมกลุ่มของเกษตร และผู้เลี้ยงสัตว์
  * พัฒนาความรู้และความร่วมมือในการป้องกันโรค

- **องค์กรปกครองส่วนท้องถิ่น**

  พัฒนาเครือข่าย และสนับสนุนทรัพยากรในการพัฒนาเครือข่าย

- **ชุมชน ผู้นำชุมชน รวมทั้งอาสาสมัครชุมชน**

  มีส่วนร่วมในการเป็นเครือข่ายเฝ้าระวังโรค เผยแพร่ความรู้และสื่อสารประชาสัมพันธ์ข่าวสารภายในเครือข่ายเพื่อป้องกันโรค

7.2.3 เสริมสร้างความรู้ ทัศนคติ และการปฏิบัติการป้องกันเลปโตสไปโรซิสในประชาชน

7.2.3.1 ผลิต และพัฒนาสื่อที่มีความรู้ทันสมัยและถูกหลักวิชาการ เพื่อใช้ในการถ่ายทอดองค์ความรู้เผยแพร่ความรู้เรื่องโรคเลปโตสไปโรซิสแก่เครือข่ายและประชาชน

7.2.3.2 ประชาสัมพันธ์ถ่ายทอดองค์ความรู้ และส่งเสริมให้เกิดพฤติกรรมสุขภาพในการป้องกันและควบคุมโรคเลปโตสไปโรซิสแก่ประชาชนในแนวกว้างและแนวลึก

1) จัดให้มีการรณรงค์ในการป้องกันโรคในประชาชน โดยเน้นกลุ่มเป้าหมายในผู้ที่เคยป่วยด้วยโรคเลปโตสไปโรซิส เกษตรกร และผู้เลี้ยงสัตว์

2) ประชาสัมพันธ์ให้ความรู้ทางหอกระจายข่าว

7.2.3.3 ติดตามประเมินผลการรับรู้ข่าวสารของประชาชนในการป้องกันและควบคุมการแพร่ระบาดของโรคเลปโตสไปโรซิส

หน่วยงานรับผิดชอบหลัก

- **ผู้ว่าราชการส่วนจังหวัด**

ติดตามการเสริมสร้างความรู้ ทัศนคติ และการปฏิบัติในการป้องกันควบคุมโรคเลปโตสไปโรซิสในประชาชน

- **สาธารณสุข**

* ผลิตสื่อในการให้ความรู้ในการป้องกัน และควบคุมโรคเลปโตสไปโรซิสในประชาชน
* ติดตามพฤติกรรมสุขภาพในการป้องกันและควบคุมโรคเลปโตสไปโรซิสในประชาชน
* จัดการณรงค์ และให้ความรู้แก่ประชาชน

- **ปศุสัตว์**

ร่วมในจัดการณรงค์ และให้ความรู้แก่ประชาชน

- **องค์กรปกครองส่วนท้องถิ่น**

สนับสนุนงบประมาณในการให้ความรู้ และจัดกิจกรรมพัฒนาความรู้และพฤติกรรมสุขภาพในประชาชน

- **ชุมชน ผู้นำชุมชน รวมทั้งอาสาสมัครชุมชน**

มีบทบาทในการให้ความร่วมมือในการปฏิบัติงานของหน่วยงานภาครัฐ และเผยแพร่ประชาสัมพันธ์ข่าวสารในการให้ความรู้แก่ประชาชน

7.2.4 การจัดระบบการเลี้ยงสัตว์ให้ถูกหลักสุขาภิบาล

7.2.4.1 ปรับปรุง เตรียมแนวทาง และคำแนะนำการเลี้ยงสัตว์ตามหลักสุขาภิบาล

7.2.4.2 ถ่ายทอดและส่งเสริมการเลี้ยงสัตว์ตามหลักสุขาภิบาล

1) อบรมและส่งเสริมให้เกษตรผู้เลี้ยงสัตว์ เลี้ยงสัตว์อย่างปลอดโรค และลดความเสี่ยงต่อการเกิดโรคตามหลักสุขาภิบาล

2) อบรมและสนับสนุนให้มีการจัดการในการเลี้ยงสัตว์ให้ถูกหลักสุขาภิบาล รวมทั้งการควบคุมการปล่อยของเสียที่เกิดจากการเลี้ยงสัตว์ลงแหล่งน้ำ

3) พัฒนาการใช้แหล่งน้ำ

4) ให้คำแนะนำประชาชนในการป้องกันตนเองจากโรคเลปโตสไปโรซิสในการเลี้ยงสัตว์ที่ใกล้แหล่งที่มีความลาดเอียงต่ำ

7.2.4.3 จัดทำฐานข้อมูลสัตว์เลี้ยง

7.2.4.4 ประชาสัมพันธ์ ให้ความรู้เกษตรกรและผู้ประกอบการด้านปศุสัตว์

ให้ความรู้เกษตรกรและผู้ประกอบการด้านปศุสัตว์ โดยสามารถเข้าใจ สาเหตุ อาการ การป้องกัน และแนวทางดูแลสัตว์จากโรคเลปโตสไปโรซิส

1) จัดทำสื่อประชาสัมพันธ์ให้ความรู้แก่เกษตรกร และผู้ประกอบการด้านปศุสัตว์เกี่ยวกับอาการของโรคเลปโตสไปโรซิสและป้องกันโรคเลปโตสไปโรซิสในสัตว์

2) ดำเนินการประชาสัมพันธ์ให้ความรู้แก่เกษตรกร และผู้ประกอบการด้านปศุสัตว์เกี่ยวกับอาการของโรคโรคเลปโตสไปโรซิสและป้องกันโรคเลปโตสไปโรซิสในสัตว์

7.2.4.5 พัฒนานโยบายและมาตรการในการควบคุมการเลี้ยงสัตว์ให้ถูกหลักสุขาภิบาลและได้มาตรฐาน

1) พิจารณากฎหมายที่เกี่ยวข้อง และสร้างมาตรการร่วมกันในชุมชน เพื่อให้ผู้เลี้ยงสัตว์ดำเนินการเลี้ยงสัตว์ที่ถูกหลักสุขาภิบาล และได้มาตรฐาน เพื่อลดผลกระทบที่เกิดจากการแพร่เชื้อจากสัตว์สู่คน และลดการแพร่เชื้อจากสัตว์ลงสู่สิ่งแวดล้อม

2) กำหนดพื้นที่สำหรับแหล่งน้ำสำหรับคนและสัตว์ โดยแหล่งน้ำควรแยกการใช้ประโยชน์แหล่งน้ำอย่างชัดเจน

3) กำหมดมาตรการในการควบคุมการปล่อยของเสียจากการเลี้ยงสัตว์ลงแหล่งน้ำสาธารณะ สร้างความเข้าใจแก่ผู้เลี้ยงสัตว์ในการดำเนินการตามมาตรการ และควบคุมให้มีการปฏิบัติตามมาตรการที่กำหนด

หน่วยงานรับผิดชอบหลัก

- **ผู้ว่าราชการจังหวัด**

ติดตามการเลี้ยงสัตว์ให้ถูกหลักสุขาภิบาล

- **สาธารณสุข**

ร่วมกันหน่วยงานอื่นๆ ในการส่งเสริมให้มีการเลี้ยงสัตว์ให้เป็นไปตามแนวทาง และมาตรการที่กำหนด

- **ปศุสัตว์**

  * จัดทำสื่อให้ความรู้ด้านการป้องกันโรคเลปโตสไปโรซิสในสัตว์

  * รณรงค์ให้ความรู้ในการป้องกันโรคเลปโตสไปโรซิสในสัตว์

  - พัฒนาบุคลากร ถ่ายทอดความรู้ให้แก่เกษตรกรในการปรับปรุง และพัฒนารูปแบบการเลี้ยงสัตว์

- **องค์กรปกครองส่วนท้องถิ่น**

  * สร้างมาตรการร่วมกับชุมชนในการใช้แหล่งน้ำสำหรับคนและสัตว์

  * ควบคุมให้มีการปฏิบัติตามมาตรการที่ตกลงร่วมกับชุมชนในการใช้แหล่งน้ำสำหรับคนและสัตว์

  * ร่วมกันหน่วยงานอื่นๆ ในการส่งเสริมให้มีการเลี้ยงสัตว์ให้เป็นไปตามแนวทาง และมาตรการที่กำหนด

- **ชุมชน ผู้นำชุมชน รวมทั้งอาสาสมัครชุมชน**

  ร่วมสนับสนุนการดำเนินการของหน่วยงานรัฐ และควบคุมระบบการเลี้ยงสัตว์

7.2.5 บูรณาการการควบคุมการแพร่ระบาดของโรคเลปโตสไปโรซิสในคนและสัตว์

7.2.5.1 การควบคุมการแพร่ระบาดของโรคเลปโตสไปโรซิสในคน

เมื่อพบผู้ป่วยด้วยโรคเลปโตสไปโรซิส ให้ดำเนินการมาตรการทางวิชาการ “หลัก 4E+2C” ประกอบด้วยขั้นตอนดังต่อไปนี้

1) Early detection ผู้ป่วยรู้ตัวว่าอาจเป็นโรคหรือ อสม. ประเมินพบว่ามีความเสี่ยงให้รีบไปพบบุคคลากรทางการแพทย์ในสถานพยาบาลตั้งแต่ระดับโรงพยาบาลส่งเสริมสุขภาพระดับตำบลโดยเร็ว

2) Early diagnosis บุคลากรทางการแพทย์ แพทย์วินิจฉัยโรคเบื้องต้นจากประวัติและผู้ป่วยแสดงอาการกลุ่มไข้เฉียบพลัน ปวดศีรษะ ปวดเจ็บกล้ามเนื้อตามเกณฑ์การวินิจฉัยในคู่มือแนวทางการดำเนินงานป้องกันควบคุมโรคเลปโตสไปโรซิส

3) Early treatment การให้การรักษาเบื้องต้นโดยเร็วโดยบุคลากรทางการแพทย์ แพทย์ ปฏิบัติตามเกณฑ์การรักษาในคู่มือแนวทางการดำเนินงานป้องกันควบคุมโรคเลปโตสไปโรซิส

4) Early control ดำเนินการควบคุมป้องกันโรคในพื้นที่เสี่ยงโดย CDCU หลังจากได้รับรายงานมีผู้ป่วยในพื้นที่ภายใน 1 สัปดาห์

5) Coordination ประสานงานการสอบสวนโรคร่วมกับปศุสัตว์ และจัดทำข้อเสนอแนะสำหรับเกษตรกร ประชาชนเพื่อกำหนดมาตรการเฉพาะสำหรับพื้นที่ เช่น การเลี้ยงสัตว์ การเฝ้าระวังโรคในสัตว์ และระบบการรายงานผู้ป่วย

6) Community involvement ชุมชนมีส่วนร่วมป้องกันควบคุมโรค เช่น การออกแนวทางเตือนภัย การสื่อสารความเสี่ยง การรายงานผู้สงสัยว่าติดโรค หรือ การออกมาตรการเพื่อลดความเสี่ยง (Department of Disease Control, 2016)

7.2.5.2 การควบคุมการแพร่ระบาดของโรคเลปโตสไปโรซิสในสัตว์

เมื่อพบสัตว์ป่วยด้วยโรคเลปโตสไปโรซิส ให้ดำเนินการควบคุมโรคในสัตว์ดังต่อไปนี้

1) แยกสัตว์ป่วย หากจำเป็นให้ทำการฆ่าเพื่อควบคุมการแพร่ระบาดของเชื้อ

2) ทำการให้ยาเพื่อรักษาอาการป่วยในสัตว์

3) ทำการให้วัคซีนเพื่อสร้างภูมิคุ้มกันโรคเลปโตสไปโรซิสในสัตว์

4) กำจัดสิ่งขับถ่ายจากสัตว์เลี้ยงเพื่อหลีกเลี่ยงการปนเปื้อนของเชื้อในสิ่งแวดล้อม (World Health Organization, 2003)

7.2.5.3 ติดป้ายเตือนสถานที่ที่เป็นแหล่งรังโรค เช่น เมื่อสอบสวนประวัติการเจ็บป่วยและพบว่ามีผู้ได้รับเชื้อเลปโตสไปโรซิสจากแหล่งน้ำ ให้ดำเนินการจัดทำป้ายเตือนเพื่อหลีกเลี่ยงการใช้แหล่งน้ำดังกล่าวเป็นต้น

7.2.5.4 จัดตั้งศูนย์ปฏิบัติการแก้ไขปัญหาการระบาดโรค

ในกรณีที่แนวโน้มการระบาดของโรคที่รุนแรง ให้จัดระบบบัญชาการและสั่งการวิเคราะห์สถานการณ์และปัญหา และกำหนดมาตรการสำคัญในการแก้ไขปัญหาระหว่างหน่วยงานที่เกี่ยวข้อง

7.2.5.5 ประชาสัมพันธ์ให้ประชาชนทราบถึงปัญหาการแพร่ระบาดของโรค

1) แจ้งเตือนประชาชนถึงสถานการณ์ระบาดของโรค

2) รณรงค์ให้ประชาชนลดการสัมผัสปัจจัยเสี่ยงต่อการเกิดโรค พัฒนาความรู้และมีทักษะในการป้องกันตนเองที่ถูกต้อง

หน่วยงานรับผิดชอบหลัก

- **ผู้ว่าราชการจังหวัด**

ติดตามการควบคุมการแพร่ระบาดของโรคในคนและสัตว์

- **สาธารณสุข**

  * ควบคุมการแพร่ระบาดของโรคเลปโตสไปโรซิสในคน

  * พัฒนาความรู้และมีทักษะในการป้องกันตนเองจากโรคเลปโตสไปโรซิส

- **ปศุสัตว์**

  * ควบคุมการแพร่ระบาดของโรคเลปโตสไปโรซิสในสัตว์

  * พัฒนาความรู้และมีทักษะในการป้องกันตนเองจากโรคเลปโตสไปโรซิส

- **องค์กรปกครองส่วนท้องถิ่น**

  * สนับสนุนทรัพยากรในการควบคุมการระบาดของโรค

  * ประชาสัมพันธ์การลดความเสี่ยงต่อการสัมผัสเชื้อในสิ่งแวดล้อม และจัดทำป้ายเตือนการหลีกเลี่ยงการสัมผัสสถานที่เป็นรังโรค และแหล่งที่คาดว่าจะเป็นแหล่งที่ผู้ป่วยได้รับเชื้อ ให้ประชาชนทราบ

- **ชุมชน ผู้นำชุมชน รวมทั้งอาสาสมัครชุมชน**

  ให้ความร่วมมือในการควบคุมการแพร่ระบาดของโรคเลปโตสไปโรซิสในชุมชน

7.3 กลไกในการประเมิน (Evaluation)

การประเมินการดำเนินจะช่วยให้สามารถติดตามสถานการณ์ของโรค และสามารถกำหนดแนวทางการป้องกันโรคได้อย่างเหมาะสม การสร้างกลไกการประเมินประกอบด้วยขั้นตอนดังต่อไปนี้

7.3.1 กำหนดบทบาทหน้าที่และสถานการณ์ที่ต้องรายงานผลการเฝ้าระวังแก่คณะกรรมการโรคติดต่อระดับจังหวัด

7.3.1.1 กำหนดผู้ควบคุมฐานข้อมูลและผู้รายงานผลการเฝ้าระวังในระดับตำบล

1) เจ้าหน้าสาธารณสุขต้องทำการตรวจสอบความถูกต้องของข้อมูล เมื่อได้รับข้อมูลการเฝ้าระวังที่เกี่ยวข้องกับคนก่อนที่จะนำข้อมูลเข้าสู่ฐานข้อมูล

2) เจ้าหน้าปศุสัตว์ต้องทำการตรวจสอบความถูกต้องของข้อมูล เมื่อได้รับข้อมูลการเฝ้าระวังที่เกี่ยวข้องกับสัตว์ ก่อนที่จะนำเข้าสู่ฐานข้อมูลกลาง

หน่วยงานรับผิดชอบหลัก

- **ผู้ว่าราชการจังหวัด**

  ร่วมพิจารณาเลือกตัวบุคคลในการดูแลฐานข้อมูลโรคในคนและในสัตว์ระดับจังหวัด

- **สาธารณสุข**

ร่วมกำหนดสถานการณ์ที่ต้องมีการรายานการแพร่ระบาดของโรคเลปโตสไปโรซิส

- **ปศุสัตว์**

ร่วมกำหนดสถานการณ์ที่ต้องมีการรายานการแพร่ระบาดของโรคเลปโตสไปโรซิส

- **องค์กรปกครองส่วนท้องถิ่น**

ร่วมกำหนดสถานการณ์ที่ต้องมีการรายานการแพร่ระบาดของโรคเลปโตสไปโรซิส

- **ชุมชน ผู้นำชุมชน รวมทั้งอาสาสมัครชุมชน**

ร่วมกำหนดสถานการณ์ที่ต้องมีการรายานการแพร่ระบาดของโรคเลปโตสไปโรซิส

7.3.2 วิเคราะห์และถอดบทเรียน ระหว่างหน่วยงาน เพื่อสรุปประเด็นปัญหาและเตรียมการแก้ไขปัญหาในปีต่อๆ ไป

7.3.2.1 ประชุมเพื่อวิเคราะห์และถอดบทเรียนการดำการป้องกันและควบคุมโรคของแต่ละหน่วยงานในระดับตำบล

7.3.2.2 พิจารณาแนวทางการพัฒนาแนวทางการป้องกันและควบคุมโรค เพื่อใช้เป็นฐานข้อมูลในการจัดทำแผนในการป้องกันและควบคุมโรคในปีต่อไป

หน่วยงานรับผิดชอบหลัก

- **ผู้ว่าราชการจังหวัด**

ติดตามการติดตามการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **สาธารณสุข**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **ปศุสัตว์**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **องค์กรปกครองส่วนท้องถิ่น**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

- **ชุมชน ผู้นำชุมชน รวมทั้งอาสาสมัครชุมชน**

ร่วมติดตามการติดตามและพัฒนาแนวทางการดำเนินงานการป้องกันและควบคุมโรคเลปโตสไปโรซิส

References

Abgueguen P, Delbos V, Blanvillain J, Chennebault JM, Cottin J, Fanello S, et al. Clinical aspects and prognostic factors of leptospirosis in adults. Retrospective study in France. Journal of Infection 2008; 57(3): 171-8.

Adler B. Pathogenesis of leptospirosis: Cellular and molecular aspects. Veterinary Microbiology 2014; 172(3–4): 353-8.

Adler B. (2015). Leptospira and leptospirosis: Springer Berlin Heidelberg.

Adler B, de la Peña Moctezuma A. Leptospira and leptospirosis. Veterinary Microbiology 2010; 140(3-4): 287-96.

Alston JM, Brown HC. The Epidemiology of Weil's Disease. Pro R Soc Med 1937; 30(6): 741–56.

Amilasan A-sT, Ujiie M, Suzuki M, Salva E, Belo MCP, Koizumi N, et al. Outbreak of leptospirosis after flood, the Philippines, 2009. Emerging Infectious Diseases 2012; 18(1): 91-4.

Antonovics J. Transmission dynamics: critical questions and challenges. Philosophical Transactions of the Royal Society B: Biological Sciences 2017; 372(1719): 20160087.

Azfar ZM, Nazri SM, Rusli AM, Maizurah O, Zahiruddin WM, Azwany YN, et al. Knowledge, attitude and practice about leptospirosis prevention among town service workers in northeastern Malaysia: a cross-sectional study. Journal of Preventive Medicine and Hygiene 2018; 59(1): E92-E8.

Barragan V, Nieto N, Keim P, Pearson T. Meta-analysis to estimate the load of Leptospira excreted in urine: beyond rats as important sources of transmission in low-income rural communities. BMC Research Notes 2017; 10: 71.

Bates D, Mächler M, Bolker B, Walker S. Fitting Linear Mixed-Effects Models using lme4. Journal of Statistical Software 2015; 67(1): 1-48.

Bedard BA, Kennedy BS, Weimer AC, Petruso A, Magnussen R. Leptospirosis and an animal bite. Annals of Tropical Medicine & Public Health 2014; 7(3): 182-4.

Benacer D, Thong KL, Min NC, Verasahib KB, Galloway RL, Hartskeerl RA, et al. Epidemiology of human leptospirosis in Malaysia, 2004–2012. Acta Tropica 2016; 157: 162-8.

Bharti AR, Nally JE, Ricaldi JN, Matthias MA, Diaz MM, Lovett MA, et al. Leptospirosis: a zoonotic disease of global importance. The Lancet Infectious Diseases 2003; 3(12): 757-71.

Bhattacherjee A. Social science research: Principles, methods, and practices. 2012.

Bidaisee S, Macpherson CN. Zoonoses and one health: a review of the literature. Journal of parasitology research 2014; 2014.

Binot A, Morand S. (2015). Implementation of the One Health Strategy: Lessons learnt from community-based natural resource programs for communities' empowerment and equity within an EcoHealth Approach. In: Morand S, Dujardin J-P, Lefait-Robin R, Apiwathnasorn C, editors. Socio-ecological dimensions of infectious diseases in Southeast Asia: Springer.

Biscornet L, Dellagi K, Pagès F, Bibi J, de Comarmond J, Mélade J, et al. Human leptospirosis in Seychelles: A prospective study confirms the heavy burden of

the disease but suggests that rats are not the main reservoir. PLOS Neglected Tropical Diseases 2017; 11(8): e0005831.
Bivand R, Gómez-Rubio V, Rue H. Spatial data analysis with R-INLA with some extensions. Journal of Statistical Software 2015; 63(30): 1-31.
Bivand R, Keitt T, Rowlingson B. (2018). rgdal: Bindings for the 'Geospatial' data abstraction library. R package version 1.3-6., https://CRAN.R-project.org/package=rgdal
Bivand R, Nowosad J, Lovelace R, Monmonier M, Snow G. (2018). Package 'spData'.
Blasdell KR, Morand S, Perera D, Firth C. Association of rodent-borne Leptospira spp. with urban environments in Malaysian Borneo. PLOS Neglected Tropical Diseases 2019; 13(2): e0007141.
Brodersen KH, Gallusser F, Koehler J, Remy N, Scott SL. Inferring causal impact using Bayesian structural time-series models. The Annals of Applied Statistics 2015; 9(1): 247-74.
Brownrigg R, Minka T, Deckmyn A. (2015). maps: Draw geographical maps, R package version 3.0.1.
Budihal SV, Perwez K. Leptospirosis diagnosis: Competancy of various laboratory tests. Journal of Clinical & Diagnostic Research 2014; 8(1): 199-202.
Bureau of Emerging Infectious Disease Department of Disease Control MoPH. (2016). Thailand's National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response 2017 - 2021. Nonthaburi Thailand: The War Veterans Organization of Thailand Under Royal Patronage of His Majesty the King.
Bureau of Emerging Infectious Diseases Department of Disease Control MoPH. (2016). Thailand National Strategic Plan for Emerging Infectious Disease Preparedness, Prevention and Response (2017-2021). Thailand: Office of Printing The Veterans Administration under the Royal Patronage.
Bureau of Epidemiology Department of Disease Control. (2000). Annual epidemiology surveillance report 1993-2000. Bangkok, Thailand.
Bureau of Epidemiology Department of Disease Control MoPH. (2007). Leptospirosis clinical practice. Thailand [in Thai]: Community Cooperative Thailand Corporation.
Bureau of General Communicable Department of Disease Control MoPH. (2000). Academic leptospirosis handbook. Bangkok, Thailand: Community Cooperative Thailand Corporation.
Buriwath C. (2012). The applied program of the participatory learning and social support theory to improve the preventive behavior of the enrisked farmer in leptospirosis disease at the Chunghan District Roi-et Province Mahasarakham University, Mahasarakham, Thailand.

Chadsuthi S, Bicout DJ, Wiratsudakul A, Suwancharoen D, Petkanchanapong W, Modchang C, et al. Investigation on predominant Leptospira serovars and its distribution in humans and livestock in Thailand, 2010-2015. PLOS Neglected Tropical Diseases 2017; 11(2): e0005228.
Chadsuthi S, Modchang C, Lenbury Y, Iamsirithaworn S, Triampo W. Modeling seasonal leptospirosis transmission and its association with rainfall and

temperature in Thailand using time–series and ARIMAX analyses. Asian Pacific Journal of Tropical Medicine 2012; 5(7): 539-46.
Chathongyot K. (2001). Effectiveness of health education programme in promotion leptospirosis prevention behaviors among framers at Nong Hin District of Loei Province Mahidol Uinversity, Bangkok, Thailand.
Chompoochan T, Prasitrat M, Ekatat M. (1996). Dairy care guideline. Bangkok Thailand: Funny publishing.
Cochran WG. (2007). Sampling techniques: John Wiley & Sons.
Coker RJ, Hunter BM, Rudge JW, Liverani M, Hanvoravongchai P. Emerging infectious diseases in southeast Asia: regional challenges to control. The Lancet 2011; 377(9765): 599-609.
Cosson J-F, Picardeau M, Mielcarek M, Tatard C, Chaval Y, Suputtamongkol Y, et al. Epidemiology of Leptospira transmitted by rodents in Southeast Asia. PLoS Neglected Tropical Diseases 2014; 8(6): 1-10.
Costa F, Hagan JE, Calcagno J, Kane M, Torgerson P, Martinez-Silveira MS, et al. Global morbidity and mortality of leptospirosis: a systematic review. PLoS Neglected Tropical Diseases 2015; 9(9): 1-19.
De Smith MJ, Goodchild MF, Longley P. (2015). Geospatial analysis: A comprehensive guide to principles, techniques and software tools (5 ed.): Leicester, UK: Troubador Ltd.
Dechet AM, Parsons M, Rambaran M, Mohamed-Rambaran P, Florendo-Cumbermack A, Persaud S, et al. Leptospirosis outbreak following severe flooding: A Rapid Assessment and Mass Prophylaxis Campaign; Guyana, January-February 2005. PLoS ONE 2012; 7(7): 1-6.
Delignette-Muller M, Dutang C. An R package for fitting distributions. 2015; 64(4): 1-34.
Della Rossa P, Tantrakarnapa K, Sutdan D, Kasetsinsombat K, Cosson J-F, Supputamongkol Y, et al. Environmental factors and public health policy associated with human and rodent infection by leptospirosis: a land cover-based study in Nan Province, Thailand. Epidemiology & Infection 2016; 144(7): 1550-62.
Dennis S, Fisher D. Climate change and infectious diseases: The next 50 years. Annals of the Academy of Medicine, Singapore 2018; 47(10): 401-4.
Department of Disease Control MoPH. (2016). District health system disease control handbook. Mahasarakham, Thailand [In Thai]: Mahasarakham Provincial Public Health Office.
Department of Disease Control MoPH, Office of the Basic Education Commission MoE. (2003). Strategy of supervision and school development for leptospirosis prevention and controlling Bangkok, Thailand: The War Veterans Organization of Thailand.
Department of Health Service Support MoPH. (2011). Modern village health volunteers handbook. Thailand: The Community of Agriculture and Cooperatives of Thailand.
Department of Medical Service MoPH. (2007). Clinical practice guidelines for leptospirosis 2007. Thailand.

Department of Mineral Resources and Minister of Natural Resources and Environment. (2009). Zone classification for mineral and natural management of Mahasarakham province. Bangkok,Thailalnd: Janwanit security printing

Dhewantara PW, Hu W, Zhang W, Yin W-W, Ding F, Mamun AA, et al. Climate variability, satellite-derived physical environmental data and human leptospirosis: A retrospective ecological study in China. Environmental Research 2019; 176: 108523.

Edwards G, Domm B. Human leptospirosis. Medicine 1960; 39: 117-55.

Evans J. (2015). spatialEco. R package version 2.0-0.

Friman G, WesslÉN L, Friman G. Infections and exercise in high-performance athletes. Immunology & Cell Biology 2000; 78(5): 510-22.

Gibbs BB, Hergenroeder AL, Katzmarzyk PT, Lee I-M, Jakicic JM. Definition, measurement, and health risks associated with sedentary behavior. Medicine and science in sports and exercise 2015; 47(6): 1295.

Glanz K, Rimer BK, Viswanath K. (2008). Health behavior and health education: theory, research, and practice: John Wiley & Sons.

Goarant C, Picardeau M, Morand S, Mcintyre KM. Leptospirosis under the bibliometrics radar: evidence for a vicious circle of neglect. Journal of Global Health 2019; 9(1).

Gochenour WS, Smadel JE, Jackson EB, Evans LB, Yager RH. Leptospiral etiology of Fort Bragg fever. Public Health Reports 1952; 67(8): 811-3.

Gouhier TC, Grinsted A, Simko V. (2018). R package biwavelet: Conduct univariate and bivariate wavelet analyses (version 0.20.17). https://github.com/tgouhier/biwavelet

Gracie R, Barcellos C, Magalhães M, Souza-Santos R, Barrocas PRG. Geographical scale effects on the analysis of leptospirosis determinants. International journal of environmental research and public health 2014; 11(10): 10366-83.

Guerra MA. Leptospirosis: Public health perspectives. Biologicals: journal of the International Association of Biological Standardization 2013; 41(5): 295-7.

Guglielmini J, Bourhy P, Schiettekatte O, Zinini F, Brisse S, Picardeau M. Genus-wide Leptospira core genome multilocus sequence typing for strain taxonomy and global surveillance. PLOS Neglected Tropical Diseases 2019; 13(4): e0007374.

Haake DA, Dundoo M, Cader R, Kubak BM, Hartskeerl RA, Sejvar JJ, et al. Leptospirosis, water sports, and chemoprophylaxis. Clinical Infectious Diseases 2002; 34(9): 40.

Hagan JE, Moraga P, Costa F, Capian N, Ribeiro GS, Wunder EA, Jr., et al. Spatiotemporal determinants of urban leptospirosis transmission: Four-year prospective cohort study of slum residents in Brazil. PLOS Neglected Tropical Diseases 2016; 10(1): e0004275.

Hastie TJ, Tibshirani RJ. (1990). Generalized Additive Models: New-York: Chapman and Hall - CRC.

Hinjoy S. Epidemiology of leptospirosis from Thai National Disease Surveillance System 2003–2012. Outbreak Surveill. Investig. Rep 2014; 7: 1-5.

Inada R, Ido Y, Hoki R, Kaneko R, Ito H. The etiology, mode of infection, and specific therapy of Weil's disease (spirochaetosis icterohaemorrhagica). The Journal of experimental medicine 1916; 23(3): 377-402.

Isaaks EH, Srivastava RM. (1989). An introduction to applied geostatistics: Oxford: Oxford University Press.
Ittyachen AM, Krishnapillai TV, Nair MC, Rajan AR. Retrospective study of severe cases of leptospirosis admitted in the intensive care unit. Journal of Postgraduate Medicine 2007; 53(4): 232-5.
John TJ. The prevention and control of human leptospirosis. Journal of Postgraduate Medicine 2005; 51(3): 205-9.
Kamath R, Swain S, Pattanshetty S, Nair NS. Studying risk factors associated with human leptospirosis. Journal of Global Infectious Diseases 2014; 6(1): 3-9.
Kamsopa T. (2014). A model of leptospirosis disease prevention and control for risk people in Sisaket Province. Rajabhat Masasarakham University Regional Development Stategies.
Kaufman ND, Chasombat S, Tanomsingh S, Rajataramya B, Potempa K. Public health in Thailand: Emerging focus on non communicable diseases. The International journal of health planning and management 2011; 26(3).
Keatikun B, Keatiwut A, Aungsupakhon S. (1974). Zoonoses: Bateris , Parasit, Virus and Micotoxin. Bangkok, Thailand: Mahidol University.
Kendall MG, Stuart A. The advanced theory of statistics. Griffin 1983; 3: 410-4.
Khomtang W. (2001). Risk factors of health environment and behavior associated with immunological level of leptospirosis. Khonkean University, Khonkean.
Kloos H, Berhane Y. Zoonotic diseases of public health importance. Epidemiology and Ecology of Health and Diseases in Ethiopia. 1st edition. Edited by: Berhane Y, Hailemariam D, Kloos H. Addis Ababa: Shama books 2006: 692-700.
Kobayashi Y. Clinical observation and treatment of leptospirosis. Journal of Infection and Chemotherapy 2001a; 7(2): 59-68.
Kobayashi Y. Discovery of the causative organism of Weil's disease: historical view. Journal of Infection and Chemotherapy 2001b; 7(1): 10-5.
Kumnuan Ungchusak TY, Wanchai Ardkean, , Nipapan Saritapirak UN, Darin Areechokchai,, Wanna Hanchaoworakul SI, Preecha Prempree,, Saruvudh Suwannathapa. (2011). Chapter 9: Kingdom of Thailand Implementation of Thailand's SRRT (Surveillance and Rapid Response Team) for Outbreak Containment. Retrieved 21 Jan, 2017, http://aseanplus3fetn.net/tree_cd_pdf/kingdomofthailand.pdf
Lau CL, Clements ACA, Skelly C, Dobson AJ, Smythe LD, Weinstein P. Leptospirosis in American Samoa – Estimating and mapping risk using environmental data. PLOS Neglected Tropical Diseases 2012; 6(5): e1669.
Lau CL, Smythe L, Weinstein P. Leptospirosis: An emerging disease in travellers. Travel Medicine and Infectious Disease 2010; 8(1): 33-9.
Lau CL, Smythe LD, Craig SB, Weinstein P. Climate change, flooding, urbanisation and leptospirosis: fuelling the fire? Transactions of the Royal Society of Tropical Medicine and Hygiene 2010; 104(10): 631-8.
Lau CL, Watson CH, Lowry JH, David MC, Craig SB, Wynwood SJ, et al. Human leptospirosis infection in Fiji: An eco-epidemiological approach to identifying risk factors and environmental drivers for transmission. PLoS Neglected Tropical Diseases 2016; 10(1): 1-25.

Law Center Department of Disease Control MoPH. (2015). Thai national Communicable Diseases 2015. Bangkok, Thailand: Printing of Chulalongkorn University.

Ledien J, Sorn S, Hem S, Huy R, Buchy P, Tarantola A, et al. Assessing the performance of remotely-sensed flooding indicators and their potential contribution to early warning for leptospirosis in Cambodia. PLoS ONE 2017; 12(7): e0181044.

Levett PN. Leptospirosis. American Society for Microbiology 2001; 14(2): 296-326.

Mahasarakham Provincial Labor Office. (2017). Mahasarakham statistic 1st Quarter 2017. Mahasarakham.

Mahasarakham Provincial Public Health Office. (2000). Folk wisdom on methods of catching and cooking rats. Mahasarakham, Thailand: Mahasarakham Provincial Public Health Office.

Mahasarakham Provincial Public Health Office. (2016). Population information. Mahasarakham, Thailand: Mahasarakham Provincial Public Health Office.

Ministry of Public Health. (2012). 11th National Health Development Plan under the National Economic and Social Development Plan B.E. 2555-2559(A.D.2012-2016). Nonthaburi: Bureau of Policy and Strategy Office of the Permanent Secretary Ministry of Public Health.

Mohan ARM, Chadee DD. Knowledge, attitudes and practices of Trinidadian households regarding leptospirosis and related matters. International Health 2011; 3(2): 131-7.

Morand S, Chaisiri K, Karnchanabanthoeng A, Hinjoy S. (2018). Environment and health in Thailand: investigating epidemiological trends of three infectious diseases to infer scenarios. In Y Trisurat, RP Shrestha & P Havmoller (Eds.), Environmental Management (pp. 161-79). New York: Nova Science Publishers.

Mwachui MA, Crump L, Hartskeerl R, Zinsstag J, Hattendorf J. Environmental and behavioural determinants of leptospirosis transmission: a systematic review. PLoS Neglected Tropical Diseases 2015; 9(9): 1-15.

New Zealand government. (2019). Prevention and control of leptospirosis. New Zealand.

Nikratok S. (2012). Community participation in prevention and control for leptospirosis: Chumphuang District, Nakhonratchasima Province. Khonkean University, Khonkean.

Nozmi N, Samsudin S, Sukeri S, Shafei M, Wan Mohd W, Idris Z, et al. Low levels of knowledge, attitudes and preventive practices on leptospirosis among a rural community in Hulu Langat District, Selangor, Malaysia. International journal of environmental research and public health 2018; 15(4): 693.

O'Toole SM, Pathak N, Toms GC, Gelding SV, Sivaprakasam V. Fever, jaundice and acute renal failure. Clinical Medicine 2015; 15(1): 58-60.

Ottar N, Bjornstad. (2019). ncf: Spatial Covariance Functions. R package version 1.2-8. https://CRAN.R-project.org/package=ncf

Pappas G, Papadimitriou P, Siozopoulou V, Christou L, Akritidis N. The globalization of leptospirosis: worldwide incidence trends. International Journal of Infectious Diseases 2008; 12(4): 351-7.

Parker J, Walker M. Survival of a pathogenic Leptospira serovar in response to combined in vitro pH and temperature stresses. Veterinary Microbiology 2011; 152(1–2): 146-50.

Picardeau M. Diagnosis and epidemiology of leptospirosis. Médecine et Maladies Infectieuses 2013; 43(1): 1-9.

Plank R, Dean D. Overview of the epidemiology, microbiology, and pathogenesis of Leptospira spp. in humans. Microbes and Infection 2000; 2(10): 1265-76.

Pubmed. (2019). Search results. Retrieved 3, 2019, https://www.ncbi.nlm.nih.gov/pubmed/?term=leptospirosis

R Core Team. (2018). R: A Language and environment for statistical computing. R foundation for statistical computing, Vienna. Retrieved 12 January, 2019, https://www.R-project.org

Ratsameeyoongthong P. (2001). Epidemiologic situation and factors related to leptospirosis in Saraburi Province. Chulalonkhon University, Bangkok, Thailand.

Regional Health 5. (2000). Prevention, controlling disease and treatment leptospirosis patient.

Reis RB, Ribeiro GS, Felzemburgh RDM, Santana FS, Mohr S, Melendez AXTO, et al. Impact of environment and social gradient on Leptospira infection in Urban Slums. PLOS Neglected Tropical Diseases 2008; 2(4): e228.

Ricardo T, Bergero LC, Bulgarella EP, Previtali MA. Knowledge, attitudes and practices (KAP) regarding leptospirosis among residents of riverside settlements of Santa Fe, Argentina. PLoS Neglected Tropical Diseases 2018; 12(5): e0006470.

Rivera B, Bower WA, Guerra M, Blau D, Tomashek KM, Swaminathan M, et al. Investigation of leptospirosis underreporting -- Puerto Rico, 2010. MMWR: Morbidity & Mortality Weekly Report 2012; 61(22): 421-.

Rodríguez-Vidigal FF, Vera-Tomé A, Nogales-Muñoz N, Muñoz-García-Borruel M, Muñoz-Sanz A. Leptospirosis in South-western Spain. Revista Clínica Española (English Edition) 2014; 214(5): 247-52.

Roesch A, Schmidbauer H. (2015). WaveletComp. http://www.hs-stat.com/projects/WaveletComp/WaveletComp_guided_tour.pdf

Rood EJ, Goris MG, Pijnacker R, Bakker MI, Hartskeerl RA. Environmental risk of leptospirosis infections in the Netherlands: Spatial modeling of environmental risk factors of leptospirosis in the Netherlands. PLoS ONE 2017; 12(10): e0186987.

Sakundarno M, Bertolatti D, Maycock B, Spickett J, Dhaliwal S. Risk Factors for leptospirosis infection in humans and implications for public health intervention in Indonesia and the Asia-Pacific Region. Asia Pacific Journal of Public Health 2013; 26(1): 15-32.

Samarakoon Y, Gunawardena N. Knowledge and self-reported practices regarding leptospirosis among adolescent school children in a highly endemic rural area in Sri Lanka. Rural & Remote Health 2013; 13(4).

Sergio ADM, Figureueroa EG, María Saadia VG, Elizabeth SH, Beatriz RS, Altuzar Aguilar Víctor M, et al. Leptospirosis prevalence in patients with Initial diagnosis of dengue. Journal of Tropical Medicine (16879686) 2012: 1-5.

Sethi S, Sharma N, Kakkar N, Taneja J, Chatterjee SS, Banga SS, et al. Increasing trends of leptospirosis in Northern India: A Clinico-Epidemiological study. PLoS Neglected Tropical Diseases 2010; 4(1): 1-7.

Shah I. Leptospirosis. Pediatric Infectious Disease 2012; 4(1): 4-8.

Sharp TM, Rivera García B, Pérez-Padilla J, Galloway RL, Guerra M, Ryff KR, et al. Early Indicators of fatal leptospirosis during the 2010 epidemic in Puerto Rico. PLoS Neglected Tropical Diseases 2016; 10(2): 1-15.

Shin-ichi Y. Knowledge, attitudes and practices of the community residents concerning the prevention and control of leptospirosis in the National Capital Region (NCR), Philippines. Acta Medica Philippina 2016; 50(3): 129-35.

Simpson GL. (2019). gratia: Graceful 'ggplot'-Based Graphics and other functions for GAMs Fitted Using 'mgcv'. R package version 0.2-8. https://gavinsimpson.github.io/gratia

Sing T, Sander O, Beerenwinkel N, Lengauer T. ROCR: Visualizing classifier performance in R. Bioinformatics 2005; 21(20): 7881.

Skelly AC, Dettori JR, Brodt ED. Assessing bias: the importance of considering confounding. Evidence-based spine-care journal 2012; 3(1): 9-12.

Sommanustweechai A, Iamsirithaworn S, Patcharanarumol W, Kalpravidh W, Tangcharoensathien V. Adoption of One Health in Thailand's National strategic plan for emerging infectious diseases. Journal of Public Health Policy 2016: 1-16.

Sommanustweechai A, Patcharanarumol W, Iamsirithaworn S, Kalpravidh W, Ratanakorn P, Tangcharoensathien V. Evolution of collaborations under the "One Health" concept in Thailand. Journal of Health Systems Research 2014; 8(3): 292-305.

South East Asia One Health University Network. (2018). What we do 2018. Retrieved 16 February, 2018, Available from: http://seaohun.org/index.php?option=com_content&view=article&id=155&Itemid=667.

Sudjanham W. (2005). Factors related to leptospirosis in Khonkaen Province. Khonkaen University, Khonkaen.

Sugunan AP, Vijayachari P, Sharma S, Roy S, Manickam P, Natarajaseenivasan K, et al. Risk factors associated with leptospirosis during an outbreak in Middle Andaman, India. Indian Journal of Medical Research 2009; 130(1): 67-73.

Sukhothaithummatirat. (1994). Teaching Series: infectious disease and noninfectious disease. Bangkok, Thailand: SukhoThai Thummatirat

Sulistyawati S, Nirmalawati T, Mardenta RN. Spatial analysis of leptospirosis disease in Bantul Regency Yogyakarta. Jurnal Kesehatan Masyarakat 2016; 12(1): 111-9.

Suwancharoen D, Limlertvatee S, Chetiyawan P, Tongpan P, Sangkaew N, Sawaddee Y, et al. A nationwide survey of pathogenic leptospires in urine of cattle and buffaloes by Loop-mediated isothermal amplification (LAMP) method in Thailand, 2011–2013. Journal of Veterinary Medical Science 2016; 78(9): 1495-500.

Suwanpakdee S, Kaewkungwal J, White L, Asensio N, Ratanakorn P, Singhasivanon P, et al. Spatio-temporal patterns of leptospirosis in Thailand: is flooding a risk factor? Epidemiology & Infection 2015; 143(10): 2106-15.

Tangkanakul W, Smits H, Jatanasen S, Ashford D. Leptospirosis: an emerging health problem in Thailand. Southeast Asian Journal of Tropical Medicine and Public Health 2005; 36(2): 281.

Tassinari WS, Pellegrini DCP, Sá CBP, Reis RB, Ko AI, Carvalho MS. Detection and modeling of case clusters for urban leptospirosis. Tropical Medicine & International Health 2008; 13(4): 503-12.

Tennekes M. tmap: Thematic Maps in R. Journal of StatisticalSoftware 2018; 84(6): 1-39.

Terpstra WJ. Historical perspectives in leptospirosis. Indian Journal of Medical Microbiology 2006; 24(4): 316-20.

Thailand. (1914). Act of Local administration in 1914(Revised to current). Retrieved 13 July 2018, http://pab.dopa.go.th/main/law/pab2457_12.pdf

Thailand. (1999). Act of District Council and Subdistrict Administrative Organization in 1994 (And revised to version 3, 1999). Retrieved 14 July, 2018, http://www.local.moi.go.th/law28.htm

Thailand. (2001). Government gazette of regularity of village health volunteers in 2001. Retrieved 14 July, 2018, http://www.klongchanak.go.th/2011/upfile/law/rulehealt54.pdf

Thailand. (2016). Memorandum of Understanding On the Implementation of One Health Initiative for National Health Security Retrieved 21 February, 2018

Thaipadungpanit, Janjira, Wuthiekanun V, Chantratita N, Yimsamran S, Amornchai P, et al. Leptospira species in floodwater during the 2011 floods in the Bangkok Metropolitan Region, Thailand. The American journal of tropical medicine and hygiene 2013; 89(4): 794-6.

The World Health Organization. (2017). One Health. Retrieved 21 February, 2018, http://www.who.int/features/qa/one-health/en/

Topic MB, Habus J, Milas Z, Tosev EC, Stritof Z, Turk N. Human leptospirosis in Croatia: current status of epidemiology and clinical characteristics. Transactions of the Royal Society of Tropical Medicine and Hygiene 2010; 104(3): 202-6.

Tullu MS, Karande S. Leptospirosis in children: a review for family physicians. Indian Journal of Medical Sciences 2009; 63(8): 368-78.

U.S. Department of Health and Human Services, National Institutes of Health, National Cancer Institute. (2005). Theory at a glance: A guide for health promotion practice. Retrieved 20 July, 2018, https://cancercontrol.cancer.gov/brp/research/theories_project/theory.pdf

Vanasco NB, Schmeling MF, Lottersberger J, Costa F, Ko AI, Tarabla HD. Clinical characteristics and risk factors of human leptospirosis in Argentina (1999–2005). Acta Tropica 2008; 107(3): 255-8.

Victoriano AFB, Smythe LD, Gloriani-Barzaga N, Cavinta LL, Kasai T, Limpakarnjanarat K, et al. Leptospirosis in the Asia Pacific region. BMC Infectious Diseases 2009; 9(1): 147.

Vincent AT, Schiettekatte O, Goarant C, Neela VK, Bernet E, Thibeaux R, et al. Revisiting the taxonomy and evolution of pathogenicity of the genus Leptospira through the prism of genomics. PLOS Neglected Tropical Diseases 2019; 13(5): e0007270.

Viroj J, Lajaunie C, Morand S. Evolution of Public Health prevention of leptospirosis in Mahasarakham Province (Thailand) in a One Health perspective. Un published.

Weinberger D, Baroux N, Grangeon J-P, Ko AI, Goarant C. El Niño southern oscillation and leptospirosis outbreaks in New Caledonia. PLOS Neglected Tropical Diseases 2014; 8(4): e2798.

Wibulpolprasert S, Sirilak S, Ekachampaka P, Wattanamano N, Taverat R. Thailand health profile report 2005–2007. Bureau of Policy and Strategy, Ministry of Public Health, Thailand 2007.

Wiwanitkit V. A note from a survey of some knowledge aspects of leptospirosis among a sample of rural villagers in the highly endemic area, Thailand. Rural remote health 2006; 6(1): 526.

Wongbutdee J, Saengnill W, Jittimanee J, Daendee S. Perceptions and risky behaviors associated with leptospirosis in an endemic area in a village of Ubon Ratchathani Province, Thailand. African Health Sciences 2016; 16(1): 170-6.

Wood, Simon N. (2017). Generalized Additive Models: An Introduction with R (2nd edition). New-York: Chapman and Hall/CRC.

World Health Organization. Human leptospirosis: guidance for diagnosis, surveillance and control. 2003.

World Health Organization. (2007). Leptospirosis laboratory manual. India: World Health Organization,.

World Health Organization. (2008). Advocacy, communication and social mobilization for TB control: a guide to developing knowledge, attitude and practice surveys. Switzerland: WHO Library Cataloguing-in-Publication Data.

World Health Organization. Informal Expert consultation on Surveillance. Diagnosis and Risk Reduction of Leptospirosis Chennai 2009: 17-8.

World Health Organization, Food and Agriculture Organization of the United Nations, World Organisation for Animal Health. (2019). Taking a Multisectoral, One Health Approach: A Tripartite Guide to Addressing Zoonotic Diseases in Countries Available from www.who.int

Wu X, Lu Y, Zhou S, Chen L, Xu B. Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. Environment International 2016; 86: 14-23.

Zinsstag J, Tanner M. (2015). Summary and outlook for practical use of One Health. In: Zinsstag J, Schelling E, Waltner-Toews D, Whittaker M, Tanner M, editors. One Health: the theory and practice of integrated health approaches: CABI.

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Résumé

La leptospirose est une maladie tropicale négligée qui touche surtout les habitants des régions rurales en Thaïlande. A l'échelle de la province de Mahasarakham en Thaïlande, les objectifs de cette étude sont d'identifier les facteurs expliquant l'épidémiologie de la leptospirose, de décrire les politiques qui ont été mises en place pour sa prévention et son contrôle, et d'analyser les représentations, les attitudes et les pratiques des patients, des habitants, des volontaires en santé et des personnels de santé publique au regard de la maladie et de sa prévention.

L'étude des politiques mises en place montre que la Thaïlande a progressivement développé un ensemble de politiques de prévention à l'échelle nationale dont elle a transféré la mise en oeuvre à une échelle administrative locale. Malgré cela, le contrôle et la prévention de la leptospirose pourraient être améliorés en stimulant la collaborations entre les services de santé publique, les services vétérinaires, et les services agriculturaux avec une implication forte des communautés locales dans une approche de type "One Health".

L'analyse spatiotemporelle de la distribution des cas de leptospirose humaine montre que les facteurs associés avec les nouvelles infections sont multiples et complexes, incluant la densité de population humaine, la densité de bétail, les précipitations atmosphériques, l'étendue des aires inondables et d'autres paramètres de la géographie physique comme la pente moyenne. Le rôle du bétail dans la transmission à l'homme est mis en évidence et discutée. Cibler des zones géographiques à risque (avec une densité de bétail élevée et d'importantes surfaces inondables) peut permettre de limiter les risques, et doit être complétée en améliorant la communication avec les publics les plus exposés (c.a.d. les fermiers).

L'analyse intersectorielle pour estimer les connaissances, attitudes et pratiques montre que les patients, leurs voisins, les volontaires en santé, et les chefs de villages et de sous-districts n'ont pas une compréhension suffisante de la maladie et de ces modes de transmission pour permettre une bonne prévention et un bon contrôle. Pour être mieux informé, ces publics doivent pouvoir avoir accès aux dernières informations scientifiques parfois complexes.

Finalement, l'ensemble de ces résultats a permis d'établir un ensemble de recommandations pour développer la coopération entre différents services et popuations locales en vue d'améliorer la prévention et la prévention de la leptospirose dans la province de Mahasarakham.

Mots clés : Leptospirose, épidémiologie, Thaïlande, One Health, écologie de la santé, statistiques spatio-temporelles, représentation

Abstract

Leptospirosis is a neglected tropical disease that affects mostly rural people in Thailand. This study aims to identify the factors explaining leptospirosis epidemiology, to describe the health policy implemented for leptospirosis prevention and control and its implementation in the rural province of Mahasarakham (Thailand), and to analyse the representations, attitudes and practices of patients, people, health volunteers and health officers toward the disease and its prevention.

The analysis of health policies showed that Thailand has progressively developed a national prevention and control policy framework and transferred its implementation to local administrative levels. However, leptospirosis prevention and control still need enhanced collaboration between public health, livestock, and agriculture departments with an important local community involvement under the One Health approach.

The analysis of the spatiotemporal distribution of human leptospirosis cases showed that the factors associated with leptospirosis infection are complex and multifactorial, including human population density, livestock density, rainfall, flood cover and physical geography, i.e. average slope. The results stressed the importance of livestock that may contribute to leptospirosis transmission to humans. Targeting areas prone at risk, i.e. with high livestock or in flooded areas, should be complemented by improving communication to people at risk, i.e. farmers.

The cross sectional study conducted to assess knowledge, attitudes, and practices showed that patients, neighbors, village health volunteers and community leaders did not have a clear comprehension of the disease and its transmission to really improve the prevention of infections. People need to have access to a complex and up-to-date scientific knowledge in order to improve their awareness about leptospirosis.

Finally, taking results of above issues allowed "Guidelines for developing cooperation between departments for prevention and control leptospirosis of Mahasarakham Province, Thailand" to be produced.

Keywords: Leptospirosis, epidemiology, Thailand, One Health, health ecology, spatiotemporal statistics, representation