UNIVERSITÉ DU QUÉBEC À MONTRÉAL

ÉVALUATION DE DIFFÉRENTES TECHNIQUES D'EFFAROUCHEMENT DES GOÉLANDS DANS LES LIEUX D'ENFOUISSEMENT TECHNIQUE

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AVANT-PROPOS

Ce mémoire est constitué de deux chapitres, soit deux articles scientifiques rédigés en anglais. Le premier sera soumis pour publication à *Applied Animal Behaviour Science* et le second à *Environmental Management*. Ces deux chapitres sont encadrés d'une introduction et d'une conclusion générales, rédigées en français. J'ai effectué la collecte des données aux sites d'enfouissement en 2010, ainsi que l'ensemble des analyses statistiques et de la rédaction du mémoire. Jean-François Giroux, initiateur du projet sur l'*Étude du comportement des Goélands à bec cerclé en milieu urbain et périurbain dans une perspective de gestion intégrée*, m'a appuyée dans l'élaboration du projet et dans les discussions avec les collaborateurs industriels. Il a grandement participé à la construction du mémoire et à la rédaction des articles par ses corrections et ses suggestions, et m'a particulièrement aidé à améliorer les textes en anglais. En tant que directeur de recherche, il est aussi co-auteur des deux articles composant ce mémoire. Pierre Molina, de Service Environnementaux Faucon, est aussi co-auteur des deux articles, pour souligner son partenariat dans l'élaboration du projet et son aide logistique, ainsi que pour l'utilisation que nous avons faite des données prises par Services Environnementaux Faucon depuis 1995 au site d'enfouissement de Terrebonne. Martin Patenaude-Monette, un de mes collègues de laboratoire, est co-auteur du deuxième article pour avoir trié et fourni les données GPS des goélands s'étant rendus dans les sites étudiés. Enfin, Yves Leblanc est aussi co-auteur du deuxième article puisque nous avons utilisé les données prises depuis 2004 dans le cadre du suivi qu'il a dirigé à Tecsult sur l'utilisation de l'abattage au site d'enfouissement de Ste-Sophie. Les co-auteurs ont de plus apporté plusieurs commentaires constructifs quant aux articles. Je remercie aussi François Racine, Martin Patenaude-Monette et Tanya Drapeau pour leurs commentaires sur le premier article.

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RÉSUMÉ

La nécessité de gérer certaines espèces surabondantes entrant en conflit avec l'humain devient de plus en plus fréquente avec l'étalement urbain. La présence de nombreux goélands attirés dans les lieux d'enfouissement techniques (LET) est un problème répandu car ces oiseaux peuvent être une nuisance importante pour les employés du site et les résidents de la région. Les gestionnaires de LET sont donc souvent incités à mettre en place des programmes d'effarouchement afin de dissuader les goélands de se nourrir dans les déchets. C'est le cas de deux LET de la région de Montréal situés à proximité de la plus grande colonie de Goélands à bec cerclé (*Larus delawarensis*) au Québec. Le choix des méthodes d'effarouchement doit considérer à la fois leur efficacité, l'aspect éthique et social et les coûts financiers. Notre premier objectif était d'évaluer l'efficacité du tir de billes de caoutchouc, une méthode non létale n'ayant jamais été testée pour l'effarouchement des oiseaux, en combinaison avec l'utilisation de pyrotechnie. Nous avons comparé cette technique à l'abattage sélectif, une méthode éthiquement discutable. Notre deuxième objectif était de comparer l'efficacité à court et long terme de l'abattage sélectif à un programme intégré de fauconnerie, méthode *a priori* plus acceptable éthiquement mais impliquant des coûts importants. Des décomptes quotidiens en 2010 et l'utilisation de données historiques ont permis de quantifier l'efficacité des différentes méthodes. Nous avons aussi utilisé les données d'une étude concomitante suivant les mouvements des goélands depuis la colonie vers leurs sites d'alimentation. Le tir de billes de caoutchouc s'est avéré inefficace pour dissuader les goélands de fréquenter les LET par rapport aux périodes sans effarouchement. L'abattage permettait de diminuer l'utilisation du site de 38% par rapport au tir de billes de caoutchouc. Cette méthode d'effarouchement, si utilisée comme durant notre expérience, ne pourra donc pas servir d'alternative à l'abattage. Le programme de fauconnerie s'est avéré plus efficace que l'abattage sélectif à court et long terme. Ceci résultait de la quasi impossibilité pour les goélands de se nourrir dans le LET, et ce du lever au coucher du soleil, sept jours par semaine. La mortalité des goélands associée à la fauconnerie était négligeable et 56 fois moindre qu'avec l'abattage. La fauconnerie demeure donc la méthode éthique la plus efficace grâce à l'utilisation de prédateurs naturels.

Mots-clés : Goéland à bec cerclé, effarouchement, lieux d'enfouissement technique, gestion des espèces nuisibles

INTRODUCTION

L'aménagement de la faune en milieu urbain

Le développement des villes et de leurs banlieues est un phénomène mondial associé à tous les pays développés et à la plupart des pays en voie de développement. Son impact négatif sur la biodiversité est bien documenté, et dû à la fragmentation des habitats naturels et à l'exclusion de certaines espèces sensibles (DeStefano et DeGraaf, 2003). Cependant, la perte de biodiversité n'est pas toujours synonyme de réduction des effectifs des populations sauvages. En effet, alors que certaines espèces négativement affectées par l'urbanisation et la perte de leur habitat déclinent et disparaissent, quelques unes s'adaptent et tirent profit des perturbations anthropiques (Adams, Lindsey et Ash, 2006). L'augmentation de ces populations en milieu urbain entraîne parfois des conflits avec d'autres espèces animales ou avec l'humain (Adams, Lindsey et Ash, 2006; Blokpoel et Tessier, 1986). C'est le cas, par exemple, du Cerf de Virginie (*Odocoileus virginianus*), du Castor du Canada (*Castor canadensis*), du Raton laveur commun (*Procyon lotor*) et de la Bernache du Canada (*Branta canadensis*) que l'absence de prédateurs, de chasse et de trappage, ainsi que l'abondance de nourriture font prospérer dans les milieux urbains et périurbains (Ankney, 1996; DeStefano et DeGraaf, 2003).

Lorsqu'une espèce est ainsi jugée nuisible suite à son adaptation aux milieux anthropiques, plusieurs solutions sont disponibles pour les gestionnaires de la faune. Certaines méthodes permettent d'influencer directement la dynamique des populations, comme la réduction de la natalité (arrosage des œufs par exemple) ou l'augmentation de la mortalité, par exemple par l'abattage d'individus. D'autres, comme la manipulation de l'habitat ou l'association à des stimuli provoquant la peur, peuvent rendre un site moins accessible, moins attractif ou moins vulnérable aux espèces nuisibles. Les opportunités d'alimentation ou d'établissement dans les lieux indésirables peuvent ainsi être réduites (Conover, 2001). Les goélands sont de ces espèces généralement jugées nuisibles. Plusieurs études se sont penchées sur ses nuisances et les solutions possibles tant en Australie (Temby, 2000), qu'en Europe (Bosch *et al.*, 2000; Cook *et al.*, 2008; Soldatini *et al.*, 2008) et en Amérique du Nord (Belant, 1997; Dolbeer, 1998). Nous nous intéressons ici au cas du Goéland à bec cerclé (*Larus delawarensis*), une des espèces de goélands des plus abondantes en Amérique du Nord (Howell et Dunn, 2007).

Le Goéland à bec cerclé au Québec

Le Goéland à bec cerclé se retrouve presque exclusivement en Amérique du Nord. Sur la côte est, le patron de migration de ces oiseaux les amène à passer leur saison de reproduction au sud du Québec et en Ontario d'avril à fin août. Ils se regroupent alors en colonies pouvant comprendre plusieurs milliers de couples reproducteurs. À la fin de la saison de reproduction, les adultes et les juvéniles se dispersent puis passent l'hiver sur la côte est des États-Unis entre la nouvelle Angleterre et la Floride (Blokpoel et Tessier, 1986; Howell et Dunn, 2007; Ryder, 1993).

Bien qu'ayant subi un important déclin entre les années 1850 et 1920 à cause de la surexploitation de ses plumes et de ses œufs, le Goéland à bec cerclé est aujourd'hui l'espèce de goéland la plus répandue en Amérique du Nord (Blokpoel et Tessier, 1986; Mousseau, 1984; Ryder, 1993). La population y est estimée à 1,7 millions d'oiseaux, dont 240 000 au Québec (Chapdelaine et Rail, 2004). En effet, l'espèce étant protégée par le traité sur les oiseaux migrateurs depuis 1916, une augmentation très importante de ses effectifs a été observée principalement à partir de 1945. Dans la grande région de Montréal, l'espèce a commencé à s'établir en 1953, avec au moins 150 couples reproducteurs (Mousseau, 1984). Aujourd'hui, leur effectif s'élève à environ 68 000 couples, dont 48 000 couples reproducteurs sur l'île Deslauriers à Varennes, issue des travaux de dragage de la voie maritime. Il s'agit de la plus importante colonie de goélands au Québec. Globalement, dans le sud du Québec le nombre de Goélands à bec cerclé s'est stabilisé depuis les années 1990 et commence à décroître (P. Brousseau, SCF, données non publiées).

Nuisances et utilisation des lieux d'enfouissement techniques par les goélands

Le Goéland à bec cerclé est une espèce opportuniste et très adaptable (Blokpoel et Spaans, 1991). Il tire profit des modifications anthropiques de son habitat qui lui offrent des sources de nourriture et des refuges sûrs. La création de sites de nidification artificiels, comme les îles ou les toits plats, ainsi que les sources d'alimentation constantes et très accessibles ont ainsi favorisé la croissance des populations à proximité des centres urbains (Blokpoel et Scharf, 1991; Dwyer, Belant et Dolbeer, 1996).

La présence de lieux d'enfouissement technique (LET, ou plus communément dépotoirs) à proximité des grands centres urbains est particulièrement profitable pour les goélands car ces lieux représentent une source de nourriture stable, quasiment illimitée, et par conséquent, très prévisible (Baxter et Robinson, 2007; Blokpoel et Scharf, 1991). Plusieurs études ont montré que les déchets comestibles provenant des LET forment une part très importante du régime alimentaire des goélands nichant à proximité des centres urbains, facilitant ainsi leur reproduction (Patton, 1988; Pons, 1992). Dans la région de Montréal, les jeunes goélands sont nourris principalement de déchets comestibles mais l'origine exacte de ces déchets n'est pas connue (LET, poubelles de centres d'achat, aires de restauration, etc.). En 1993, les déchets composaient 37% du volume des régurgitations des jeunes de l'île de la Couvée, soit la plus grosse part de leur alimentation (Brousseau, Lefebvre et Giroux, 1996). L'enfouissement des déchets n'était que très peu règlementé jusqu'en 1985 environ, ce qui suggère que les LET ont joué un rôle dans l'augmentation exponentielle des effectifs de goélands observée dans cette région dans les années 80 (P. Brousseau, communication personnelle, Belant 1997).

La présence de centaines ou de milliers d'oiseaux venant se nourrir dans les LET peut gêner le travail des conducteurs de machinerie lourde chargés de compacter et de recouvrir les déchets en leur réduisant la visibilité et en encrassant les machines de déjections, causant alors un problème de santé et de sécurité. Les goélands s'alimentant en grand nombre peuvent aussi être une nuisance sonore importante pour les travailleurs. De plus, les allées et venues des goélands entre leur colonie et ces sites d'alimentation créent des corridors de déplacement indisposant les résidents logeant en dessous par la souillure de leurs déjections

(NOVE Environnement Inc., 2002). Ils indisposent aussi les résidents se trouvant à proximité des LET, car ils se reposent sur les terrains et les plans d'eau alentours après s'être alimentés (Moreau, 2012). La majorité des résidents craignent le goéland en tant que vecteur de maladies (Moreau, 2012). D'importants effectifs de goélands dans les milieux agricoles ou urbains peuvent potentiellement causer des problèmes de santé publique, la transmission de certaines maladies aux volailles ou aux humains demeurant un risque. Les importants regroupements de goélands dans les LET et leur dispersion dans la région avoisinante à partir de ces sites augmentent les risques de transmission (Blokpoel et Tessier, 1986; Broman *et al.*, 2002; Ellis *et al.*, 2004; Monaghan *et al.*, 1985; Nelson *et al.*, 2008). Un autre problème, particulièrement exacerbé par la proximité des LET, est la présence de groupes de goélands sur les installations aéroportuaires qui peuvent fournir des aires de repos ou de nidification attirantes pour les oiseaux (Blokpoel et Tessier, 1986; Sodhi, 2002). Les goélands peuvent causer de graves accidents à cause de leur tendance à former des groupes de dizaines ou centaines d'individus sur les aéroports et ce sont les responsables de la majorité des collisions rapportées avec les avions (Allan, 2006; Sodhi, 2002). Les gestionnaires de LET sont donc de plus en plus sollicités pour mettre en place des programmes d'effarouchement permettant de limiter la fréquentation de leurs sites par les goélands, tant pour réduire les désagréments à leurs employés et aux résidents de la région immédiate, que pour limiter le péril aviaire et éviter de favoriser la croissance des populations à proximité des centres urbains.

Dissuader les goélands de s'alimenter dans les lieux d'enfouissement techniques

Afin de dissuader les goélands de se rendre dans les LET à long terme, il est prioritaire d'aménager ces zones pour qu'elles soient moins attirantes. Ceci se fait en ensemençant les zones inutilisées avec des graminées pour limiter les aires de repos disponibles, en éliminant les plans d'eau utilisés par les goélands pour le toilettage, en réduisant la surface du front de déchet et en recouvrant les déchets régulièrement pour limiter la quantité de nourriture disponible (Belant, 1997). Les surfaces disponibles étant réduites, il est alors plus facile de mettre en pratique un programme d'effarouchement actif pour dissuader les goélands de se nourrir et de se poser sur le site (Services Environnementaux Faucon, 2007; Sodhi, 2002).

Le but de tout programme d'effarouchement est de dissuader les animaux nuisibles d'utiliser une ressource (aire de repos ou d'alimentation en général) en augmentant le risque de prédation ou en leur faisant croire que ce risque existe. L'augmentation du risque de prédation augmente les coûts associés à l'utilisation d'un site, qui devient moins attractif, ce qui permet éventuellement d'avoir un impact sur la décision des animaux qui délaissent alors le site, selon leur degré de motivation (ici les besoins alimentaires) (Krebs et Davies, 1993).

Les techniques d'effarouchement

Il existe de nombreuses méthodes d'effarouchement utilisées couramment pour dissuader les goélands de fréquenter les LET. Les méthodes non létales comprennent principalement les méthodes visuelles, les méthodes acoustiques et les patrouilles de prédateurs (fauconnerie de spectacle). Les méthodes létales comprennent l'utilisation de prédateurs chasseurs (fauconnerie de chasse) et l'abattage par armes à feu (Belant, 1997).

Les méthodes d'effarouchement non létales testées individuellement dans les études antérieures ont donné des résultats très variables. Les épouvantails, les silhouettes de prédateurs, les drapeaux (méthodes visuelles) sont inefficaces (Baxter et Robinson, 2007; Belant et Ickes, 1997), alors que certaines méthodes acoustiques (pyrotechnie, canons à gaz, générateurs de sons et émission de cris de détresse) peuvent avoir un effet initial marqué sur les goélands mais s'atténuant avec le temps (Baxter et Robinson, 2007; Bomford et O'Brien, 1990; Soldatini *et al.*, 2008). La pyrotechnie est la méthode la plus utilisée et la plus efficace des méthodes acoustiques. L'avantage de ces fusées est que la détonation se fait plus proche du groupe d'oiseaux visé. L'utilisation de prédateurs naturels a aussi un impact initial important sur les effectifs de goélands (Soldatini *et al.*, 2008). L'art de la fauconnerie est ainsi souvent utilisé dans les aéroports, et parfois dans les sites d'enfouissement. Cependant, lorsque les faucons ne sont pas dressés à attraper les goélands et ne font que voler au dessus du site, une diminution d'efficacité est notable en quelques jours seulement (Soldatini *et al.*, 2008). Cette perte d'efficacité progressive observée lorsque les méthodes non létales sont testées individuellement est due à la capacité d'habituation des goélands.

Le potentiel d'habituation des goélands

Chez les animaux, l'apprentissage est défini comme un processus d'interaction entre un individu et son environnement, menant à un changement de son comportement face à la même expérience dans le futur (Kirkpatrick et Hall, 2005). La forme d'apprentissage la plus communément observée est l'habituation, soit la diminution de la réaction de l'animal face à un stimulus répété (Kirkpatrick et Hall, 2005). Ce phénomène a été observé chez plusieurs espèces de goélands face aux techniques d'effarouchement qui ne s'avèrent pas effectivement dangereuses pour eux (Cook *et al.*, 2008; Soldatini *et al.*, 2008). Par conséquent, en plus de son effet initial dû au risque de prédation perçu par les oiseaux, un aspect fondamental pour l'efficacité d'une technique d'effarouchement à long terme est le potentiel d'habituation dont les oiseaux font preuve face à cette technique. Si le risque de prédation ne s'avère pas réel, l'efficacité d'effarouchement tend à diminuer (habituation). Si le risque de prédation est réel (méthodes létales), l'efficacité d'effarouchement tend à augmenter (Cook *et al.*, 2008). L'habituation peut-être mesurée par la variation du nombre d'oiseaux présents au cours d'une période d'effarouchement (Baxter et Robinson, 2007).

Plusieurs techniques d'effarouchement ont été comparées quant à leur efficacité et au potentiel d'habituation des oiseaux face à elles. Il s'avère que lorsqu'une seule technique est utilisée, aucune méthode non létale n'a d'impact réel sur les oiseaux, car ces derniers s'habituent de façon plus ou moins importante (Baxter et Robinson, 2007; Cook *et al.*, 2008; Soldatini *et al.*, 2008). Les méthodes non létales doivent donc être associées à des méthodes renforçant leur effet.

L'abattage et la fauconnerie sont des techniques impliquant un aspect létal pour les oiseaux nuisibles, ce qui leur confère une bonne efficacité et un plus faible potentiel d'habituation relativement aux autres méthodes (Baxter et Allan, 2008; Baxter et Robinson, 2007). Baxter et Allan (2008) recommandent que dans le cas de l'utilisation de tir au fusil, l'utilisation régulière de balles à blanc soit renforcée par l'abattage d'oiseaux grâce à l'utilisation de vraies munitions, ceci permettant d'éviter l'habituation causée par l'utilisation constante d'une technique d'effarouchement n'ayant aucun impact physique sur les oiseaux (Baxter et Allan, 2008). Dans le cas de la fauconnerie, il est important que les oiseaux de proie soient dressés à attaquer les oiseaux pour éviter l'habituation (Soldatini *et al.*, 2008).

Baxter et Robinson (2007) ont montré que la fauconnerie et l'abattage ont un effet de plus en plus important avec le temps : les effectifs d'oiseaux présents au LET continuent de diminuer tout au long des essais pour chacune de ces techniques (Baxter et Robinson, 2007). En effet, les goélands peuvent ajuster leur comportement face à l'observation des interactions de leurs congénères avec les prédateurs (Conover, 1987; Kruuk, 1976). Ces méthodes d'effarouchement létales s'avèrent ainsi efficaces dans les aéroports et les LET (Baxter et Allan, 2008). Cependant, ces mesures ne peuvent être utilisées seules dans un programme d'effarouchement. L'abattage est souvent limité par le nombre d'oiseaux qu'il est permis de tuer alors que la fauconnerie peut être limitée par les conditions météorologiques (précipitations ou vents forts).

La méthode non létale la plus utilisée et la plus efficace est la pyrotechnie (Baxter et Robinson, 2007). L'émission de cris de détresse enregistrés est aussi souvent utilisée pour rassembler les goélands et ainsi renforcer l'effet des autres méthodes (Conover, 1994). Par contre, la majorité des évaluations de ces techniques d'effarouchement ont été réalisés en les testant individuellement. De plus, l'efficacité des méthodes d'effarouchement a jusqu'ici été évaluée sur des courtes périodes alors que l'efficacité à long terme sur plusieurs années a rarement été évaluée.

Considérations éthiques

Les techniques létales comme l'abattage ou la fauconnerie posent un problème d'éthique (Baxter et Allan, 2008). Lorsqu'une espèce nuisible est protégée comme l'est le Goéland à bec cerclé, des permis d'abattage sont parfois accordés en cas de nécessité d'effarouchement dans les LET, mais toute alternative potentielle à l'abattage des individus est à examiner. La fauconnerie de chasse nécessite aussi un permis, mais tue cependant beaucoup moins de goélands que l'abattage (P. Molina communication personnelle, TECSULT, 2009). De plus, l'opinion publique (très importante pour les gestionnaires de LET et les agences gouvernementales en environnement) est plus positive face à l'utilisation de prédateurs « naturels » que face à l'abattage par armes à feu (Baxter et Robinson, 2007). Cependant, la fauconnerie peut engendrer des coûts élevés à cause de l'acquisition et de l'entretien des oiseaux de proie, leur dressage ainsi que le besoin de personnel qualifié

(Baxter et Allan, 2006). Il serait alors intéressant de trouver une méthode alternative efficace impliquant à la fois moins de mortalité que l'abattage et moins de coûts financiers que la fauconnerie. Or, il existe des cartouches contenant des billes de caoutchouc dont l'utilisation serait non létale et plus acceptable éthiquement. Cette méthode n'a jamais été testée pour effaroucher des oiseaux.

Objectifs

Le premier objectif de notre étude était de tester la faisabilité et l'efficacité du tir de billes de caoutchouc pour effaroucher des Goélands à bec cerclé du LET géré par la compagnie Waste Management à Ste-Sophie. Nous avons développé un protocole expérimental afin de comparer cette technique à l'abattage sélectif (Chapitre 1). Notre deuxième objectif était de comparer l'efficacité à long terme de deux programmes d'effarouchement déjà en place dans deux LET de la région de Montréal. Nous avons cherché à voir si l'utilisation de la fauconnerie au site de BFI à Terrebonne était aussi efficace que l'abattage sélectif utilisé au LET de Ste-Sophie. Notre évaluation était basée sur des données récoltées durant plusieurs années et sur des observations détaillées durant une saison de reproduction (Chapitre 2).

CHAPITRE I

RUBBER SHOTS NOT AS EFFECTIVE AS SELECTIVE CULLING IN DETERRING GULLS FROM LANDFILL SITES

Ericka THIÉRIOT, Pierre MOLINA and Jean-François GIROUX

Résumé

Les grands nombres de goélands présents dans les lieux d'enfouissement technique (LET) sont une problématique mondiale, ces oiseaux pouvant être une nuisance importante pour les employés du site et les résidents de la région avoisinante. Les gestionnaires des LET doivent souvent mettre en place des programmes d'effarouchement afin de dissuader les goélands de s'alimenter dans ces sites. Notre objectif était d'évaluer l'efficacité du tir de billes de caoutchouc, une méthode non létale n'ayant encore jamais été testée pour l'effarouchement des oiseaux, en combinaison avec l'utilisation de pyrotechnie. Nous avons comparé cette méthode à l'abattage sélectif, une méthode létale bien connue pouvant être éthiquement inacceptable dans certaines régions. Notre étude s'est déroulée au LET de Ste-Sophie, proche de Montréal (Québec), situé à 37 km d'une colonie de Goélands à bec cerclé (*Larus delawarensis*) où nichent 48 000 couples. Des décomptes quotidiens et des observations comportementales nous ont permis de quantifier l'efficacité de ces deux méthodes. Le tir de billes de caoutchouc était inefficace pour dissuader les goélands d'utiliser le site car le même nombre d'oiseaux a été observé pendant ce traitement et lors des périodes actives (journées avec enfouissement de matières résiduelles) sans effarouchement ($P = 0,949$). Il y avait 38 % moins d'oiseaux sur le site pendant les journées avec abattage qu'avec le tir de billes de caoutchouc. Nous n'avons détecté aucun signe d'habituation au cours des périodes de sept jours que duraient les traitements d'abattage. L'efficacité de l'abattage résidait aussi dans la plus grande probabilité de faire fuir les goélands hors du site qu'avec les billes de caoutchouc. De plus, les événements d'abattage généraient un délai plus important avant le retour du premier goéland dans la zone d'alimentation que les tirs de billes de caoutchouc ($P = 0,005$). Enfin, la méthode non létale nécessitait un usage accru de fusées pyrotechniques pour réduire la présence des goélands par rapport à l'abattage ($P < 0,001$). La différence entre l'abattage et l'utilisation des billes de caoutchouc pourrait résider dans l'absence de carcasses, dont la vue serait un élément dissuasif pour les goélands. De plus, la détonation plus faible produite par les tirs de billes de caoutchouc pourrait réduire l'impact de cette méthode. Nos résultats suggèrent aussi que l'effort d'effarouchement doit être adapté aux variations saisonnières des nombres d'oiseaux, leurs besoins alimentaires étant plus importants lors de la période d'élevage des jeunes, et que tous les programmes d'effarouchement devraient être appliqués du lever au coucher du soleil. En conclusion, le tir de billes de caoutchouc ne peut pas être utilisé comme alternative à l'abattage pour dissuader les goélands de s'alimenter dans les LET et des études ultérieures sont nécessaires pour développer les méthodes d'effarouchement non létales.

Abstract

Landfill managers often need to implement scaring programs to deter gulls from feeding at their sites because they can be a significant nuisance for both site employees and residents of the surrounding area. Our objective was to assess the efficiency of firing rubber shots, a non-lethal method never tested in a bird deterrence context, in combination with the use of pyrotechnics. This method was compared to selective culling, a well-known lethal technique that may be ethically unacceptable in some areas. Our study was conducted at the Ste-Sophie landfill site near Montreal (Quebec) located 37 km from a Ring-billed gull (*Larus delawarensis*) colony supporting 48,000 pairs. Daily counts and behavioral observations were conducted throughout the breeding and post-breeding periods. Firing rubber shots was ineffective in deterring gulls as we observed the same number of birds at the landfill during periods with and without deterrence ($P = 0.949$). However, we counted 38 % less birds during the culling periods than during the rubber shot treatment. We detected no sign of habituation during the seven-day culling trials. Culling was more effective in getting the gulls to leave the site and generated longer delays before the first gull returned than did rubber shots ($P = 0.005$). Finally, the non-lethal method required an increased use of pyrotechnics to reduce the number of gulls at an acceptable level when compared to culling ($P < 0.001$). The difference between culling and the use of rubber shots may be related to the absence of carcasses, which may be a visual deterrent factor for gulls. Our results also suggest that the deterrence efforts have to be adapted to seasonal variations in bird numbers as dietary needs are higher during the chicks' rearing period. Any scaring program should also be performed from dawn to dusk. In conclusion, the use of non-lethal rubber shots to deter gulls from feeding at landfill sites cannot be used as an alternative technique to culling.

Keywords: Gull, *Larus delawarensis*, scaring, landfill, anthropogenic food, pest management.

1.1 Introduction

Gulls are opportunist birds that have a great ability to adapt to anthropogenic environments (Blokpoel & Spaans, 1991; Vidal, Medail & Tatoni, 1998), notably waste disposal. Landfill sites represent stable, predictable, and near limitless food sources for scavenging birds (Blokpoel & Scharf, 1991; Brousseau, Lefebvre & Giroux, 1996; Coulson *et al.*, 1987). Edible refuse obtained at landfill sites can represent a significant part of the diet of gulls nesting near urban centers (Patton, 1988; Pons, 1992).

Large numbers of gulls attracted to landfill sites can cause various problems. First, by improving their reproductive success, the use of landfills can directly influence population dynamics and increase the number of birds near urban areas (Duhem *et al.*, 2008; Pons & Migot, 1995). Second, it can be a nuisance for residents of the surrounding area when gulls use private lands or fly over their houses between the colony and the landfill site often leaving droppings (Moreau, 2012). Groups of gulls can also be an aircraft hazard when landfills are located near airports; accidents generally cause considerable economics losses and are a real threat to human security (Allan, 2006; Blokpoel & Tessier, 1986; Sodhi, 2002). Moreover, large numbers of gulls flying around heavy machinery at a landfill site can reduce the operators' visibility with an increased risk of accidents. Hearing the constant noisy calls of gulls all day long can also be stressful for site employees. Finally, the machinery becomes quickly covered with dejections, causing a further possible health and safety issue.

The development and improvement of deterrence methods would offer a greater choice of tools to landfill managers. To limit their access to anthropogenic food, different ways to deter gulls from feeding at landfill sites have been developed with variable success. Some studies have shown that using on-demand deterrence systems is more effective than regular event systems because gulls quickly become habituated to predictable repeated stimuli (Ronconi & Cassady St. Clair, 2006; Soldatini *et al.*, 2008). Moreover, using on-demand systems based on a single deterrence technique (e.g. sound generator, pyrotechnics) has been shown to have a temporary impact on gull numbers because of the birds' habituation to these specific stimuli (Baxter & Robinson, 2007; Cook *et al.*, 2008; Soldatini *et al.*, 2008). This implies that when testing deterrence systems, a combination of several devices should be used (Baxter & Allan, 2008; Cook *et al.*, 2008; Soldatini *et al.*, 2008).

The habituation phenomenon can also be reduced by implying a mortality risk in the deterrence program, reinforcing the gulls' fear associated to non-lethal techniques (Baxter & Allan, 2008). However, lethal methods as culling may be ethically questionable, and non-lethal methods are thus preferable when possible (Baxter & Allan, 2008; Haag-Wackernagel, 2000; Littin & Mellor, 2005). Moreover, when the nuisance species is legally protected as in the case of all gull species in North America, culling permits may sometimes be difficult to obtain and may involve detailed monitoring, which increase the cost of the operation. Falconry may provide an effective non-lethal alternative that rarely involves killing of birds but is sometimes considered expensive (Baxter & Allan, 2006; Thiériot *et al.*, in prep.). As such any other potential alternatives to lethal methods would be desirable.

Our objective was to compare the efficiency of firing rubber shots with selective culling, two on-demand methods used in combination with pyrotechnics to scare gulls from a landfill site. The use of rubber shots as a non-lethal method has never been tested in a bird deterrence context. The originality of using rubber shots is the harmless physical impact of these pellets on gulls which may reduce habituation without killing the birds. Our experience was conducted at a landfill known to attract large numbers of gulls during the reproductive season when their dietary needs are the most important.

1.2 Material and methods

Study site

The experiment was conducted in 2010 at the Ste-Sophie landfill located approximately 40 km north of Montreal, Quebec, Canada. The site is situated at 37 km from Deslauriers Island in the St-Lawrence River where 48,000 pairs of Ring-billed gulls nest (unpublished data, Canadian Wildlife Service, 2009). The Ste-Sophie site is regularly visited by Ring-billed gulls nesting at the Deslauriers Island as shown by telemetry (Patenaude-Monette, 2011) and to a lesser extent by Herring gulls (*Larus argentatus*) and Great Black-backed gulls (*Larus marinus*). Refuse are dumped and compacted in an active tipping area covering approximately 2000 m^2. The other parts of the landfill are covered with grass, clay, or sand. Gulls often loaf on a sandy site near the active tipping area. Burying operations only take place on week days between 06:00 and 19:00. After the operating hours, a portion of the active tipping area is covered with a 25 x 25 m tarpaulin and earth. During the study, approximately 350 000 tons of refuse were brought to the site on an annual basis. The main objective of the landfill manager was to keep the birds away from the machinery at the tipping zone and to keep a minimum number in the surrounding area dominated by agricultural lands.

Deterrence trials

Each deterrence trial lasted 7 days and was preceded by a 3-day period when burying activities occurred (operating period), but without scaring. The deterrence trials were interrupted during weekends as no refuse was brought to the landfill. Five selective culling trials were conducted and alternated with four rubber shot trials. The experimental period was divided into three biological stages based on the breeding chronology of Ring-billed gulls at Deslauriers Island: (1) the nesting stage lasted from April 5th to May 14th and coincided with nest establishment, egg laying, and incubation; (2) the rearing stage took place between May 15th and June 25th when adults travelled back and forth to the colony to feed their juveniles; and (3) the post-rearing stage from June 26th to August 7th concurred with the departure of juveniles from the colony. Culling and rubber shots were tested during each stage to take into account the different energy requirements of gulls.

Selective culling involved shooting of a maximum of 35 gulls per week using a 3-inch 12-gauge gun and BB steel shots ($0.54 CAD per round) under scientific permit (SC-1583, Canadian Wildlife Service), unlimited pyrotechnic shots (screamers, $0.52 CAD per round, Margo Supplies Ltd., Alberta, Canada), and the use of a gas cannon that fired approximately every minute. Rubber shots were limited by the number of available rounds (about 25 per day) and were complemented by the use of unlimited pyrotechnic shots and the gas cannon. The same gun was used for firing rubber shots (12 gauge Rubber Buckshot, 15 pellets of 8.4 mm in diameter and 577 mg, $3.50 CAD per round, Margo Supplies Ltd.,). A minimal distance of 60 m from the birds was imposed to prevent injuries to the birds based on preliminary tests using various targets at different distances. During the trials, distance from the birds was estimated using a rangefinder. Two fake falcon kites were permanently placed at proximity of the active tipping area but their effectiveness was minimal (Cook *et al.*, 2008; Ronconi & Cassady St. Clair, 2006).

Deterrence took place on week days between 07:00 and 15:00 and was conducted by a non-specialized employee who recorded, on an hourly basis, the number of culled gulls and the number of used rounds for each device. Culling and rubber shots being limited by the number of killed gulls and rounds, respectively, the number of pyrotechnics fired was used as an index of the deterrence effort required to supplement the main methods in achieving the objectives established by the landfill manager.

Gull use of the landfill

During the experimental period, birds were counted every 30 min during 5-h observation periods alternating between morning (05:00 - 10:00), mid day (10:00 - 15:00), and evening (15:00 - 20:00). Surveys were conducted five days per week including one weekend day every other week, for a total of 89 days of surveys. Gulls located within 100 m of the center of the dumping operations were considered to be in the tipping area and were counted separately from those observed in the loafing area. Gulls flying above the site were included in the counts for each zone. For each count, a subsample of birds was tallied to determine the proportion of the different species of gulls and the proportion of birds that were actually feeding at the site. This scan sampling allowed us to determine the time spent by gulls feeding on refuse (Altmann, 1974). Observations were conducted using binoculars and a telescope.

Gull behavior

For each deterrence event, we recorded whether the gulls left the site or fled to another portion of the landfill. We also noted the time elapsed between the scaring event that resulted in the departure of the birds from the area where the deterrence took place and the return of the first bird to this area (generally the active tipping area). Finally, the type of events (culling, rubber shot, pyrotechnic during culling trial or pyrotechnic during rubber shot trial) and the number of consecutive shots fired within 30 s were also noted.

Statistical analyses

The number of pyrotechnics used per day was compared with an ANOVA including deterrence methods and biological stages as independent variables. Data were transformed with square roots to meet parametric assumptions of normality. Bird use of the landfill was based on the mean daily numbers computed from the repeated surveys. We considered each day as independent because we found no correlation between the numbers of gulls on successive days during the nesting ($r = 0.20$, $n = 22$, $P = 0.361$) and rearing stages ($r = 0.05$, $n = 18$, $P = 0.843$) and a weak correlation during the post-rearing stage ($r = 0.43$, $n = 23$; $P = 0.043$). Numbers of gulls present at the whole site and at the active tipping area were analyzed separately using ANOVAs with treatments and biological stages as independent variables. The effect of the daily period was tested using one-way ANOVAs. Gull numbers were also transformed with square roots and Tukey's Honestly Significant Difference tests (Tukey's HSD) were used to check for differences between each pair of means. The proportion of gulls feeding was calculated as the sum of the number of gulls feeding during the day divided by the total numbers of gulls observed during that day. It was also analyzed with an ANOVA to determine the effect of treatments and biological stages after applying an angular transformation. We explored whether there was a pattern in bird use during the seven-day trials for both the culling and rubber shot methods using simple linear regressions of the day number (1 - 7) and the square-rooted daily number of birds.

The effectiveness of a deterrence event in evicting the gulls from the site was analyzed with a logistic regression including the number of shots (1, 2-3 or ≥ 4), the type of events, and the biological stage as independent variables. We focused on the individual effect of each factor using likelihood ratio tests. Finally, the time required for the first gull to return to the disturbed area was analyzed with an ANOVA on log-transformed data considering the type of events and the biological stage as independent factors. Tukey's HSD tests were used to see the difference between each pair of means.

All the analyses were performed with JMP® 9 of SAS Institute Inc. The statistical level of significance was established at 0.05 and all means are presented ± 1 SE.

1.3 Results

Deterrence effort

During culling trials, an average of 19 steel rounds was used per day while 21 rubber rounds were used during the rubber shot trials. The supplemental deterrence effort measured as the number of pyrotechnics needed to keep the number of gulls as low as possible was significantly greater during the rubber shot trials ($F_{1, 53} = 72.54$; $P < 0.001$) and the rearing stage ($F_{2, 53} = 8.53$; $P = 0.001$; Fig. 1.1). There was no interaction between the two factors. The difference in the use of pyrotechnics between the two deterrence methods was observed for all three biological stages. For rubber shot trials, the use of pyrotechnics was more than twice during the brood rearing period than during the first and last stage. The seasonal difference was not significant for culling (Fig. 1.1).

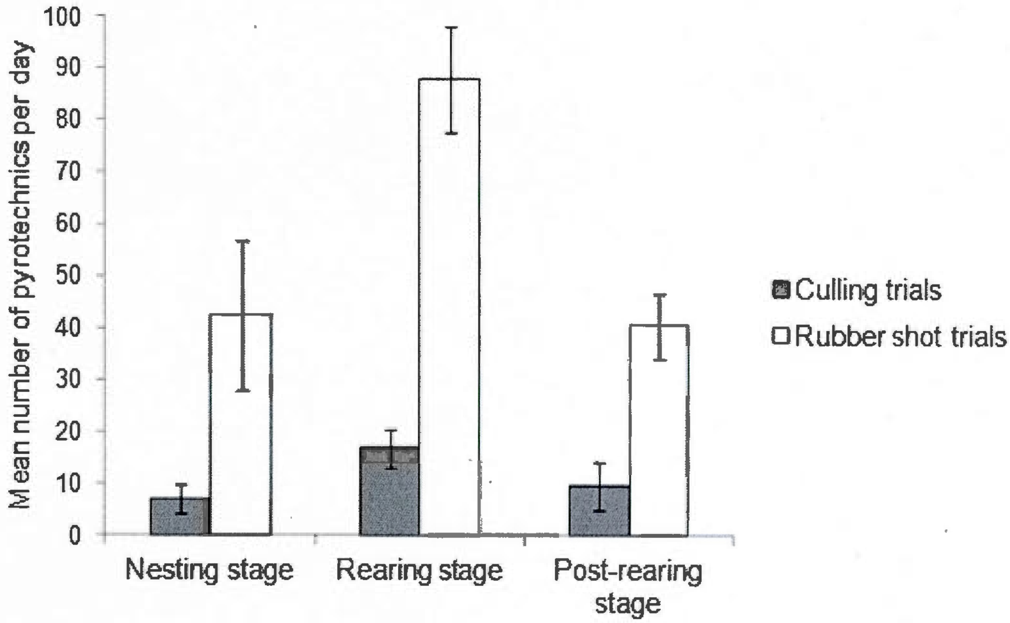

Figure 1.1: Mean (± SE) number of pyrotechnics used per day to deter Ring-billed gulls from using the Ste-Sophie landfill during culling and rubber shot trials at three periods.

A total of 180 Ring-billed gulls were killed during the 32 days of the culling trials for a mean of 5.6 ± 0.4 per day. The number of gulls culled varied during the season with 50 during the nesting stage, 84 during the rearing period, and 46 during the post-rearing stage. Although rubber shots were considered non-lethal, 12 gulls wounded during these trials were euthanized for an average of 0.5±0.1 dead gull per day. Juvenile birds began to be culled on June 24th, shortly after the first birds fledged from Deslauriers Island. They represented 15 % of the total number of birds killed.

Gull use of the landfill

During the experimental period, Ring-billed gulls represented 94% of the birds counted at the site followed by Herring gulls and Great Black-backed gulls. The mean number of gulls using the landfill site varied among treatments ($F_{3, 83} = 8.99$, $P < 0.001$) and biological stages ($F_{2, 83} = 5.68$, $p = 0.005$). There was no interaction between these factors indicating that the relative effects of the treatments were similar throughout the season (Fig. 1.2). Overall, there was no significant difference in the number of gulls during the non-scaring operating periods and rubber shot trials ($P = 0.949$) and no difference between culling and weekend periods ($P = 0.659$). There were 38% less birds using the site during culling treatments than during the rubber shot trials ($P = 0.014$). Significantly more gulls ($P < 0.016$) were present during the rearing stage (583±66 gulls/day) than during nesting (400±50 gulls/day) or post-rearing stages (429±66 gulls/day); there was no difference between the first and last stages ($P = 0.982$). The mean number of gulls using the landfill site also depended on the daily period ($F_{2, 86} = 6.06$, $P = 0.003$). More gulls were present after 15:00 (623±68 gulls/day) when deterrence activities were adjourned compared to morning (322±42 gulls/day) or mid-day periods (461±62 gulls/day).

When we limit the analysis to birds counted near the active tipping area, the effect of the treatment was not significant ($F_{3, 83} = 1.74$, $P = 0.165$) while biological stage still had a strong effect ($F_{3, 83} = 15.18$, $P < 0.001$) with no interaction between these factors (Fig. 1.2). Overall, significantly more gulls ($P < 0.001$) were present during the rearing stage (256±41gulls/day) than during nesting (95±14 gulls/day) or post-rearing stages (91±15gulls/day) with no difference between the first and last stages ($P = 0.865$). The mean number of gulls at the tipping area site also depended on the daily period ($F_{2, 86} = 13.35$, $P < 0.001$). Significantly more gulls were present after 15:00 (249±38 gulls/day) compared to morning (92±22 gulls/day) or mid-day periods (99±16 gulls/day). There was no difference between the first two periods ($P = 0.935$).

The proportion of gulls observed feeding varied according to treatments ($F_{3, 83} = 8.55$, $P < 0.001$) and biological stages ($F_{2, 83} = 12.83$, $P < 0.001$) with no interaction between the two factors (Fig. 1.2). Overall, there was no significant difference in the proportion of birds feeding during the non-scaring operating periods, culling and rubber shot trials ($P > 0.753$).

During weekends, however, the proportion of birds feeding was much greater than during the three other situations ($P < 0.001$). A greater proportion of gulls ($P < 0.001$) were feeding during the rearing stage (26.2±4.0%) than during the nesting (10.1±2.6 %) or the post-rearing stages (10.6±2.4%); there was no difference between the first and last stages ($P = 0.997$). The mean proportion of gulls feeding also depended on the daily periods ($F_{2, 86} = 10.26$, $P < 0.001$). More gulls were feeding on refuse after 15:00 (26.0±3.6%) compared to the morning (12.1±3.1%) or the mid day periods (9.7±2.6%) with no difference between the first two periods ($P = 0.769$). This increase in the proportion of birds feeding between mid day and the evening period was much more important during the culling trials (4.0±1.6 % to 26.7±6.0 %) compared to the increase observed during the non-operating periods (8.1±2.1 % to 15.0±3.8 %).

There was a trend for a reduction in the number of gulls using the site during the seven-day culling trials but it was not statistically significant ($r = -0.31$; $F_{1, 25} = 2.76$; $P = 0.109$). No such trend was observed during the rubber shot trials when the mean daily number of gulls stayed constant throughout the seven days ($r = -0.06$; $F_{1, 21} = 0.07$; $P = 0.795$).

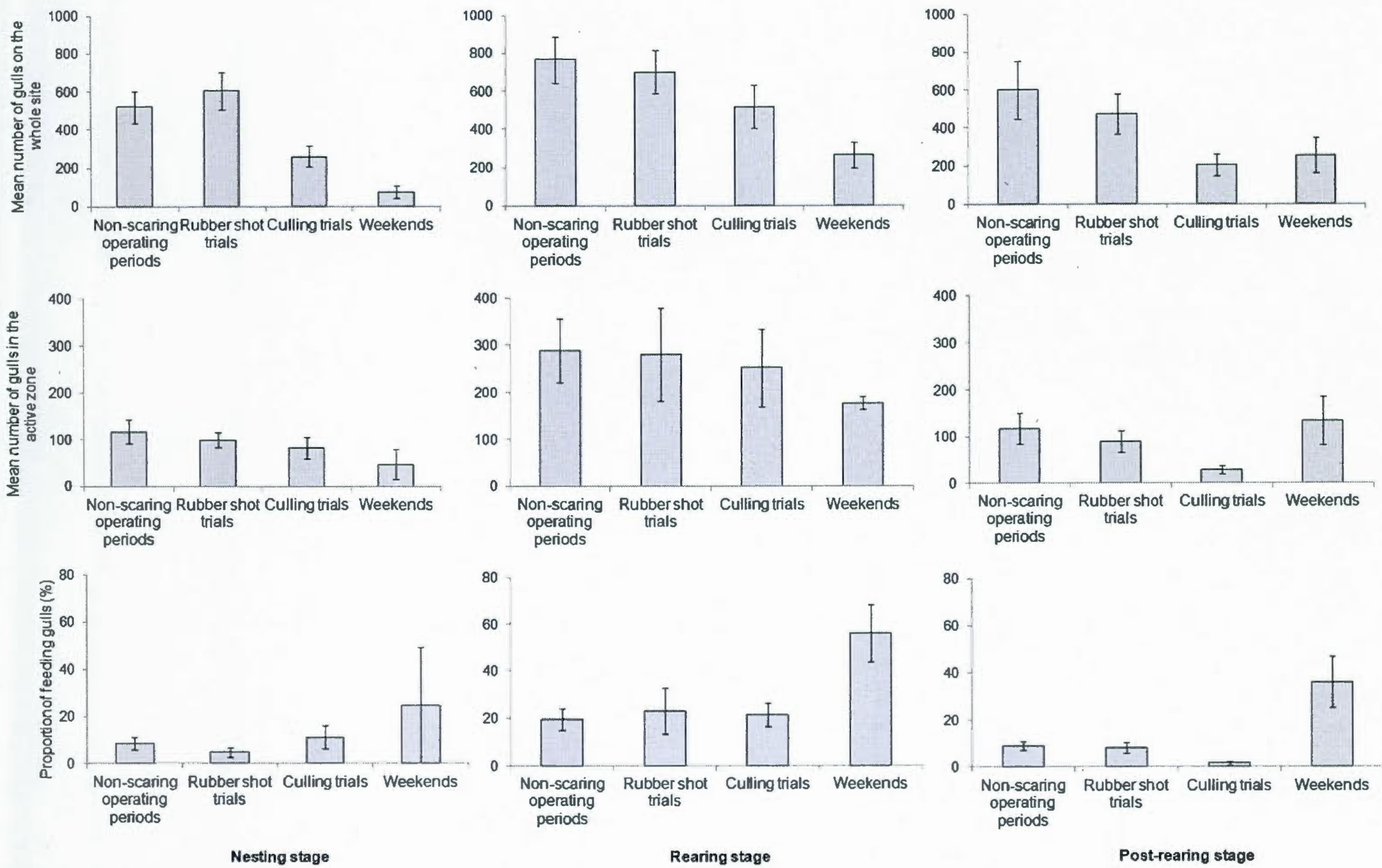

Figure 1.2: Mean (± SE) number of gulls present at the whole site and at the active tipping area and mean (± SE) percentage of gulls feeding at the Ste-Sophie landfill site during operating periods without scaring, rubber shot and culling trials, and week-ends, 2010.

Gull behavior

The success in evicting the gulls from the site was determined by the type of events (χ^2_3 = 32.61, P < 0.001) and the biological stages (χ^2_2 = 9.36, P = 0.009). The effect of the number of consecutive shots was not significant (χ^2_2 = 4.17, P = 0.124). Globally, culling succeeded more often than the other techniques in evicting the gulls from the site (Fig. 1.3). During the nesting stage, it was nearly twice as easy to repulse the birds out of the landfill as during the other two periods when considering all types of events (Fig. 1.3).

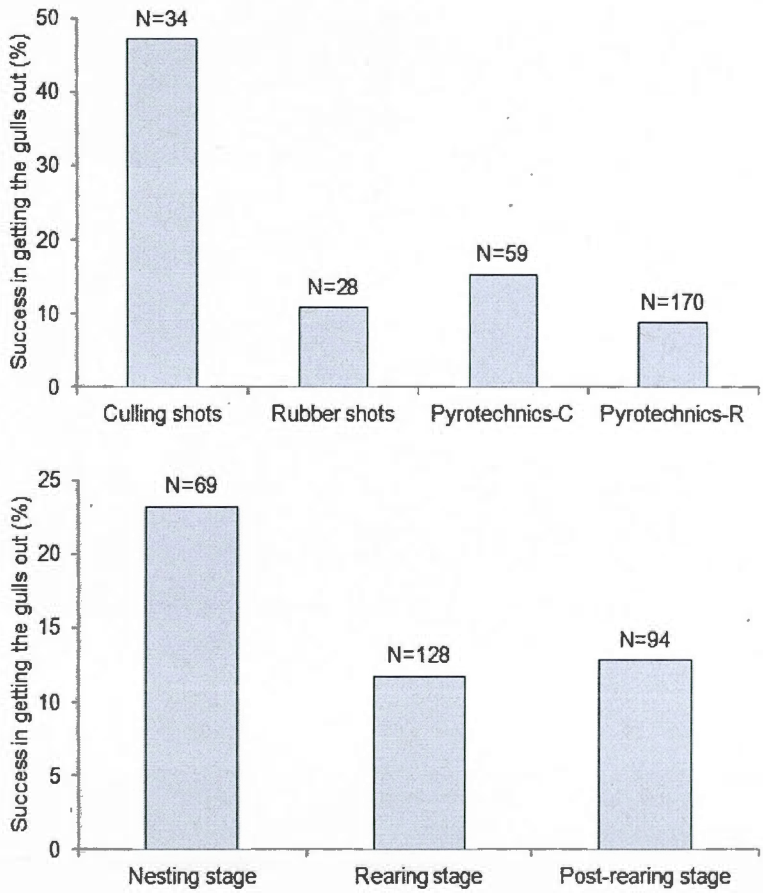

Figure 1.3: Proportion of events that succeeded in evicting gulls from the Ste-Sophie landfill site after different deterrence events and during three biological stages. Pyrotechnics-C: pyrotechnic events during a culling trial. Pyrotechnics-R: pyrotechnic events during a rubber shot trial.

The time required for the first gull to return to the disturbed area varied according to the type of events ($F_{3, 171} = 6.64$; $P < 0.001$) but not to the biological stage ($F_{2, 171} = 1.05$, $P = 0.351$). Culling events resulted in a longer delay before the first gull came back than following the other types of deterrence events that did not differ among each other's (Fig. 1.4). There was no difference in the number of consecutive shots fired during the different types of events with an average of 2.8±0.1 rounds ($F_{3, 313} = 0.52$; $P = 0.67$). The number of consecutive shots had no effect on the returning time after a culling event ($F_{2, 21} = 1.31$; $P = 0.290$).

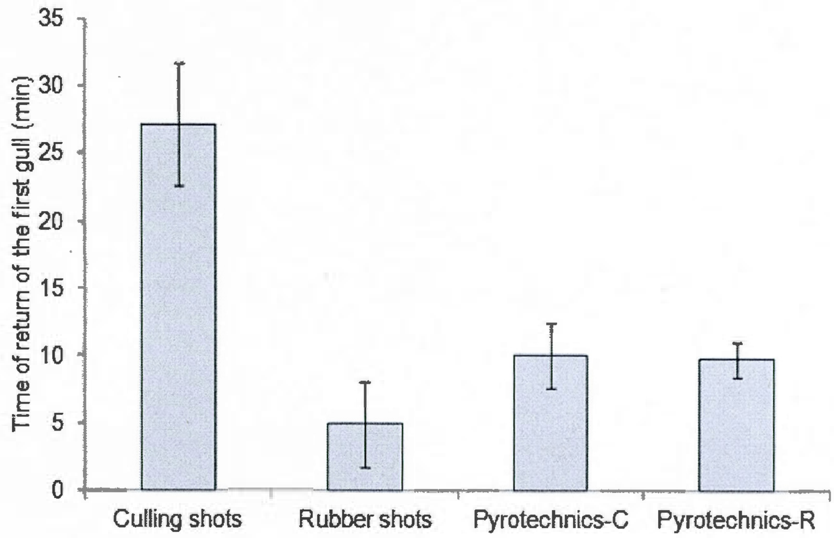

Figure 1.4: Mean (± SE) number of minutes before the return of the first gull after different deterrence events at Ste-Sophie landfill site. Pyrotechnic-C: pyrotechnic event during a culling trial. Pyrotechnic-R: pyrotechnic event during a rubber shot trial.

1.4 Discussion

The use of non-lethal rubber shots, as tested in our study, was ineffective in reducing the number of birds present at the landfill site in general or at the active tipping area. This deterrence method also required a greater supplemental effort with pyrotechnics compared to the culling method. Selective culling was effective and reduced the total number of gulls nearly at the level observed during weekends when the site was less attractive because no refuse was delivered. Culling was more efficient because of a greater probability of scaring the gulls out of the site than when using rubber shots or pyrotechnics, and in the longer time required for the gulls to return to the site after a deterrence event. The inefficiency of rubber shots may be related to the weak detonations generated because they are lighter than steel rounds and contain less gunpowder. Steel shot detonations are much noisier, and combined with visible carcasses recovered by the deterrence employee, it led to a greater deterrence potential (Baxter & Allan, 2008). The harmless physical impact of rubber pellets did not appear to compensate for the sight of a dead bird.

We detected no sign of habituation during the seven days of the culling trials. The fact that the mean daily number of gulls did not increase with time shows that gulls reacted with at least the same intensity at the end of the trial than at the beginning. Using selective culling with pyrotechnics avoid short term habituation, unlike non-lethal methods to which gulls can habituate within a week (Soldatini *et al.*, 2008).

Ring-billed gulls spent a small proportion of their time feeding during operating hours when refuse was transported and buried even in absence of deterrence. This may result from the vehicle activity within the tipping area which limited the availability of feeding surfaces. During the rearing stage, gulls spent over 50% of their time feeding during weekends when no deterrence activity took place. It probably took more time for the gulls to find food when refuse are covered with earth and not turned over by the machinery. This could also explain why we observed a similar number of gulls in the active tipping area during the culling trials and the non-scaring operating periods. The majority of gulls spent their time in the loafing area even during non-scaring operating periods because of the intense human activity in the active tipping area. This indicates the importance of planning and managing the landscape of the landfill to limit the size of the active tipping area and to avoid large open surfaces devoid of grass cover where water can accumulate. These areas represent ideal loafing areas for gulls.

When the deterrence employee left the site at 15:00, gulls increased their use of the tipping area despite the intense activity and increased their time feeding. The gulls could settle without risk in the active tipping area and have access to fresh refuse until about 19:00 h. Deterrence activities should therefore be maintained throughout the daylight period to reduce the overall site utilization by gulls. In the long term, this could result in a reduction of the number of culled gulls and of required ammunitions (Baxter, 2008; Risley & Blokpoel, 1984).

The brood rearing stage represented the period when the number of gulls at the landfill was the greatest and when it was more difficult to drive them away. This corresponds to the period when the needs for food acquisition are maximal to feed the juveniles at the colony. Managers must anticipate these seasonal changes by carefully planning their pyrotechnic supply and increasing the number of deterrence employees.

Although described as a non-lethal technique, rubber shots wounded some birds even if the minimal distance of 60 m from the bird group was respected. Some gulls moved towards the deterrence employee while fleeing and were then hit resulting in injuries that required their euthanasia. Nevertheless, the number of birds killed was much smaller than for selective culling.

1.5 Conclusion

Rubber shots have not been designed for gull deterrence. Nevertheless, we were hoping that this non-lethal technique could be used in combination with pyrotechnics to deter gulls from visiting landfill sites but it was ineffective. Other tests could be performed to improve the technique. A possibility would be the use of naturalized gull carcasses or model carcasses to elicit avoidance behavior by other gulls. Another potential improvement could be the use of a double cannon gun enabling to consecutively shoot a rubber round and a noisier blank round.

Although selective culling was effective, it would result in a large number of dead birds if applied during a whole season over many years. If the objective of the program also includes a reduction of the size of the population, the technique can then be considered appropriate. If this is not the case or if the public opinion is not favorable based on ethics, alternative methods are therefore needed. Some jurisdictions may be even reluctant of issuing culling permits. Moreover, these permits are often associated with the obligation of maintaining a close monitoring of the activity, which increases the costs. A well known and effective deterrence method is falconry. It is not noisy thus avoiding public complaints and it usually well perceived by the public (Baxter & Allan, 2006; Baxter & Robinson, 2007; Cook *et al.*, 2008; Erickson, Marsh & Salmon, 1990). The only drawback may be the financial investment.

We recommend that landfill managers choose the appropriate deterrence program based on the tolerable number of gulls on the site. This depends on the degree of urbanization in the surrounding area, their financial capabilities and the bird population status. In all cases, the deterrence effort should be adapted to seasonal variations in bird numbers and dietary needs, and the program should be performed from dawn to dusk to maximize its efficiency (Baxter, 2008; Risley & Blokpoel, 1984).

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CHAPITRE II

COMPARING AN INTEGRATED FALCONRY PROGRAM WITH SELECTIVE CULLING TO DETER GULLS FROM LANDFILLS

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Résumé

Les lieux d'enfouissement techniques (LET) sont très attractifs pour les goélands qui peuvent devenir une nuisance dans ces sites et la région alentour. Les gestionnaires de LET sont donc souvent incités à mettre en place des programmes d'effarouchement devant être éthiques et rentables. Bien que plusieurs méthodes aient été proposées, peu ont été jugées efficaces en dehors de l'abattage et de la fauconnerie. Cependant, la plupart des tests ont été effectués sur de courtes périodes de temps. Dans la région de Montréal, deux LET sont situés à proximité d'une colonie de 48 000 couples de Goélands à bec cerclé (*Larus delawarensis*). Notre objectif était de comparer l'efficacité d'un programme intégré de fauconnerie à celle d'un programme d'abattage sélectif, grâce à des observations détaillées lors de la saison de reproduction des goélands et à des données quant à l'utilisation à long terme des sites par les goélands. La mortalité des goélands associée à la fauconnerie était négligeable et résultait en 56 fois moins d'oiseaux morts que l'abattage. En 2010, il y avait 59±15 goélands/jour utilisant le site avec le programme de fauconnerie, sans variation au cours de la journée. Seulement 0,4±0,2 % de ces oiseaux étaient en alimentation. Au site avec abattage, il y avait 347±55 goélands/jour dont 13±3 % en alimentation. Les goélands étaient plus nombreux après 15:00 (582±107) quand les activités d'abattage cessaient que plus tôt dans la journée (225±44). Des résultats similaires étaient observés en considérant seulement les oiseaux comptés dans la zone d'enfouissement active. Dix-neuf goélands suivis grâce à des consignateurs de données GPS depuis la colonie ont effectué 41 trajets jusqu'à ces sites: 25% des trajets au site utilisant la fauconnerie menaient à un arrêt (22±7 min, n = 7), comparativement à 85 % pour l'autre site (63±15 min, n = 11). Enfin, la fauconnerie a résulté en une diminution de 99 % du nombre de goélands entre 1995 et 2010, alors que nous avons observé une réduction de 77 % du nombre de goélands entre 2007 et 2010 au site utilisant l'abattage. Considérant que ce dernier était situé plus loin de la colonie et recevait moins de déchets annuellement, nous concluons qu'un programme intensif de fauconnerie est plus efficace et plus éthique pour réduire l'utilisation des LET par les goélands que l'abattage sélectif.

Abstract

Landfills are very attractive for gulls that often become a nuisance on the site and in the surrounding area. Managers are thus required to put in place cost-effective and ethical deterrence programs. Although several methods have been proposed, few have been found successful except for culling and falconry. However, most tests have been conducted over a short period of time. In the Montreal area, two landfill sites are located close to a large Ring-billed gull (*Larus delawarensis*) colony. Our objective was to compare the effectiveness of an integrated falconry program to selective culling using both detailed observations during the gull breeding season and long-term data on landfill use by gulls. Gull mortality associated to falconry was negligible and resulted in 56 times less dead birds than culling. In 2010, there was an average of 59±15 gulls/day using the site with the falconry program with no variation during the daylight period. Only 0.4±0.2% of these birds was feeding. On the site with culling, there was an average of 347±55 gulls/day including 13±3% feeding birds. More gulls used this site after 15:00 (582±107) when culling activities ceased than earlier during the day (225±44). Similar results were obtained when considering only the gulls counted at the active tipping area. Twenty-two gulls tracked with GPS data loggers from the colony made 41 trips to these sites: 25% of the trips to the site using falconry resulted in stopovers (22±7 min, n=7) compared to 85% for the other site (63±15 min, n=11). Finally, falconry resulted in a decrease of 99 % in gull numbers between 1995 and 2010 while we observed a decrease of 77% between 2004 and 2010 at the site with culling. Considering that the site with culling was located further from the colony and received less refuse on an annual basis, we conclude that an intensive falconry program is both more effective and ethical in reducing number of gulls at landfills than selective culling.

Keywords: Gull, *Larus delawarensis*, scaring, landfill, anthropogenic food, pest management.

2.1 Introduction

Several species of gulls have adapted to anthropogenic environments and have learned to take advantage of waste disposal (Blokpoel & Spaans, 1991; Vidal, Medail & Tatoni, 1998). Landfill sites represent predictable and nearly limitless food sources for scavenging birds (Blokpoel & Scharf, 1991; Coulson *et al.*, 1987). However, large numbers of gulls attracted to landfills can cause various problems. First, it is a nuisance for nearby residents when gulls loaf on their properties or fly over their houses letting droppings down (Moreau, 2012). Groups of gulls can also be a risk to aircrafts when landfills are located near airports (Burger, 2001). Accidents generally imply considerable economics losses and are a threat to human security (Allan, 2006; Blokpoel & Tessier, 1986; Sodhi, 2002). Large numbers of gulls flying around heavy machinery at a landfill site can reduce the operators' visibility with an increased risk of accidents while the constant noisy calls of gulls can be stressful for these employees. The machinery can also become quickly covered with dejections, causing a potential health and safety issue. Finally, gulls can improve their reproductive success by feeding at landfill sites, which may contribute to population growth (Duhem *et al.*, 2008; Pons & Migot, 1995). There is therefore a need to develop efficient methods to deter gulls from using landfill sites.

Land use management is the first step to wildlife control. Reducing the active tipping area surface and regular covering of the refuse with inedible materials should limit access to garbage and make the site less attractive. Moreover, avoiding water accumulation in shallow depressions and sowing tall grasses in inactive zones should prevent gulls from using these sites for preening and loafing (Belant, 1997). Nevertheless, active scaring programs will be always required to deter gulls from using landfills, especially the tipping areas. Short-term effects of various deterrence programs have been established in many studies but their long-term effects have been rarely documented (Baxter & Robinson, 2007; Cook *et al.*, 2008; Soldatini *et al.*, 2008; Thiériot, Molina & Giroux, in prep.). One exception is the study by Dolbeer (1998) who assessed the effectiveness of culling and falconry. His study, however, was conducted at an airport that provides less feeding opportunities for gulls than a landfill site. Moreover, the detailed use of the site by gulls was not evaluated and the birds of prey had not been trained to catch birds.

Our objective was to assess the effectiveness of selective culling and falconry to deter Ring-billed gulls (*Larus delawarensis*) from using two landfills located near a large breeding colony. The deterrence programs implemented at each site varied both in methods and intensity because of different prevailing conditions and ultimate objectives. Culling and falconry involve a lethal aspect that may reinforce their effect and impede the habituation of gulls (Baxter & Allan, 2008). Because deterrence is more efficient when several devices are combined (Baxter & Robinson, 2007; Cook *et al.*, 2008; Soldatini *et al.*, 2008), we compared an integrated falconry program that involved the use of trained birds of prey, pyrotechnics, and playback of gull distress calls, with a selective culling program that included shooting of a limited number of birds and the use of pyrotechnics and a gas canon. We based our evaluation on both detailed observations during one breeding season and long-term survey data. We also tracked the movements of individual gulls from the colony to the landfills to study their behavior in response to the deterrence programs.

2.2 Methods

Study sites

The study was conducted at the Terrebonne and Ste-Sophie landfill sites in the vicinity of Montreal, Quebec, Canada. These two sites are located respectively at 8 and 37 km from the Deslauriers Island in the St-Lawrence River where 48,000 pairs of Ring-billed gulls are nesting (Canadian Wildlife Service, unpublished data). The number of breeding pairs using this colony has been stable for the last 20 years. The area surrounding the Terrebonne site includes suburban settlings and agricultural lands while the Ste-Sophie site is entirely surrounded by agricultural lands. An average of 857,800 ± 46,500 metric tons were brought annually to the Terrebonne site between 1995 and 2003 and this increased to 1,265,100 ± 15,300 metric tons between 2004 and 2010. At the Ste-Sophie site, an average of 744,300 ± 76,700 metric tons was brought annually (2004-2010). At both landfills, refuse are dumped and compacted in an active tipping area where it is rapidly covered with earth or inedible material. The other portions of the landfills are covered with grass, clay, or sand. Burying operations took place every day but Sundays at both sites, except at the Ste-Sophie site in 2010 when no refuse was brought on Saturdays.

Deterrence programs

At the Ste-Sophie landfill site, selective culling was first tested during 12 days in 2004. There were no deterrence and no monitoring in 2005-2006 before the implementation of the culling program in 2007. Between 2007 and 2009, the deterrence program remained unchanged and was performed on week days between 7:00 and 15:00 by a site employee unspecialized in wildlife control. Selective culling involved shooting of a maximum of 21 gulls per week using a 3-inch 12-gauge gun and BB steel shots ($0.54 CAD per round) under scientific permit (SC-1583, Canadian Wildlife Service, from April 1st to November 30th) combined with an unlimited use of pyrotechnic shots (screamers, $0.52 CAD per round, Margo Supplies Ltd., Alberta, Canada) and a gas cannon. In 2010, an experiment was conducted between April and August to compare the effectiveness of culling and the use of rubber shots (Thiériot, Molina & Giroux, in prep.). Trials lasted 7 days, with 5 replicates for culling and 4 for rubber shots with a 3-day non-deterrence period between each trial. The same schedule as in previous years was maintained but the number of gulls that could be culled was increased to 35 per week. After this experiment, the usual selective culling program was resumed until the end of November. No deterrence took place on weekends at this site. The objective of the manager was to keep the birds away from the tipping zone and to minimize the number of gulls in the surrounding area.

At the Terrebonne landfill site, a falconry program has been performed since 1995 involving trained falcons and hawks, the use of pyrotechnics and the playback of recorded distress calls. Experienced falconers flew falcons above the site with a lure, whereas hawks were trained to catch gulls that came near the ground and to fly among groups of gulls. Deterrence took place 8 to 12 hours per day until 2004 and from dawn to dusk since 2005. The mean number of hours of deterrence per year was increased from 1227 between 1995 and 2004 to 4511 thereafter. Since 2006, two falconers are involved during week days and 1 on Saturdays and Sundays. However, the number of falconers can be increased up to 5 on week days during periods of high gull abundance. Their task was to deter all gulls from using the entire landfill. At each site, the number of birds culled or caught by the hawks and the number of pyrotechnics used was noted by the deterrence employees and weighted by the number of deterrence hours completed each day.

Gull surveys

At Ste-Sophie, gulls present at the active tipping area and in the surroundings were counted separately in the morning, mid day, and afternoon, twice a week in 2004, once a week between 2007 and 2009 and 5 days per week in 2010. Gulls flying above the site were included in the counts for each zone. At Terrebonne, surveys were performed daily from 1995 to 2010 in the morning, mid day, and afternoon when deterrence took place. Gulls observed within a 200-m radius of the active tipping area were counted. We summed the maximum number of gulls observed each day between April 1st and August 31th to obtain the number of bird-days for each year. For days with missing data, we took the mean between the previous and next counts.

In 2010, detailed observations were conducted at both landfills during the breeding season. Birds were counted every 30 min during 5-h observation periods alternating between three daily periods: morning (05:00-10:00), mid day (10:00-15:00) and evening (15:00-20:00). Surveys were conducted five days per week at Ste-Sophie, including a weekend day once every two weeks, and twice a week at Terrebonne. For each count, a subsample of birds was tallied to determine the proportion of each species of gulls and their proportion of time spent feeding (Altmann, 1974). We tallied 29 days of observation at each site. At Ste-Sophie, we limited our analysis to periods with culling.

The observation period was divided into three biological stages based on the breeding chronology of Ring-billed gulls at Deslauriers Island: (1) the nesting stage lasted from April 5th to May 14th and coincided with nest establishment, egg laying, and incubation; (2) the rearing stage took place between May 15th and June 25th and corresponded to the period when adults have to feed juveniles; and (3) the post-rearing stage from June 26th to August 7th concurred with the departure of the gulls from the colony when juveniles can feed by themselves.

Telemetry

In 2009 and 2010, we used GPS-tracking devices to determine how Ring-billed Gulls breeding on Deslauriers Island reacted when flying near the landfill sites. The gulls were captured and recaptured with nest traps or dip nets and fitted with 10-15 g GiPSy-2 data loggers (Technosmart, Italy) that represented 2.8 ± 0.5 % of the body mass of the birds (485 ± 49 g). The loggers were attached on the two median rectrices with white TESA tape (no. 4651) and programmed to acquire locations (± 5 m) at 4-min intervals for 2-3 days. Animal handling methods were approved by the Institutional Animal Protection Committee of the Université du Québec à Montréal (No.646). Based on the maximum flying speed of Black-headed gulls (*Larus ridibundus*, 14.7 $m.s^{-1}$) and Lesser Black-backed gulls (*Larus fuscus*, 15.5 $m.s^{-1}$) (Shamoun-Baranes & Van Loon, 2006), which are respectively slightly smaller and larger than Ring-billed gulls, we calculated that a gull could cover 3 – 4 km during 4 min and this exceeded the area covered by the landfills. We thus considered that a single location above a landfill site represented a bird that passed through without stopping whereas 2 or more locations represented a stopover that lasted 8 min or more depending on the number of locations. Only days with culling or weekends were considered at Ste-Sophie.

Statistical analyses

Bird use of the landfill sites was based on the mean daily numbers of birds computed from the repeated surveys. We assumed that each day was independent because the GPS-tracked birds did not return the following day to the visited landfill in 55% of the cases (n=20 trips), indicating a large turnover. The proportion of gulls feeding was calculated as the sum of the number of gulls feeding during the day divided by the total numbers of gulls observed that day. Numbers of pyrotechnics used per hour, the number of gulls present at the whole site and at the active tipping area and the proportion of gulls feeding were analyzed with ANOVAs including deterrence program and biological stage as independent variables. The effect of the daily period was tested using one-way ANOVAs. Count data were transformed with square roots to respect normality whereas an angular transformation was applied to proportions. T-tests and Tukey's Honestly Significant Difference tests (Tukey's HSD) were used to check for differences between each pair of means. The proportion of foraging trips that resulted in a stopover at each landfill was analyzed with a χ^2 test while the duration of the stopovers was compared with a *t* test. The difference in the number of bird-days between the first and last year of the surveys at each site was tested with Mann-Whitney U tests. Analyses were completed with JMP® 9 of SAS Institute Inc. and the statistical level of significance was established at 0.05. All means are presented ±SE.

2.3 Results

Deterrence effort

In 2010, the number of pyrotechnics used per hour to supplement the main deterrence technique was significantly greater at Terrebonne for the falconry program ($F_{1, 152} = 10.64$; P =0.001; Fig. 2.1) and during the rearing stage ($F_{2, 152} = 25.39$; $P < 0.001$). There was no interaction between these two factors. The difference in the use of pyrotechnics between the two deterrence programs was observed only during the rearing stage. For the falconry program, the use of pyrotechnics was more than three times greater during brood rearing that during the first and last stage. There was no seasonal difference for the culling program.

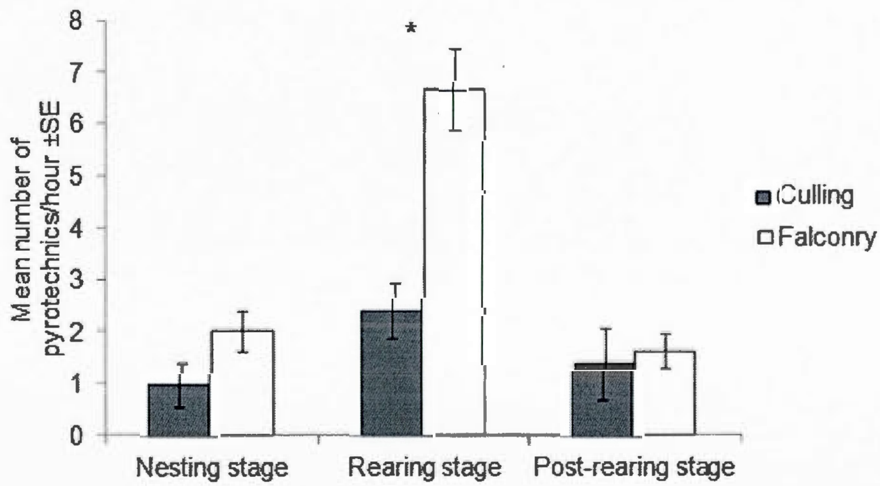

Figure 2.1: Mean (± SE) number of pyrotechnics used per hour in the culling and falconry programs to deter gulls from using the landfill sites at Ste-Sophie and Terrebonne, respectively, 2010. * P < 0.05.

At the Ste-Sophie landfill, a total of 180 gulls were culled over the 32-day trial period for a mean of 5.6 ± 0.4 per day. Juveniles began to be culled on June 24th, shortly after the first birds fledged from Deslauriers Island. They represented 15 % of the total number of birds killed. During the culling program, an average of 19 steel rounds was used per day. At the Terrebonne landfill, 10 gulls were caught by the trained birds of prey over 124 days for an average of 0.1±0.02 dead gull per day. The falconry program thus resulted in 56 times less gulls being killed.

Gull use of the landfills

Both deterrence programs resulted in a significant decrease in gull use at the landfills (Fig. 2.2). The overall use of the Ste-Sophie site decreased by 77% between 2004 and 2010 ($Z = 6.81$, $P < 0.001$) despite the fact that the regular culling program only began in 2007. A much important decline (99%) was observed at the Terrebonne site where falconry has been used since 1995 ($Z = 13.24$, $P < 0.001$). The decline was notably accentuated in 2005 and onwards when more falconers were involved and when operating hours were extended from dawn to dusk including week-ends.

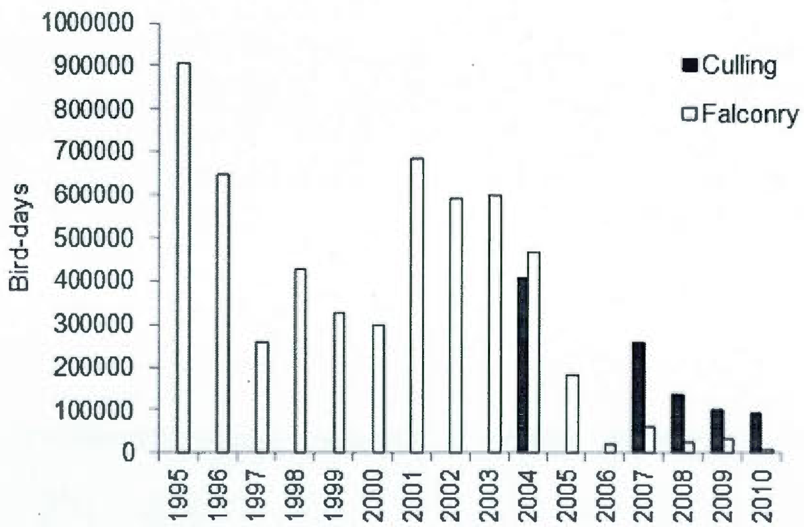

Figure 2.2: Use of the Ste-Sophie (2004, 2007-2010) and Terrebonne (1995-2010) landfill sites by gulls (Bird-days =∑daily maximum from April 1st to August 31th).

In 2010, Ring-billed gulls represented 94% of the gulls present at the landfills between April 1st and August 31st with no major difference between sites. Other gull species included Herring gulls (*Larus argentatus*) and Great Black-backed gulls (*Larus marinus*), which become increasingly more important as fall progresses (E. Thiériot and P. Molina, unpubl. data).

There were fewer gulls using the landfill site with the falconry program and this was true during all three stages ($F_{1, 54} = 50.43$, $P < 0.001$; Fig. 2.3a). The mean number of gulls was greater during the rearing stage at both sites ($F_{2, 54} = 6.06$, $p = 0.004$). There was no interaction between the two factors, indicating that the relative effect of the programs was similar throughout the breeding season. At Ste-Sophie, the mean number of gulls also depended on the daily period ($F_{2, 26} = 8.61$, $P = 0.001$). More gulls were present after 15:00 (582±108 gulls/day) when culling activity had ceased compared to morning (181±36 gulls/day) or mid day periods (225±44 gulls/day). There was no difference between the daily periods at the site with falconry ($F_{2, 26} = 1.45$, $P = 0.253$).

Very few gulls used the active tipping area at the landfill site with the falconry program compared to the other site and the difference was significant for the first two stages ($F_{1, 52} = 29.87$, $P < 0.001$; Fig. 2.3b). The mean number of gulls also varied according to biological stages ($F_{2, 52} = 5.31$, $p = 0.008$) but there was a significant interaction between programs and stages ($F_{2, 52} = 5.45$, $p = 0.007$). The biological stage had no effect at Terrebonne under the falconry program whereas there were more gulls at the tipping area at Ste-Sophie during the rearing stage. The mean number of gulls using the active tipping area also depended on the daily period at Ste-Sophie ($F_{2, 26} = 10.71$, $P = 0.000$). More gulls were present after 15:00 (283±78 gulls/day) compared to morning (48±13 gulls/day) or mid day periods (41±12 gulls/day). At Terrebonne, there was also a difference ($F_{2, 26} = 5.16$, $P = 0.01$) between morning (3±2 gulls/day) and mid day periods (16±4 gulls/day) but there was no difference between morning and evening (6±2 gulls/day) or between mid day and evening.

The proportion of gulls feeding on garbage was much higher under the culling program than with falconry but was globally low ($F_{1, 52} = 34.81$, $P < 0.001$; Fig. 2.3c). It varied according to biological stages ($F_{2, 52} = 5.75$, $p = 0.006$) in interaction with the programs ($F_{2, 52} = 6.91$, $p = 0.002$). The biological stage had no effect at Terrebonne where <1% of the birds were seen feeding. At Ste-Sophie, a greater proportion of gulls were able to feed during the nesting and rearing stages than later in the season. The proportion of gulls feeding on garbage also varied with the daily period at Ste-Sophie ($F_{2, 26}$ = 10.77, P = 0.000) with a greater percentage after 15:00 (27±6 %) compared to morning (6±2 %) or mid day periods (4±2 %). There was no difference between the daily periods at the site with falconry ($F_{2, 25}$ = 1.50, P = 0.243).

Foraging trips

Twenty-two individuals were tracked during 41 foraging trips from the Deslauriers colony towards the Terrebonne (n=28) and Ste-Sophie site (n=13). This represented 18.0% of the 122 gulls tracked during the study and 8.2% of the total number of foraging trips (n=418). At Terrebonne, 7 trips (25%) resulted in a stopover that lasted 22±7 min. This was significantly less frequent and of shorter duration than the 11 trips (85%) with a stopover at Ste-Sophie that lasted 63±15 min (Frequency: χ^2 = 13.57, P < 0.001; duration: $t_{1, 16}$ = 2.54, P = 0.024). At Ste-Sophie, the 3 trips that took place during week-ends all resulted in a stopover, whereas 5 out of the 8 stopovers recorded during week-days occurred before or after the working hours of the deterrence employee.

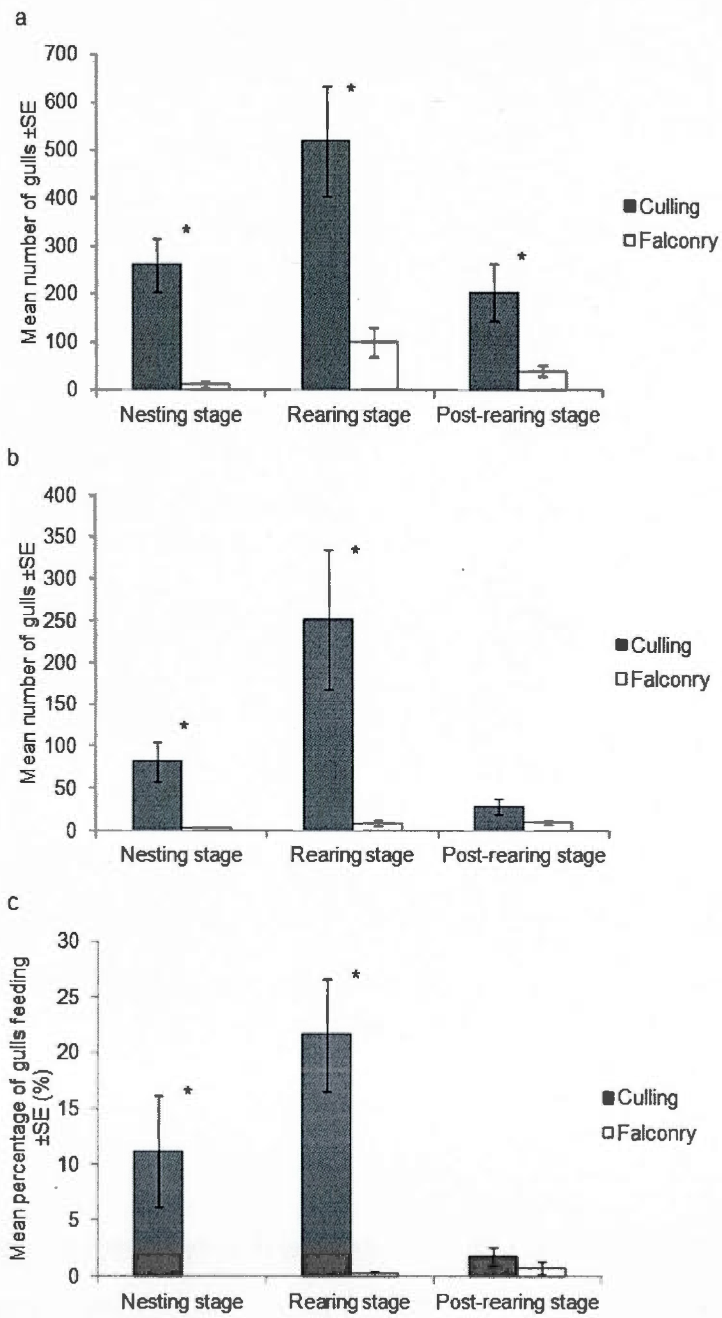

Figure 2.3: Use of the landfill sites of Ste-Sophie (culling program) and Terrebonne (integrated falconry program) by gulls during three biological stages, 2010. * $P < 0.05$. **a:** Mean (± SE) number of gulls present at the whole site. **b:** Mean (± SE) number of gulls present at the active tipping area. **c:** Mean (± SE) percentage of gulls feeding.

2.4 Discussion

The two deterrence programs were successful in reducing the number of gulls at landfills. However, because they differed both in methods and intensity, any direct comparison between the two programs must be made with caution. Moreover, the lack of control sites without any deterrence activities limits the scope of our study. Two other landfills with no deterrence programs were visited by the gulls tracked from the Deslauriers Island, but these sites were located at 42 and 64 km from the colony, which is much further that the studied landfills (8 and 37 km). In addition to distance, the amount of refuse brought to the landfills and the specific objectives set at each site in terms of the tolerable number of gulls would dictate the effort of each deterrence program. For instance, increasing the effort of culling at Ste-Sophie to a level comparable to the program used at Terrebonne with falcons could have resulted in fewer gulls using the site. However, this would have implied a much greater number of dead birds which might be ethically unacceptable increasing the difficulty to obtain a permit. Despite these limitations, we are confident that our results can be used by landfill managers.

The falconry program as performed at the Terrebonne landfill, succeeded in reducing the number of gulls to a level that was acceptable for both the site employees and the residents leaving at proximity. The number of bird-days decreased from over 900,000 in 1995 to only 10,000 in 2010. While the number of gulls nesting at the Deslauriers colony remained stable during this period, the amount of refuse brought to the site increased by nearly 50%. The decline of the landfill use by gulls was even more noticeable after 2005 when the number of falconers and the time devoted to deterrence activities were increased. We believe that the success of the falconry program can be explained by the limited opportunity (< 1%) for the gulls to feed on refuse at the Terrebonne site despite its greater attractiveness. It is located closer to the colony and receives on an annual basis more than 1.5 times as much refuse than the Ste-Sophie site. The difficulty for gulls to obtain food at Terrebonne is also shown by the smaller proportion of foraging trips that resulted in a stopover and the shorter duration of these stops. Tracking individuals to evaluate the effectiveness of deterrence programs has never been used but our results demonstrate the potential of this approach.

Here we show that gulls use landfill sites to a greater extent during the rearing season when they have to travel back and forth to the colony to feed their juveniles. More gulls were observed during this period at the tipping area at Ste-Sophie where they spent more time feeding, especially before and after the working hours of the deterrence employee. At Terrebonne, the number of gulls was also greater during that stage but not at the tipping area. Reduced number of gulls was achieved by increasing the number of falconers and by maintaining the program during 7 days a week even if garbage were not brought to the site on Sundays. During this critical period, the number of pyrotechnics shot was also increased to supplement falconry, which was not the case at Ste-Sophie. This clearly shows the importance to adjust the intensity of the deterrence programs to seasonal variation in bird use and to maintain the measures from dawn to dusk.

The cost of each deterrence program needs to be considered to evaluate their effectiveness. More pyrotechnics were used in the integrated falconry program for an average cost of $452 CAD per week during the gull rearing stage (vs. $83 for the culling program). This cost was reduced to $109 per week during the nesting and post-rearing stage (vs. $44 for the culling program). Steel ammunitions for culling averaged $59 per week. The overall cost of the culling program including the wage of an unspecialized employee, the material, and vehicle is estimated at $1,500 per week. In the integrated falconry program, the landfill hired a specialized company that charge between $250 and $800 per day, which cover the cost of maintaining the birds of prey, the specialized employees' salary, the scaring material, and vehicles. The total cost of a whole program will obviously vary with the number of deterrence employees and the number of operation days per week but can vary between $1,250 per week when gull abundance is lower to $4,000 during the rearing period. Although the use of falconry may appear more expensive than culling, the results in reducing gull use of a site may warrant the expenses. This is especially true when the landfill is located near a colony, in urban or suburban settings or in the vicinity of an airport. In other situations, where a certain number of birds can be tolerated, a less expensive technique like culling could be considered.

From an ethical point of view, an integrated falconry program is more acceptable than culling because it leads to less birds being killed. In North America, gulls are protected under the Migratory Birds Convention Act and control measures like culling requires a permit. Although the killing of gulls may not be an issue and may even be requested by people leaving near a landfill, this may not be the case for a majority of citizens (Moreau, 2012). Groups opposing to the killing of animals to control nuisance species are increasing and better organized with a greater impact on politicians (Conover, 2001; Decker & Brown, 2001). Wildlife services responsible for issuing permits may thus become more reluctant to allow culling as a deterrence method. Moreover, it might be more difficult to obtain permits to cull species other than Ring-billed Gull such as Herring, Great black-backed or Glaucous Gulls (*Larus hyperboreus*) that are more abundant at landfills in late fall and winter. Falconry is thus an interesting alternative that gets better public perception (Baxter & Robinson, 2007). It can even be used by landfill managers as an advertising and educational tool. In any cases, monitoring of the site in terms of bird use should be conducted before the beginning of the program and while it is performed to allow adjustments.

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CONCLUSION

Nous avons montré que le tir de billes de caoutchouc n'était pas efficace pour dissuader les Goélands à bec cerclé de fréquenter les lieux d'enfouissement technique. Cette méthode d'effarouchement, si utilisée comme durant notre expérience, ne pourra donc pas servir d'alternative à l'abattage même si elle est considérée plus éthique. Des expériences additionnelles pourraient être réalisées afin d'évaluer des améliorations potentielles telles que l'augmentation sonore de la détonation et l'exposition d'une carcasse de goélands (leurre). La fauconnerie demeure donc la seule méthode éthique efficace grâce à l'utilisation de prédateurs naturels (Baxter et Robinson, 2007; Soldatini *et al.*, 2008). En effet, même si les oiseaux de proie sont dressés à attraper les goélands, ils échouent souvent à les capturer.

Le programme intégré de fauconnerie du LET de Terrebonne s'est avéré plus efficace que l'abattage sélectif utilisé au LET de Ste-Sophie à court et long terme. Ceci résultait de la quasi impossibilité pour les goélands de s'y nourrir, et ce du lever au coucher du soleil, sept jours par semaine. Il est donc essentiel de ne laisser aucune fenêtre temporelle où les oiseaux peuvent se poser et se nourrir. Nos résultats montrent aussi que l'effort d'effarouchement doit être adapté aux variations saisonnières des effectifs de goélands et de leurs besoins alimentaires afin de ne pas diminuer l'effet du programme mis en place. En ce sens, la période d'élevage des jeunes constitue la période la plus critique. Pour la colonie de l'Île Deslauriers, les premières éclosions ont lieu aux alentours du 10 mai. La date où les jeunes les plus tardifs quittent la colonie varie selon les années, s'échelonnant entre la dernière semaine de juillet et la première semaine d'août pour les saisons plus tardives ou avec de la renidification comme en 2011 (F. Lagarde, données non publiées).

À long terme, la fréquentation des deux sites par les goélands a diminué graduellement avec les années, soulignant l'importance des plans d'aménagement prévus à long terme avant d'atteindre l'objectif d'un site sans goéland. Nous pouvons ajouter, de façon spéculative, que la diminution de l'accessibilité aux LET depuis la mise en place de ces programmes d'effarouchement peut expliquer la stabilisation de la population de Goélands à bec cerclé de la région de Montréal, après son augmentation exponentielle observée dans les années 80 quand l'enfouissement des déchets était peu règlementé (Service Canadien de la Faune, données non publiées).

Les LET sont des sites d'étude idéaux pour évaluer les méthodes d'effarouchement, car ils sont très attractifs pour les goélands (Soldatini *et al.*, 2008). Tester les méthodes d'effarouchement dans ces conditions permet de bien distinguer les différences d'efficacité. Ceci permet aussi d'établir une méthode efficace pour les circonstances les plus difficiles, donc de pouvoir prescrire cette méthode pour des cas d'effarouchement dans des sites moins attractifs. Ainsi, les résultats obtenus ici pourront être applicables dans les aéroports utilisés par les goélands comme aires de repos mais moins attractifs de par l'absence de déchets comestibles (Dolbeer, 1998; Sodhi, 2002). Il est essentiel d'établir les bases d'un effarouchement efficace dans les aéroports, mais surtout dans les LET qui, lorsqu'à proximité d'un aéroport, augmentent les risques de collisions entre les avions et les groupes d'oiseaux (Baxter, 2000).

Plusieurs facteurs doivent être pris en compte dans la mise en place et dans le choix d'un programme d'effarouchement. Les gestionnaires de LET doivent fixer leur objectif, soit le nombre de goélands acceptable sur le site en fonction de la localisation du site par rapport aux zones résidentielles, de l'investissement financier possible et de l'éthique. L'aspect financier est important pour le gestionnaire mais aussi pour les contribuables. En effet, un coût important de l'effarouchement se verra sans doute répercuté sur le prix d'enfouissement chargé aux municipalités. Les taxes des citoyens pourraient alors augmenter. Quant aux considérations éthiques, elles doivent elles-mêmes tenir compte du statut de la population d'oiseaux et de la perception du public quand à cette espèce et aux techniques utilisées.

Idéalement, nous aurions comparé de façon expérimentale les trois méthodes évaluées durant notre étude soit l'abattage sélectif, l'utilisation des billes de caoutchouc et la fauconnerie à chacun des deux sites afin d'avoir au moins une réplication du protocole. Cependant, les contraintes légales et publiques liées au décret autorisant l'enfouissement des matières résiduelles au site de Terrebonne n'ont pas permis la mise en place de périodes témoins sans effarouchement ni l'utilisation d'autres méthodes que la fauconnerie même pour de courtes périodes. Au site de Ste-Sophie, un protocole complet avait été autorisé mais le service des fauconniers n'a pu être maintenu pour des raisons logistiques hors de notre contrôle. Nous avons donc simplement pu observer le programme de fauconnerie tel que mis en place habituellement à Terrebonne et comparer expérimentalement le tir de billes de caoutchouc et l'abattage à Ste-Sophie pour atteindre les objectifs fixés au début du projet.

Cette situation n'est pas idéale pour la comparaison à court et long terme des programmes de fauconnerie et d'abattage effectuée dans le chapitre 2. L'intensité des deux programmes étant très différentes, il est impossible de dissocier l'effet de l'effort fourni de l'effet de la méthode utilisée. Cependant, nous avons montré une plus grande efficacité du programme de fauconnerie au site de Terrebonne qui est plus attractif pour les goélands en raison d'une quantité plus grande de déchets et de sa plus grande proximité à la colonie de l'île Deslauriers que le site de Ste-Sophie. La distance entre la colonie et les deux LET est facilement parcourue par les goélands en quête de nourriture durant la saison de reproduction. Par contre, les goélands nichant sur cette colonie effectuent la majorité (75%) de leurs trajets d'alimentation dans un rayon de 20 km autour de la colonie (M. Patenaude-Monette, communication personnelle) ce qui inclue le site de Terrebonne (8 km) mais non celui de Ste-Sophie (37 km). La différence d'efficacité entre les deux programmes d'effarouchement est possiblement biaisée par les caractéristiques intrinsèques de chaque site, mais la tendance observée est fiable.

Enfin, la présence jugée nuisible des goélands dans les LET est avant tout un fait de la gestion des déchets humains. Une meilleure gestion des matières résiduelles par le recyclage et le compostage réduirait la présence de grands groupes d'oiseaux dans les LET où se concentrent tous les déchets des grands centres urbains comme Montréal. Il sera intéressant de voir quel impact aura la nouvelle politique québécoise de gestion des matières résiduelles sur la fréquentation des LET par les goélands dans les années à venir. Le plan d'action 2011-2015 prévoit en effet la revalorisation de 60% de la matière organique putrescible résiduelle d'ici fin 2015, pour les bannir totalement des LET en 2020. Seulement 12% des restes de tables et de résidus verts municipaux étaient valorisés en 2008 (MDDEP, 2011). La diminution importante des déchets comestibles dans les LET devrait réduire l'attrait des goélands, et par là l'effort d'effarouchement à fournir. Nous pensons que l'impact anthropique sur la population de Goélands à bec cerclé de la grande région de Montréal, probablement fortement minimisé par les programmes d'effarouchement, sera complètement éliminé lorsque l'enfouissement des matières putrescibles sera interdit. Sans sites où se concentre la nourriture, les groupes de goélands seraient moins denses, et l'attrait des régions urbaines pour les goélands moindre, réduisant ainsi les problèmes connexes de cohabitation avec les humains.

ANNEXE A

ÉVOLUTION DU PROGRAMME DE FAUCONNERIE INTÉGRÉE PRENANT PLACE AU LIEU D'ENFOUISSEMENT TECHNIQUE DE TERREBONNE

Année	Début-Fin	Jours/sem.	Heures/jour	Nombre de fauconniers sur le site	Nombre d'heures d'effarouchement /an
1995	8 mai – 1er déc.	5	8 - 12	1	1225
1996	1er avr. – 13 déc.	5	8 - 12	1	1225
1997	14 avr. – 12 déc.	5	8 - 12	1	1225
1998	12 avr. – 23 oct.	5	8 - 12	1	1225
1999	1er avr. – 30 nov.	5	8 - 12	1	1225
2000	3 avr. – 22 nov.	5	8 - 12	1	1225
2001	2 avr. – 21 nov.	5	8 - 12	1	1225
2002	1er avr. – 21 nov.	5	8 - 12	1	1225
2003	1er avr. – Nov. 13th	5	8 - 12	1	1225
2004	3 mai – 11 nov.	5	8 - 12	1, ou 2 en périodes d'abondance	1246
2005	4 avr. – 31 déc.	6	Lever au coucher du soleil depuis juin	2 en semaine et 1 les Samedi	2692
2006	1er janv. – 31déc.	7	Lever au coucher du soleil	2 en semaine et 1 les fins de semaine, 3 en périodes d'abondance	5489
2007	7 fev. – 31 déc.	7	Lever au coucher du soleil	2 en semaine et 1 les fins de semaine, 3 en périodes d'abondance	4568
2008	8 janv. – 30 déc.	7	Lever au coucher du soleil	2 en semaine et 1 les fins de semaine, 3 en périodes d'abondance	5056
2009	2 mars – 31 déc.	7	Lever au coucher du soleil	2 en semaine et 1 les fins de semaine, jusqu'à 4 en périodes d'abondance	4475
2010	1er mars – 31 déc.	7	Lever au coucher du soleil	2 en semaine et 1 les fins de semaine, jusqu'à 5 en périodes d'abondance	4786

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