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Hitchhiking Bats on the Great Lakes of North America

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HITCHHIKING BATS ON THE GREAT LAKES OF NORTH AMERICA

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ABSTRACT

Bats can act as potential vectors for various zoonotic diseases and other pathogens. Therefore their interactions with people should be examined to mitigate potential risks. Bats are small flying mammals and hide in small crevices during daylight hours, making them difficult to observe. Consequently, they have a capacity to “hitchhike” on ships to be dispersed over large distances.

This study focused on anthropogenic unintentional bat translocations, i.e. hitchhiking bats. The study area is the Great Lakes region in North America. Using a web-based questionnaire survey, I asked the public about the frequency of bat-human encounters on ships, their nature, and perceived risks and incidents.

I found that bats are commonly seen by people working on ships at the Great Lakes. Bats do not cause trouble other than scaring people. Based on photographic evidence, at least one bat was seen on a ship outside of its native range. Therefore ships might act as vectors, helping bats to disperse to new areas. This might provide pathways for pathogens to spread along, from bats to bats or from bats to humans.

The risks related to hitchhiking bats seem to be rather limited. Rabies risk is the most obvious, but no cases of sailors getting rabies infections from bats were acknowledged. The possibility of ships translocating bats infected with *Pseudogymnoascus destructans* remains unknown.

This study demonstrates how by engaging the public it is possible to gather novel scientific knowledge, and deepen our understanding about the relationship between man and wildlife. There are numerous hidden ways of how people interact with animal species. This study illuminates one of these ways, but many more are yet to be studied.

1. INTRODUCTION

Previous studies have determined that bats often use manmade structures for roosting or hiding (f.e Kunz & Reynolds 2003, Lausen & Barclay 2006), but there have been no systematic studies regarding their use of transportation structures (e.g., ships, trains) that might affect their behavior or dispersal. Bats have been reported on ships quite a few times (Constantine 2003). This study aims to fill this gap and provide the first systematic study of bats moved large distances by human structures, or “hitchhiking” bats.

Why hitchhiking bats? Bats are hosts for a vast array of different pathogens, of which some can infect bats (e.g. White-Nose Syndrome; Blehert et al. 2009) and others which can also affect humans (e.g. rabies; Wong et al. 2007, Constantine 2009). The focus of hitchhiking organisms on ships is not original. Myers (1934) surveyed invertebrates present on a ship, listing 41 species, and also observed some birds on board as well. Myers stated that this phenomenon, which he called ‘insect tourism’, can be dangerous, as it can help harmful species to move to new locations undetected. The role of global transport in the unintentional transmission of living organisms has gained more recognition and popularity since Myers’s publication, and it is well known in some cases, such as Dutch Elm Disease and Emerald Ash Borer (Herms et al. 2004). These unintentional translocations have caused a lot of negative environmental and economic impacts, which could not be foreseen at the time. While it is impossible to foresee these impacts with 100 % certainty, identifying potential risk of translocations will aid in efforts to avoid them.

This study will quantify the frequency and specifics of bat observations by sailors in the Great Lakes region. Gaining knowledge of this relationship between humans and wildlife can help us to recognize potential hazards, risks and translocation pathways. The Great Lakes region is a heavily sailed, economically important region in the North America. It was chosen to be the study area of this thesis for its economic and cultural importance.

Bats can carry various diseases, some of which affect only bats themselves. If there are a lot of bat-human encounters on the ships, it might pose a rabies risk to the sailors. Also, if bats are frequently hitchhiking, it might provide possibilities for pathogens to spread, of which the most notorious in this area is the White-Nose syndrome. As White-Nose syndrome is wiping out bat populations in North America, it is urgent to study bats now while they are still present in the Great Lakes region. After a regional collapse in bat populations, it will be difficult to determine their extent of translocations by ships. Also, if it is possible to provide baseline data on bat observations, monitoring the frequency of bat sightings on ships in the coming years might help to illuminate the state of bat populations in the region.

2. OBJECTIVES

The general objective of this study is to enhance our understanding of anthropogenic translocations of animals, with a focus on bats. This was approached with a questionnaire survey, targeting people working on ships sailing in the Great Lakes.

I chose three focus points in this study: animal dispersal in general; bat dispersal specifically; and zoonotic diseases.

3. BACKGROUND

3.1 Animal dispersal

Animals can move to new areas in a variety of different ways (Udvardy 1969). In this thesis the focus is not on natural dispersal, but on human-influenced animal translocations. Therefore the natural ways of dispersal will not be discussed at great length.

There are a few terms suggested for human-influenced animal translocations. Udvardy (1969) calls these events as 'anthropochore dispersal', while Heinsohn (2003) talks about 'ethnophoresy'. Translocation also describes a method used in nature conservation (Seddon et al. 2012). Constantine (2003) uses the term 'translocation' when he discusses how people have moved bats from one place to another, intentionally or unintentionally. The IUCN (1987) defines translocation as 'the movement of living organisms from one area with free release in another'.

Because of the multitude of different terms used in the literature, for clarity the word 'translocation' is used in this thesis to describe the act of human moving living animals from a place to another, intentionally or otherwise. This gives clarity for the reader and the writer alike, and hopefully helps to avoid unnecessary confusion.

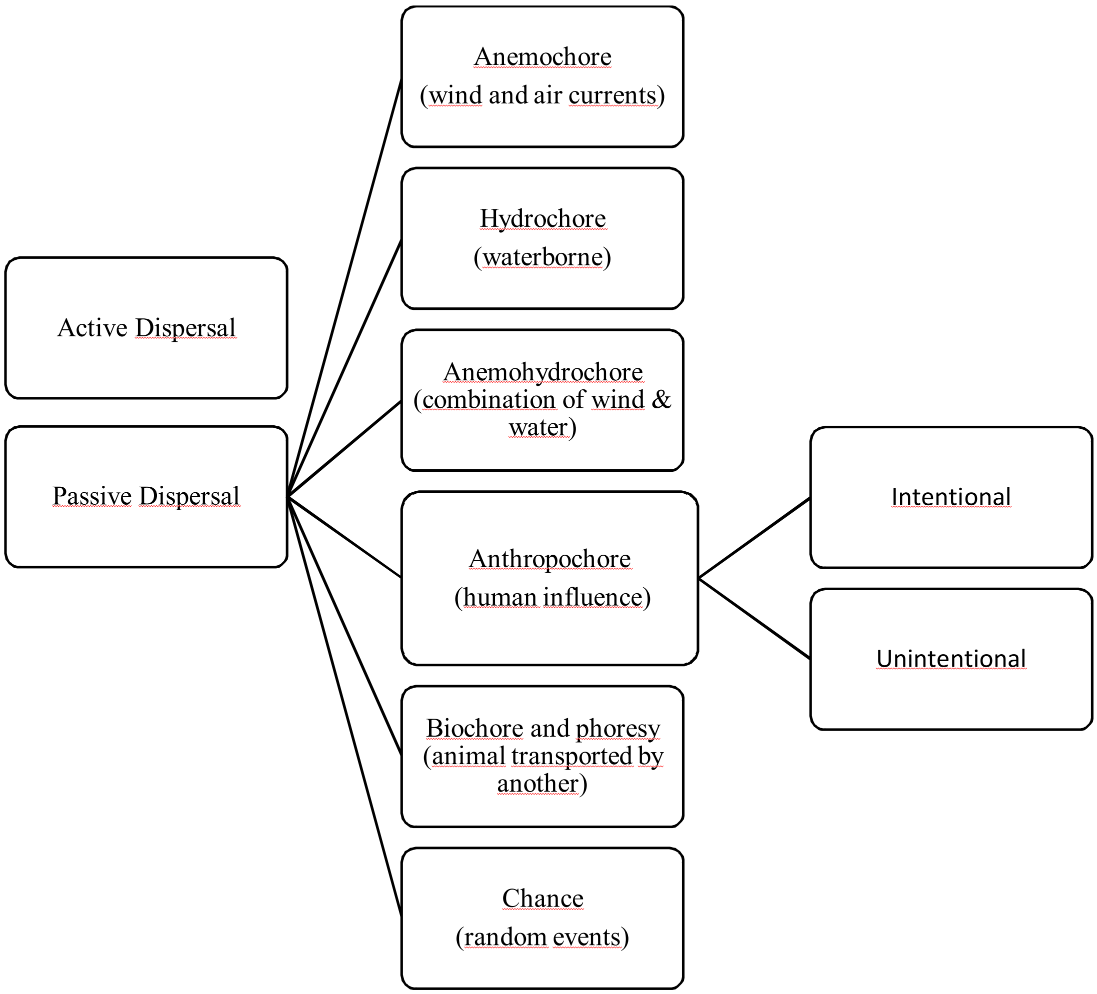

Figure 1. Different routes of animal dispersal after Udvardy (1969)

Udvardy (1969) divides animal dispersal into two main categories: active and passive (Fig. 1). The human-influenced translocations are classified under the passive dispersal section, as humans are the active component, and animals are often just passengers. This is further divided into two categories: intentional and unintentional. Intentional translocations can be conducted for example for nature conservation purposes (Seddon et al. 2012). In this thesis the focus is on unintentional translocations, as hitchhiking bats are often surprising for the people who happen to find them, and they are on board accidentally.

Animal translocation is not a new phenomenon, as people have always moved organisms when they have settled to new areas (Udvardy 1969). These organisms include e.g. the intentional translocations of domestic and otherwise useful animals and plants, but also the unintentional translocations of human bacteria, parasites, and other harmful and possibly unwanted animal or plant species. During the 1900s, global transportation became faster and spanned longer distances, and the pathways multiplied exponentially. This provided more opportunities for accidental translocations of all kinds of organisms (Udvardy 1969, Tatem et al. 2006).

Table 1. Types of human influence on zoogeography according to Heinsohn (2003)

Human influence on zoogeography
▪ Human-induced habitat modification
▪ Direct or indirect human-induced decline / extinction of animal species
▪ Translocation of pathogens
▪ Co-evolution and domestication
▪ Unintentional or deliberate animal translocation by human agency (ethnophoresy)

Heinsohn (2003) has a broader view on human influence on zoogeography. He includes a multitude of ways that humans can affect the geographical range of animals, and also mentions translocations of pathogens with the animals. For example, in the United States thousands of bats were transported for over 1500 km from their original sites for military research during the Second World War. Constantine (2003) claimed that this possibly introduced rabies to new areas. Naturally if the bats are translocated unintentionally, pathogen monitoring may be impossible to conduct. Therefore, unintentional bat translocations always possess the risk of introducing pathogens to new areas.

Conversely, McCallum and Dobson (2002) argued that usually increased movement and connectedness of populations and habitats is beneficial for species when dealing with

infectious diseases. However, McCallum & Dobson (2002) did not examine White-Nose Syndrome (and could not, as the disease was not known when they did their work). White-Nose Syndrome represents a case in which more connectedness might cause more trouble. For this reason, Park (2012) extended McCallum & Dobson's (2012) model to include other factors (such as environmental transmission). The causative agent (*Pseudogymnoascus destructans*) of White-Nose Syndrome can persist at sites for years even without bat hosts (Hoyt et al. 2014). Therefore, more connectedness and increased movement between bat populations might be harmful for them, if White-Nose Syndrome is present in the region.

3.2 Invasive Alien Species

Unintentional translocations cannot be discussed without mentioning the problems associated with invasive alien species. These species are, as the name suggests, invasive and their origin is somewhere else than where they are causing trouble. Charles Elton wrote a book called "The Ecology of invasions by animals and plants" in 1958, in which Elton criticized the state of zoogeographical science at the time, and put the phenomena of "ecological explosions" under a magnifying class. Fortunately this terminology that he used did not last, but his work and book had a great impact on the study of invasive alien species. In his book he mentions that before writing and publishing his book, he knew only of one review article about the topic, which was written by Bates (1956). These species have gained quite a lot of attention, as people have awakened since Elton's times to the problems they cause.

The Great Lakes region is heavily affected by global and local waterborne transport activities, and this can be seen in the vast variety of alien species that can be found in the region (e.g. Mills et al. 1993, Snyder et al. 2014). A lot of this work has concentrated on the risk of introductions that international vessels pose, but domestic vessels can also carry potential invaders, particularly aquatic species (Briski et al. 2012, Adebayo et al. 2014).

Within the global transportation network, unintentional translocations can introduce new harmful species to a multitude of locations. However, bats' potential for being invasive is considered to be quite low, and even intentional translocations for conservation have failed (Ruffell et al. 2009). Therefore it is quite unlikely that a few accidentally translocated bats might become invasive. What might become invasive or cause trouble is their pathogens.

Of the pathogens that bats can carry, the most harmful and scary for humans are the rabies virus (Constantine 2009) and the Ebola virus (Swanepoel et al. 1996). Bats can also carry diseases which do not cause harm for humans, but can be very harmful for bats. This can be seen in the infamous case of the White-Nose Syndrome, which is thought to have its origins in Europe, and it somehow got introduced to North America (e.g. Blehert et al. 2009). The pathway of the introduction is not known, although there is speculation that it was a common bat cave tourist or researcher in both Europe and North America, via their clothing (Puechmaille et al. 2011).

The possibility of hitchhiking bats introducing the disease to novel areas was mentioned by Wright & Moran (2011), who discussed the introduction of the disease to Alaska. Voute (1982) was the first to document a bat hitchhiking a ride across the Atlantic. Transatlantic freighter traffic is very frequent, and if infected bats are translocated, they pose a risk of spreading the disease to new areas.

3.3 Bats

Bats (Chiroptera) represent approximately 20 % of the world's mammalian species, and are present on all continents but Antarctica, so they can be encountered almost anywhere (Teeling et al. 2005).

According to the IUCN database, there are 10 bat species with a geographical range that either includes or is connected to the Great Lakes (www.iucnredlist.org/search). These

species are temperate bat species. Table 2 was constructed based on the database's information about the geographical range of North American bat species. This table only includes species with a range that either includes or is restricted by one or more of the Great Lakes. The determination was conducted by visual analysis. Some of the states or provinces might have more bat species, but with ranges unconnected to the lakes. However, it is possible that also these species sometimes are seen at the lakes, or at least close to them.

Some of these species are considered migratory (*Lasiurus cinereus* in Shump & Shump 1982, Tuttle 1995; *Lasiurus borealis* & *Lasionycteris noctivagans* in Cryan 2003), but it is possible that some individuals of these migratory species can hibernate in leaf litter, and survive the winter without migrating long distances (*L. borealis* in Mormann et al. 2004). The migration status is not fully clear on the Indiana bat (*Myotis sodalis*) and Tri-colored bat (*Perimyotis subflavus* [Previously known as Eastern pipistrelle, *Pipistrellus subflavus*]) (Kurta & Murray 2002, Fraser 2013).

Kurta & Murray (2002) suggested that Indiana bats can migrate ~400 km between winter and summer sites, but it is possible that not all individuals migrate. Fraser (2013) stated that some Tri-colored bats might be migratory, and that this is most likely sex-dependent, where the males would be migratory more often than the females.

The other species in this region are not generally considered migratory, even though some of these species can travel long distances and cover vast territory during the year. For example, Little brown bats (*Myotis lucifugus*) can have a range of up to 500 km from their hibernaculum (Sullivan et al. 2012).

Table 2. Bat species around the Great Lakes (Species data from The IUCN 2014, migration info from various sources [Shump & Shump 1982; Tuttle 1995; Kurta & Murray 2002; Cryan 2003; Fraser 2013], buoy detections from Lake Michigan by Brian Klatt [pers. comm.], roosting habits from a review by Kunz & Reynolds 2003 and Boyles & Robbins 2006, White-Nose Syndrome (WNS) disease status information from Blehert et al. 2009 and Bernard et al. 2015. Table constructed by author). Marker '*' indicates that the species is considered endangered

Scientific name	**Common name**	**Migratory**	**Buoy detection**	**Roosting habits**				**WNS status**
				Caves or mines	Buildings	Trees or foliage	Bridges	
Eptesicus fuscus	Big Brown Bat		Yes	x	x		x	Yes
Lasionycteris noctivagans	Silver-haired Bat	x	Yes			x	x	Fungus only, no disease
Lasiurus borealis	Eastern Red Bat	x	Yes			x		Fungus only, no disease
Lasiurus cinereus	Hoary Bat	x	Yes			x		No
Myotis leibii	Small-footed Myotis		No	x	x		x	Yes
Myotis lucifugus	Little Brown Bat		Yes	x	x	x	x	Yes
Myotis septentrionalis	Northern Long-Eared Myotis		No	x	x	x	x	Yes
Myotis sodalis *	Indiana Bat	(x)	No	x	x	x	x	Yes
Nycticeius humeralis	Evening Bat		No		x	x	x	No
Pipistrellus/Perimyotis subflavus	Eastern Pipistrelle/Tri-colored Bat	(x)	No		x	x	x	Yes

The "buoy detection" row in Table 2 indicates if the species has been detected on a buoy study by B. Klatt (2014, personal comm.). Klatt's research team placed a buoy with an echolocator on it out on Lake Michigan. They detected some bat species in the middle of the Lake, and these species are marked with a 'yes' in this row. They have not analyzed all the data yet (Feb 2015), but are doing so. Further analysis might reveal that more species are occasionally flying out on the lake. Most of the calls that they were able to identify were Eastern Red Bats, and the second most common calls were made by Silver-haired bats, followed by other species (Klatt 2014, personal comm.).

The "roosting habits" columns indicate where the bat species commonly roost. From the table it is clear that the bat species in this region use a large variety of roosting sites. Some of the species are more specific to certain sites, but some species might be considered as more generalist. For example, the Little brown bat (*Myotis lucifugus*) seems to roost about anywhere, whereas Eastern red bats (*Lasiurus borealis*) and Hoary bats (*L. cinereus*) only roost in tree crevices or foliage, based on the information reviewed in Kunz & Reynolds (2003). These differences in roosting habits and habitats might suggest why some bats are found on ships and others not, as some of the species are known to roost in manmade structures.

Roosting habits of all the species are not fully clear, and even though some individuals might be found in a multitude of different roosting sites, the bat species might prefer a certain type. For example, Northern long-eared myotis (*Myotis septentralis*) is considered to be a generalist in this manner, but Foster & Kurta (1999) stated that they prefer trees over other roosting sites, and are mostly found in trees. During the maternity period, especially the tree-favoring bats change roosting sites quite often (Foster & Kurta 1999).

The 'WNS status' row indicates if the White-Nose Syndrome has been detected in the species or not. It should be noted that out of the ten species present in the Great Lakes region, only two have seemingly been able to evade the fungus, at least according to current knowledge and published findings. The fungus has been detected in two other species, but with no pathological signs of the disease, nor mass mortality (Bernard et al. 2015). All the other species in the region are negatively impacted by the disease, causing

mortality (Blehert et al. 2009). This is of great concern when studying the bats in the region, as the disease can have a huge impact on bat populations.

Generally the seasonal behavioral patterns of these species are quite similar to each other, regarding mating and swarming (Langwig et al. 2015). The migratory species are usually more active during winter, when compared to the non-migratory species (Bernard et al. 2015). During the winter the bat species of the Great Lakes region mostly hibernate. The location of these hibernacula depends on the species, as some species like to hibernate in caves, and some use hollow tree crevices or foliage. During the hibernation period, bats are not hibernating all the time, as they “wake up” once in a while. These arousals account approximately for 1 % of the hibernation period, but 80 % of the energy expenses (Thomas et al. 1990).

During the spring and early summer after the hibernation, bats usually form maternity colonies where they give birth to new pups (Langwig et al. 2015). They spend the summer in these colonies, lactating and nursing the young. In the fall, bats usually swarm before the hibernation period, and this is when most of the species also mate (Langwig et al. 2015). Migratory species migrate usually during the spring and fall seasons (e.g. Tuttle 1995).

As an example of a migratory bat, Hoary bats (*Lasiurus cinereus*) are usually separated by sexes during the summer, during which the males are often not found in the areas where females are raising the pups. However, during the fall, the hoary bats gather in large groups, in which both sexes are found (Tuttle 1995). These groups can include hundreds of bats, and mating is believed to happen during flight in the fall season.

During the past few centuries, people have turned more wild habitats into human-controlled environments, which has brought bat habitats closer to humans. Manmade structures, such as mines, tombs, buildings, bridges etc. can serve as roosting habitats for bats (f.e Kunz & Reynolds 2003, Lausen & Barclay 2006). While the expansion of human civilization has caused harm to some wildlife species, some bat species might have actually benefitted from it by way of increased roosting sites (Davis et al. 1962,

Greenhall 1964, Kunz 1982). Lausen & Barclay (2006), studied colonies of Big brown bats (*Eptesicus fuscus*), and found that roosting in buildings versus rocks saves energy, which is a clear benefit. Other benefits were better juvenile growth, lower predation risk and earlier births. Kunz (1982) also mentioned other building-favoring factors, such as darkness, shelter from weather conditions and closeness to prey. In the context of this thesis, it is quite plausible that in case of ships, their bright lights might attract insects, which might in turn attract bats.

In England, Brown long-eared bats (*Plecotus auritus*) preferred buildings which were close to forests and water bodies, which suggests that feeding grounds are also an important factor when selecting a roosting site (Entwistle et al. 1997). Since ships are quite often close to forests (when being at the dock or near shore) and are on a water body almost all the time, it might be no surprise that bats can choose them as roosting sites sometimes.

If there is human and bat activity in these same locations, human-bat encounters are possible, which might represent an infection risk by pathogens which bats can host. Not only humans are in danger, but also their pets and livestock, which can be involved in some pathogen infections (Wong et al. 2007).

3.4 Zoonotics and zoonoses

Zoonotic pathogens are pathogens that can jump from an animal species host to humans or the other way around and cause a disease (when it is usually called anthroponotic), e.g. from birds to humans or from humans to frogs etc. (PAHO 2001). In their literature review, Woolhouse & Gowtage-Sequeria (2011) found that of 1407 identified human pathogens 58 % are zoonotic, and the pathogens that are considered as emerging or reemerging are twice more likely to be zoonotics than not. This emphasizes the importance of understanding zoonotics and their vectors.

These emerging and reemerging zoonoses are often associated with changes in land use, demographics and agriculture (Woolhouse & Gowtage-Sequeria 2005, Chomel et al. 2007, FAO 2011, Plowright et al. 2015). Therefore when considering disease and wildlife management, the human interface has to be taken into account, and a broader perspective should be used (FAO 2011). This multidisciplinary approach to zoonose and wildlife management, when interpreted widely, includes also accidental translocations.

While a wide variety of different vertebrate species can host zoonotic diseases, bats are considered as high-risk species. Firstly, they are the only mammals with true flying ability, which means that the geographical range of an individual animal is quite large (Wong et al. 2007). Secondly, they host a multitude of different pathogens, of which some are known to be zoonotic (Calisher et al. 2006). Thirdly, as they are small, fly, and prefer to roost in small nooks, they can potentially hitchhike on cargo ships and airplanes, and therefore move unnaturally fast from one environment to another, potentially transporting diseases to new areas (Constantine 2003). Due to these reasons, and to a few others, research about bats and their diseases has gained more attention in the recent years; especially microbes with zoonotic potential have been identified as an important topic (Mühldorfer et al. 2011).

According to Calisher et al. (2006), bats evolved very early in the history of the Earth, and due to this they share a lot of common basic biological elements with other mammals, such as cellular receptors and other biochemical pathways. These can enhance the spillover-capability of viruses that are associated with bats to other mammals.

There are a few additional biological and ecological characteristics that make bats susceptible virus reservoirs: high species diversity, longevity, vagility (long-distance traveling), roosting behavior in dense and large colonies, social behavior (greagariousness), hibernation, immunology and population structures (Barclay & Harder 2003, Calisher et al. 2006, Dimitrov et al. 2007).

An example of bats' vagility was demonstrated in a study by Ahlén et al. (2009) of the migration of Scandinavian bats. They found that bats can fly over 400 km over open sea

(distance from Gotland to German coast). This is not unique among bat species, as there are a few migrating species also in North America (Calisher et al. 2006).

A lot of bat species hibernate during the winter if they don't migrate to southern areas, and this can also contribute to their potential as hosts for viruses (Calisher et al. 2006). In their paper, Calisher et al. (2006) mentioned that because of low body temperatures during hibernation, bats' immune system might not work well enough to eliminate the viruses. Therefore the viruses can survive long times in bats, if they don't die from the infection, and meanwhile the infected bat can spread the virus.

The immunology of bats is still relatively under-studied compared to their abundance and special role as important pathogen reservoirs (Calisher et al. 2006, Wibbelt et al. 2010, Mandl et al. 2015). Wibbelt et al. (2010) mentioned several gaps in present knowledge, such as how the immune responses engage organisms and parasites. They also mentioned that because of White-Nose Syndrome (WNS) (see e.g. Blehert et al. 2009) bats' immune system is gaining more attention and research, which can be seen in the recent trend of bat immunology studies.

Baker et al. (2013) conducted a review about current knowledge of bats' immune system, but they concluded that further research is needed. In 2014, O'Shea et al. suggested that bats' ability to fly, linked to raised body temperature, might be behind their capability of acting as asymptotic hosts. However, they could not prove nor test their hypothesis, and suggested further research to be conducted.

Bats' long life spans can also contribute to their potential of transmitting zoonotic pathogens. Calisher et al. (2006) mentioned that the longest living Little brown bat (*Myotis lucifugus*) was 35 years old, and when taken into account that bats can be hosts for multiple pathogens asymptotically, an infected individual can have multiple opportunities to transmit the pathogens to other mammals during its life span.

Bats' roosting behavior is beneficial for the spread of pathogens, as some species like to roost in massive colonies in tight groups of bats, where there is frequent bat-to-bat contact (Kunz 1982, Calisher et al. 2006). If different species are using the same roosting

site, then it provides an opportunity for a cross-species infection. Also the dynamics between migratory and nonmigratory populations might affect the spreading dynamics of these diseases. If the virus survives in a non-migrating bat population, which is relatively stable and stays in the same location, which happens to be intersected with another species' migration pathway, then encounters between individuals of these populations might provide a way for the pathogen to spread. The virus can have a reservoir in the stationary bats, and then spread to new areas via the migrating bats.

3.5 Selected diseases associated with bats

3.5.1 Bat-associated zoonotics

Wong et al. (2007) found that there are at least 59 RNA viruses associated with bats. They stated that these might play an important role in the generation of emerging and reemerging infections in humans. The findings also give hints of the co-evolution of bats and some of these viruses and bats as their hosts. They also discussed that cross-infection between bat species might create new types of viruses. White-Nose Syndrome is not a zoonotic disease. It is also not a viral disease, but caused by a fungus (Lorch et al. 2011). It has devastated bat populations across Northeastern North America, and is therefore of great concern in the bat science community.

3.5.2 Viruses

Hantaviruses

There are many viruses belonging to this group, but the most interesting case is probably the Kaen Khoi virus. It was first found in 1969 from the Wrinkle-lipped free-tailed bat

(*Chaerephon plicata*) and Theobold's tomb bat (*Taphozous theobaldi*) in Thailand (Williams et al. 1976). The virus was also isolated from bedbugs (*Stricticimex parvus* & *Cimex insuetus*) that were collected from the same study sites (bat caves) (Williams et al. 1976). It is very likely that these bedbugs can act as vectors of this virus. According to Wong et al. (2007) it is possible that bedbugs can also cause an influenza-like illness in humans who collect bat guano. This emphasizes the importance of bats' parasites in the disease transmission between bats and humans, as no direct contact with bats was required in this case.

Coronaviruses

The most famous case of bat-derived coronavirus infection is the SARS epidemic, which was caused by the SARS-CoV virus (Wong et al. 2007). These viruses have diverse hosts, which was also the case in this epidemic. The first case of SARS was in 2002 in southern China, and the first patient was a chef who was working in a local restaurant where they also served wild game meat (Zhong et al. 2003). This suggested that the virus was a zoonotic one, as the outbreak apparently started at a wildlife market (Wong et al. 2007). Live animal retail markets in Shenzhen and Guangdong were sampled, and the virus was found in Himalayan palm civets (*Paguma larvata*), Chinese ferret badgers (*Melogale moschata*) and raccoon dogs (*Nyctereutes procynoides*) (Guan et al. 2003). The animal origin of the disease was further confirmed by Leung et al. (2005), when they found that people who had been working in close contact with wild animals had much higher probability of having SARS-CoV antibodies in their blood.

The Chinese authorities responded to these findings and restricted the sale and consumption of game animals during the epidemic (Wong et al. 2007). While the virus was firstly tightly linked to the Himalayan palm civets (since other animals were able to carry the virus without symptoms of infection), they were not the primary hosts of the virus (Wong et al. 2007). SARS-CoV was not commonly found in wild or farmed civets, so the researchers looked somewhere else for the primary reservoir. This was found in Chinese horseshoe bats at first, and then in other Chinese bat species (Lau et al. 2005).

This suggested that bats were the natural reservoir of the SARS-CoV, and the palm civets served as amplifying hosts, increasing the viral burden of the virus and providing a lot of opportunities for close contacts with humans (Wong et al. 2007). These contacts at the markets and restaurants would have been rather unlikely without the mid-vector, which in this case was the civet. While the SARS-CoV is a rather rare zoonotic virus, because unlike many others, it can spread from human-to-human contact, without the need of another animal host in between (WHO 2003). This increases the spreading potential, when compared to e.g. rabies, which is quite unlikely to spread between people.

Flaviviruses

This group of viruses is diverse, and their distribution is global (Wong et al. 2007). They are also important from a public health point of view, as some infamous viruses belong to this group, e.g. West Nile virus, dengue viruses, yellow fever virus and tick-borne encephalitis virus (Mackenzie & Williams 2010). According to Wong et al. (2007) bats are not important vectors of these viruses, although they can be found in various bat species. However, there is a lot about the role of bats in the ecology of these viruses that is still unknown.

Paramyxoviruses

These viruses include important human pathogens, like human parainfluenza viruses (Wong et al. 2007). The most interesting case, however, is the case of Nipah virus and pigs in Malaysia, which was documented by Chua et al. (1999). The virus spilled over from bats to pigs, and from pigs to pig farmers (Chua et al. 1999). Over 200 pig farmers died due to the disease, and one million pigs were culled to stop the virus from spreading. That measure was successful, and it stopped the epidemic from spreading further. Nipah virus and its spreading potential to Europe was also discussed in a recent paper by Simons et al. (2014). So far the risk it poses has been taken seriously, although global transport might be a vector for this disease as well.

Lyssaviruses

These are the most important bat-related viruses (Constantine 2009). Lyssaviruses are the viruses causing rabies, which typically leads to the death of the host. Bats and carnivores are the only natural hosts known, and other infected mammals usually die without spreading the disease (Constantine 2009). According to Badrane & Tordo (2001), the rabies viruses first evolved in bats, from which they then spilled over to carnivores. Therefore carnivores serve as amplifying hosts and a conduit to humans. But this is under scientific debate, and further studies are needed to determine the real original source of lyssaviruses, if it is even possible (FAO 2011).

In the 1950s, some people died due to rabies from bat bites in the United States (Constantine 2009). In the United States, 23 % of all laboratory-confirmed rabid animals were bats in 2010 (Blanton et al. 2011). During 2010, two cases of rabies in humans were reported, and they both were linked to bats: one caused by a Vampire bat (*Desmodus rotundus*), and the other caused by a virus which is associated with Tri-colored bats (*Perimyotis subflavus*) (Blanton et al. 2011). In 2012 one person died after being exposed to a Mexican free-tailed bat (*Tadarida brasiliensis*) in California (Dyer et al. 2013). Between 2002 and 2011, 24 humans became infected with rabies in the USA, and of those 87,5% infections were associated with bats (Blanton et al. 2012). However, of all the bats submitted for rabies testing in the USA during 2011, only 5,9 % were rabies positive (Blanton et al. 2012). Nowadays, bat-associated rabies causes around 1–4 human deaths in the United States annually (FAO 2011).

It should also be noted, that while bats are hosts to various lyssaviruses, the viruses do not seem to have a significant effect on bat populations (FAO 2011). This is also a sign of a long co-evolution, where the disease and its host have adapted to each other.

Rabies risk

The probability of a person getting a rabies infection (or other pathogen infection) from a bat is relatively low. In the United States, only 1-4 persons get rabies from a bat annually, so it is by no means a common incident (Blanton et al. 2012). Human-to-human spreading is extremely rare (one known case is that a rabid organ donor spread it to four organ receivers (Blanton et al. 2012)), so rabies spreads quite poorly in a human population. However, the risk of rabies is taken quite seriously, because of the fatal consequences of an infection.

Filoviruses

Known Filoviruses which can infect humans are Marburg viruses and Ebola viruses (Wong et al. 2007, Towner et al. 2007). The Ebola viruses were discussed widely and frequently in the mainstream media in 2014, due to an Ebola epidemic in West Africa (Plowright et al. 2015). The risk of introducing Marburg viruses through bats in to Europe was discussed in a paper by Simons et al. (2014).

It is known that bats can be asymptotic hosts of Ebola viruses (Swanepoel et al. 1996). This is not necessarily dangerous to humans, however some of the fruit bat species that people consume for food in some parts of the world, for example in West Africa, can also act as Ebola reservoirs (Leroy et al. 2005).

The Ebola epidemic of 2014 most likely started from a single human source (Baize et al. 2014). How this person got the virus is not 100 % sure, but the family said that they regularly hunt two bat species which are known hosts of the virus (MSF 2014). This led to speculation that this outbreak might have resulted from a spillover from a bat. Currently (in February 2015) the epidemic has caused a total of 8918 deaths, making it the deadliest Ebola outbreak since the virus was identified in 1976 (Frieden et al. 2014, WHO 2015).

3.5.3 Bacteria

In 2014 Veikkolainen et al. demonstrated that bats can act as reservoirs for bacteria called *Bartonella spp*. Veikkolainen et al. (2014) mentioned that a number of different *Bartonella spp.* have been suggested to be zoonotic human pathogens, although the risk of human infection is quite low. What should be noted is that most of the research focusing on bat zoonoses has been about viruses. This finding reveals that bats can also act as vectors for bacteria-based diseases, but how common they are is still unknown.

3.5.4 The White-Nose Syndrome

It is nearly impossible to discuss bat related topics in North America without mentioning White-Nose Syndrome (WNS). WNS is caused by a fungus called *Pseudogymnoascus destructans* (formerly known as *Geomyces destructans*) (Lorch et al. 2011, Minnis & Lindner 2013). It has devastated bat populations across northeastern North America, in the US and Canada since its discovery in 2006 in the state of New York (Blehert et al. 2009). The disease has caused mass mortality in hibernating bat populations, with a mean survival rate in affected caves being only 27% (Frick et al. 2010). The fungus is present in Europe, but no mass mortality has been detected, suggesting that it might be an introduced pathogen from Europe where bats may have had longer to adapt to the fungus (Wibbelt et al. 2010, Puechmaille et al. 2011).

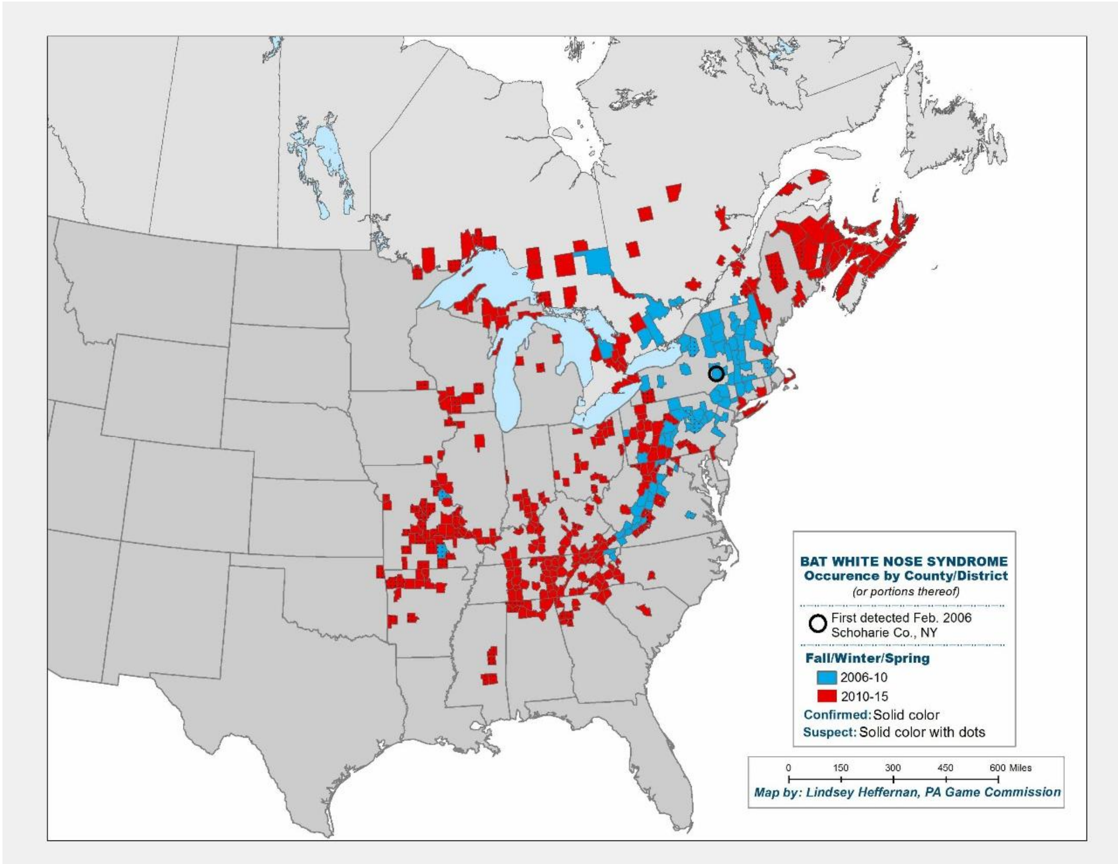

Figure 2. White-Nose Syndrome distribution in North America. Map created by Lindsey Heffernan, PA Game Commission, used with her permission.

Since 2006 the disease has spread south along the Appalachians, and north to the states of Maine and the Canadian provinces of New Brunswick and Nova Scotia (USFWS 2014). Currently it has been detected in states or provinces connected to all of the Lakes. Minnesota is an exception however, as there are no confirmed findings from there, at least not yet.

The most western findings in the north are northwest of Michigan's Upper Peninsula, and in the south the most western point is in western Missouri. The southernmost findings are from the state of Mississippi. The spread to Michigan's Upper Peninsula was detected during the winter of 2013–2014, making it quite a recent event (USFWS 2014).

The infection of *Pd* is quite easy to detect in the later stages of the infection, when the fungus has colonized non-furred skin, such as wings, muzzles and ears of hibernating bats (Cryan et al. 2010, Verant et al. 2014). The white fungal hyphae gave the syndrome its' name 'White-nose syndrome', as it is an easy visual cue of the disease. The infection causes damage especially to the wings, and makes them lose their elasticity and tensile strength (Meteyer et al. 2009, Cryan et al. 2010). They also rupture easier than healthy wings, affecting infected bats' flying capabilities.

The exact pathogenesis of the disease is not yet fully understood, but the most widely accepted theory is that the infection causes dehydration, which leads to more frequent arousals from torpor, leading to fatal premature depletion of fat reserves (Cryan et al. 2010, Willis et al. 2011, Warnecke et al. 2012, Warnecke et al. 2013,Verant et al. 2014). The infection is not only limited to the upper layers of the skin, but the fungus penetrates the tissues and colonizes also muscles, blood veins, lymph vessels and follicles (Cryan et al. 2010). The link between pathophysiology and these changes in hibernation mechanics is still unclear, but it is hypothesized that they are somehow connected.

It has been proved that the infection causes more arousals, both in laboratory (Warnecke et al. 2012) and in nature (Reeder et al. 2012), but the exact reason behind the arousals remains a mystery. In 2013 Cryan et al. found out that levels of certain electrolytes in infected bats' blood were lower than usually, and they think that the electrolyte levels might be linked to the mortality.

Fortunately, all is still not lost, as bats can survive the disease sometimes (Meteyer et al. 2011), and European bats do not generally die due to it (Puechmaille et al. 2011, Warnecke et al. 2012). However, the fungus seems to cause a serious infection in European bats, and the reason why they are able to survive the hibernation season is yet not known (Bandouchova et al. 2014). The pathogen is the same on both continents, so it is essential to find out the reasons behind the different mortality rates. Therefore comparative studies about European and American bats are highly suggested (Bandouchova et al. 2014).

P. destructans is psychrophilic, which means that it grows best at relatively low temperatures, and its growth stops when temperature exceeds 20°C (Blehert et al. 2009). Therefore when the bats wake up from the hibernation and leave the hibernacula in the spring, usually their body temperature is high enough to stop the fungus from growing (Thomas et al. 1990, Langwig et al. 2015). If they are not too weak from the infection, they can then clear the fungus and recover, as was demonstrated in an experiment by Meteyer et al. (2011). *Pd* can remain viable in the hibernacula long after the bat population has gone extinct, or after the survivors moved out in the spring, further complicating the recolonization of these sites by bats (Lorch et al. 2013, Hoyt et al. 2014).

Evidence suggests that it came to the North America from Europe, but the means of this translocation are not known (Frick et al. 2010, Warnecke et al. 2012). It is hypothesized that it came along with cave-visiting tourists or researchers, because it was first detected in a popular touristic bat cave, but the evidence supporting this theory is difficult to find (Wibbelt et al. 2010). Another hypothesis is that it was introduced by a hitchhiking bat (Wright & Moran 2011). This is certainly possible, as there are a few documented cases of bats being transported long distances in containers or hiding in ships (Voute 1982, Daniel & Yoshiyuki 1982, Constantine 2003).

3.6 Transportation and bat-human encounters

3.6.1 Transportation and translocation

Global transportation is an important vector for invasive alien species, and they are well addressed both in science and management strategies. Global guidelines to suppress their impact have been developed by various organizations. For example, the EU has their own strategy to mitigate the spread of invasive species, and it is constantly updated (EU

2014). The role of transportation is well-known in the case of alien invasive species (e.g. Hulme 2009), but in the case of spreading bat pathogens its importance is not yet fully understood (e.g. Constantine 2003, Wright & Moran 2011).

The likelihood of bats being invasive is quite low, due to their slow reproduction rate and other factors, which is demonstrated by the difficulties faced with attempts to translocate bats for conservation purposes (Ruffell & Parsons 2009). But as was discussed in the previous chapter, they host a multitude of zoonotic pathogens. Therefore hitchhiking bats should be studied, in order to understand the frequency of accidental bat transport, conduct risk assessments, and develop sufficient management strategies and guidelines to prevent epidemics and pathogens from spreading.

Constantine (2003) lists a lot of different cases of documented bat translocations. There are various ways of how bats can be translocated, accidentally or purposely. Some of these translocations can be just pure bad luck, as was demonstrated in a paper by Fleming & Murray (2009), where they studied bats in the West Indian islands after a hurricane. They found that in island ecosystems, bats can be translocated from an island to another by hurricane winds, and regarding diseases this means that it provides an opportunity for translocation. However, the role of humans is certainly more important in bat translocation. With modern vehicles it is possible to cross the globe in a relatively short time, which opens doors for unnaturally long-distance bat translocation. Constantine (2003) described bats that have been accidentally translocated after the bats used freighters for shelter and roosting: some bats were translocated in shipping containers, some bats have been translocated in aircrafts, and of course bats have been transported for the purpose of scientific studies and human recreation (zoos) from a continent to another. There are also a few bat translocations that were conducted for conservation purposes (Ruffell et al. 2009). These all ways of translocation act as potential pathways for pathogens to new areas and bat populations.

3.6.2 Shipping/Freighters

There are a few documented cases of bats found on ships or in shipping containers (e.g. Voute 1982, Constantine 2003, Wright & Moran 2011). Some of the papers where these incidents are mentioned were difficult to find, so Table 4 is not fully comprehensive. These references were found by reading articles, and back-tracing the references mentioned in those. It should be noted that none of these papers was a study about hitchhiking bats, as the subject has not been systematically studied before. Therefore the frequency of bat sightings, or hitchhikings is not clear. Constantine (2003) stated that it is likely that most incidents go unreported, and suggests that hitchhiking bats are more common than thought.

Petersen et al. (2014) studied bats in the North East Atlantic and North Sea on islands and different installations. They say that bats are getting more common, possibly due to increased shipping traffic. There are at least ten known incidents in Iceland when bats have been transported there by shipping, and one of those is via airplane. One bat was translocated to the Faroe Islands in a timber shipment according to Petersen et al. (2014). *Lasiurus borealis* and *Lasiurus noctivagans* have been reported to land on ships at sea, and *Lasiurus noctivagans* have been detected hibernating in the hulls of ships (Greenhall & Frantz 1994). Unfortunately they do not mention sources for these observations.

There are also a few sources which have been said to contain information about bat encounters on ships or containers, but unfortunately could not be obtained. However, the number of them is rather small, as is the overall number of bat encounters mentioned in the scientific literature regarding shipping.

Table 3. Some documented bat observations linked to shipping/freighters, not a comprehensive list. It includes only the sources which could be verified by the author.

Year	Species	Location	Observer	What is interesting	Role of transportation	Source
1943	*Lasiurus cinereus*	Iceland	Gudmundsson	Might be a hitchhiker, but could be explained by storms	Unclear/possible	Hayman 1959
1944	*Vespertilo gryphus or Myotis lucifugus*	Iceland	Gudmundsson	Was found from a port	Unclear/possible	Hayman 1959
1944	*Myotis lucifugus*	Iceland	Gudmundsson	Dr. Koopman thinks that the bat might have arrived on a freighter from Canada	Possible	The American Biology Teacher 1969
1957	*Lasiurus cinereus*	Iceland	Gudmundsson	Was found as wet and exhausted. Might have flown naturally.	Unclear	Hayman 1959
1960	*Dasypterus ega*	Argentina	Murphy	Bat flew onto an icebreaker 335 km off the coast	Certain	Deusen 1961
1980	*Eptesicus fuscus*	The Netherlands	Unknown	Bat was transported from Canada to the Netherlands	Certain	Voute 1982
1982	*Pipistrellus javanicus abramus*	New Zealand	Factory workers	A Japanese bat was transported from Japan to NZ in a container of car parts	Certain	Daniel & Yoshiyuki 1982
1989	Unidentified	Faroe Islands	Two fishermen	Found a bat on a boat, but the bat escaped when they reached the shore	Certain	Baagoe & Bloch 1994
1995	Unidentified	USA	Unknown	A group of bats found from a container that came to LA from Puerto Rico	Unclear	Constantine 2003
1997	*Eptesicus serotinus*	USA	Constantine	A stevedore working on a ship got bitten by a bat	Unclear	Constantine 2003

2011	Unidentified	USA	Wright & Moran	The authors observed a bat outside Alaska, over 1 km away from the closest shore. They suggest that the bat had been roosting on the ship.	Unclear	Wright & Moran 2011

3.6.3 Airplanes

In 2011 a single bat flew inside a passenger airplane after takeoff, on a flight from Wisconsin to Georgia (CDC 2012). The CDC (2012) mentions that this potentially put the passengers in danger of rabies infection. They conducted a rabies risk assessment, including the flight crew, passengers and ground crew. No rabies infections were found, but the strange behavior of the bat might suggest it being rabid, as one of the symptoms is unnatural behavior (Constantine 2009, CDC 2012). The CDC (2012) mentions that one problem regarding this investigation was that the airline didn't have sufficient information about the passengers; out of the 50 passengers on the plane they could not reach five. Also it should be noted that the ground crew members told the CDC that they had seen bats at the airport before, so it seems likely that bats are not too uncommon there. However, no feces or other evidence for the presence of bats were found from the airport. But the fact that bats have been encountered there before does suggest that accidental translocation via passenger airplanes is possible.

Another reported incident of bat-airplane contact was reported in 2006, when a bat collided with an aircraft (Leader et al. 2006). The aircraft was on its way from London to Tel Aviv, where the ground crew found the remains of the bat while performing a routine inspection of the aircraft. This demonstrates how a bat can be transported over continents, and how easily zoonotic pathogens can be accidentally translocated (Leader et al. 2006). What makes this case interesting is that the bat was identified as a Straw-colored fruit bat (*Eidolon helvum*), with a distribution range strictly in sub-Saharan Africa. The aircraft departed from London to Tel Aviv, but on the previous day it had flown from Accra to

London, so it is likely that the bat collision occurred during this flight, and it was noticed later. This is a highly curious case of a bat crossing multiple continents and thousands of kilometers, and it also demonstrates how the ground inspections might easily overlook these small animals.

What should be noted in this case, is that Ebola virus is present in bats in Africa, and therefore this kind of accidental translocations might spread Ebola virus to other continents as well (Leroy et al. 2005, Leader et al. 2006). The route of transmission can also include animals living at the airport, as they are known hosts of multiple wildlife species (Leader et al. 2006). For example, dogs can act as Ebola virus carriers asymptomatically (Allela et al. 2005). They also might feed on dead animal carcasses, which might be the source of their infections (Leader et al. 2006). The risk of canine species spreading Ebola from airports is low, but it still is a potential pathway (Allela et al. 2005, Leader et al. 2006). If the personnel at the airport are not aware of the risks possibly included in handling dead animal carcasses, their improper handling might increase the risk of exposure to introduced pathogens, both Ebola and others (Leader et al. 2006).

In 2014 there was an Ebola outbreak in West Africa, and its origin might be the wide-spread use of bush meat, including fruit bats, in the region (BBC 2014, Baize et al. 2014). Airplanes, shipping containers, and other vehicles departing from this region should therefore be inspected for fruit bats to prevent Ebola spread because of accidental bat translocation.

Other means of bat-human encounters

3.6.4 Ecotourism

One unfortunate case demonstrating the risks of ecotourism was presented by van Thiel et al. in 2009. A Dutch woman contracted a rabies infection while in Kenya. A bat fell

against her face in a National Park, and she received two small wounds (van Thiel et al. 2009). The local park rangers told her that in that area the only rabid animals are dogs and cats, but after returning to the Netherlands, the patient developed rabies symptoms.

She received intensive care, but unfortunately it was too late (van Thiel et al. 2009). This demonstrates the importance of proper communication and education, because if the patient had known the dangers of bats, or if the personnel in the park had known the possibility of rabies in bats, or if there had been rabies assessment conducted about bats, this case could have been avoided. This does not mean that traveling should be avoided altogether, but that the risks should be known. Also education about the risks should be improved, as was demonstrated clearly by this case of uneducated park rangers.

4. METHODS

4.1 Study area

The Great Lakes

Figure 3. Map of the continental USA and Canada with highlighted Canadian provinces and American states that belong to the Great Lakes region.

The Great Lakes region is located in northern North America, consisting of 8 American states and one Canadian province (Fig. 2). The region has been named after the five interconnected large lakes that straddle the border between Canada and the US. These lakes are Lake Superior, Lake Michigan, Lake Huron, Lake Erie and Lake Ontario. In Figure 4 a more detailed map of the region is presented.

Figure 4. Map of the Great Lakes.

The Lakes differ in their properties quite remarkably (Table 4). Lake Superior is the largest of the five, with a surface area of 82 100 km^2 (Habermann et al. 2012). It is also the largest freshwater lake in the world, and the third largest by volume. Superior also has the longest maximum length and width of all the Lakes, with its maximum length being 560 km.

The Lakes are connected and can be sailed through either natural waterways, or artificial lock systems. Lake Superior and Lake Huron are connected with locks, called Soo Locks, located in St. Mary's River, close to the town of Sault Ste. Marie, on the border of Canada and the US. Lake Huron and Lake Michigan are connected by the Straits of

Mackinac, which is a natural passageway. Therefore they could be considered to be only a single lake, and hydrologically are so. Lake Huron and Lake Erie are connected through St. Clair River, Lake St. Clair and Detroit River. Lake Erie and Ontario are connected through Niagara River, including Niagara Falls, where the use of Welland Canal is required to bypass the falls. St. Lawrence River connects Lake Ontario to the Atlantic Ocean through the St. Lawrence Bay.

Table 4. The Lakes in numbers (Source: EPA Great Lakes Factsheet http://epa.gov/greatlakes/atlas/gl-fact1.html and Global Great Lakes http://www.globalgreatlakes.org/lgl/)

Lake	Superior	Michigan	Huron	Erie	Ontario	Total
Average depth (m)	147	85	59	19	86	
Maximum length (km)	560	494	332	241	311	
Maximum width (km)	260	190	245	57	85	
Water area (km^2)	82 100	57 800	59 600	25 700	18 960	244 160
Land drainage area (km^2)	127 700	118 000	134 100	78 000	64 030	521 830
Total area (km^2)	209 800	175 800	193 700	103 700	82 990	765 900
Retention time (years)	191	99	22	2,6	6	

Through the artificial and natural passageways, it is therefore possible to transport cargo all the way from Duluth, MN (at the western end of Lake Superior) to over the rest of the world, by using freighters and the lakes as transportation pathways. Because of this connection between the Great Lakes and the Atlantic Ocean, the Lakes have been, and still are, very important for the transportation of goods, and vessel traffic in the region is frequent.

Shipping from the Great Lakes to Europe began as early as 1840s (Mills et al. 1993). The opening of Welland Canal (1829), Soo Locks (1855) and St. Lawrence River canal system (1847) connected Lake Superior to the Atlantic, allowing the transportation through all the lakes to the Atlantic (Mills et al. 1993).

Because of the vessel traffic, numerous alien species have been introduced to the lakes (Mills et al. 1993). Mills et al. (1993) stated that the opening of the renewed St. Lawrence Seaway (in 1959) and the increase in the rate of introductions of species are connected, mainly because of increased ballast water deposits. Fouling was also a common mean of the species to translocate into the Great Lakes water system (Mills et al. 1993). In all, ships account for 29 % of all introductions of alien species. While Mills et al. (1993) categorize most means by which ships can introduce species to the ecosystem, they did not consider hitchhiking as one of these possible pathways.

4.2 Methodology

4.2.1 Choosing the methods

There are several possible ways to obtain information about bats on ships. The most obvious methods are either a questionnaire or survey of shipworkers and/or passengers, or a monitoring project using echolocator technology. Both of the methods have their pros and cons (Table 5).

An echolocator installed on a ship would provide timely and accurate data, with the possibility to identify the species detected by call. This design would provide a data set that is collected systematically, with some possibility for establishing controls (e.g., ships in dry-dock). However, the temporal scope of this kind of a study is quite limited, and would require a number of years to get representative results, to take annual variations in ships' and bats' movement into account. A study design like this would also require extensive funding, and numerous echolocators installed on various ships to broaden the geographical scope.

A questionnaire targeted to sailors provides less accurate data, but is very cost-effective. The temporal scale is also very broad, as the respondents can have careers that span through a few decades. The information they provide might not be very reliable, as their

sightings can date back to the 1970's for example. The geographical range might be very broad, but it depends on the respondents and their history. With sufficient sampling, the temporal and spatial coverages can be very extensive. This method also provides practical knowledge and insights about human-bat encounters, which a study based on strictly echolocator monitoring would not provide. It is also quite unlikely that the sailors can identify bat species very accurately, making species level information difficult to obtain.

Table 5. Evaluation of the two different methods

	Questionnaire/ Survey	**Monitoring**
Funding	Cheap	Expensive
Temporal scale	Wide	Narrow
Geographical scale	Wide	Narrow
Data accuracy	Poor	Precise
Data reliability	Fair	Good
Data interpretation	Easy, fast	Difficult, slow

Given the small size of the research team, lack of funding and time resources, a questionnaire was the more feasible method. The research methodology used in this thesis is *mixed methods research*. This is defined by Johnson & Onwuegbuzie (2004) as

"the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts or language into a single study."

This study used a questionnaire comprised of open-ended and closed-ended questions. The closed-ended questions can be classified as quantitative research, and the open-ended questions have a qualitative nature. However, the answers to open-ended questions are

also coded and analyzed using quantitative methods, but they still provide information that can be regarded as qualitative.

This approach was believed to provide the best information for the purposes of this study; *quantitative* information about the location and number of bats observed, and also *qualitative* information about the observer's perceptions of bat behavior and physical condition.

Open-ended questions provide the respondents an opportunity to give a response in their own words, and they might know something that the researchers do not. Closed-ended questions do not give this opportunity, as they have strictly predetermined answer categories, from which the respondent has to choose their preferred answer. These are easier and less time consuming to analyze, but the information that they provide might not be as rich as the information received through open-ended questions (Johnson & Onwuegbuzie 2004). The closed-ended questions with predetermined answer possibilities might also cause a bias, as the respondent can only choose from the answers that the researchers thought are applicable (Reja et al. 2003).

Taking these pros and cons into consideration, it was decided to use both of the question types in this study. Closed-ended questions were used for questions for which it was thought that predetermined answer classes could be generated. Open-ended questions were used to either gain further knowledge about the issues the closed questions examined, or they were used to gather information about issues for which it was considered difficult, impossible or imprecise to determine classes beforehand

Web-based surveys have been gaining popularity during the past decade, but while they are very abundant, the quality of their design might be lacking (Emde & Fuchs 2012, Shropshire et al. 2009). They have some advantages over pen-and-paper surveys, as they can be interactive and include multimedia which can engage the respondents, possibly lowering the nonresponse rate. They can also have sections that are presented only to a certain group of the respondents, based on their previous answers (Shropshire et al. 2009).

However, web-based approach has its own problems. In my study, the invitation to participate was sent to an open internet forum, and whoever who visited the page was able to answer. This does not prevent people from filling multiple surveys, or people who are not working at the lakes from answering. Also reaching people who do not actively use internet might be difficult, or impossible, when using solely web-based methods. In this study, a web-based survey was thought to work better than a pen-and-paper survey, even when taking these possible disadvantages into account. People who are working on ships can answer directly from the ship if they are on duty when seeing the invitation, and they do not need to wait to get to the closest post office to mail their answers.

The questionnaire form was designed carefully to ensure the quality of the data gathered (Reja et al. 2003). The design includes the wording of the questions, visual design and the order of the questions, to minimize the loss of data due to respondents answering incorrectly or failing to complete it (Reja et al. 2003). My questionnaire was reviewed and cleared by the Institutional Review Board (IRB) at Michigan Technological University.

4.2.2 The Questionnaire/Survey

This thesis project was initially started in the fall of 2012. In the beginning the idea was to use a web-based questionnaire, but that method was changed into structured telephone interviews because those were thought to be more feasible. During the spring of 2013 the questionnaire form was finalized and IRB approval was received. However, after some cargo companies were approached, it was evident that telephone interviews would not work due to crew schedules, significant time zone differences between myself and the interviewees, and lack of telephone access while sailing.

During the spring of 2013 two emailed free-form answers were received, and both of these contained information about bats. Unfortunately it was impossible to reach the sailors who sent those emails. In the fall of 2013 the decision was made to return to the

original idea of a web-based questionnaire. An online questionnaire was developed, using the "e-lomake" survey platform provided by the University of Helsinki (http://elomake.helsinki.fi). Graduate students posed as respondents to test the usability and stability of the platform, and once those tests were successful the questionnaire was considered to be functional.

The questionnaire form was finalized and opened in the fall 2014. Seven North American cargo companies were contacted, and it was possible to reach some sailors through two of them. Also I posted an invitation to the BoatNerd discussion forums (www.boatnerd.com), which are visited by Great Lakes shipping enthusiasts. The post gained a lot of visibility (over 1000 page views), and produced a significant amount of data. A third way I reached sailors was through a Great Lakes Science Vessel e-mailing list. The subscribers of this list are primarily scientists who are frequently sailing around the Great Lakes. Through this e-mailing list it was possible to gather more information. Overall the questionnaire received 59 completed answers between September 25th and October 31st 2014.

My intention was also to compare the bat sightings between the regions of the Baltic Sea and the Great Lakes. The questionnaire was translated into Finnish and directed towards Finnish sailors through their union contacts. I reached 75 of the union contacts, but did not receive any answers to the questionnaire. As unfortunate as this is, it was just a side-track in the project, and it was decided to just continue with the main project and not invest more time into this side branch of the study.

4.3 Population of the study

4.3.1 The respondents

The average age of the respondents was 46 years, while the youngest respondent was 22 and the oldest 85 years old. Career lengths spanned from 1 year to 43 years. Summing all

the career-years gives a number of 1021 years on the Great Lakes worked by the respondents. Therefore all the observations and information provided by the respondents represents a large number of hours spent on the lakes.

Table 6. Age and the length of the careers of the respondents in years

	Age	Career
Avg	46,1	17,3
Median	45,0	14,0
Min	22,0	1,0
Max	85,0	43,0

The smallest ship was only 28,5 ft. long, and the largest one was 1013 ft. The median sized ship was 640 ft. long (Table 2). When classified into size categories, we can see that 17 of the ships are larger than the Seawaymax limit, which means that they cannot go through the Welland Canal to the Atlantic, and therefore stay within the Great Lakes.

Table 7. The sizes of the ships the respondents are working on

Statistic	Ft.	Size class	Nr. Of Ships
Avg	550,4	Larger than Seawaymax (740 Ft.)	17
Median	640	550-740 Ft.	21
Min	28,5	Smaller than 550 Ft.	20
Max	1013		

One respondent gave the size of the ship in gross tonnage, and therefore this answer was excluded, and only the answers with the ship size reported in feet were included. Some respondents had been working on multiple ships with various sizes, and of those answers the median number was chosen to represent the size of their ship.

Table 8. The types of the ships the respondents are working on

Type	Nr. Of Ships
Bulk Carrier	22
Self-unloader	15
Research	10
Articulated Tug Barge (ATB)	3
Passenger	2
Tug Barge	2
Lifeboat	1
Training Ship	1
Trawler	1
Patrol Vessel	1

The most common types of ships were bulk carriers, self-unloaders and research vessels. What should be noted is that bulk carriers can also be self-unloading, but only some respondents further defined the exact type of the bulk carrier. Therefore it is likely that some of the ships in the 'Bulk Carrier' category should belong to the 'Self-unloader' category. 10 respondents were working on research vessels, which tend to be smaller than the ships that are used for cargo shipping.

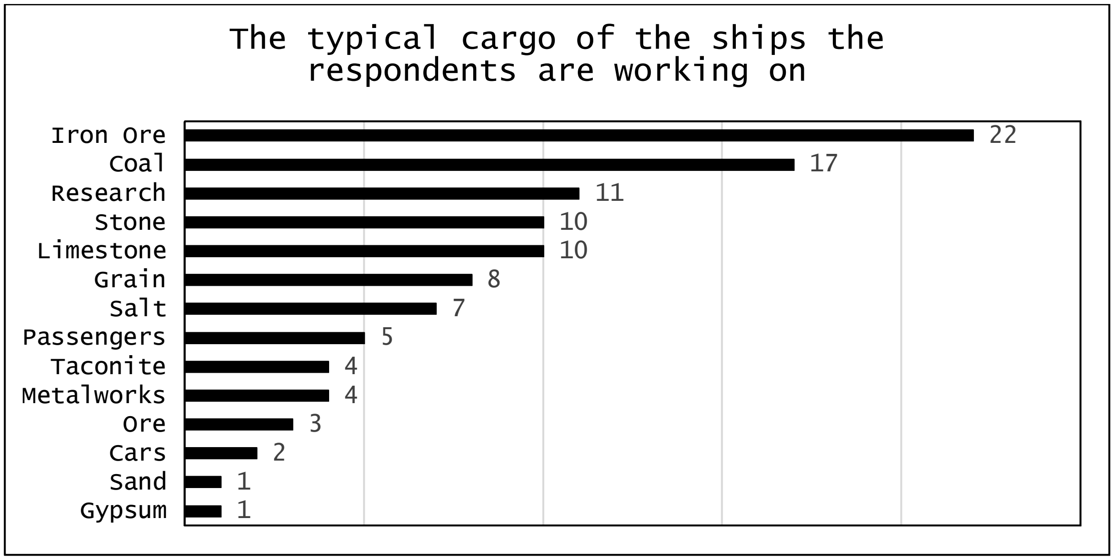

Figure 5. The typical cargo of the ships the respondents are working on

The respondents were also asked about the typical cargo of the current ship that they are working on. It was an open question, and they could provide multiple answers. Iron ore was the most common cargo, while coal was the second most common. It should be noted that while the questionnaire was initially targeted to sailors who are working on freighters, it was also sent to the research vessel mailing list. This explains the unusual group of cargo titled 'Research'. There is also one situation where the vessel was classified as being a trawler, but the cargo of that vessel was classified as research, as the respondent was doing fishery surveys.

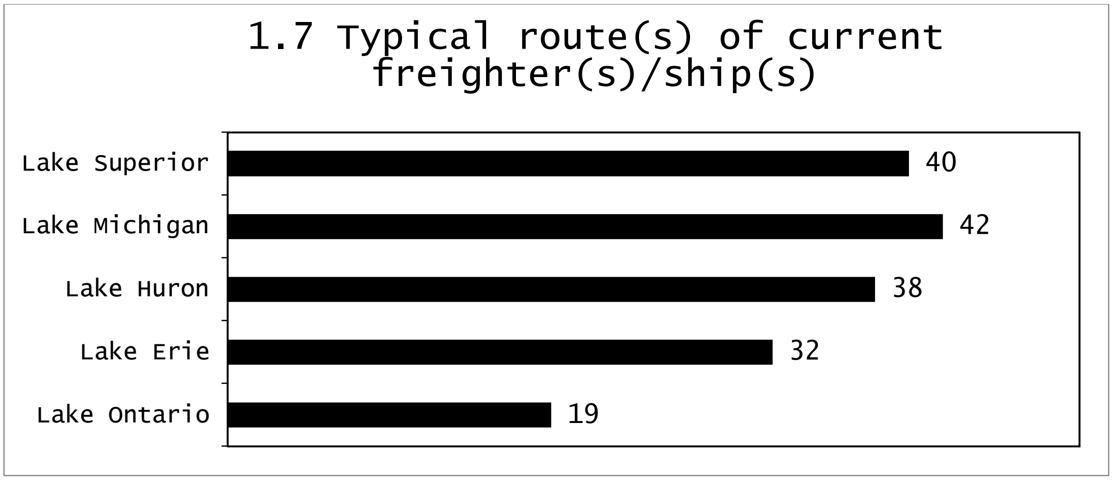

Figure 6. Question 1.7. Typical route(s) of current freighter(s)/ship(s)

Figure 6 presents the answers to a question early on in the questionnaire. It represents the geographical scope of this study, and the typical routes that the respondents are sailing. Their answers were grouped based on the lakes they sail. Some respondents stated that they sail all of the lakes, and then their answers were assigned to all of the groups. Overall it can be said that the geographical scope of the study included all of the lakes, and therefore it is quite representative sample.

4.3.2 Representativeness of the data

There are numerous people working in the Great Lakes shipping industry, and exact numbers are hard to reach. Overall the Great Lakes cargo industries generate over 92 000 jobs in the US and Canada (Martin Associates 2011). This number includes all the people working directly in the cargo business, either in ships, ports, railroads, etc. Therefore it excludes the sailing researchers who answered my questionnaire, but includes a vast number of other people who were not the target demographic of this study. However, even with inaccurate estimates, it is safe to say that the sample size of this study (n = 59) compared to the overall number of people working and sailing on the Lakes is minuscule.

Compared to the statistics provided in Status of the U.S.-Flag Great Lakes Water Transportation Industry (U.S. Department of Transportation 2013), my population is a bit skewed towards smaller vessels, and therefore it is not fully representable of the situation on freighters. According to the report, vessels which are smaller than 400 feet are not usually classified as being Lakers, but in this study these smaller vessels are also included, in addition to the larger ones. The majority of Lakers belong to size classes of 730< feet, and in our study only 29 % of the vessels belong to that size category.

The respondents might also be biased towards people who are interested in wildlife and/or nature. In the invitation emails and forum posts, bats were mentioned, and that might have attracted people who are interested in them. Also, it might have caused aversion in people who have not seen bats, even though in the invitations it was mentioned that it is important to know if people have not encountered bats. It is also possible that while some people had encountered bats, they are just not willing to answer web-based questionnaires.

The distribution of cargo type classes is quite similar to the official statistics (Lake Carriers Association 2013). Iron ore was the top reported category of cargo in my study and is as well in the official numbers, followed by coal and limestone. The category derived from the answers which stated 'stone' most likely means limestone, as it can be an abbreviation used by the sailors. Cement is quite a large class in the statistics, but was not mentioned at all in our answers. However, this can be explained by the small overall number of cement-carrying vessels (5), so my sample might not include anyone working on those particular vessels (U.S. Department of Transportation 2013).

Most of the commercial freighters sailing on the lakes are self-unloading bulk carriers (US Department of Transportation 2013). In the whole U.S. Laker fleet there are 48 self-unloading dry-bulk vessels, 2 straight-deck dry-bulk vessels, and 5 cement vessels (U.S Department of Transportation 2013). In this study there were respondents from 37 bulk carriers, if the self-unloader answers and bulk carrier answers are combined. Therefore the coverage of this study is quite good, when considering that none of the respondents were working on the same ship. Some of the respondents were working for Canadian

companies and ships, and unfortunately the Canadian statistics do not tell the whole size of their fleet. So comparison of the number of my respondents to the whole US & Canadian fleet sailing on the lakes is impossible to make.

4.4 Data handling and analysis

E-lomake survey platform offers various ways for exporting the data. I exported the data entries in Microsoft Excel file format, and checked the data for integrity and organized in Microsoft Excel 2013. I also analyzed and grouped the open-ended questions in Excel. I performed statistical analyses (chi-squared) using IBM SPSS Statistics for Windows version 22 (IBM 2013) for only the closed-ended questions. I inputted these data to SPSS manually from the excel tables.

Five respondents answered that they had not seen bats, but later on in the questions regarding bat sightings, two of them mentioned that they had in fact seen bats. The reason behind this is unclear, but I decided to include these answers in the data set. Their answers to the question ‘Have you seen bats on board?’ was corrected to be ‘yes’. I made no other corrections or modifications to the answers. Some of the three respondents who had not seen bats on boards had answered some of the questions regarding bats generally, but I omitted these answers from the results.

I generally assigned the answers to the open-ended questions into classes and/or groups according to common themes that occurred across the answers. If an answer could not be assigned to an existing group, I created a new group.

All maps that I created were created with QGIS version 2.6.1 (Quantum GIS 2014). The background maps were made with free Natural Earth vector maps and Global Administrative Areas data layers (Global Administrative Areas 2012, Natural Earth 2015).

One map was created by Audrey Mayer with CartoDB online GIS service (CartoDB 2015). The White-Nose Syndrome distribution map was kindly created for me by Lindsey Heffernan of the PA Game Commission. The map with ship densities was obtained from Marine Traffic online service (www.marinetraffic.com), and I got a permission from them to use it in this thesis.

5. RESULTS & DISCUSSION

In this section I present the results of the study following the structure of the questionnaire. However, the *Section 1* of the questionnaire covered background questions such as demographic and ship information. Those were already discussed in the Methods & Materials chapter, and therefore are not presented and discussed again here, and the results section starts from *Section 2* of the questionnaire.

The questionnaire sections included multiple choice closed questions and open-ended questions. In some of the multiple choice questions the respondents could choose more than one answer, and in some of them they could only choose one. Therefore the overall number of answers is not constant across the questions.

5.1 The questionnaire

Section 2: Bats

The first question (Question 2.1.) of the second section was "Have you ever seen bats on board?" Out of the respondents (n = 59) three had not seen bats, so ~95 % of the people who answered to the questionnaire had seen bats or a bat at least once in their career on

the Great Lakes. This indicates that most people who are working on the lakes have seen bats. But our sample might also be biased towards people who have observed bats and are willing to share their observations. If one has not seen bats on board, their eagerness to answer to the survey might be low.

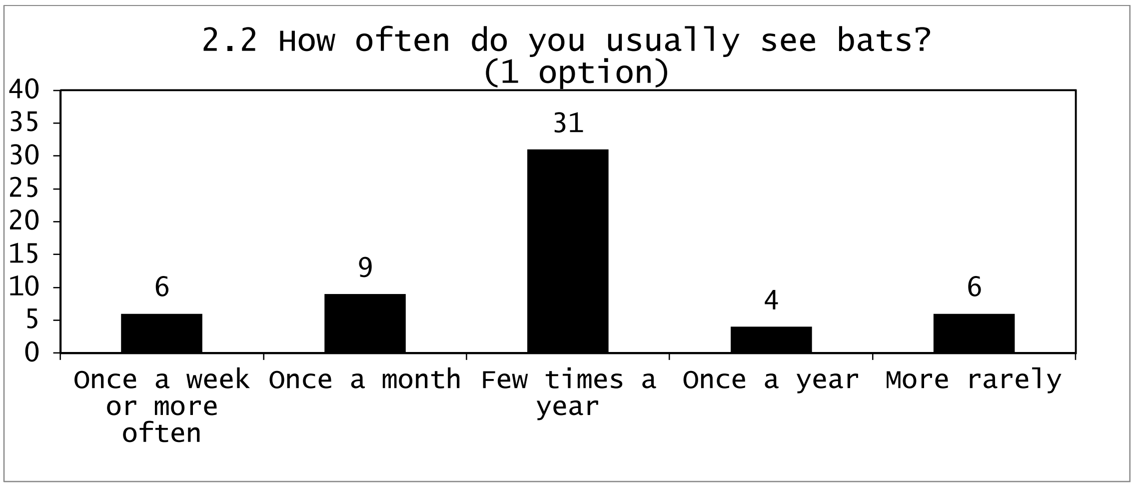

Figure 7. Question 2.2. How often do you usually see bats?

Figure 7 describes the answers to the second question, "How often do you usually see bats?" The respondents could only choose one option for this question. The option 'Few times a year' clearly stands out from the rest, having been selected 30 times. Six people said that they see bats very frequently, at least once a week.

Differences in the frequencies were statistically different ($X^2 = 44,89$, $n = 56$, $p < 0,05$), the category 'Few times a year' clearly differing from the expected frequencies.

These results agree with those found in Constantine (2003); most of the incidents of accidental translocations of bats most likely go unreported, and my results also suggest this. If most of our respondents have seen bats during their career, and most of them see bats at least on a yearly basis, bats on board ships is not rare.

Therefore it is quite surprising that this issue is given so little attention, given that bats can be hosts for various zoonotic diseases. The risk that bats pose to sailors' health is not great, but it should be taken into consideration however, as the consequences of a rabies infection are serious.

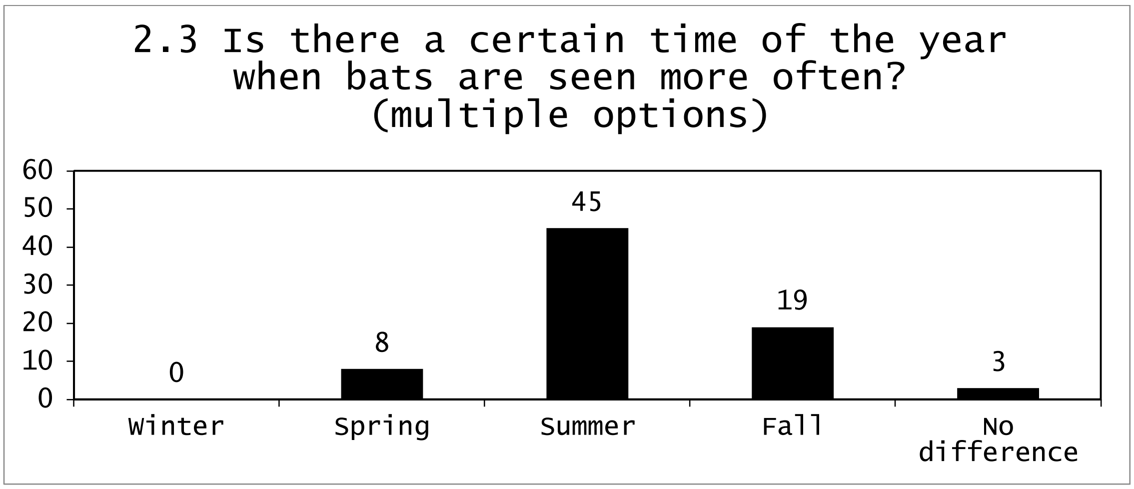

Figure 8. Question 2.3. Is there a certain time of the year when bats are seen more often?

The next question dealt with the temporal aspect of the sightings. The respondents could choose more than one option in this question, and also one of the options was a 'No difference' category, indicating that there are no differences between the commonness of bat sightings across seasons. Summer stands out as the most chosen category, with 45 people choosing it. Fall was chosen approximately twice as often as Spring. Winter received 0 answers, which is quite logical, as bats should be hibernating during the winter. Only three respondents chose 'No difference', indicating that most respondents noticed a difference in bat sightings among the seasons.

According to chi-squared goodness of fit statistical testing there was a statistical difference between the number of answers between the groups (X^2= 56,15, n = 75, p <

0,05). The category ‘Winter’ was excluded from the test because it did not gather any answers.

In the question about the temporal nature of the bat sightings, Summer was the most popular answer (60 %). This might be due to a few reasons. Days are longer in the summer time, providing the sailors more light to observe bats. During other seasons, when the sun sets earlier, it might be too dark to observe bats that are flying out of the lights of the ship.

Bats are also most active during the summer time, when they are feeding and raising their young (Langwig et al. 2015). The numbers in the categories ‘Fall’ and ‘Spring’ might be explained by the migratory behavior of some of the species in the region (Shump & Shump 1982, Tuttle 1995, Cryan 2003, Fraser 2013). Cryan (2003) mentions that most of the sightings of migrating bats in the families of *Lasiurus* and *Lasionycteris* are encountered during the fall migration. This might be also suggested by our results, as 25 % of the respondents chose fall to be the season with the highest number of bat sightings. These observations might be explained by the fall migration of these tree-dwelling migratory bat species. Fall was also chosen more often than spring, gathering over double the numbers of answers. However, due to our small sample size, one has to be careful before drawing conclusions.

Also, one of the reason why most of the sightings are done in summer might be that this is the busiest shipping season. Therefore, the sailors have more opportunities to observe bats. In the wintertime there is less activity out at the lakes, so there are less chances to observe bats. Bad weather during the fall or spring seasons might limit the amount of time the crew can spend outside, thus limiting the number of hours when it is possible to see bats.

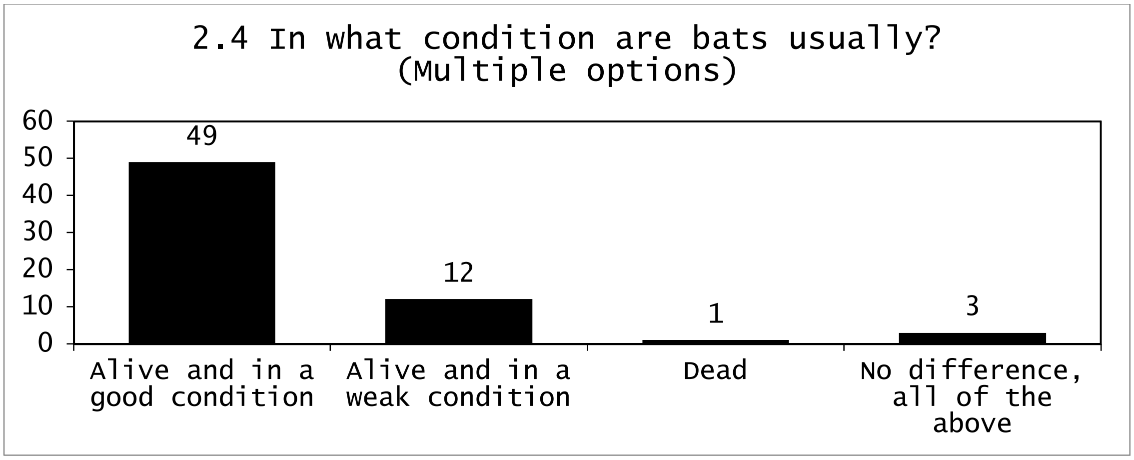

Figure 9. Question 2.4. In what condition are bats usually?

Question 2.4 asked about the condition of the bats that have been seen. Most of the respondents answered that the bats seem to be in a good condition. Only one person had seen a dead bat on board. Some people had seen bats that seemed to be in a weakened condition, but it looks like that the most of the bats that end up on board the ships are alive, and they seem to be healthy.

Differences in the frequencies were statistically different ($X^2 = 92{,}23$, $n = 65$, $p < 0{,}05$).

The responses to this question may be somewhat unreliable, as it might be difficult for an untrained person to say if a bat is in a good condition. Some people answered that they had seen weakened bats, which raises some questions. The reason behind these weak bats settling on board a ship would be interesting to know, as they might be long-distance migrants whose fat reserves were depleted prematurely for example. There might be a lot of reasons, but unfortunately they cannot be derived from the answers.

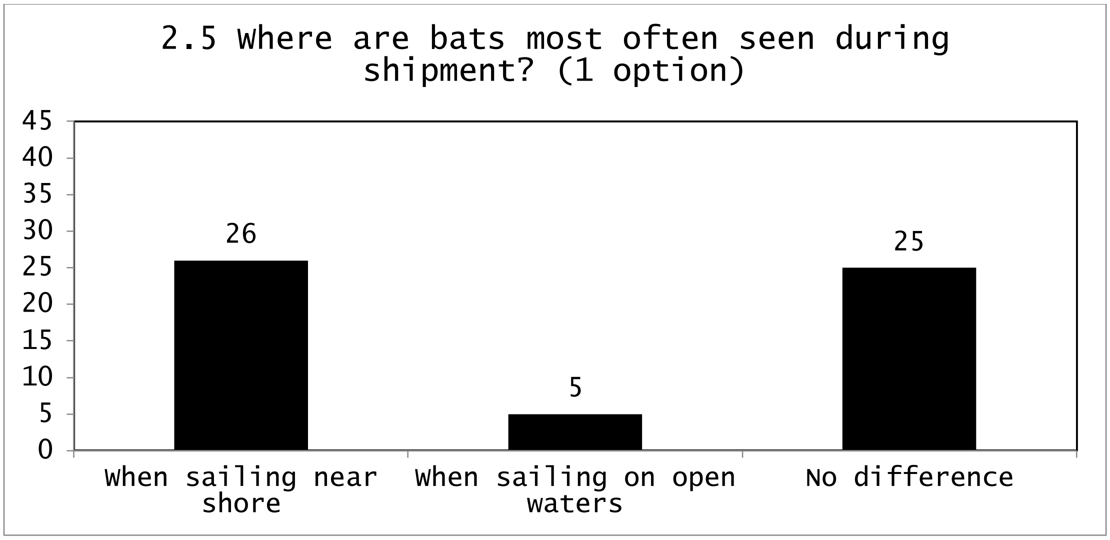

Figure 10. Question 2.5. Where are bats most often seen during shipment?

The question number 2.5 asked about the location of the ship in relation to land mass when bats have been observed. The most common answer was ‘When sailing near shore’, which gathered 26 answers. ‘When sailing on open waters’ was selected by five participants, standing out as the least popular answer. The second most common answer was ‘No difference’.

Differences in the frequencies were statistically different ($X^2 = 15{,}04$, $n = 56$, $p < 0{,}05$). This is caused by the low number of answers in the category ‘When sailing on open waters’.

The result is not a surprise, as bats are not aquatic animals, and the species in the region generally live in forested landscapes. Therefore the proximity of suitable habitats might explain why they are seen more often when sailing near shore. In a study by Entwistle et al. (1997) they found out that the roost selection of a bat species, which is known to roost in manmade structures, could be explained by the distance from the roosting site to forested areas and water bodies. The same explanation might be appropriate here.

Corkum et al. (2006) found that adult mayflies are easily pushed to the shore by winds, and when we take into account that mayflies can account up to 32 % of little brown bats’ diet (Clare et al. 2011), it is not far-fetched to at least speculate that the bats might go

after these insects, especially as bats are known to follow their prey, also insects which emerge from water (Fukui et al. 2006).

'No difference' was the second most common answer, suggesting that bats are seen both near shore and in open waters. But when comparing the frequencies in the categories 'When sailing near shore' and 'When sailing on open waters', the difference is quite large, and should be noted. It seems that people do not see bats in open waters as often as close to the shore. The popularity of choosing 'No difference' could also be explained by that people do not remember where the ship was sailing when they've seen bats, and in that case it was the "safest" answer to choose.

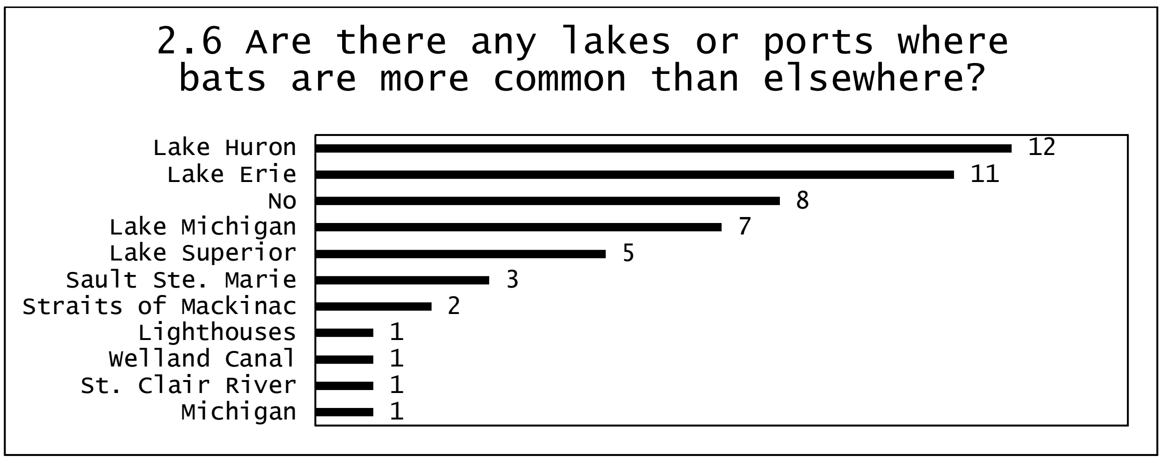

Figure 11. Question 2.6. Are there any lakes or ports where bats are more common than elsewhere? (Open question)

The question 2.6 was an open question, and it continued the theme about the location where bats are seen. Whereas question 2.5 dealt with the location of the ship in relation to shore, the question 2.6 was about the geographical location of the ship. It was an open-ended question, so the respondents were asked to write the locations where they think that bats are more common. Some respondents had listed some islands or very small-scale, detailed locations, and these locations were grouped under bigger classes (e.g. islands belong to the lake where they are located).

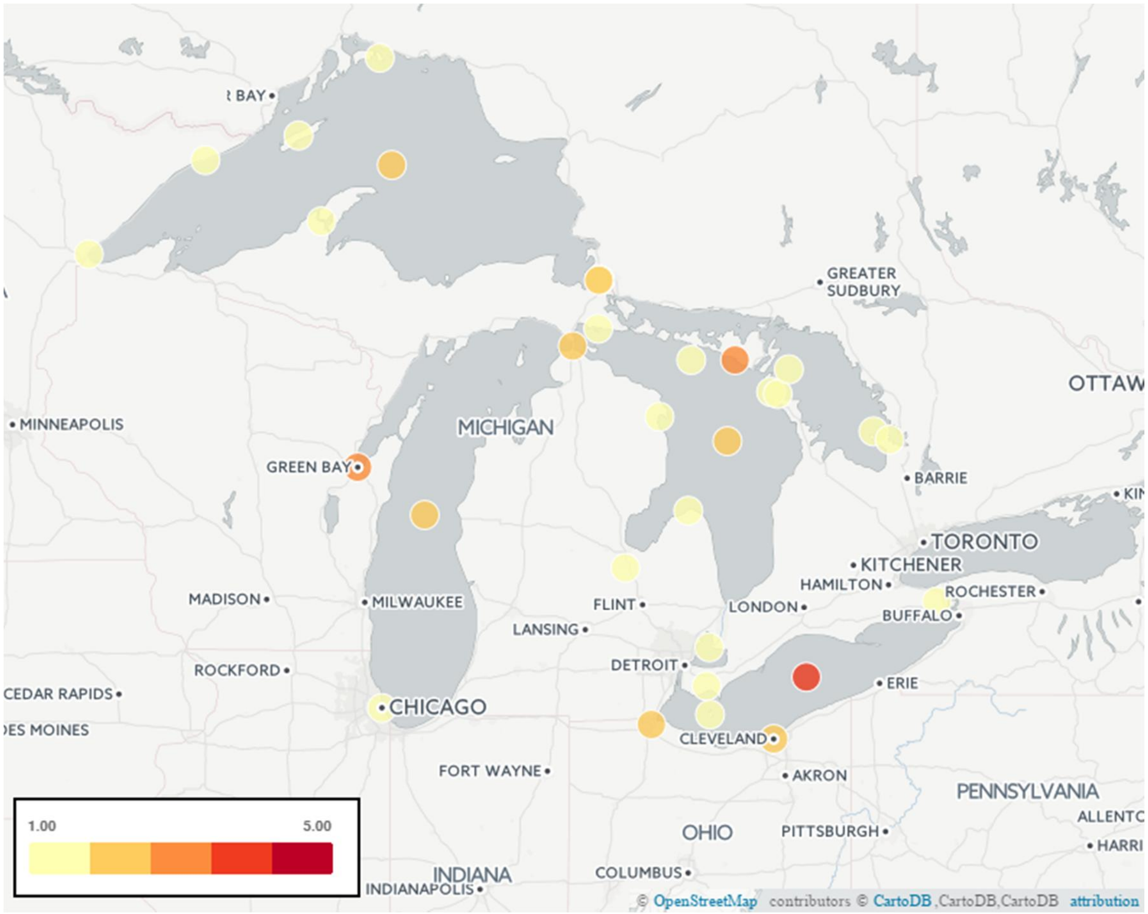

Figure 12. Map of the bat 'hot spots' according to our data. Map created by Audrey Mayer with CartoDB (CartoDB 2015), OpenStreetMap under ODbL license, CartoDB under CC-BY 3.0 license. Map used with the creator's permission.

As Sault Ste. Marie and Straits of Mackinac are located on the border of two of the lakes (Lake Superior/Lake Huron and Lake Michigan/Lake Huron respectively), they could not be assigned to a single lake, so they received their own categories. The same applied for the St. Clair River. Lighthouses were mentioned once, but the respondent did not declare if there are any specific lighthouses where bats are more commonly seen. Welland Canal was also mentioned once and could not be assigned to a larger group. One respondent simply answered 'Michigan', but it was impossible to determine if they meant the lake or the state, so the answer could not be assigned to any of the groups. Of the lakes, Lake Ontario was not mentioned in the answers.

Lake Huron (or parts of it) was mentioned most often. Lake Erie was the second most common lake to be mentioned, followed by Lake Michigan and Superior. Lake Huron was mentioned almost twice as often as Lake Superior. There were also eight respondents who mentioned that they have not noticed that any areas are more common for bat sightings.

Some excerpts from the answers:

"We seen bats on the boat when anchoring in Northern Lake Huron. They will go into the folds of the sail and rest. When we raise the sail in the morning the bat will be forced out of this resting spot. Then they will fly around and land on the deck a couple times before eventually leaving." [Lake Huron]

"In the early 1990's I saw them more frequently in the Toledo area" [Lake Erie]

"Lake Erie, especially east of Cleveland. Off the thumb of Michigan and Alpena" [Lake Erie, Lake Huron]

"Straits of Mackinac swarmed by bats when we were anchored off of St. Ignace MI. late Sept. 2014" [Straits of Mackinac]

"Green Bay area the best for bats. Accumulate the most in foggy weather." [Lake Michigan]

"Seem to pick them up in the vicinity of Lighthouses" [Lighthouses]

"Yes there are for instance we see more in the Welland canal, Lake Erie, and the Straits of Mackinaw, and St. Mary's River" [Welland Canal, Lake Erie, Straits of Mackinac, Sault Ste. Marie]

"The waters of Green Bay have been common lately" [Lake Michigan]

"I saw them primarily on Lakes Michigan and Huron and the St. Mary's River area to Sault Ste. Marie." [Lake Michigan, Lake Huron, Sault Ste. Marie]

"Thunder Bay anchorages North shore of Lake Superior amongst islands about one mile offshore" [Lake Superior]

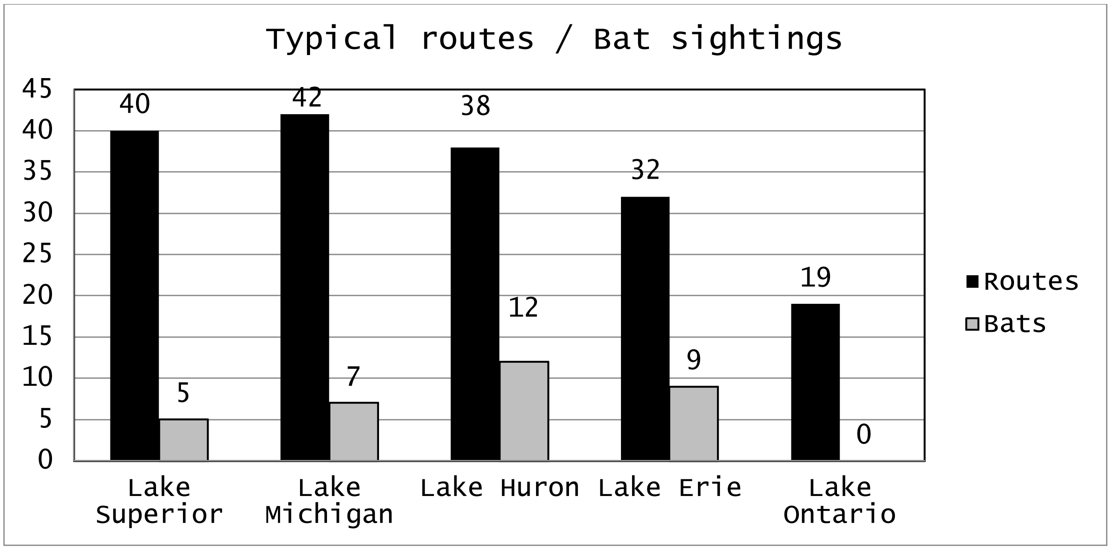

Figure 13. Typical routes the respondents are sailing and Lakes where bats are often seen.

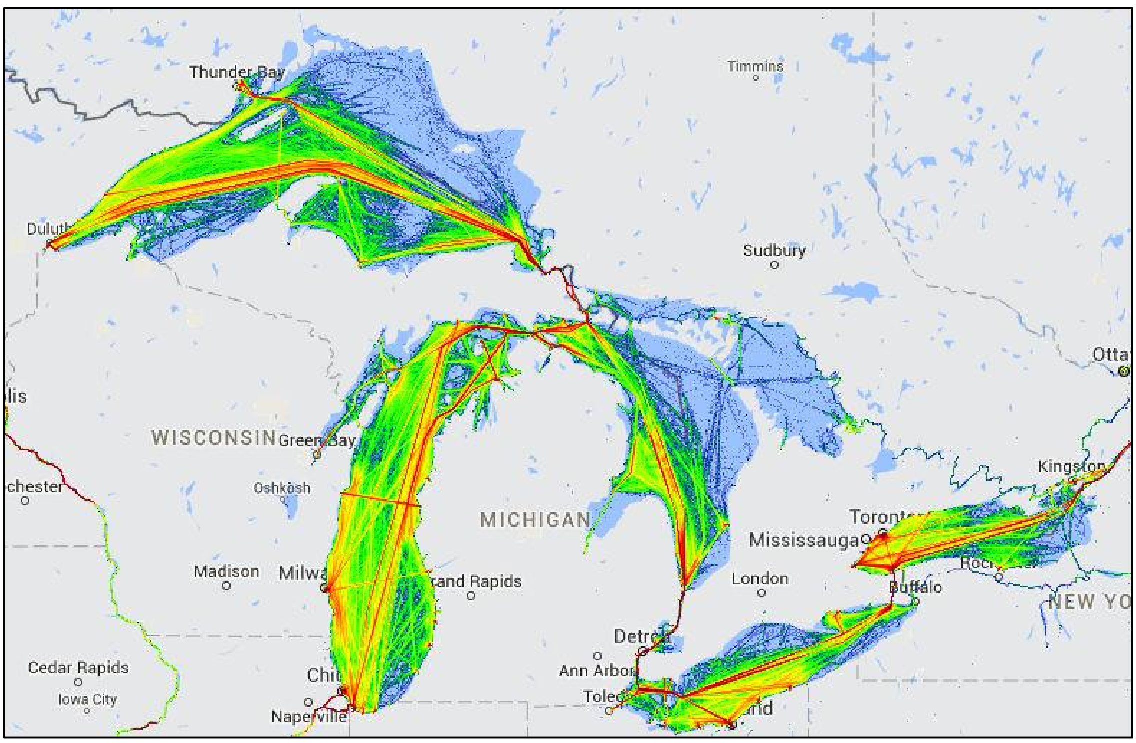

Figure 14. Ship density map of the year 2014 (map obtained from www.marinetraffic.com (Marinetraffic 2015)). Red color indicates the most active routes. Permission granted by the copyright holder acquired to use this map.

In Figure 13 the answers to question 1.7 and question 2.6 are plotted to a same chart. These questions dealt with the typical routes the respondents are sailing (question 1.7) and if they see bats more commonly in some areas or Lakes (question 2.6). Figure 14 presents the amount of shipping traffic in different lakes (Marinetraffic 2015). It seems quite logical that the most travelled routes would also spawn most of the bat sightings, but there is one case in my data where the situation is not so.

What can be seen in the Figure 13 is that Lake Ontario quite clearly differs from the other lakes, where as in Figure 14 it looks like the other lakes. It was not sailed by the respondents as often as the other lakes, and bats were not seen there as often either. It was mentioned only 19 times in the route question, whereas all the other lakes were more common amongst the respondents. It was not mentioned at all in the question regarding bat sightings, being the only one of the lakes with a 0 count.

This can also be seen in statistical comparisons. Lake Ontario differs from the other lakes significantly regarding the routes, which can be seen in X^2 analyses. When the other lakes are compared to each other, no significant differences are found ($X^2 = 1{,}47$, df $= 3$, n $= 152$, p $= 0{,}688$), but when Lake Ontario is taken into the comparison, a difference is found ($X^2 = 10{,}08$, df $= 4$, n $= 171$, p $= 0{,}039$).

A X^2 goodness-of-fit analysis cannot be performed if an observed count is 0, so the same analysis could not be done with the answers to the bat sightings question, with Lake Ontario included. Without Lake Ontario, the bat sightings are not significantly different among the other lakes ($X^2 = 3{,}24$, n $= 33$, p $= 0{,}356$).

Therefore the low count of bat observations in Lake Ontario could be explained by the fact that it was not sailed as much as the other lakes by the respondents. Bat sightings in the other lakes are relatively proportional to their sailing frequencies. Lake Ontario is different in sailing frequency and in bat observations, being the least sailed and without bat observations.

These results might be connected, as less people sailing on Lake Ontario means less opportunities to observe bats, but there could be also other factors in play. Maybe the

surroundings of Lake Ontario do not support suitable bat habitats, and therefore the bat populations there are low and people are not likely to see them. It is also the smallest of the Great Lakes, and maybe bats just fly over, or around it, so quickly that the sailors do not see them.

It might also be due to chance, as the sample size of this study is quite small, and might just not include people who have seen bats flying to or around ships in Lake Ontario. A few respondents mentioned that there are no areas where bats are more common than elsewhere, and Lake Ontario might be included in these answers. This seems to be the most plausible explanation, as the surroundings of Lake Ontario are included in the distribution ranges of almost all of the bat species which can be seen at the other lakes as well.

One should not neglect the possibility that bats are concentrated to some important stopover sites, or fly-over sites. This was demonstrated in an article by Dzal et al. (2009), where they documented bats using an important stopover site, which migratory birds were also using. In their article Dzal et al. (2009) say that bats are most likely using the same stopover site for their migration to south, as they observed the highest number of bats during the migration season. This applies only to migratory bats, such as *Lasionycteris noctivagans*. This might explain some of the bat observations, as the vessels might be sailing close to this kind of sites.

Northern Lake Huron was mentioned three times in the answers we got as being a bat 'hot spot', while according to ship activity data (Figure 14), there is not a lot of ship activity going on in that area. Therefore this area could perhaps serve as a fly over site, or maybe it was highlighted just because of our small sample size caused a biased sample.

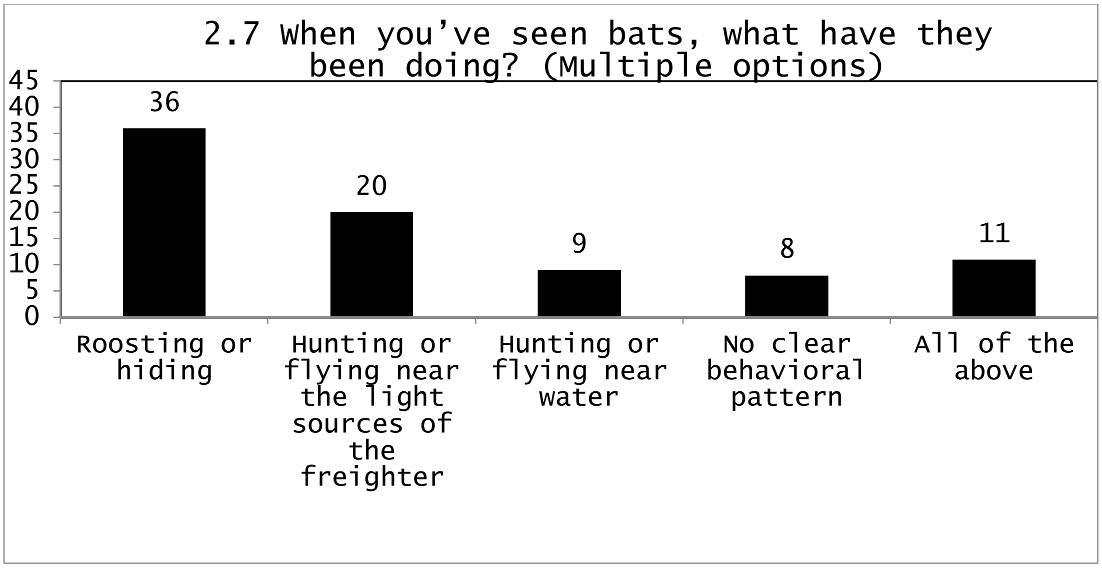

Figure 15. Question 2.7 When you've seen bats, what have they been doing?

After the questions about the locations of the bat sightings, the next question (2.7) went into the quality of the bat sightings. It asked what the bats were doing when they were seen. The respondents could choose multiple options. The most common answer was 'Roosting or hiding', followed by 'Hunting or flying near the light sources of the freighter'. 13 respondents chose 'All of the above', indicating that bats are roosting, hiding and flying around the ships.

'Hunting or flying near water' was not chosen as often as hunting around the freighter. This could be explained by the fact that it might be difficult to see if bats are flying over the water, particularly at dusk, dawn or during the night. Bats flying over water in the darkness might be almost impossible to detect, compared to bats flying around the ship, which can be illuminated and seen fairly easily.

Differences in the frequencies were statistically different ($X^2 = 32{,}79$, $n = 84$, $p < 0{,}05$).

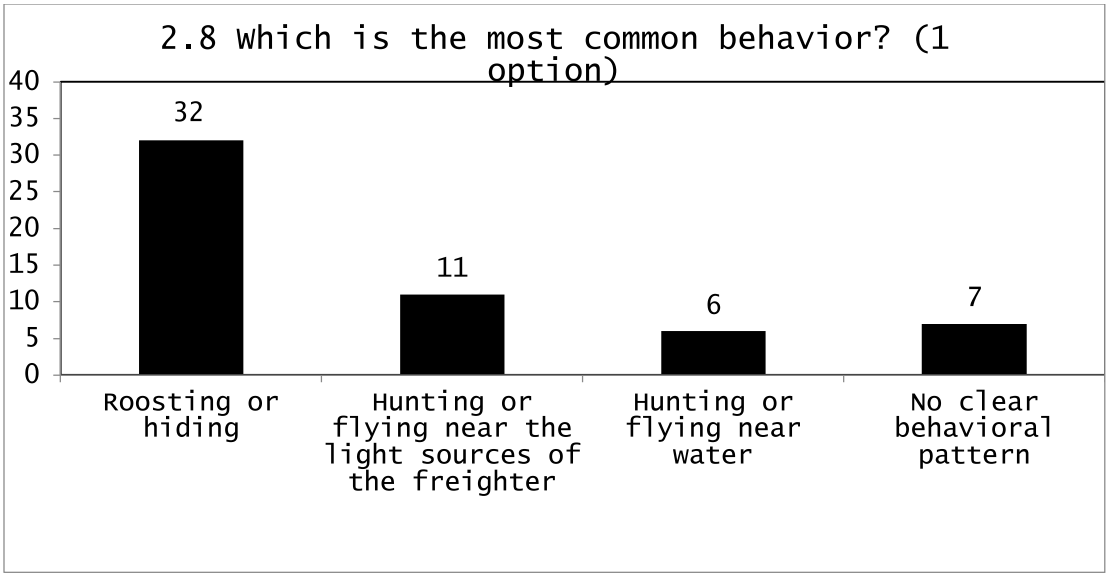

Figure 16. Question 2.8 Which is the most common behavior?

The Question 2.8 continued in the footsteps of the previous question (2.7). In this question the respondents were asked to choose one type of bat behavior which they thought was the most common based on their experiences. So instead of multiple answers, in this question only one was accepted.

The distribution of the answers is quite similar to the question 2.7. 'Roosting or hiding' is still the most common answer, followed by 'Hunting or flying near the light sources of the freighter'. What should be noted, is that 'Roosting or hiding' was chosen almost as often as in the previous question (n = 33 in question 2.8, while it is 37 in question 2.7), further indicating that bats are most often seen when they are stationary.

'Hunting or flying near water' gathered approximately half of the amount of answers as 'Hunting or flying near the light sources of the freighter', which was also the situation in the previous question. However, 'No clear behavioral pattern' got one more answer in the question 2.8 than in the question 2.7, even though in the question 2.8 the respondents could only choose one answer that applies.

Differences in the frequencies were statistically different ($X^2 = 31,86$, $n = 56$, $p < 0,05$).

These results can be explained by the primarily nocturnal behavior of bats, and therefore it might be difficult to observe them if it is dark outside. But if they fly close to light sources, they can be seen. An overall pattern in the answers to the open questions was also that the bats that people encounter are usually hiding somewhere. This aligns well with the results of this question, as if people are working during the day, they will most usually encounter roosting or hiding bats.

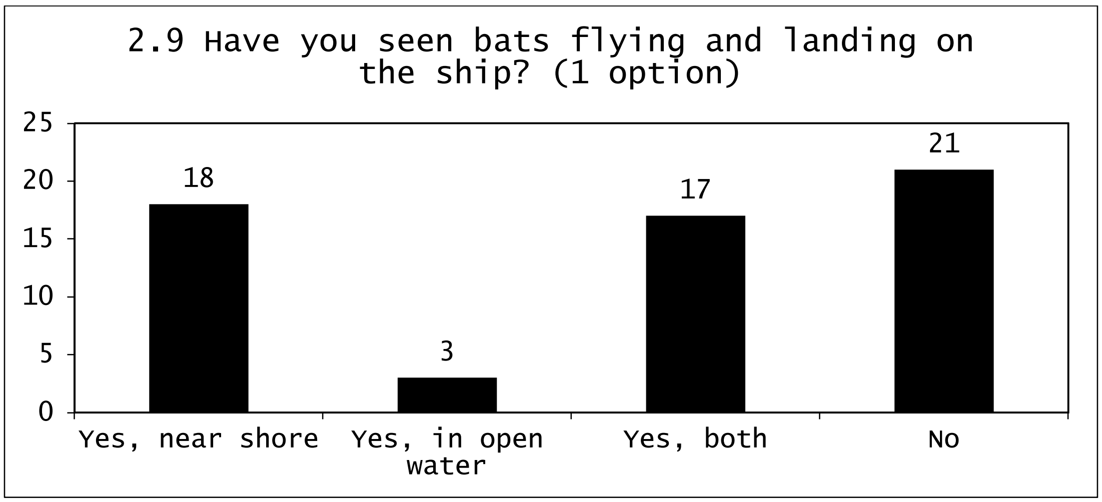

Figure 17. Question 2.9. Have you seen bats flying and landing on the ship?

The question 2.9 asked if the respondents had seen bats flying or landing on the ship. The answer ‘No’ was the most common. This aligns well with the results of the previous questions (2.7 & 2.8), as bats were most commonly seen when they are roosting or hiding. Quite a few people (64 % of the respondents) had seen bats flying and landing on the ship, which indicates that the bats are not just passing by, but are actively landing on the ship and/or seeking shelter, food, etc. As in the question 2.5, the bats were seen more often near shore than when sailing in open waters. These results demonstrate that there is coherence in the answers, as the same trend can be seen in two separate questions. However, in this question people also chose the option ‘Yes, both’, indicating that they have seen bats both near shore and in open waters. The option of only seeing bats when

sailing in open waters was chosen only three times, so it seems to be a rather rare event, compared to seeing them closer to the shore.

Differences in the frequencies were statistically different ($X^2 = 13{,}07$, n = 59, p < 0,05). This is explained by the low number of answers in the category of ‘Yes, in open water’, which seems to be different from the other categories. The frequencies in the other categories are quite similar to each other.

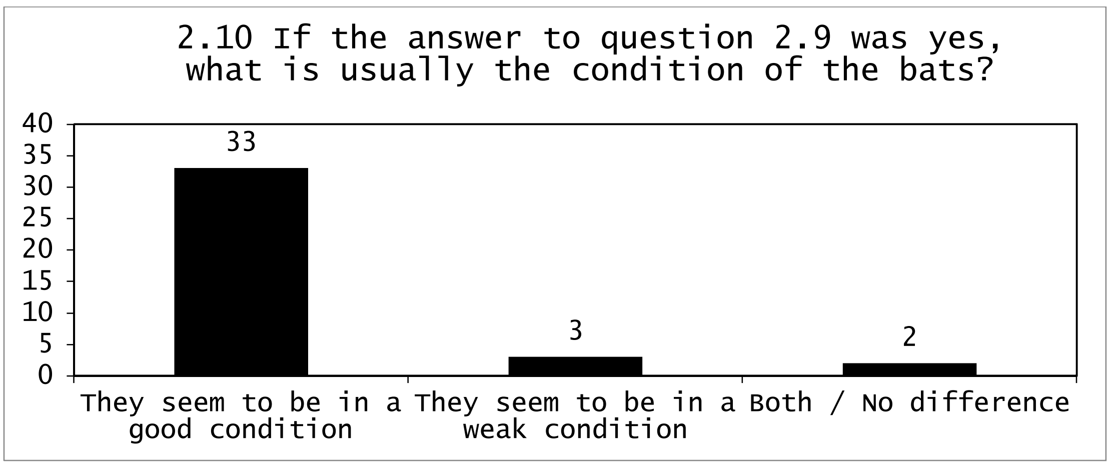

Figure 18. Question 2.10 If the answer to question 2.9 was yes, what is usually the condition of the bats?

The question 2.10 asked the people who chose ‘yes’ in the previous question about the condition of the bats. Most of the people who had seen bats flying and landing on a ship said that the bats seemed to be in a good condition. This might indicate that the bats are not attracted to the ships because they are weakened, sick, exhausted or some other reason. Their health therefore might not affect the reason why they are landing on the ship. Differences in the frequencies were statistically different ($X^2 = 49{,}0$, n = 38, p < 0,05). However, it is quite difficult to determine the health of a bat if you are not an expert. Therefore these results should be interpreted with caution.

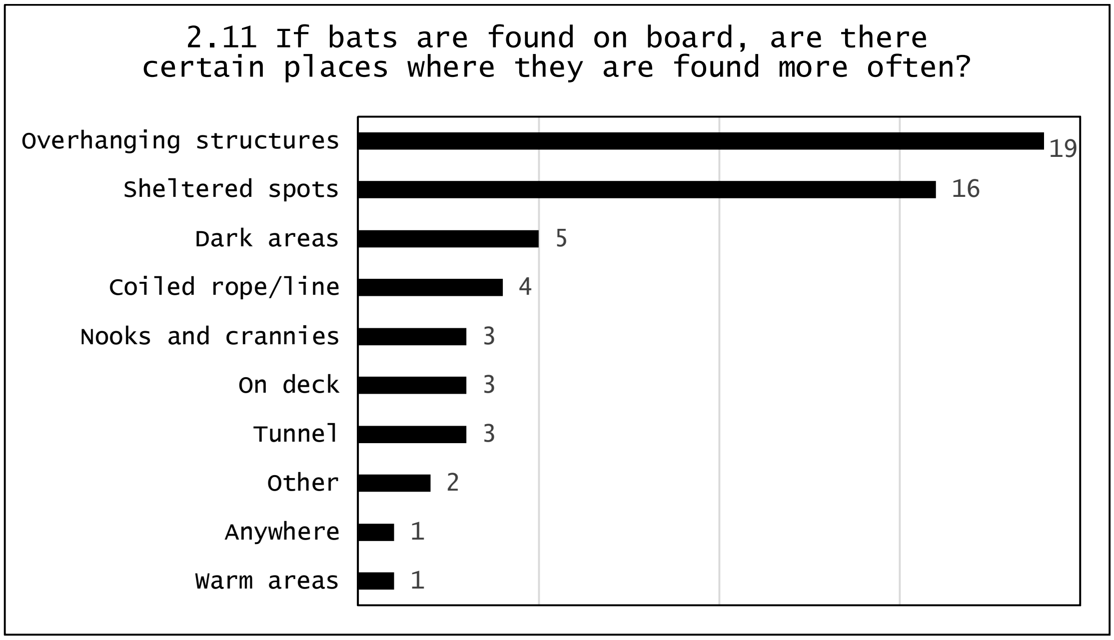

Figure 19. Question 2.11 If bats are found on board, are there certain places where they are found more often?

Question 2.11 was an open-ended question. I assigned the answers to larger groups according to the similar type of information/theme they contained. 'Overhanging structures' was the largest group, gathering 19 mentions in the answers. 'Sheltered spots' was the second most common theme occurring in the answers. These can easily be explained by the fact that bats like to hang from overhangs when they are resting, and that they are most likely to go to dark, sheltered places to do so. Therefore these results are not surprising.

It looks like that there is a multitude of different places where bats can be encountered on a ship. Usually they are hiding, as was mentioned already in the question 2.8., which can also be seen in the answers of this question. The places where bats are most often seen are also good hiding places for the bats.

The results of this question are not a surprise, as they follow the results presented in the scientific literature about bats roosting in manmade structures (e.g. Kunz 1982, Kunz 2003, Lausen & Barclay 2006). Bats tend to favor structures which can act as substitutes for their natural roosting habitats. Ships can have diverse spaces, and based on the results of this question, it seems that bats have found quite a few suitable roosting sites inside them.

Some excerpts from the answers:

"Under overhangs or any place they can get out of the daylight sun." [Overhanging structures, Dark areas]

"Aside from simply flying near buy we've had them get in the unloading tunnel. Also found on deck hiding during day in some dark area." [Tunnel, Dark areas]

"In cargo holds/unloading hopper areas. If in poor condition they are usually struggling on deck." [Overhanging structures, On deck]

"Roosting in recessed areas where they probably feel protected" [Sheltered spots]

"Each time they have rested in the folds of the sail, probably entering during the night." [Sheltered spots]

"Under steps or other structural shelter" [Overhanging structures, Sheltered spots]

"The bats feed in the wee hours of the morning eating bugs attracted by the anchor lights. As the sun rises, bats realize they are far from shore. Struggling to grasp the ships sides and smooth shell they finally roost under tarps covering boats and equipment." [Sheltered spots]

"On deck, hanging on the outside wiring under the various decks outside, the unloading boom, and any dark, confined space on deck." [On deck, Overhanging structures, Dark areas]

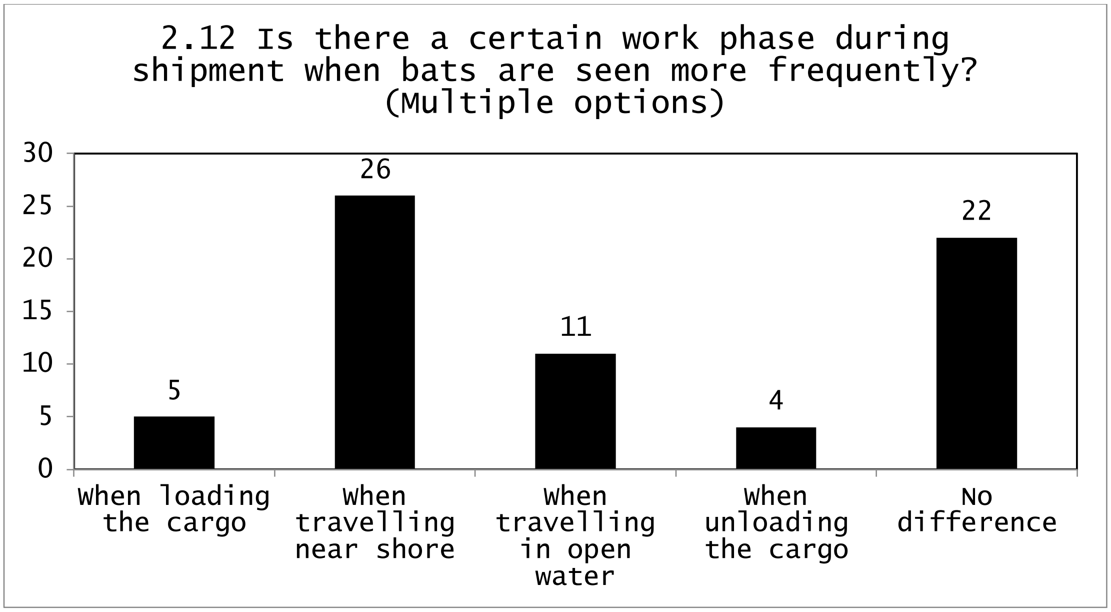

Figure 20. Question 2.12 Is there a certain work phase during shipment when bats are seen more frequently?

The question 2.12 asked about the work shifts during a shipment and the commonness of bat observations during those work shifts. The most common answer was 'When travelling near shore', followed by 'No difference'. This aligns with the answers to some of the previous questions, which indicated that bats are seen near shore more often than when in open water.

The popularity of the answer 'No difference' might indicate that the sailors are observing bats during all the work shifts, and could not point out a single work phase where bats are seen most often. It might also be explained by the fact that the sailors might not remember when they've seen the bats.

Differences in the frequencies were statistically different ($X^2 = 29,20$, $n = 68$, $p < 0,05$). This is most likely caused by the low numbers of answers to the categories of 'When loading the cargo' and 'When unloading the cargo'. This could be explained by the fact that not everyone is directly involved with cargo loading and unloading operations, and therefore they cannot even see bats during them. Also the second most popular answer 'No difference' includes all the other answers.

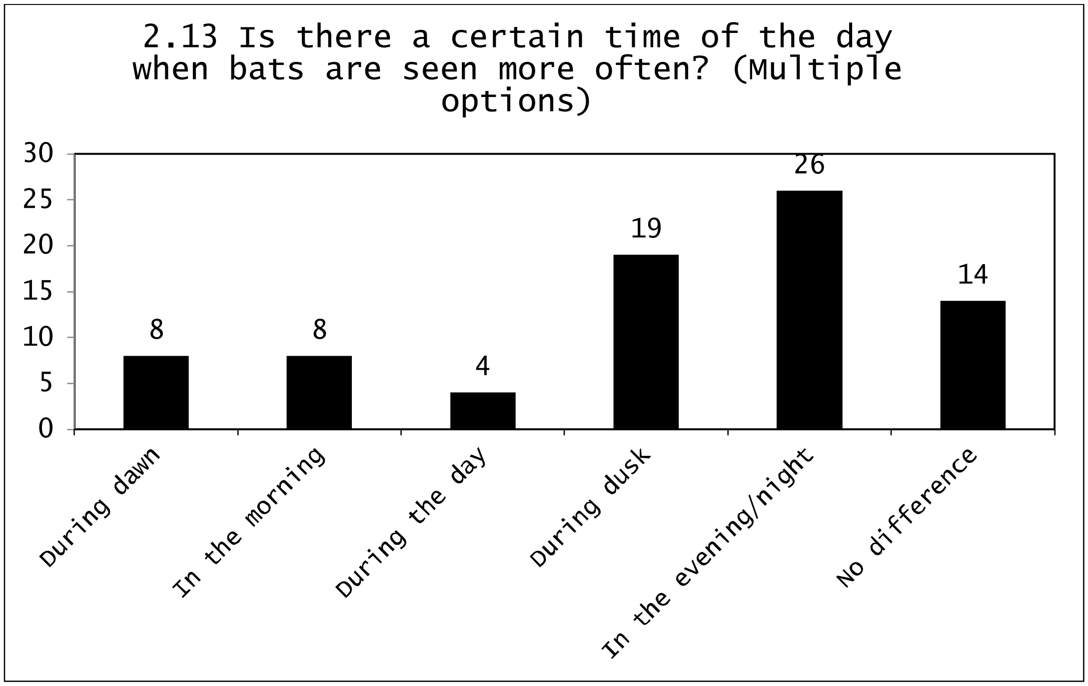

Figure 21. Question 2.13 Is there a certain time of the day when bats are seen more often?

The question 2.13 asked the respondents to choose the times of a day when they see bats most often. They could choose multiple options in this question. ‘In the evening/night’ was the most popular answer, gathering 27 answers. ‘During dusk’ was chosen by 19 respondents, and ‘No difference’ by 16. ‘During the day’ was the least popular answer, which is quite logical as bats are nocturnal animals, and are usually hiding during the daylight hours.

Differences in the frequencies were statistically different ($X^2 = 25,58$, $n = 79$, $p < 0,05$). This is explained by the low numbers of answers in the categories ‘During the day’, ‘During dawn’ and ‘In the morning’.

However, as some people mentioned in the previous questions that they often see bats roosting or hiding, and not so often flying, it is a bit curious to see that the daylight hours are not well represented here. Maybe these people answered ‘No difference’, as they might see bats flying when it is darker outside, and then they might find hiding and/or

roosting bats during the daylight hours. It is also possible that they see the hiding bats during dusk or in the evening, and therefore chose that option in this question.

Judging by the answers, it seems that bats can be seen throughout the day, as all the options were chosen at least four times. The popularity of the 'No difference' category further suggests that this is the case. The most plausible conclusion is that people see flying bats during the time of the day when bats are active, and then they encounter roosting bats during the daylight hours.

However, these results contradict the results obtained with the question which dealt with what bats are doing when they are seen, in which people stated that they most often encounter hiding bats. The second most popular answer to that question was that people see flying bats, and the case might be that these encounters are slightly over-represented here.

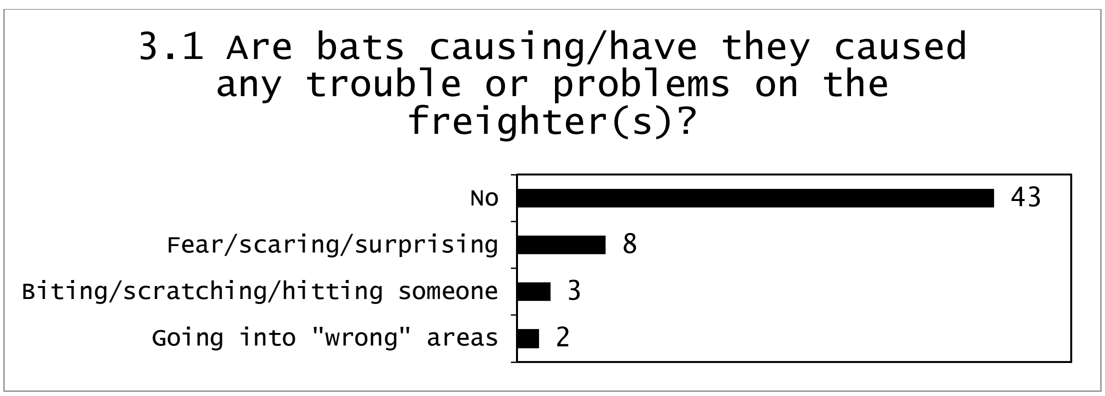

Figure 22. Question 3.1 Are bats causing/have they caused any trouble or problems on the freighter(s)?

The question 3.1 asked if bats are causing or have caused troubles or problems on the ships. It was an open-ended question, and the answers were grouped into four different categories.

'No' was clearly the most common answer, standing well out from the rest. 'Fear/scaring/surprising' was the second most common. Bats can surprise people, as they

are small and good at hiding. 'Biting/scratching/hitting someone' was also mentioned a couple of times, which raises concerns about rabies risk. This was also mentioned in the answers, as some people were afraid of rabies. Two of the respondents also mentioned that bats can go into some places where they should not go, causing trouble that way, as they have to be somehow moved away from these kinds of places.

Some excerpts from the answers:

"Had a crew member get bit onetime on board." [Biting/scratching/hitting someone]

"They surprise deckhands removing tarps in the morning and fly off disoriented in the daylight" [Fear/scaring/surprising]

"They do not cause any problems, although there are crewmembers who are afraid of them." [Fear/scaring/surprising]

"No, though they do occasionally find themselves inside the accommodations." [Going into "wrong" areas]

"not really, other than fear of them. It only takes 1 to clear a room of 6 grown men." [Fear/scaring/surprising]

"No we leave them alone, they tend to disappear at the dock at night." [No]

"only if there are individuals who are "distressed" by their presence" [Fear/scaring/surprising]

"Only in that some people are scared of them. A bat getting into the unloading tunnel usually causes a problem for the bat." [Fear/scaring/surprising]

"NO PROBLEM SOME PEOPLE FEAR RABIES" [Fear/scaring/surprising]

"No problem noted by me at the time I worked." [No]

"A weak bat made contact with my shoulder once in heavy fog" [Biting/scratching/hitting someone]

Based on the answers, it looks like bats do not generally cause harm on the ships to the sailors, or to the ship. This is not a surprise, as bats rarely cause harm. When they might cause trouble is if they decide to roost in a building in huge numbers, as their fecal matter and urine might cause damage to the structures (Greenhall & Frantz 1994). Greenhall & Frantz (1994) also mention that bats might cause unpleasant noises, such as scratching, crawling, and vocalizations. Certainly if bats decide to establish a colony close to a ship's living quarters it might disturb the quality of the sleep of the sailors. Bat colonies in

buildings are also linked to some arthropods, which can become an annoyance to the residents (Greenhall & Frantz 1994).

One incident of a bat biting someone was mentioned, and this is a serious health hazard, as North American bats are known hosts of rabies viruses. Therefore every bat contact should be considered as being a risk of rabies transmission (e.g. Constantine 2009, Blanton et al. 2011). In these cases, medical attention should be received immediately. Rabies vaccination kits should be on board, and the personnel should receive some kind of education on their proper use, to mitigate the risk.

The largest problem that bats seem to cause is that they might surprise or scare people. This should be considered as a minor inconvenience, and does not require major corrective actions or preventive measures. The only way of preventing bats from surprising people is to somehow keep bats off of ships. This might be difficult, or nearly impossible, as they are very small and good at hiding. An easier option is to just inform people that bats are generally harmless, and there is no need to be afraid of them. Usually the bats are more afraid of the sailors than the sailors of the bats.

One interesting way of analyzing this question was to look if the type of the ship affected the answers. I divided the ships to research and cargo vessels, and looked if the answers differ. The people working on research vessels did not report any problems with bats, except for one incident of a bat coming into contact with a person. Therefore it looks like that scientists are not afraid of bats, which might be due to their education or some other factor. However, it must be kept in mind that the number of responses from science vessels (11) was a lot smaller than the number of answers from cargo vessels (48).

The last question (3.2) of the questionnaire was an open question “Is there anything else about bats you would like to share with us?”

There were many things that the respondents wanted to share. Here are some of them grouped into categories:

Only a few sightings on board:

"I have not had many sightings of them, so other than one or two isolated instances of seeing bats, I can share more. Even that is a very limited observation."

"I have been working off and on as a sailor on the Great Lakes since 1999, and that first year was the only time I have seen bats on board my ship. It happened only once, in the early fall, and I did not even see them board when we were loading in Silver Bay (I think) until the next morning when they were hanging upside down everywhere. There had to be at least a hundred of them on board, maybe twice that. They did not interfere with ship operations, so we mainly avoided them and they eventually left a few days later, probably when we arrived at the next dock. Did not see when they actually left."

"We see a lot of bats at certain times of the year feeding on insects around the ports and harbors but rarely do those bats land or wind up on our vessel. The bats we do see on our boat (which is rare) are found during the day during inspections and prior to sailing, They are normally always sleeping and fly off once provoked to do so."

Bats are common:

´"They just show up and you take note and then you don't see them again. When they show up again you take note. We have plenty of birds from owls, hawks, and herrons, to commonly finches that all hitch rides across the lakes. I believe they land qhen we are close to shire and as we move farther out they are stuck until we reach another close point to shore."

"Unfortunately the crew disturbs them instead of leaving them to rest and depart of their own accord. I often see bats flying over open water in the north end of Lake Michigan. The ones I see never seem to land on the ship. Not sure when those found roosting actually come aboard."

"I have seen several bats on every ship I have been on, some even in the crew living areas but the mostly stay to areas that are rarely visited by crew, like inside rafter storage, ect."

"very numerous at times, dozens maybe 100's, attracted to lights and insects hatching"

Attracted by lights, or active during the night, feeding:

"active at night in the lights hide in the day"

"i have only seen bats flying around at night but never come to the boat"

"They are probably active at night and are only active during the day because we set the sail. We wake them up and then they are forced to come out of hiding"

"We were 22 miles from shore and had all our bright flood lights on working fish samples at night. We were swarmed by hunreds of bats eating the bugs that were attracked by our bright lights."

“They really help with the bugs and spiders.”

“the bats seem to feed when midge/mayfly hatch is prolific.”

“Had one below deck in the dunnage room. There is deck personell housed down there and a bat was flying around. How it got down there is anyone's guess. Could have come through a porthole or flew down the stair well. I had seen another at an earlier date in the stairwell tucked in a corner. Another time we were in the Straits of Mackinac abreast of Mac. Island in the fog. I was the watchman on the bow and suddenly a bat hit my hat. They were everywhere so I went and grabbed my hardhat. The Captain said he had heard there were caves on the island and that's where they came from. I saw them regularly in that area flying around on a calm evening over the water I guess eating bugs. We would have these mayfly attractions to the decklights and I wondered if this attracted them.”

Number of bats declined in the recent years:

“Have not seen as many this year as previous years.”

“over the last few years, there have been less sightings.”

“They seem to have become less common on the Great Lakes over the past 5-10 years.”

Different kinds of attitudes, funny observations and interactions:

“They terrify some people, so that's always amusing. I don't mind them at all.”

“SEEN ONE ALBINO”

“I don't have a problem with them being around. Lots of flying insects on board.”

“I am fascinated by them.”

“Species seems to be some sort of small brown bat. Bats will roost for a few days and then disappear. "Hitchhiking" behavior is similar to that of many birds also encountered on the Great Lakes.”

“The bat was flying around inside the pilot house and the skipper looked at me with a blank stare and said, "Well, get 'im!" I looked at him and thought, "YOU get 'im!" But I put on a leather work glove, caught the bat like a baseball, and flung it outside. It looked like it flew back to the stern towards the stack, but I couldn't tell where it went.”

“Aboard the [name of the ship omitted] *we go into port every night so I am unsure if the bats we encounter are coming from being near shore or during the day in open water. We have also observed bats clinging to our gill net staff buoys in the open water.”*

“we were cautious about coming into contact with bats, we were told they carried rabies.”

There are a few really interesting things in the answers to open questions. A couple of people mentioned that they had seen a lot of bats on one instance: *"very numerous at times, dozens, maybe 100's ..", "".. the next morning they were hanging upside down everywhere. There had to be at least a hundred of them on board, maybe twice that ..", ".. We were swarmed by hundreds of bats eating the bugs ..".* It appears that the bats can also come as a really big flock, in addition to being seen as only a few wandering individuals. One hundred bats occupying a ship must be quite an experience for the sailors, especially if they are a little scared of the bats, as was mentioned to be the case in the previous question.

Another really interesting notion was that some people mentioned that bats do not seem to be so common anymore *"over the last few years there have been less sightings", "They seem to have become less common on the Great Lakes in the past 5-10 years", "Have not seen as many this year as previous years."* What should be noted is that the White-Nose Syndrome has caused a massive decline in the bat populations around the Great Lakes since approximately 2009/2010 (USFWS 2014). It is possible that it can be seen in these answers, but it can be just a coincidence.

One respondent mentioned that *"we were cautious about coming into contact with bats, we were told they carried rabies."*, and rabies was also mentioned in the question about the trouble that bats might cause. It is true that one should be cautious when encountering bats, because while the rabies risk is not substantial, it is still a risk that should be avoided. It is a little surprising, and also alarming, that the respondents did not mention rabies more often. A couple of the respondents mentioned that bats had been encountered in the crew living areas. This kind of interactions might put the personnel in risk of getting an infection.

Some respondents mentioned that bats were probably attracted to the insects that were attracted by the bright lights that the ships have. Also other notions about bats being after the insects where shared: "*We were swarmed by hunreds of bats eating the bugs that were attracked by our bright lights",*

"I saw them regularly in that area flying around on a calm evening over the water I guess eating bugs. We would have these mayfly attractions to the decklights and I wondered if this attracted

them.", "I don't have a problem with them being around. Lots of flying insects on board.", "They really help with the bugs and spiders.", "the bats seem to feed when midge/mayfly hatch is prolific.". It seems logical that people observe that the insectivorous bats are eating the flying insects.

One respondent mentioned that they had seen an albino bat. This is a very curious observation.

5.2 Miscellaneous results

During the research process I also collected some unexpected results, which are presented in this section. What was the most unexpected was that it was possible to get to species-level identification of some of the bats that had been seen on board. This was unexpected as it is not likely that sailors can identify bats.

Figure 23. An Eastern red bat (*Lasiurus borealis*) on a freighter near Sault Ste. Marie, MI. Photo courtesy of Erik Wlazlo. Species identification by Bill Scullon.

Figure 23 is a nice photograph of an Eastern red bat (*Lasiurus borealis*) that we received from one of the respondents. It was taken in the fall 2014, near Sault Ste. Marie, Michigan, USA. We also received three more photos of Eastern red bats from another photographer, which could not be reached for permission to use the photographs.

In addition to the Eastern red bats, one photo was received of a bat which was identified to be either a Little brown bat (*Myotis lucifugus*) or a Northern long-eared bat (*Myotis septentrionalis*). The photograph was sent to Mr. Bill Scullon from Michigan Department of Natural Resources for identification, but it was not detailed enough to distinguish the species from one another. Both of the bats have been abundant in the region, so encountering them is not a surprise.

Myotis lucifugus and *Myotis septentrionalis* have been affected by WNS, but the population of *Lasiurus borealis* has remained unaffected (Blehert et al. 2009, Bernard et al. 2015). *Lasiurus borealis* can still act as a host of the fungus, and therefore if these species meet on ships, it might provide one pathway of transmitting the disease. There might not be a lot of hiding places for bats on these ships, and therefore species who might not come into contact with each other in the wild might have more interactions on ships. Ships with their closed spaces and limited possibilities for roosting might therefore enhance the spreading of the disease, not only by translocating hitchhiking, potentially infected bats, but also putting bat species into increased contact with bat species that are carriers.

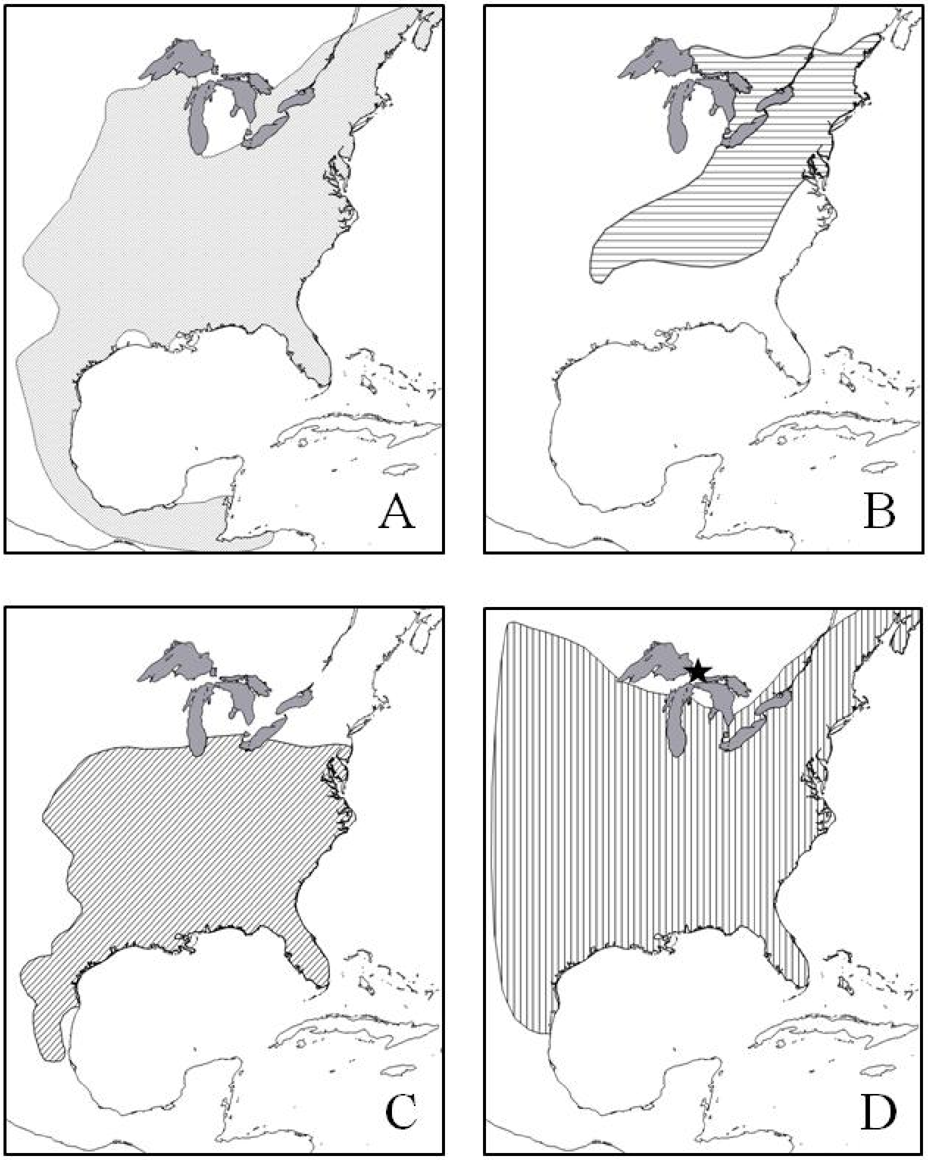

Figure 24. Distributions of four different bat species. A. Tri-colored bat (*Perimyotis subflavus*), B. Small-footed myotis (*Myotis leibii*), C. Evening bat (*Nycticeius humeralis*), D. Eastern red bat (*Lasiurus borealis*). In map D the location of the city of Sault Ste. Marie, MI is marked with a star. Source of the spatial data: The IUCN (2014).

Figure 24 presents the distribution ranges of four bat species, which are present in the Great Lakes region, but whose ranges do not cover all of the lakes. Therefore if these species hitchhike, they might get transported outside of their native range. As can be seen from the maps, the species can potentially hitch rides and extend their ranges to two

different major cardinal points. In the cases of *Perimyotis subflavus*, *Nycticeius humeralis* and *Lasiurus borealis* they can extend their range to north. *Myotis leibii* could mostly extend its range to west along the lakes.

During this study, one case was documented of a bat which was encountered outside of its native range on a ship. We received a photograph of *L. borealis* (Figure 23), which was seen on a ship at Sault Ste. Marie, MI. As can be seen from the Figure 24, map D, Sault Ste. Marie is not in the range of *L. borealis*. Therefore the individual bat was outside of its range. How it got there is unfortunately not known.

This raises questions about the accuracy of these range maps; maybe the range of *Lasiurus borealis* covers all the lakes? One possibility is that the bat which was seen was just a lonely wanderer, which flew to Sault Ste. Marie for some unknown reason. The most interesting possibility, in the framework of this thesis, is naturally the explanation that the bat hitchhiked, and got there from another port.

I also received an email from a sailor, who said that he had seen peregrine falcons feeding on some bats which were hitchhiking on their freighter. This is a fascinating story and incident. The sailor said that he has some pictures, but unfortunately he could not be reached for further questions or the photos. The respondents of the questionnaire did not report bats interacting with other wildlife, but if this story is true, there is at least one occasion when both bats and birds have been aboard on a ship and had interesting interaction.

6. CONCLUSIONS

The conclusions are organized starting from the objectives presented in Section 2 of this thesis.

a) Animal dispersal

The major background theme of this thesis was animal dispersal. Based on the results and discussion, it is quite safe to conclude that ships might act as vectors, and bats can hitchhike on ships in the Great Lakes. The size of the role that ships play in bat dispersal still remains unknown however. My results illustrate the possibility that if certain species are unintentionally translocated, they can be transported outside of their native range.

b) Bat-human interactions

The second focus point was on the relationship between bats and people. Most of the respondents (~95 %) had seen a bat on board at least once, so it is quite safe to say that they are rather commonly seen. A couple of sailors had even gotten close enough to bats to take detailed photographs. Sailors also shared stories of their bat encounters. It seems that interactions occur, and the nature of them is generally that people disturb roosting bats, which then escape by flying away.

Bats are not known to cause any trouble on ships, other than scaring some people. Sometimes they might get into the living quarters, but some brave individual sailors have then removed the bats. Someone had got bitten by a bat, which is a serious health risk, and incidents like this should not be taken lightly, as will become clear when reading the next section.

c) Diseases

The third theme was diseases. The zoonotic spill potential of bats is quite high, and they have caused disease outbreaks before. They are also suspected as being the source of the most recent and notable Ebola outbreak in 2014. In the Great Lakes region Ebola viruses are not present, but the bat species which are present in the region can host other viruses, such as rabies. Rabies risk is the major zoonose risk in this region, but no known cases of sailors getting a rabies infection from a hitchhiking bat was brought to our knowledge. Therefore the risk seems to be quite low, but rabies vaccination kits should probably be on board of the ships, just in case.

During the past decade, North America's bat populations have faced an enormous disaster in the form of a fungal disease, called White-Nose Syndrome. The spreading dynamics and mechanics are not yet fully understood, but if the ships help bats move to new areas, they might assist the spread of the disease. Based on the photographic evidence we received from two individual sailors, bat species which have faced mass-mortality from the disease, and species whose populations have not declined, have both been seen on ships.

This might provide opportunities for the disease to spread from a species to another, if individual bats choose to hide in a same place in a ship. Hiding was the most common behavior of bats on ships, and given the limited hiding place opportunities on board, it seems likely that species-to-species contact might occur. Also, if a bat from an affected hibernaculum hitches a ride across the lakes, and enters a previously unaffected hibernaculum in a new site, it might enhance the potential of WNS spreading.

d) Limitations of the study

I recognize that there are a few limitations to my study due to its methods. The biggest uncertainties are connected to how I collected the data. There are a few issues which affect the reliability.

Firstly, I got quite a lot of responses after posting a link to the questionnaire to an online forum, which is accessible for everybody who uses the internet. Therefore it is possible that some of the answers came from people, who are just pretending to be sailors, and in reality are just random people using the internet. Judging by the coherence in the data this does not seem likely, but it is still a possibility.

Secondly, people who have not seen bats are probably less likely to respond. Therefore our sample population is most likely skewed towards people who have seen bats, and have a positive attitude towards science; thus they're more likely to answer.

Thirdly, the information I received about the locations of bat sightings might be connected to better lightning, more ship activity and other external factors, and not to actual higher bat activity in the areas that were mentioned most often.

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APPENDIX 1. THE QUESTIONNAIRE

Hitchhiking Bats on Great Lakes Freighters

A study about the relationship of man and bats in ship transport business in the Great Lakes region.

CONSENT

You have been asked to take part in this study because you work in the Great Lakes. This study is about hitchhiking bats, and it aims to improve our understanding about the relationship between man and wildlife.

What the study is about: As mentioned before, the study is about hitchhiking bats. That means that we would like to find out how often/when/where bats hide in freighters or other kinds of ships, or if that happens at all. We have heard that it happens sometimes, but to what extent remains unknown.

What we will ask you to do: If you want to take part in this study, we only ask you to fill a questionnaire form. It includes questions about bats, and how often you might have seen them, where and when. It should not take more than 10 minutes to fill, so we do not ask for a long time commitment.

Why have you been asked to take part? You have been asked because you are working in the Great Lakes region and the American part of our study is focused there.

Do you have to take part? No, if you do not want to. Participation is fully voluntary.

Will your participation in the study be kept confidential? Yes, we do not aim to identify the respondents. However, if you would like to receive a short summary of our key findings when the research is completed, we ask for your email address. Other than that we do not ask for your identity, so the study is anonymous. If we quote some of your answers in the thesis or publication, the quotes will be anonymous and cannot be linked to you.

What will happen to the information which you give? It will be kept confidential, and will only be accessed by the researchers. It will be used for the study and then kept locked in an encrypted file.

What will happen to the results? The results will be presented in the thesis and possibly in a published scientific article. They might also be discussed in a newspaper if the topic is considered interesting enough for the public.

Risks and benefits:

The risks posed to you if you wish to participate in this study are minimal.

We cannot provide any benefits for participating other than that you get to be a part of an interesting scientific study and help us fill a knowledge gap with your contribution. You can also receive a summary of our key findings if you wish to.

What if there is a problem? If there are any problems, you are kindly asked to contact the principal investigator, whose contact information can be found in the end of this page.

Who has reviewed this study? This study was reviewed and approved by the Office of Compliance, Integrity, and Safety of Michigan Tech University.
Any further queries?

If you have any questions about the study, you can contact the principal investigator Mr. Saska Lohi through email (selohi@mtu.edu) or by phone +358400482176 (Finnish phone number) or Assistant Prof. Audrey Mayer who is the supervisor of this study via email (almayer@mtu.edu) or by phone +1 906 487 2864.

If you have any questions about your rights as a research subject, you may contact the Office of Compliance, Integrity, and Safety by mail at 1400 Townsend Drive, 302 Lakeshore Center, Houghton, MI 49931, by phone at 906 487-2902, or by e-mail at IRB@mtu.edu. This study (IRB #435033-1) was approved by the IRB on 04/04/2013.

By clicking "I agree to participate" you consent to participate in the study on a voluntary basis and that you understand the risks involved.

If you do not wish to participate, or you want to withdraw from the study, you can always leave the page without saving.

Consent ?

	I agree and I am willing to participate	I do not agree
Consent	○	○

SECTION 1 - BACKGROUND INFORMATION

Background information of the respodent

	Please type your answers
1.1 Age of the respodent	
1.2 Years worked at the Great Lakes	
1.3 Name of current company	
1.4 Name(s) of current freighter(s)/ship(s)	

The freighter(s)

	Please type your answers
1.5 Size of current freighter(s)/ship(s)	
1.6 Type of current freighter(s)/ship(s)	
1.7 Typical route(s) of current freighter(s)/ship(s)	
1.8 Typical cargo of current freighter(s)/ship(s)	

SECTION 2 - BATS

2.1 Have you ever seen bats on board?

* ◯ Yes

◯ No

SECTION 2 - BATS CONTINUED

2.2 If yes, how often do you usually see/have you seen bats?

- ☐ Once a week or more often
- ☐ Once a month
- ☐ Few times a year
- ☐ Once a year
- ☐ More rarely

2.3 Is there a certain time of the year when bats are seen more often? (You can choose more than one option if bats are seen more often in two or three seasons, but if they're seen constantly during the year please choose "No difference")

- ☐ Winter (Dec - Feb)
- ☐ Spring (Mar - May)
- ☐ Summer (Jun - Aug)
- ☐ Fall (Sept - Nov)
- ☐ No difference

2.4 In what condition are bats usually? (You can choose more than one option, if it is necessary)

- ☐ Alive and in a good condition
- ☐ Alive and in a weak condition
- ☐ Dead
- ☐ No difference, all of the above

2.5 Where are bats most often seen during shipment? (Please choose only one option)

- ☐ When sailing near shore
- ☐ When sailing on open waters
- ☐ No difference

2.6 Are there any lakes or ports where bats are more common than elsewhere?

2.7 When you've seen bats, what have they been doing? (You can choose more than one option)

- ☐ Roosting or hiding
- ☐ Hunting or flying near the light sources of the freighter
- ☐ Hunting or flying near water
- ☐ No clear behavioral pattern
- ☐ All of the above

2.8 Which is the most common behavior? (Please choose one)

- ☐ Roosting or hiding
- ☐ Hunting or flying near the light sources of the freighter
- ☐ Hunting or flying near water
- ☐ No clear behavioral pattern

2.9 Have you seen bats flying and landing on the ship? (Please choose only one option)

- ☐ Yes, near shore
- ☐ Yes, in open water
- ☐ Yes, both
- ☐ No

2.10 If the answer to question 2.9 was yes, what is usually the condition of the bats?

- [ ] They seem to be in a good condition
- [ ] They seem to be in a weak condition
- [ ] Both / No difference

2.11 If bats are found on board, are there certain places where they are found more often?

2.12 Is there a certain work phase during shipment when bats are seen more frequently? (You can choose more than one option)

- [ ] When loading the cargo
- [ ] When travelling near shore
- [ ] When travelling in open water
- [ ] When unloading the cargo
- [ ] No difference

2.13 Is there a certain time of the day when bats are seen more often? (You can choose more than one option)

- [ ] During dawn
- [ ] In the morning
- [ ] During the day
- [ ] During dusk
- [ ] In the evening/night
- [ ] No difference

SECTION 3 - THE END

3.1 Are bats causing/have they caused any trouble or problems on the freighter(s)?

3.2 Is there anything else about bats you would like to share with us?

If you want to get a short report about the results of this study once it is completed, please type in your email address.

GOODBYE

Thank you for your participation! We greatly appreciate your effort. If you have any feedback/comments please let us know.

You have now answered to all questions. Press Previous If you want to change your answers.
The answers will be submitted when you press Finish and they can't be changed after that.
Thank you!

PROCEED

<< Previous | Finish (Send all Data)