EFFECT OF TOUR BOAT ACTIVITY WITHIN AN ECOLOGICAL RESERVE ON THE BEHAVIOR OF THREE ATLANTIC ALCIDS: COMMON MURRES *Uria aalge*, RAZORBILLS *Alca torda*, AND ATLANTIC PUFFINS *Fratercula arctica*

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EFFECT OF TOUR BOAT ACTIVITY WITHIN AN ECOLOGICAL RESERVE ON THE BEHAVIOR OF THREE ATLANTIC ALCIDS: COMMON MURRES *Uria aalge*, RAZORBILLS *Alca torda*, and ATLANTIC PUFFINS *Fratercula arctica*

by

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A thesis submitted to the

School of Graduate Studies

in partial fulfillment of the

requirements for the degree of

Master of Science

Department of Biology
Memorial University of Newfoundland

1999

St. John's Newfoundland

Abstract

To assess the impact of tourism on breeding alcids, Common Murre, Razorbill, and Atlantic Puffin alarm behavior before, during, and after tour boat passages was quantified on Gull Island (47° 15' N, 52° 46' W), Witless Bay Seabird Ecological Reserve, Newfoundland, Canada in 1996 and 1997. Tour boat disturbance induced murre alert-posture and alarm-bowing. Tour boat activity did not provoke murre fly-offs or inhibit arrivals at breeding ledges throughout most of the incubating and brooding periods. However late in the brooding period, boat activity induced murres to move to the edge of breeding ledges and fly-off. Moreover, tour boat passages caused murres to entirely vacate club sites until the boat left the area for up to an average of 15 min. Incubating and brooding Razorbills left their nesting crevices with eggs and chicks unattended during boat passages. For Razorbills at club locations, tour boat passages induced fly-offs, arrivals, alert-posture, and standing. In addition, tour boat activity caused off-duty and non-breeding Razorbills to both enter and leave nesting crevices. Common Murres and Atlantic Puffins entirely vacated inshore island waters during tour boat passages until the boat left the area for approximately 10 min. Tour boat activity induced puffins to fly from inshore island waters to breeding slopes but did not normally cause puffin fly-offs or panic flights from land.

Loud and slow boats induced the greatest amount of disturbance to Common Murres. Likewise, loud boats caused the greatest disturbance to Razorbills. Overall, a decrease in boat distance to Common Murres and Razorbills induced greater proportions of birds to exhibit alarm behavior.

These forms of disturbance could be significantly affecting alcid recruitment and reproductive performance at the colony by disrupting self-maintenance and social (mate and nest-site selection) activity. I did not find any direct evidence that gull predation of alcid eggs, chicks, or adults was exacerbated by tour boats. Findings from this study indicate tour boats can negatively impact breeding alcids regardless of breeding period or seabird breeding status.

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Acknowledgments

This thesis is dedicated to my parents. My interest in birds was started by my father. We spent many days after school in the field observing birds. In addition, I wish to thank my parents for traveling the gravel roads of wildlife refuges and hiking preserve trails on summer trips. However, I did not necessarily enjoy being followed by an alligator. Our travels across North America helped me to realize there is a need to conserve and preserve many species of wildlife. Thank you for not taking away my binoculars after I disappeared for a time in Big Bend National Park. Lastly, thank you for all your support and often taking the road 'less traveled by.' It has made all the difference.

I would like to thank Stephen W. Kress who gave me my start in studying seabirds. You have been an inspiration toward wildlife conservation and a role model. I have many fond memories working with those involved in Project Puffin.

Some of the most valuable time I spent at Memorial University was in conversation with my two supervisors — John W. Chardine and Ian L. Jones. Thank you for freely giving many hours of your time both at the office and in the field. Your many detailed comments on earlier drafts of the thesis improved every chapter. Moreover, thank you for your financial contributions toward field costs and personal support.

In particular, I would like to thank John for all his efforts toward this project which would not have been as successful without his help. The idea of determining the effect of boat activity on seabirds was John's. Very few supervisors would go to the grocery, pack all the food in boxes, drive to the study site, and then make sure all the food got to the

field camp. John did this throughout two field seasons. Thanks for also showing great concern for my injuries on Gull Island. Most of all, I would like to thank John for sharing his extensive knowledge of seabird ecology and statistics. John played an important role in helping me interpret many of the results.

Major contributions to this study were also made by Ian. Ian was critical in helping to determine the methodology I used to quantify the effects of tour boat disturbance on alcids. I learned how important proper experimentation is in science from Ian. Thank you for sending me to Atlantic Cooperative Wildlife Ecology Research Network meetings in Nova Scotia and New Brunswick as well as a Cooper Ornithological Society meeting in Hawaii. 'Rocky Road' ice cream never tasted so good as the day Ian brought a gallon of it out to Gull Island. Finally, thanks for all of your sound advice and patience.

The Newfoundland Parks and Natural Areas Division of the Department of Tourism, Culture, and Recreation provided a large operating grant for the study. Specifically, I wish to thank Glen Ryan and Doug Ballam for their support and for issuing permits for me to work on Gull Island.

V. Dedreic Grecian helped me in the field for two summers. You were a pleasure to work with and are a good friend. May we never have to carry plywood blind pieces down the saddle again. Thanks for being such a hard worker. "Do you hear a boat? I think I hear a boat?"

From day one of the study, O'Brien's Whale and Bird Tours provided the bulk of logistical services to Gull Island. I would especially like to thank Joe and Liola O'Brien for unwavering support and enthusiasm throughout the study. Joe, Liola, Wayne Maloney, Chris and Stephen Hearn, and Danny and Michael O'Brien's expert seamanship made often tough landings on Gull Island appear easy. The O'Briens's often interrupted their tours to deliver much needed food, water, and field gear to Gull Island or to get us off the island in an emergency situation. Gatherall's Puffin and Whale Watch tours and Captain Murphy's Bird Island Charters also aided in logistics to and from Gull Island.

Glen Ryan, Doug Ballam, Joe Brown, and Bill Montevecchi provided useful comments on the results of the study that were incorporated into the thesis. I wish to also thank Pierre Ryan and Scott Gilliland of the Canadian Wildlife Service at Mount Pearl, Newfoundland for their help throughout my project.

I would like to thank Donald L. Miles, Scott M. Moody, Brian J. Powell, and Mark M. Mullenix at Ohio University for providing much encouragement and setting an example in wildlife conservation.

Lastly, I wish to thank Jen for her incredible patience and support.

Chapter I

General introduction

1.1 Introduction

Human activity can have profound negative effects on local wildlife populations, and colonial nesting birds are especially susceptible to human disturbance (Gotmark 1992). The effects of human disturbance on colonial nesting birds include reduced breeding success (DesGranges & Reed 1981, Pierce & Simons 1986, Anderson 1988), lowered nesting density (Ellison & Cleary 1978, Tremblay & Ellison 1979, Safina & Burger 1983), and abandonment of nest sites (Conover & Miller 1979). Factors important in causing reduced avian nesting success in disturbed areas may include predators (Fetterolf 1983), nest desertion by adult birds (Anderson & Keith 1980), extreme temperatures in relation to eggs and chicks (Hunt 1972), decreased incubation attentiveness by parents (Cairns 1980), and trampling of chicks during adult panic departures from the nest (Nettleship 1972). Furthermore, human activity may negatively impact the behavior of colonial nesting birds such as disrupt equal sharing of incubation duties between the sexes (Burger 1981a) or increase alarm behavior (Burger 1981b). Human disturbance can also cause the young of colonial nesting birds to fledge with lower weights (Harris & Wanless 1984, Hatchwell 1989), and this is of significance because survival to breeding age has been found to be directly proportional to fledging weight in a colonial nesting species (Perrins *et al.* 1973). Lastly, human activity has been shown to cause adverse physiological conditions in colonial nesting birds such as increased heart rate (Wilson *et al*. 1991, Nimon *et al*. 1995).

Alcids are an example of a colonial nesting seabird that possess particular life history traits that can make them vulnerable to disturbance particularly if it occurs over an extended time period. Because most alcids attain breeding maturity at a relatively late age and lay one egg each year, annual recruitment and hence population growth rate are low (Brown & Nettleship 1984). Thus, the reproductive strategy of alcids can make it difficult for local populations to recover if human activities such as disturbance are severe (Brown & Nettleship 1984). A decrease in adult survivorship or reduced breeding success over many years would cause a local alcid population to decline unless colony numbers were maintained through immigration of individuals from other breeding localities. Very few studies have provided quantitative estimates of emigration among alcids (Hudson 1985). Harris (1983) estimated that about 23% of Atlantic Puffin fledglings produced at the Isle of May, Scotland subsequently bred at other locations. Emigration of breeding adult alcids to other colonies appears to be very low (Lloyd & Perrins 1977, Harris 1976, Asbirk 1979). Since individual auks have relatively long life-spans (Bedard 1985) and high breeding-site fidelity (Hudson 1985), the population effects of such long term disturbance would be initially impossible to detect, but eventually the population would show declines after many years of low productivity.

Alcids often breed in very large numbers at a few localized colonies (Lock *et al*. 1994). As a result, severe natural or human disturbance may have a large impact on local populations. For example, very high levels of pleasure craft traffic produced a total collapse in Atlantic Puffin *Fratercula arctica* and Common Murre *Uria aalge* populations in southern Norway (Barrett & Vader 1984).

The Witless Bay Seabird Ecological Reserve (47° 15' N, 52° 46' W) in southeast Newfoundland, Canada is an important site for breeding alcids. Over 294,000 pairs of alcids in addition to approximately 830,000 pairs of other seabirds currently breed within the reserve at Gull, Green, and Great Islands (Lock *et al.* 1994, Rodway *et al.* 1996). Approximately 60% of the North American Atlantic Puffin population breeds within the reserve (Rodway *et al.* 1996). Furthermore, the breeding Common Murre population in Witless Bay is presently the second largest in the western Atlantic Ocean (Lock *et al.* 1994). Over one million seabirds including approximately 71,000 pairs of Atlantic Puffins (Rodway *et al.* 1996), 700 pairs of Common Murres, and 60 pairs of Razorbills *Alca torda* breed on Gull Island alone (Lock *et al.* 1994). Common Murres are the predominant species on Green Island with 74,000 pairs (Lock *et al.* 1994), and an estimate of 123,000 pairs of Atlantic Puffins breed on Great Island (Rodway *et al.* 1996). Thus, one of the larger concentrations of seabirds in eastern North America breed on islands within the Witless Bay Seabird Ecological Reserve.

As a result, the Witless Bay Seabird Ecological Reserve has become the focus of a thriving ecotourism business (Lock *et al.* 1994). Tour boat operators have been viewing seabirds and whales within the reserve for approximately 15 years. The number of tour boats given access to the reserve is limited by a provincial permit system. Currently 10 tour boats are allowed to view seabirds in the reserve. During the peak tourist season, over 30 tour boat passages a day took place to view breeding seabirds at Gull Island. The greatest number of tour boat trips occurred around Gull and Green Islands where most tour boat operators concentrate their seabird viewing. Smaller numbers of tour boat trips occurred around Great Island.

Boat activity can have negative impacts on breeding birds. Nettleship (1975) speculated a large volume of tour boat traffic may have been one of the prime causes in a 16% decline of Northern Gannets *Morus bassanus* breeding at Bonaventure Island, Quebec, Canada. Tour boats viewing gannets appeared to seriously disturb non-breeding birds which were trying to establish nest sites on the cliff-face (Nettleship 1975). This factor could lower annual production and reduce the rate of recruitment of gannets to the colony (Nettleship 1975). Moreover, boating activity can severely impact fledgeling production of Common Eiders *Somateria mollissima* (Ahlund and Gotmark 1989) and Velvet Scoters *Melanitta fusca* (Mikola *et al.* 1994) by increasing gull predation rates on ducklings.

Therefore, the purpose my study was to determine the effect of tour boat activity on the behavior of Common Murres, Razorbills, and Atlantic Puffins and ultimately develop tour boat management guidelines to protect seabirds in the Witless Bay Seabird Ecological Reserve. Specifically, I attempted to quantify the responses of non-breeding and breeding alcids to tour boat passages and the relationship of boat distance, noise level, and speed on alcid alarm behaviors at Gull Island. In addition, I determined if the responses of alcids to boat passages differed depending on the breeding period.

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Chapter II

Effect of tour boat activity on the behavior of Common Murres *Uria aalge*

2.1 Abstract

To assess the impact of tourism on breeding seabirds, murre behavior before, during, and after tour boat passages was quantified on Gull Island (47° 15' N, 52° 46' W), Witless Bay, Newfoundland, Canada in 1996 and 1997. Tour boat disturbance induced murre alert-posture and alarm-bowing. Boat passages caused murres to entirely vacate club locations until the disturbance event dissipated for up to an average of 15 min. Tour boat passages also caused murres to entirely vacate inshore island waters until the boat left the area for approximately 10 min. Tour boat activity did not provoke murre fly-offs or inhibit arrivals at breeding ledges throughout most of the incubation and brooding periods. However late in the brooding period, boat activity induced murres to move to the edge of breeding ledges and fly-off. Loud and slow boats induced the greatest amount of disturbance to murres. Moreover, a decrease in boat distance to murres induced greater percentages of murres to exhibit alarm behavior. These forms of disturbance could be significantly affecting murre recruitment and reproductive performance by disrupting self-maintenance and social (mate and nest site selection) activity at the colony. I did not find any direct evidence that gull predation of murre eggs, chicks, or adults was related to tour boat activity. Although the effects of tour boat disturbance on murres do not appear to be severe, these findings indicate tour boats can negatively impact breeding murres.

2.2 Introduction

With humans pervading even the remotest regions of the biosphere, the issue of human disturbance of wildlife populations has grown to crucial importance. An increasing human population continues to threaten seabird populations (Manuwal 1978). In addition, disturbance at some seabird colonies has increased within the last decade due to an increasing human interest in ecotourism. Tour boat companies that market seabird viewing now operate at a number of sites throughout the world. An example is the Witless Bay Ecological Reserve located in southeast Newfoundland, Canada. The reserve has been utilized by tour boat operators since approximately 1982, and economic pressures may lead to expansion of tour boat visitation to the reserve. Reserve managers are faced with the difficult question as to whether the effects of disturbance such as those produced by boats in Witless Bay are negatively affecting local seabird populations or alternatively represent a sustainable exploitation of this resource.

Previous studies have shown boat disturbance can produce negative effects on breeding water-birds. Bratton (1990) found large percentages of wading bird groups altered their behavior or flushed in response to boats. During boat disturbance, Velvet Scoter *Melanitta fusca* ducklings lengthened swimming distances, decreased foraging time, and were attacked by gulls at higher rates (Mikola *et al.* 1994). Ahlund and Gotmark (1989) found gull encounter and predation rates were higher on Common Eider *Somateria mollissima* creches during boat disturbance. Great Crested Grebe *Podiceps cristatus* nesting success was lower on lakes with boating than on an undisturbed lake (Keller 1989). Pleasure craft traffic produced a total collapse in Common Murre *Uria* *aalge* and Atlantic Puffin *Fratercula arctica* populations in southern Norway (Barrett & Vader 1984). Murre (*Uria* spp.) are often the focus of tourism operations.

Other forms of human disturbance have negatively impacted murres. Investigator disturbance caused Common Murre chicks to fledge earlier with lower weights (Hatchwell 1989). Similarly, investigator disturbance reduced Common Murre nesting success and induced chicks to fledge with lower weights and shorter wings (Harris & Wanless 1984). Helicopter disturbance induced orienting responses and fly-offs of Thick-billed Murres *Uria lomvia* located on breeding ledges at a remote arctic colony (Olsson & Gabrielsen 1990, Fjeld *et al.* 1988).

Common Murres exhibit distinctive stereotyped alarm behaviors. As a reaction to disturbance, Common Murres first exhibit an alert-posture in which individuals attain an upright stance with extended neck (Cramp 1985). The head is rapidly shifted in short horizontal movements and the eyes are opened widely. If the disturbance continues, a murre may engage in alarm-bowing where the neck is rotated downward through an arc of 90° then quickly upward again (Cramp 1985). During alarm-bowing the bill may remain horizontal or point downward (Cramp 1985). If disturbance intensifies, Common Murres may move to the edge of their breeding ledges and ultimately fly-off from ledges.

The purpose of my study was to quantify the effects of tour boat disturbance on Common Murres in order to help develop tour boat management guidelines to protect murres in the Witless Bay Ecological Reserve. In particular, I aimed to quantify in detail the responses of breeding and non-breeding murres to tour boats and the relationship of boat distance, noise level, and speed on murre behavior.

2.3 Study area and methods

2.3.1 Study area

Gull Island (47° 15' N, 52° 46' W) is located in the Witless Bay Seabird Ecological Reserve, NF, Canada (Figure 2.1). The reserve includes the water surrounding the island, out to 1 km from shore. Over one million seabirds including approximately 700 pairs of Common Murres breed on Gull Island (Lock *et al.* 1994). Murres nest in relatively small pockets of birds on low cliffs surrounding Gull Island. I established five observation plots of murres on breeding ledges, two observation plots of murres attending clubs, and an observation plot on nearby inshore island waters. Murre clubs consisted of birds socializing on rock points close to the island's intertidal zone. Inshore island waters were defined as the area of water within 60 m of the shoreline. Locations of observation plots and observation blinds are in Figure 2.2.

2.3.2 Tour boat operations around Gull Island

Tour boats cruised along the western shore of Gull Island from April to September for the purpose of seabird viewing. A peak of tour boat activity took place during July when over 30 boat passages a day occurred to view seabirds. I observed that tour boats approached as close as 22 m to nesting murres. Tour boats were Cape Islander vessels 40-60 ft in length with inboard diesel engines. The number of tour boats given access to

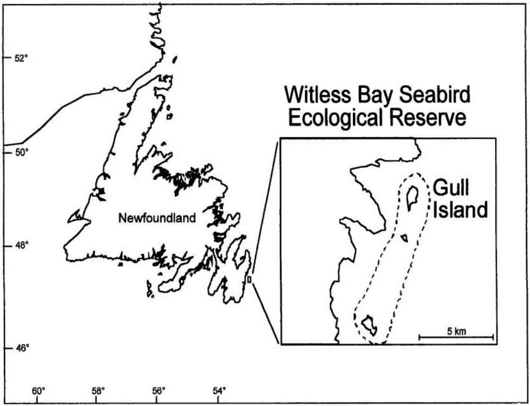

Figure 2.1. Locations of the Witless Bay Seabird Ecological Reserve and Gull Island study site in Newfoundland, Canada.

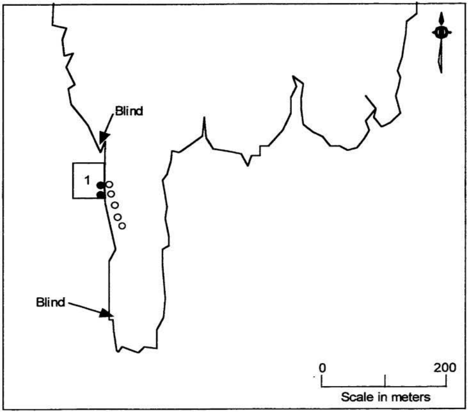

Figure 2.2. Locations of Common Murre observation plots and observation blinds on Gull Island. Open circles represent observation plots of murres on breeding ledges. Filled circles represent observation plots of murres attending clubs. 1 represents the inshore island waters observation plot.

the reserve is limited by a provincial permit system. Four tour boat companies are currently each allowed two vessels in the reserve. *Seabird Ecological Reserve Regulations* (Newfoundland Regulation 66/97) do not allow a person to operate a boat within 20 m (motor) or 15 m (no motor) of Gull Island from April 1 to September 1. However, tour boat operators are exempt from distance restrictions and normally approach as closely as possible to nesting seabirds. In addition, a person may not 'operate a boat in a manner that disturbs wildlife or allows noise from the boat or persons on board to disturb wildlife' within a Seabird Ecological Reserve (Newfoundland Regulation 66/97).

2.3.3 Observations of murre behavior

I assessed the impacts of tour boat operations on murre alarm behavior using three approaches: (1) by quantifying groups' alarm behavior at breeding ledges throughout short observation periods of several minutes during the presence and absence of boats (2) by examining the alarm behavior of focal individual murres on breeding ledges to boat passages to determine at what distance murres first reacted to boat disturbance and (3) by recording murre group alarm-behavior at clubs and on inshore island waters throughout observation periods of approximately one hour that included at least one boat passage.

Murres occupying ledges at Gull Island were categorized as incubators and non-incubators (during the incubation period) or brooders and non-brooders (during the chick-rearing period). The brooding period began when I estimated half of the breeding murres on ledges had chicks. Brooders and incubators were located at the middle to rear of breeding ledges. A murre was classified as an incubator if observed (1) with an egg or (2) in incubating posture during the incubating period. Likewise, a murre was classified as a brooder if observed (1) with a chick or (2) in a brooding posture during the brooding period. Non-incubators and non-brooders were located near the outer perimeter of breeding ledges. A murre was classified as a non-incubator if observed without an egg or chick during the incubating period. Similarly, a murre was classified as a non-brooder if observed without an egg or chick during the brooding period.

During all experiments, birds were observed from within plywood blinds to exclude the possibility of investigator disturbance. I never approached murre nesting ledges closely nor did I attempt to capture and mark birds so except for boat disturbance the study population was left undisturbed. Situations when a tour boat was present (defined as *boat observation periods*) began when a vessel was within 400 m of a seabird site and ended before the boat was beyond 400 m of a seabird site. Situations when no tour boat was present within 400 m of the study colony were referred to as *no-boat observation periods*. These distances were estimated using a laser rangefinder, compass, and trigonometry. The methods for each approach are discussed in detail below.

1) Boat and no-boat experiments (murre group responses): Proportions of murres exhibiting alarm behaviors were recorded throughout boat and no-boat observation periods to determine if murre behaviors indicative of disturbance or stress occurred more often when a boat was present than when absent.

During a boat observation period, one observer estimated the distance of the boat when it was adjacent to the murres (closest approach), boat noise, and boat speed. Estimations of boat distance were made using a laser rangefinder, compass, and trigonometry. The measuring accuracy of the rangefinder was ± 1 m. The maximum distance for determining boat distance with the rangefinder was approximately 400 m. Bearings were measured in degrees with a compass to estimate distances between the boat and parts of the seabird colony. Boat noise was categorized as quiet or loud. A quiet noise level consisted of (1) a person talking quietly with a microphone and or audible boat engine noise to us on the island (2) a person talking loudly with a microphone and minimal boat engine noise to us on the island or (3) no audible boat noise to us on the island. A loud noise level comprised (1) human shouting, whistles, horns, or music playing from a tour boat or (2) a person talking loudly with a microphone and moderate to high boat engine noise to us on the island. Boat speed was categorized as slow or fast as the vessel traveled alongside of the murres I was observing. A slow boat consisted of (1) stopping and or backing-up (2) changing speed to slower or (3) traveling at a constant speed estimated at < 7 knots. A fast boat comprised traveling at a constant speed estimated at > 7 knots.

Throughout the same boat observation period, a second observer recorded the proportion of murres exhibiting alarm behaviors. The same individual birds were viewed throughout the observation period. For the behaviors of alarm-bowing and alert posture, the number of murres viewed was 3 to10 individuals. Likewise for the behaviors of fly-offs, arrivals, and movement to edge of ledges, the number of murres viewed was 3 to 79 individuals. Average observation period duration was 1 min 59 sec ($n = 634$).

Murre behavior was also quantified in the absence of tour boats (no-boat observation periods). The no-boat observation periods represented the controls against which murre alarm behavior in presence of tour boats could be assessed. Except for the absence of recording boat parameters, the methods for no-boat observation periods were the same as boat observation periods. Observation periods (boat/ no-boat) were matched with respect to interval duration, number of murres observed, location of murres, breeding status of murres in the sample, and day. Start times for no-boat observation periods were at least 15 min after any boat passage. The average amount of time a no-boat observation period was performed after a corresponding boat observation period was 1 h 44 min ($n = 634$).

2) Focal individual experiments: The behavior of individuals was observed to determine at what distance from tour boats murres first exhibited alarm-bowing. As a boat approached, 3 murres at a breeding site were observed simultaneously by one observer. If a murre responded to the boat by exhibiting alarm-bowing, the behavior was recorded and a second observer (watching the boat) was informed immediately. The second observer then estimated boat distance at the point when the murre first responded using the rangefinder and compass. Breeding ledges were divided into 6 sections. Three individuals for an experiment were located within the same ledge section. For a

subsequent experiment, focal individuals were selected from an alternate ledge section to avoid repeated measurement of the same individuals.

3) *Murre alarm behavior before, during, and after a boat passage*: Murre behavior was recorded to determine how long it took for murres to resume normal behavior after the passage of a tour boat. Counts of murres within my club and inshore island water observation plots were performed throughout observation periods that contained at least one boat passage. All boats recorded during observation periods passed within 100 m of my observation plots. The average duration of an observation period was 1 h 46 min (n = 24). Counts of murres on inshore island waters and at club locations were invariably conducted as boats passed the observation plots and these counts were regularly performed throughout the remainder of observation periods. Time of day was recorded at the end of all murre counts.

2.3.4 Statistical analyses

Proportions of murres exhibiting a behavior were used as dependent variables unless indicated differently. Proportions were transformed into arcsin square-root values to fit a linear model. Murre behaviors were pooled across years, locations, periods (incubating and brooding), and breeding status where appropriate to increase sample sizes. To determine if data could be pooled, a general linear model was used with independent variables of year, location, period, breeding status, and the interaction terms of those variables. Proportions of murres exhibiting a particular behavior were only pooled across the independent variables that were not significant in the general linear model. In all analyses, measures of behavior were treated as independent samples only if they were obtained from different individuals.

Proportions of murres exhibiting a behavior were compared between paired boat and no-boat experiments by means of paired t-tests. When experiments were paired, paired t-tests were more suitable for the experimental design and used instead of ANOVA's.

I examined the effects of boat distance, speed, and noise levels on the proportions of murres exhibiting alarm behaviors. Due to limitations in sample size, a multivariate analysis could not be used. As a result the effects of boat distance, speed, and noise on murre behaviors were examined using one-way analyses of variance. Thus each of the three boat factors was tested univariately, while keeping the other boat factors constant. If it was not possible to keep the other boat factors constant, then interactions with confounding variables were checked.

Plots of residuals and fitted values from the one-way analyses of variance were examined visually to determine if the residuals were not associated with the linear model. Residuals were checked for normality by (1) examining histograms of the residuals (2) comparing the frequency distribution of residuals to the normal distribution using a rootogram with 95% confidence intervals and (3) plotting normal equivalent deviates of the residuals and residuals.

2.4 Results

2.4.1 Effect of tour boat passages on murre alert-posture

Proportions of murres exhibiting alert-posture were on average greater by 79% for non-incubators, 33% for incubators, 50% for non-brooders, and 35% for brooders during boat passages compared to boat absence (Figure 2.3, paired *t*-tests, P's ≤ 0.001). In addition, proportions of murres exhibiting alert-posture were on average greater by 19% for non-incubators ($P = 0.3$), 30% for incubators ($P = 0.06$), and 17% for non-brooders ($P = 0.03$) during loud boat passages compared to quiet boat passages (Figure 2.4, ANOVA). Furthermore, proportions of murres exhibiting alert-posture were on average greater by 10% for incubators ($P = 0.4$), 14% for non-brooders ($P = 0.2$), and 42% for brooders ($P = 0.02$) during slow boat passages compared to fast boat passages (Figure 2.5, ANOVA). An overall increase in the proportions of non-brooding murres exhibiting alert-posture was observed as tour boats approached closer than 100 m to breeding ledges (Figure 2.6). Similarly, an overall increase in the proportions of brooding murres exhibiting alert-posture was found as tour boats approached closer than 50 m to breeding ledges (Figure 2.7).

2.4.2 Effect of tour boat passages on murre alarm-bowing

Proportions of murres alarm-bowing were on average greater by 53% for non-incubators, 26% for incubators, 58% for non-brooders, and 42% for brooders during boat

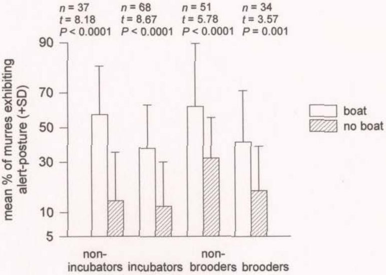

Figure 2.3. Effect of tour boat passages on murre alert-posture. Probability scale used for y-axis.

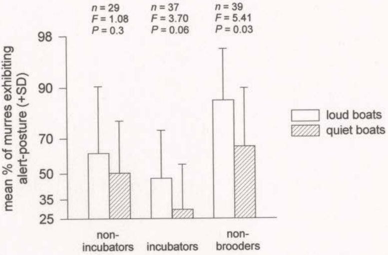

Figure 2.4. Effect of tour boat noise on murre alert-posture. Probability scale used for y-axis.

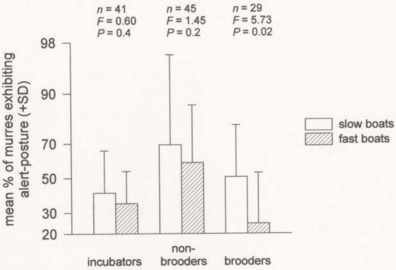

Figure 2.5. Effect of tour boat speed on murre alert-posture. Probability scale used for y-axis.

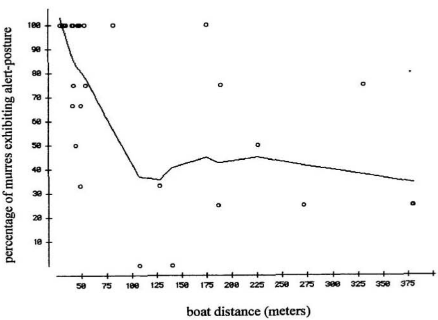

Figure 2.6. Effect of tour boat distance on the alert-posture of non-brooding murres. Lowess smoothed at a span of 30%. $n = 29$ boat passages.

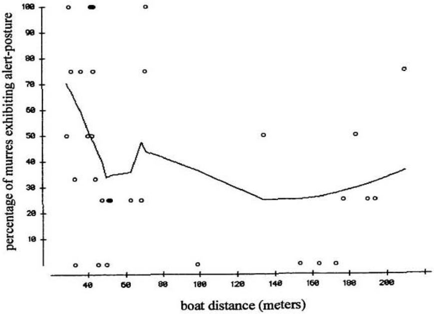

Figure 2.7. Effect of tour boat distance on the alert-posture of brooding murres. Lowees smoothed at a span of 30%. $n = 32$ boat passages.

passages compared to boat absence (Figure 2.8, paired *t*-tests, *P*'s < 0.0001). Furthermore, proportions of murres alarm-bowing were on average greater by 32% for incubators ($P = 0.03$) and 25% for the brooding period ($P = 0.04$) during loud boat passages compared to quiet boat passages (Figure 2.9, ANOVA). In addition, proportions of murres alarm-bowing were on average greater by 26% during the incubating period and 29% for non-brooders during slow boat passages compared to fast boat passages (Figure 2.10, ANOVA, *P*'s = 0.02). While examining the effect of boat distance on murre behavior, I observed an overall increase in the proportions of murres exhibiting alarm- bowing as tour boats approached closer to breeding ledges (Figures 2.11 & 2.12). During focal experiments I determined distances from tour boats murres first exhibited alarm-bowing and found as a response to boat disturbance murres first exhibited alarm-bowing at greater distances from tour boats during the brooding period compared to the incubating period (Table 2.1).

2.4.3 Effect of boat passages on murre fly-offs and arrivals at breeding ledges

Proportions of murres flying from breeding ledges did not vary significantly between tour boat passages and tour boat absence (Table 2.2, paired *t*-tests, *P*'s > 0.05). However, proportions of murres moving to the edge of breeding ledges and flying from breeding sites late in the brooding period were on average over 3 times greater during tour boat passages than during tour boat absence (Figure 2.13, paired *t*-tests, P's < 0.01). During the incubation period, proportions of murres arriving at breeding ledges did not

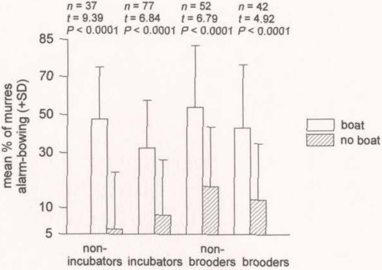

Figure 2.8. Effect of tour boat passages on murre alarm-bowing. Probability scale used for y-axis.

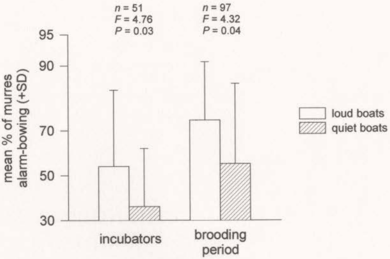

Figure 2.9. Effect of tour boat noise on murre alarm-bowing. Probability scale used for y-axis.

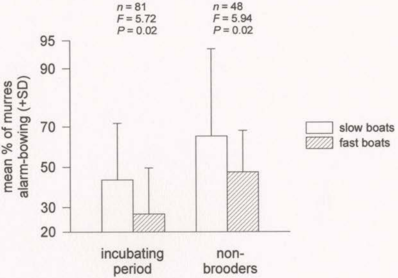

Figure 2.10. Effect of tour boat speed on murre alarm-bowing. Probability scale used for y-axis.

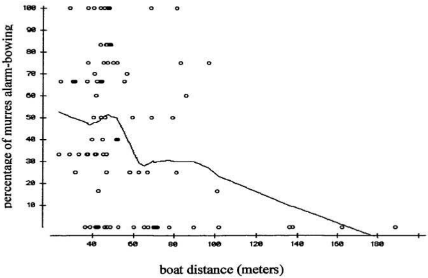

Figure 2.11. Effect of tour boat distance on murre alarm-bowing during the incubating period. Lowess smoothed at a span of 30%. $n = 89$ boat passages.

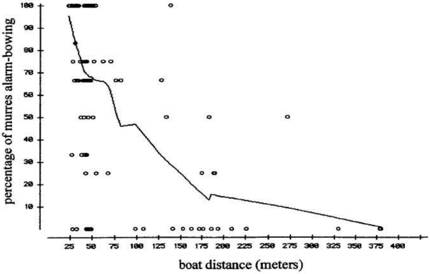

Figure 2.12. Effect of tour boat distance on murre alarm-bowing during the brooding period. Lowess smoothed at a span of 30%. $n = 88$ boat passages.

Table 2.1. Distances from tour boats murres first exhibited alarm-bowing during focal experiments.

Period	Percentage of murres alarm-bowing during boat passages	Mean distance (± SD) from boats individuals first alarm-bowed
Incubating	49 $n = 61$	82.8 m ± 53.8 $n = 30$
Brooding	76 $n = 58$	101.4 m ± 53.3 $n = 44$

Table 2.2. Effect of tour boat passages on murre fly-offs from breeding ledges.

Period	Status of birds	Mean percentage of murres flying from breeding ledges: arcsin transformed mean (± SD), back-transformed mean BOAT	NO BOAT
Incubation	Non-incubators	2 (± 6.24), 0 $n = 37$	4 (± 10.03), 0 * $n = 37$
	Incubators	0 (± 0.00), 0 $n = 68$	0 (± 0.00), 0 ** $n = 68$
Brooding	Non-brooders	3 (± 8.93), 0 $n = 52$	6 (± 12.18), 0 * $n = 52$
	Brooders	0 (± 0.00), 0 $n = 34$	0 (± 0.00), 0 ** $n = 34$

paired t-tests
* $P = 0.2$
** $P = 1.0$

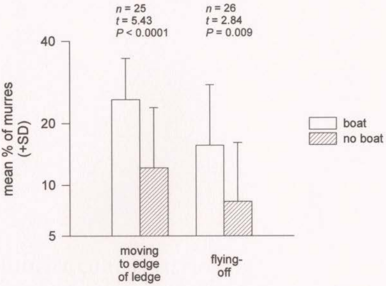

Figure 2.13. Effect of tour boat passages on murre movement to the edge of breeding ledges and fly-offs late in the brooding period. Probability scale used for y-axis.

vary significantly between tour boat passages and tour boat absence (Figure 2.14, paired *t*-tests, *P*'s > 0.05). Although a very small sample size, throughout the breeding season kayaks and pleasure crafts 10-20 ft in length caused on average 8 times more murres to fly from breeding ledges (*mean* = 47%, *n* = 5, *range* = 21—71, *SD* = 20.8) compared to boat absence (*mean* = 6%, *n* = 5, *range* = 0 —15, *SD* = 5.9). The mean kayak and pleasure craft distance was 95 m (*n* = 5, *range* = 35—200, *SD* = 62.2).

2.4.4 Effect of boat passages on murres located on inshore island waters and in clubs

Boat passages displaced murres located on inshore island waters for approximately 10 minutes (Figure 2.15). But, murre numbers on inshore island waters were on average consistently lower for at least 2 hours after a boat passage compared to inshore island water attendance prior to a boat passage. Similarly, boat passages completely displaced murres located in clubs for up to an average of 15 minutes (Figure 2.16). Murre numbers in clubs were on average consistently lower for at least one hour after a boat passage compared to murre club attendance prior to a boat passage.

2.5 Discussion

The impact of tour boat activity on breeding and non-breeding murres was assessed by examining murre alarm behavior before, during, and after tour boat passages and by examining alarm behavior in presence and absence of boats. Tour boats passed by Gull Island as many as 30 times a day and approached as close as 22 m to nesting murres.

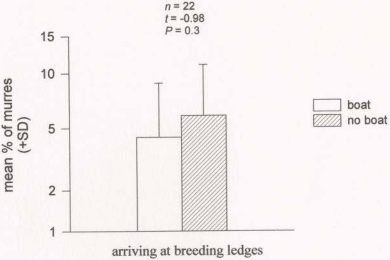

Figure 2.14. Effect of tour boat passages on murre arrivals to breeding ledges during the incubating period. Probability scale used for y-axis.

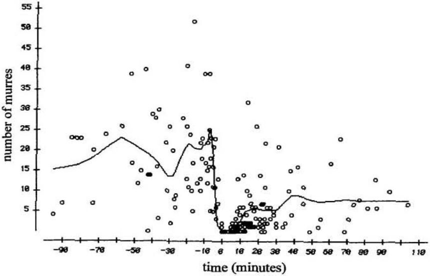

Figure 2.15. Effect of tour boat passages on murres located on inshore island waters. Zero on x-axis denotes when boat is passing through study plot. Trewess smoothed at a span of 12 %. $n = 225$ murre counts. boat passages = 40.

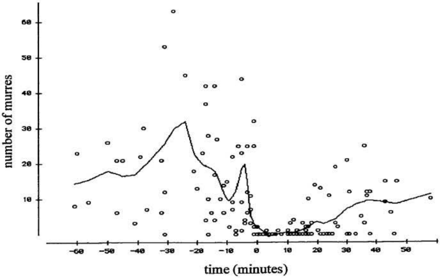

Figure 2.16. Effect of tour boat passages on murres located in clubs. Zero on x-axis denotes when boat is passing the murre club. Trewess smoothed at a span of 12%. $n = 175$ murre counts. boat passages = 23.

I found tour boat passages induced murre alarm behavior regardless of breeding period or murre breeding status. Tour boat distance, noise, and speed were found to directly affect murre alarm behaviors.

Tour boat passages consistently caused murres to exhibit alert posture and alarm-bowing at all times of season at Gull Island. During the incubation period, Birkhead (1977) found murres nesting in dense groups spent less time alarm-bowing than murres nesting in loose aggregations. Because of this finding, only murres nesting in dense areas were observed during experiments. Thus, my observations that tour boat passages induced murres to alarm-bow is further substantiated since murre individuals prone to alarm-bowing in the absence of direct disturbance were avoided in my study.

Late in the brooding period, boat activity caused murres to move to the edge of breeding ledges and eventually fly-off. This finding was noteworthy since small numbers of chicks were left unattended; however, the majority of chicks on the breeding ledges had previously fledged by this time. Herring Gulls *L. argentatus* were observed with murre chicks in their bills away from murre ledges, and unattended murre chicks were easy prey for gulls. Both Great Black-backed gulls *L. marinus* and Herring Gulls breed on Gull Island (Lock *et al.* 1994). Nonetheless, no gull predation of murre eggs, chicks, or adults was directly observed in association with the passage of tour boats.

An important finding from this study was that loud boats and slow boats induced the greatest amount of disturbance to murres. Human shouting, whistles, horns, or music playing from a tour boat induced particularly large numbers of murres to engage in alarm behavior. A tour boat exhibiting both a person talking loudly with a microphone and moderate to high boat engine noise also caused large percentages of murres to react with alarm behavior. Although not what I would have predicted, murres reacted with alarm more often to boats traveling slow compared to boats moving quickly past murre breeding sites. Tour boat passages that included intermittent stopping to view murres caused notably large percentages of murres to react with alarm behavior.

A decrease in tour boat distance to murres at Gull Island induced significantly greater percentages of murres to exhibit alarm behavior. This is consistent with results of other studies. For example, Bratton (1990) found as boat passing distance to wading birds decreased, the number of wading bird groups flushed increased. In addition Ahlund and Gotmark (1989) found as boats approached closer to Common Eider creches, the diving frequency of eiders increased. At least during the incubating period, my data suggests murres reacted to boats passing within 100 m but were unaffected by boat passages beyond 100 m (Figure 2.7). This trend was less evident but still present during the brooding period.

Although there was no trend for murres habituating to tour boats within a breeding season, murres may be habituating to tour boats over a number of years after they have been exposed to tour boat traffic throughout successive breeding seasons. Tour boats have been viewing murres on Gull Island for approximately 15 years. Because Common Murres are long lived and have very high nest site fidelity between years (Cramp 1985), there is a high probability particular pairs would have many breeding seasons over which to acclimatize to the disturbance produced by tour boats. There was large variation in murre alarm behavior when boats were within 100 m. This variation was independent of breeding status. Even when tour boats were 40 m from breeding ledges, some groups of murres showed no alarm reaction to tour boat presence. Keller (1989) suggested nesting Great Crested Grebes may be able to adapt behaviorally to rowing boats on lakes where there is a high level of recreation. Other colonial nesting birds appear to be able to adapt to humans by exhibiting less alarm behavior after being exposed to frequent disturbance events (Robert and Ralph 1975, Parsons and Burger 1982, Burger and Gochfeld 1981, Burger and Galli 1987). Further evidence for murres possibly habituating to tour boat passages at Gull Island comes from observing the reaction of murres to other vessel types. Passages of kayaks and small pleasure crafts 10-20 ft in length alongside breeding murres were rare events throughout the study. Yet when those passages occurred, large percentages of murres flew from breeding ledges during the incubating and brooding periods. Tour boats only induced large percentages of murres to fly from breeding ledges late in the brooding period when murres were most sensitive. Kayaks were virtually silent but slow in speed. Pleasure crafts observed were fast and quiet. Kayak, pleasure craft, and tour boat distances from murre ledges were similar.

Murres were frequently induced to engage in alarm behavior due to as many as 30 tour boat passages in a day. This must exert a cost to murres related to the expenditure of energy and disruption of normal behavior. For example, murres utilized club rocks and near shore waters in the Witless Bay Seabird Ecological Reserve to perform essential self-maintenance activities and in the case of non-breeding birds, behavior essential to mate and nest-site selection. Individual seabirds are not able to engage in crucial self-maintenance, resting, social, or foraging activities if they are fleeing a tour boat. Other studies have shown human activity can reduce feeding and increase flying time for birds (Belanger & Bedard 1989, Morton *et al.* 1989, Norris & Wilson 1988). Furthermore, tour boat passages induce additional energy expenditure in murres by provoking murres to fly from club locations and engage in other alarm activity throughout the breeding season. Human disturbance may impair the physiological condition of birds which could reduce survival and or nutrient reserves carried into the following season (Morton *et al.* 1989).

Moreover, recruitment of murres to the colony at Gull Island may be significantly affected by tour boat passages. Boat passages caused murres to entirely vacate club locations for at least 15 minutes after the disturbance event dissipated. Hudson (cited in Cramp 1985) found clubs mainly consisted of pre-breeding 3-year-old murres. The apparent function of a murre club is to serve as a site for preliminary mate selection and pairing (Cramp 1985). Thus, tour boats may disrupt the formation of murre pair-bonds. Providing boats do not pass murre clubs within 15 minutes of each other, my work suggests that 30 tour boat passages in a day would displace murres from clubs for over 7 hours. Other colonial species have been found to avoid disturbed areas for nesting and choose less disturbed locations (Ellison and Cleary 1978, Tremblay and Ellison 1979, Safina and Burger 1983).

Inshore island waters may be of importance to murres for determining foraging locations. Burger (1997) suggested that murres on the ocean 100 to 600 m from nest sites are optimally positioned to observe conspecifics arriving at the colony. In this way, murres view successful foragers carrying fish and may obtain information on current productive feeding locations (Burger 1997). My study showed that tour boats displace murres from inshore island waters for at least 10 minutes after a boat passage. Hence, providing boats do not pass by the colony within 10 minutes of each other, 30 tour boat passages in a day would displace murres from inshore island waters for approximately 5 hours. If murres are delayed in determining current feeding locations, murre feeding rates to chicks may be lowered, ultimately lowering their reproductive performance at Gull Island. In addition, flight costs may be substantial.

Both Common and Thick-billed Murres are under considerable stress from humans in many parts of their ranges (Brown and Nettleship 1984). In Greenland most regional Thick-billed Murre populations have declined markedly this century, with the total decline suspected to be approximately 50% (Kampp *et. al.* 1994). Declines in murre populations are due to several factors. Murres are hunted for food in Greenland and Newfoundland. The Newfoundland-Labrador winter murre hunt extends from 1 September to 31 March each year, and a toll of between 0.5 to 1 million birds are taken per annum in this hunt alone (Elliot 1991). Many murres drown in fishing nets while foraging under water (Anker-Nilssen and Barrett 1991). In 1985 approximately 200,000 Common Murres drowned in cod gill-nets off Troms County, North Norway (Strann *et. al.* 1991). Oil spills are a threat to a number of seabird species (Nisbet 1994). The fact that murres spend much time on the surface of the ocean can make them especially susceptible to oiling (Brown and Nettleship 1984). Once seabirds are covered in oil, they are unable to keep their feathers waterproof and can easily die of hypothermia in cold oceans. Findings from my study show tourism can negatively impact breeding and non-breeding Common Murres at their colonies. Murre numbers should be carefully monitored in order to detect population declines. Changes in human activities that would include seabird conservation and management plans could help alleviate the negative impacts murres are currently encountering.

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Chapter III

Effect of tour boat activity on the behavior of Razorbills *Alca torda* and Atlantic Puffins *Fratercula arctica*

3.1 Abstract

Seabird colonies are now being viewed by thousands of human visitors each year, but little is known about the impacts of tourism on seabirds. To determine the effect of ecotourism on breeding seabirds, Razorbill and puffin behavior before, during, and after tour boat passages was quantified on Gull Island, Witless Bay Seabird Ecological Reserve, Newfoundland, Canada in 1996 and 1997. Incubating and brooding Razorbills left their nesting crevices with eggs and chicks unattended during boat passages. For Razorbills at club locations, tour boat passages induced fly-offs, arrivals, alert-posture, and standing. Tour boat activity caused off-duty and non-breeding Razorbills to both enter and leave nesting crevices. Puffins entirely vacated inshore island waters during tour boat passages. The earliest return was approximately 10 minutes after disturbance. Tour boat activity induced puffins to fly from inshore island waters to breeding slopes but did not normally cause puffin fly-offs or panic flights from land. Tour boat noise, speed, and distance were found to directly affect seabird behaviors. These forms of disturbance could be significantly affecting Razorbill and puffin recruitment and reproductive performance at the colony by disrupting self-maintenance and social (mate and nest site selection) activity. I did not find any direct evidence that gull predation of Razorbill or puffin eggs, chicks, or adults was enhanced or exacerbated by tour boats. Findings from this study indicate tour

boats can negatively impact breeding alcids regardless of breeding period or seabird breeding status.

3.2 Introduction

Disturbance caused by the passage of recreational, commercial fishing , and tour boats has induced negative effects on a variety of bird species. For example, Bald Eagles *Haliaeetus leucocephalus* flushed from perches in response to boat passages during both the summer (Steidl & Anthony 1996) and winter (Stalmaster & Kaiser 1997, Knight & Knight 1984). Sailing on reservoirs can decrease the feeding activity of ducks (Wigeon Anas *penelope*, Mallard *Anas platyrhynchos*, Pochard *Aythya ferina*; Cryer *et al.* 1987) and can induce birds to fly from the water (Korschgen *et al.* 1985, Batten 1977, Hume 1976). Predation rates by gulls on Common Eider ducklings *Somateria mollissima* increased during boat activity (Ahlund & Gotmark 1989), and the frequency of gull attacks on Velvet Scoter *Melanitta fusca* ducklings was higher during boat disturbance (Mikola *et al.* 1994). Overall nesting success for Great Crested Grebes *Podiceps cristatus* was lower on lakes with rowing boats than on an undisturbed lake (Keller 1989). Furthermore, Bratton (1990) showed that wading birds could be flushed or startled by boat passages.

Human activity has been found to negatively impact breeding puffins and Razorbills. Investigator disturbance lowered reproductive success of Tufted Puffins *Fratercula cirrhata* (Pierce and Simons 1986), Razorbills (Lyngs 1994), and Atlantic Puffins (Rodway *et al.* 1996a, Harris 1984). Furthermore, Tufted Puffins deserted nests at high rates due to diurnal human activity at colonies (Manuwal 1978). Helicopter disturbance caused Tufted Puffins to abandon nesting burrows (Vermeer 1978). In addition, Pierce and Simons (1986) found investigator disturbance retarded chick development in Tufted Puffins. A regional population decrease of Atlantic Puffins breeding on the North Shore of the Gulf of St. Lawrence, Canada was attributed in part to human disturbance (Chapdelaine 1980).

In northeast North America, a burgeoning ecotourism industry including the viewing of marine wildlife has developed. People now have the opportunity to observe whales, eagles, and seabirds through tour boat and kayak excursions at a number of sites. In addition, seabird colonies have been marketed as tourist attractions by government agencies. Tour boat operators at Witless Bay in southeast Newfoundland, Canada have been conducting seabird viewing tours for over 12 years. However, the effect of tour boat disturbance on seabirds is poorly known. Witless Bay tour boat operators are uncertain about how to conduct ecologically responsible excursions at seabird colonies, and managers do not have the necessary information to develop sound management plans for these activities. Barrett & Vader (1984) reported high levels of pleasure craft traffic produced a total collapse in Common Murre *Uria aalge* and Atlantic Puffin *Fratercula arctica* populations in southern Norway. Therefore, I thought it important to conduct a study to determine the impact of tour boat activity on breeding alcids.

The purpose of my study was to quantify the effects of tour boats on breeding Razorbills and Atlantic Puffins and ultimately to develop tour boat management guidelines to protect seabirds in the Witless Bay Ecological Reserve.

3.3 Study area and methods

3.3.1 Study area

Gull Island (47° 15' N, 52° 46' W) is located in the Witless Bay Seabird Ecological Reserve, NF, Canada (Figure 3.1). The reserve includes the water surrounding the island, out to 1 km from shore. Approximately 71,000 pairs of Atlantic Puffins (Rodway *et al.* 1996b) and 60 pairs of Razorbills *Alca torda* breed on Gull Island (Lock *et al.* 1994). Razorbills nest on cliff ledges and in rock crevices at scattered localities on Gull Island. I established an observation plot of breeding Razorbills nesting in a rock crevice and two observation plots of Razorbills attending clubs. Razorbill clubs consisted of birds socializing at large flat rocks and rock outcrops close to the water (Wagner 1991). Puffins nest in burrows on all grassy seaward slopes of Gull Island and in some marginal areas such as bare peat and among dead trees (Haycock 1973). My puffin observation plots were located over a large area of grassy seaward slope and on nearby inshore island waters. Inshore island waters were defined as the area of water within 60 m of the shoreline. Locations of observation plots and observation blinds are in Figure 3.2.

3.3.2 Tour boat operations around Gull Island

Tour boats cruised along the western shore of Gull Island from April to September for the purpose of seabird viewing. A peak of tour boat activity took place during July when over 30 boat passages a day occurred to view seabirds. I found tour boats

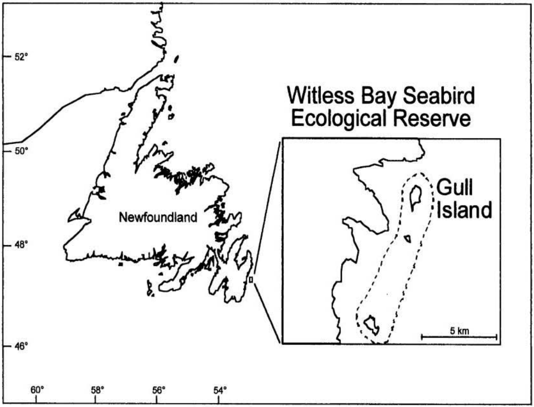

Figure 3.1. Locations of the Witless Bay Seabird Ecological Reserve and Gull Island study site in Newfoundland, Canada.

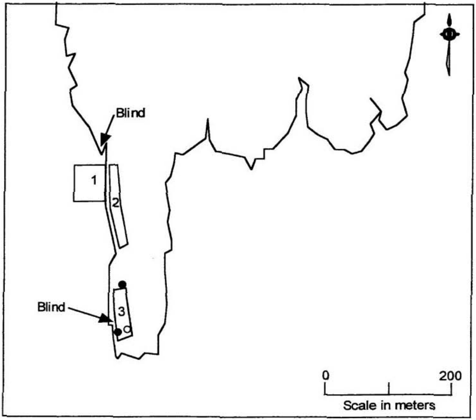

Figure 3.2. Locations of Razorbill and Atlantic Puffin observation plots and observation blinds on Gull Island. The open circle represents an observation plot of breeding Razorbills nesting in a rock crevice. Filled circles represent observation plots of *Razorbills* attending clubs. *1* represents the inshore island waters observation plot for Atlantic Puffins. 2 and 3 represent observation plots of Atlantic Puffins on grassy seaward slopes.

approached as close as 11 m to nesting Razorbills and Atlantic Puffins. Tour boats were Cape Islander vessels 40-60 ft in length with inboard diesel engines. The number of tour boats given access to the reserve is limited by a provincial permit system. Four tour boat companies are currently each allowed two vessels in the reserve. *Seabird Ecological Reserve Regulations* (Newfoundland Regulation 66/97) do not allow a person to operate a boat within 20 m (motor) or 15 m (no motor) of Gull Island from April 1 to September 1. However, tour boat operators are exempt from distance restrictions and normally approach as closely as possible to nesting seabirds. In addition, a person may not 'operate a boat in a manner that disturbs wildlife or allows noise from the boat or persons on board to disturb wildlife' within a Seabird Ecological Reserve (Newfoundland Regulation 66/97).

3.3.3 Observations of bird behavior

I assessed the impacts of tour boat operations on Atlantic Puffin and Razorbill alarm behavior using three approaches: (1) by quantifying groups' alarm behavior throughout short observation periods of several minutes during the presence and absence of boats (2) by recording puffin group alarm-behavior on inshore island waters throughout long observation periods of approximately two hours that included at least one boat passage and (3) by examining the alarm behavior of focal individual puffins to boat passages as tour boats approached puffins located on inshore waters.

During all experiments, birds were observed from within plywood blinds or distant vantage points to exclude the possibility of investigator disturbance. Situations when a tour boat was present (defined as *boat observation periods*) began when a vessel was within 400 m of a seabird site and ended before the boat was beyond 400 m of a seabird site. Situations when no tour boat was present within 400 m of the study colony were referred to as *no-boat observation periods*. All no-boat observation periods were performed at least 20 minutes after any boat passage, so boat and no-boat observation periods were treated as independent of each other. The methods for each approach were as follows:

1) Boat and no-boat experiments (Razorbill and Atlantic Puffin group responses): Proportions of Razorbills and puffins exhibiting alarm behaviors were recorded throughout boat and no-boat observation periods to determine if bird behaviors indicative of disturbance or stress occurred more often when a boat was present than when absent.

During a boat observation period, one observer estimated the distance of the boat when it was adjacent to the birds (closest approach), boat noise, and boat speed. Estimations of boat distance were made using a laser rangefinder, compass, and trigonometry. The measuring accuracy of the rangefinder was ± 1 m. The maximum distance for determining boat distance with the rangefinder was approximately 400 m. Bearings were measured in degrees with a compass to estimate distances between the boat and parts of the seabird colony. Boat noise was categorized as quiet or loud. A quiet noise level consisted of (1) a person talking quietly with a microphone and or audible boat engine noise to us on the island (2) a person talking loudly with a microphone and minimal boat engine noise to us on the island or (3) no audible boat noise to us on the island. A loud noise level comprised (1) human shouting, whistles, horns, or music playing from a tour boat or (2) a person talking loudly with a microphone and moderate to high boat engine noise to us on the island. Boat speed was categorized as slow or fast as the vessel traveled alongside of the birds I was observing. A slow boat consisted of (1) stopping and or backing-up (2) changing speed to slower or (3) traveling at a constant speed estimated at < 7 knots. A fast boat comprised traveling at a constant speed estimated at > 7 knots.

Throughout the same boat observation period, a second observer recorded the proportion of birds exhibiting alarm behaviors. The same individual birds were viewed throughout the observation period. I examined the Razorbill alarm behaviors of standing, alert-posture, fly-offs, leaving of nesting crevices, and entering of nesting crevices. The number of Razorbills viewed during observation periods was 1 to 13 individuals. Likewise for the behavior of fly-offs, the number of puffins observed during observation periods was 4 to 12. Average duration of an observation period was 2 min 4 sec ($n = 422$, *range* = 25 sec—6 min 25 sec, $SE = 2.6$ sec). This was the approximate amount of time it took for a boat to pass a colony study site.

Razorbill and Atlantic Puffin behavior was also quantified in the absence of tour boats (no-boat observation periods). The no-boat observation periods represented the controls against which seabird alarm behavior in presence of tour boats could be assessed. Except for the absence of recording boat parameters, the methods for no-boat observation periods were the same as boat observation periods. Observation periods (boat/ no-boat) were matched with respect to interval duration, location of birds, and day. Start times for no-boat observation periods were at least 20 min after any boat passage. The average amount of time a no-boat observation period was performed after a corresponding boat observation period was 2 h 2 min ($n = 413$, *range* = 21 min—6 h 46 min, $SE = 3$ min 54 sec).

Numbers of Razorbills arriving at club locations and Atlantic Puffin panic flights from breeding slopes were recorded during boat and no-boat observation periods. A puffin panic flight was defined as the simultaneous departure of 10 or more puffins from the same area of breeding slope.

2) Puffin alarm behavior before, during, and after a boat passage: Puffin behavior was recorded to determine elapsed time for puffins to resume normal behavior after the passage of a tour boat. Counts of puffins within my observation plot on inshore island waters were performed throughout observation periods that contained at least one boat passage. All boats recorded during observation periods passed within 100 m of my observation plot. The average duration of an observation period was 1 h 52 min ($n = 12$, *range* = 47 min—3 h 13 min, $SE = 14$ min 36 sec). Counts of puffins on inshore island waters were invariably conducted as boats passed the observation plot, and these counts were regularly performed throughout the remainder of observation periods. Time of day was recorded at the end of all puffin counts.

3) Puffin focal individual observations: As tour boats approached puffins located on inshore island waters, the behavioral responses of individual puffins were recorded. I examined the puffin alarm behaviors of fly-offs, diving, swimming away from boats,

skittering from boats, and wheeling flight. A puffin's response of skittering was defined as flying a short distance across the water and landing a short distance out of the boat's passage. In a wheeling flock puffins followed a path over a colony area and the adjacent sea; the flight path was circular or elliptical during calm winds and a figure-of-eight during moderate winds (see Cramp 1985). During some of the focal experiments I determined where puffins landed if they took flight from inshore island waters due to an oncoming tour boat. Focal individual puffins were initially positioned on inshore island waters in front of oncoming tour boats. Individuals were subsequently selected by being closest to the advancing boat at the time.

3.3.4 Statistical analyses

Proportions of Razorbills and Atlantic Puffins exhibiting a behavior were used as dependent variables unless indicated differently. Proportions were transformed into arcsin square-root values to satisfy assumptions of ANOVA's and paired t-tests. Seabird behaviors were pooled across years, locations, and seasons where appropriate to increase sample sizes. To determine if data could be pooled, a general linear model was used with independent variables of year, location, season, and the interaction terms of those variables. Proportions of Razorbills and Atlantic Puffins exhibiting a particular behavior were only pooled across the independent variables that were not significant in the general linear model. In all analyses, measures of behavior were treated as independent samples only if they were obtained from different individuals.

Proportions of seabirds exhibiting a behavior were compared between boat and no-boat experiments by means of paired t-tests. When experiments were paired, paired t-tests were more suitable for the experimental design and used instead of ANOVA's.

I examined the effects of boat distance, speed, and noise levels on the proportions of Razorbills and Atlantic Puffins exhibiting alarm behaviors. Due to limitations in sample size, a multivariate analysis could not be used. As a result the effects of boat distance, speed, and noise on seabird behaviors were examined using one-way analyses of variance. Thus each of the three boat factors was tested univariately, while keeping the other boat factors constant. If it was not possible to keep the other boat factors constant, then interactions with confounding variables were checked.

Plots of residuals and fitted values from the one-way analyses of variance were examined visually to determine whether the residuals were associated with the linear model. Residuals were checked for normality by (1) examining histograms of the residuals (2) comparing the frequency distribution of residuals to the normal distribution using a rootogram with 95% confidence intervals and (3) plotting normal equivalent deviates of the residuals and residuals.

3.4 Results

3.4.1 Effect of tour boat passages on Razorbill alarm behavior at nest sites and clubs

The number of Razorbills leaving their nesting crevices was 12% greater for incubators ($P = 0.01$) and 4% greater for brooders ($P = 0.09$) during boat passages compared to boat absence (Figure 3.3, Chi-square tests). Similarly during the brooding period, the number of off-duty and non-breeding Razorbills leaving nesting crevices was 9 times greater ($P < 0.001$) and entering nesting crevices was 4 times greater ($P = 0.04$) during boat passages compared to boat absence (Figure 3.4, Chi-square tests).

Proportions of Razorbills flying-off from clubs were on average 23% greater for the incubating period ($P = 0.0006$) and 6% greater at site 1 ($P = 0.02$) and 21% greater at site 2 ($P = 0.005$) for the brooding period during boat passages compared to boat absence (Figure 3.5, paired *t*-tests). Furthermore, proportions of Razorbills exhibiting alert-posture at clubs were on average 58% greater for the incubating period and at least 72% greater for the brooding period during boat passages compared to boat absence (Figure 3.6, paired *t*-tests, P's ≤ 0.0001). In addition throughout the breeding season, proportions of Razorbills standing in clubs were on average 40% greater at site 1 ($P = 0.008$) and 14% greater at site 2 ($P = 0.05$) during boat passages compared to boat absence (Figure 3.7, paired *t*-tests). Likewise during the brooding period, the mean number of Razorbill arrivals to clubs was 5 times greater at site 1 and 3 times greater at site 2 during boat passages compared to boat absence (Figure 3.8, Chi-square tests, P's < 0.005).

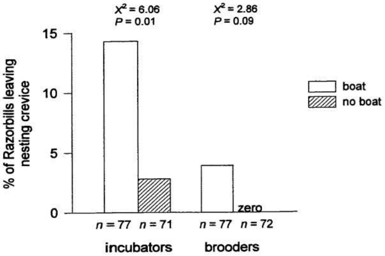

Figure 3.3. Effect of tour boat passages on incubating and brooding Razorbills leaving their nesting crevices.

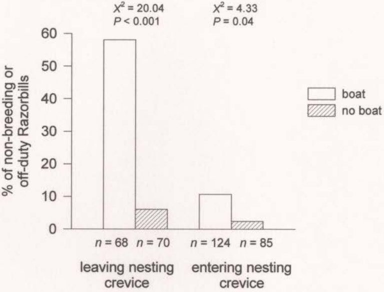

Figure 3.4. Effect of tour boat passages on non-breeding and off-duty Razorbills entering and leaving nesting crevices during the brooding period.

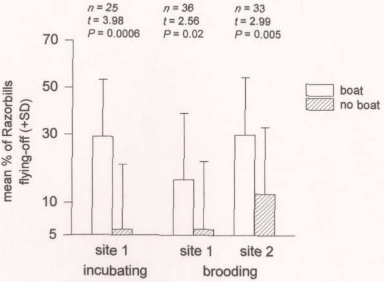

Figure 3.5. Effect of tour boat passages on Razorbill fly-offs from club locations. Probability scale used for y-axis.

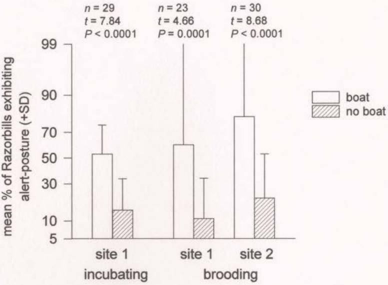

Figure 3.6. Effect of tour boat passages on Razorbills exhibiting alert-posture at club sites. Probability scale used for y-axis.

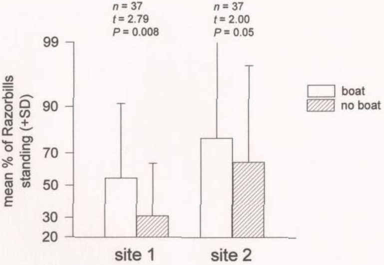

Figure 3.7. Effect of tour boat passages on Razorbills standing at club sites. Probability scale used for y-axis.

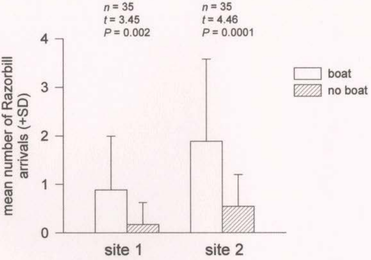

Figure 3.8. Effect of tour boat passages on Razorbill arrivals to club sites during the brooding period.

Overall, I observed an increase in the proportions of Razorbills exhibiting alarm behavior as tour boats approached closer to clubs (Figures 3.9—3.15). Proportions of Razorbills flying-off from clubs were on average over 3 times as great during loud boat passages compared to quiet boat passages for the incubating period ($P = 0.07$) and brooding period ($P = 0.04$; Figure 3.16, ANOVA). Similarly throughout the breeding season, proportions of Razorbills standing at clubs were on average 18% greater during loud boat passages compared to quiet boat passages, but this was not significant (Figure 3.17, ANOVA, $P = 0.1$). However, proportions of Razorbills flying-off, exhibiting alert-posture, and standing at clubs did not vary significantly between slow and fast boat passages (Figures 3.18—3.20, ANOVA, P's > 0.05).

3.4.2 Effect of tour boat passages on puffin alarm behavior

The mean number of puffin panic flights (± *SD*) from breeding slopes was 0.54 ± 0.71 (*range* = 0—2) during boat passages and 0.31 ± 0.68 (*range* = 0—3) during boat absence, and this was not significantly different (paired *t*-test, $n = 26$, $t = 1.24$, $P = 0.2$). Likewise, proportions of puffins flying from ridges and valleys on puffin breeding slopes did not differ significantly between boat passages and boat absence (Figure 3.21, paired *t*-test, $P > 0.05$). However, tour boat passages caused puffins to entirely vacate inshore island waters until the disturbance event dissipated for approximately 10 min (Figure 3.22). Puffin numbers on inshore island waters were on average consistently lower at least

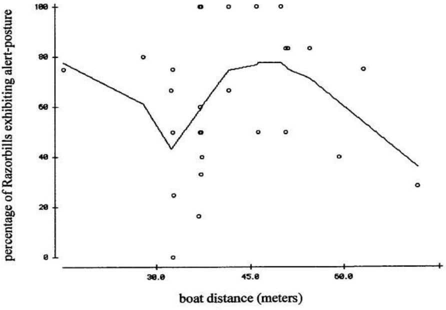

Figure 3.9. Effect of tour boat distance on the alert-posture of Razorbills at club site 1 during the incubating period. Lowess smoothed at a span of 26%. $n = 31$ boat passages.

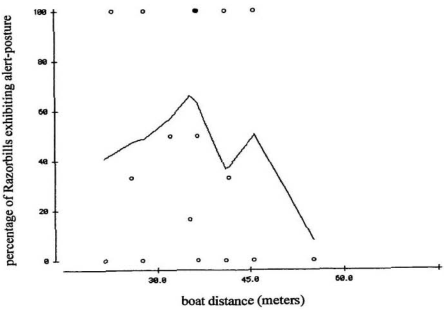

Figure 3.10. Effect of tour boat distance on the alert-posture of Razorbills at club site 1 during the brooding period. Lowess smoothed at a span of 20%. $n = 24$ boat passages.

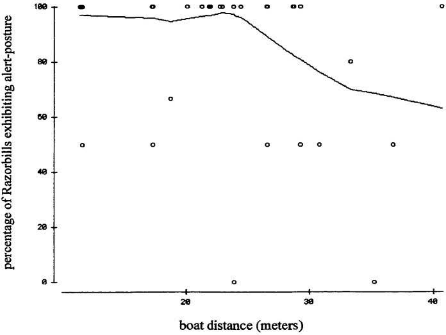

Figure 3.11. Effect of tour boat distance on the alert-posture of Razorbills at club site 2 during the brooding period. Lowess smoothed at a span of 26%. $n = 37$ boat passages.

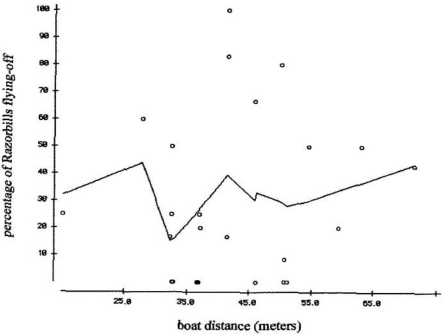

Figure 3.12. Effect of tour boat distance on Razorbill fly-offs from club site 1 during the incubating period. Lowess smoothed at a span of 26%. $n = 27$ boat passages.

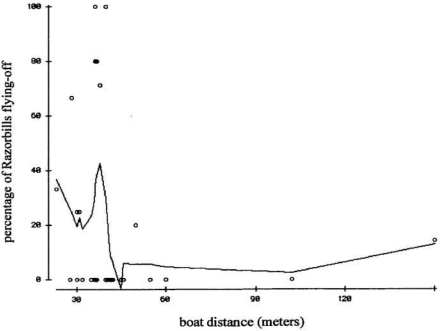

Figure 3.13. Effect of tour boat distance on Razorbill fly-offs from club site 1 during the brooding period. Lowess smoothed at a span of 20%. $n = 30$ boat passages.

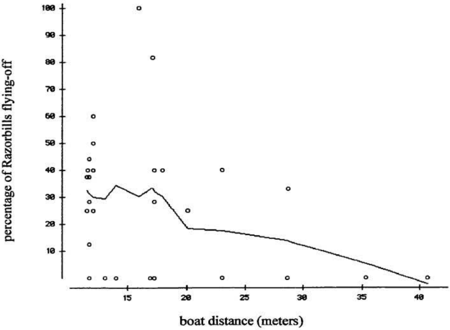

Figure 3.14. Effect of tour boat distance on Razorbill fly-offs from club site 2 during the brooding period. Lowess smoothed at a span of 20%. $n = 30$ boat passages.

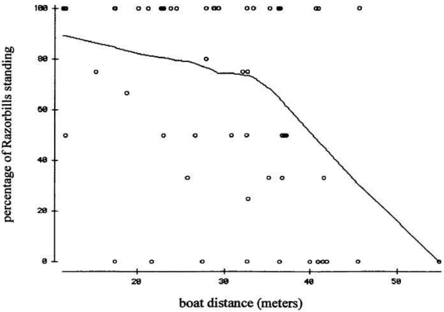

Figure 3.15. Effect of tour boat distance on Razorbills standing at clubs throughout the breeding period. Lowess smoothed at a span of 20%. $n = 68$ boat passages.

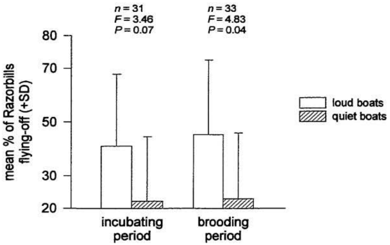

Figure 3.16. Effect of tour boat noise on Razorbill fly-offs from clubs. Probability scale used for y-axis.

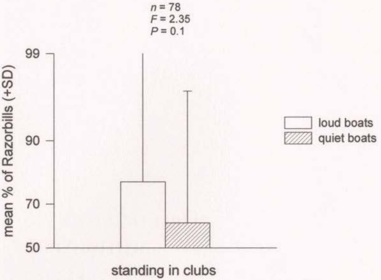

Figure 3.17. Effect of tour boat noise on Razorbills standing at club sites. Probability scale used for y-axis.

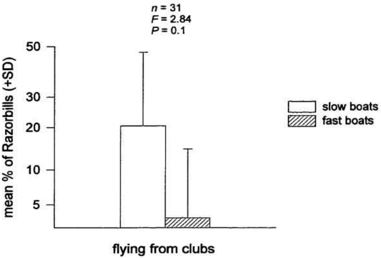

Figure 3.18. Effect of tour boat speed on Razorbill fly-offs from clubs. Probability scale used for y-axis.

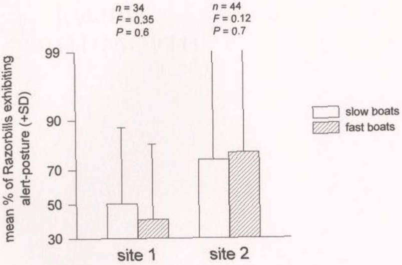

Figure 3.19. Effect of tour boat speed on Razorbills exhibiting alert-posture at clubs. Probability scale used for y-axis.

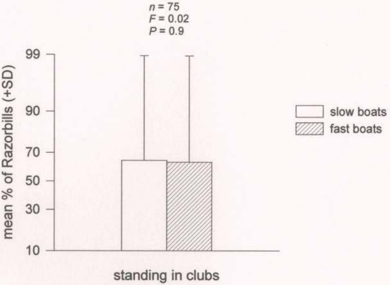

Figure 3.20. Effect of tour boat speed on Razorbills standing in clubs throughout the breeding season. Probability scale used for y-axis.

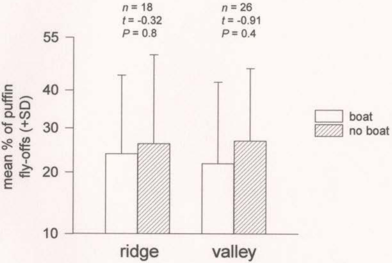

Figure 3.21. Effect of tour boat passages on puffin fly-offs from ridges and valleys on breeding slopes. Probability scale used for y-axis.

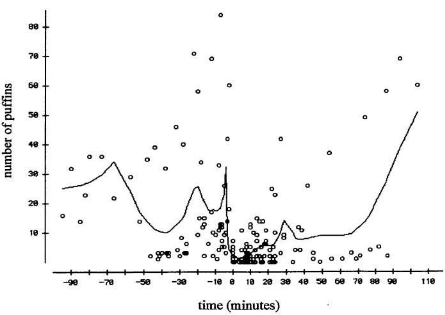

Figure 3.22. Effect of tour boat passages on puffins located on inshore island waters. Zero on x-axis denotes when boat is passing through study plot. Trewess smoothed at a span of 10%.

1 hour after a boat passage compared to inshore island water attendance prior to a boat passage.

As tour boats approached puffins located on inshore island waters, 57% of puffins flew from the water, 23% dove underwater, 15% swam from boats, and 4% skittered a short distance across the top of the water and landed a short distance out of the boat's passage ($n = 557$ puffins). When puffins flew from the water due to an oncoming boat, 24% of puffins flew back to the water while 76% entered into a wheel ($n = 172$ puffins). Of puffins that entered into wheels, 98% flew to breeding slopes and only 2% flew back to the water ($n = 46$ puffins).

3.5 Discussion

I assessed the impact of tour boat activity on breeding seabirds by examining seabird behavior before, during, and after tour boat passages. Tour boats passed by Gull Island as many as 30 times a day and approached as close as 11 m to nesting Razorbills. I found tour boat passages induced Razorbill and Atlantic Puffin alarm behavior regardless of breeding period or seabird breeding status. Tour boat noise, distance, and speed were found to directly affect seabird alarm behaviors.

Tour boat operations may be negatively impacting crucial social and self-maintenance activities of Razorbills. Findings from my study showed tour boats induced large percentages of Razorbills to fly from clubs throughout the breeding period. Clubs function as a safe location where both adult and immature Razorbills can gather for loafing (Bedard 1969). In addition Razorbills use clubs for copulating (Bedard 1969), and it is thought Razorbills select mates and pair at club locations (Cramp 1985). Thus, recruitment of Razorbills to Gull Island may be negatively impacted by tour boat activity if pairing of birds is disrupted. Moreover, a cost may occur to Razorbills in the disruption of normal behavior. Razorbills are clearly unable to perform vital self-maintenance, resting, and social activities if they are forced to fly from clubs during boat passages. Similarly, I found tour boat passages completely displaced Common Murres from club locations (Chapter 2).

Furthermore, disturbance produced by tour boats induced Razorbills located at nest sites to engage in alarm behaviors. For example, tour boat passages caused incubating and brooding Razorbills to leave their nesting crevices. This finding was significant since Razorbill eggs and chicks were left unattended for short periods of time. Herring Gulls *L. argentatus* and Great Black-backed Gulls *L. marinus* were observed with seabird eggs and chicks in their bills, and unattended Razorbill eggs or chicks would be easy prey. Both Herring and Great Black-backed Gulls breed on Gull Island (Lock *et al.* 1994). Nonetheless, no gull predation of Razorbill eggs, chicks, or adults was observed in association with the passage of tour boats. In addition, tour boat passages induced off-duty and non-breeding Razorbills to enter and leave nesting crevices during the brooding period. As a result, Razorbills prospecting for nest sites may have been disturbed during boat passages. Furthermore, I suggest the sharing of nest duties by breeding Razorbill pairs may be disrupted by tour boat activity. Burger (1981) found male Herring Gulls and Black Skimmers *Rynchops niger* were more likely to resume incubation duties after a disturbance event. Male Herring Gulls did not allow females to incubate the eggs for some time afterwards (Burger 1981). This is perhaps why I observed Razorbills entering and leaving nesting crevices during boat disturbance. Burger (1981) stated that females displaced from brooding expend more energy foraging than they would be doing in an undisturbed nest site.

An important finding from this study was that loud boats induced the greatest amount of disturbance to Razorbills in clubs. Human shouting, whistles, horns, or music playing from a tour boat induced particularly large percentages of Razorbills to engage in alarm behavior. A tour boat exhibiting both a person talking loudly with a microphone and moderate to high boat engine noise also caused large numbers of Razorbills to react with alarm behavior. Similarly, I found loud tour boats induced greater percentages of Common Murres *Uria aalge* to react with alert-posture and alarm-bowing compared to quiet tour boats (Chapter 2).

My data suggests the impact of slow and fast boats on Razorbill alarm behavior were similar. In contrast, I found greater percentages of Common Murres reacted with alarm behavior to slow boats compared to fast boats (Chapter 2). In addition, slow and fast boats caused lower percentages of Razorbills to react with alarm behavior than loud boats.

A decrease in boat distance to Razorbills located in clubs induced a greater frequency of alarm behavior. Similarly Ahlund and Gotmark (1989) found as boats approached closer to Common Eider creches, the percent diving frequency of eiders increased. In addition as boat passing distance to wading birds decreased, the number of wading bird groups flushed increased (Bratton 1990). A decrease in boat distance to

Common Murres at breeding ledges caused greater percentages of murres to react with alarm behavior (see Chapter 2). Analogously, Stalmaster and Kaiser (1997) reported flushing by Bald Eagles decreased with increasing distance from military firing events.

Razorbills appear to be more sensitive to tour boat disturbance during the incubating period compared to the brooding period. Tour boat passages induced incubating and brooding Razorbills to leave their nesting crevices. However, the proportion of incubating Razorbills leaving their nesting crevices during tour boat passages was 3 times greater than that for brooders. Furthermore, during the incubating period tour boats passing within 70 m caused large percentages of Razorbills to fly from club locations. Whereas during the brooding period, my data indicates Razorbills in clubs flew from boats passing within 40 m but appeared unaffected by boats passing beyond 40 m. Finally, tour boat passages induced a mean proportion of Razorbills to fly from club site 1 that was twice as great during the incubating period compared to the brooding period. At the same time, the mean proportion of Razorbills flying from club site 1 during boat absence was identical for the incubation and brooding periods.

Depending on their location, puffins reacted very differently to tour boat passages. All puffins located on inshore island waters exhibited an alarm behavior to oncoming tour boats. As a result of the disturbance, most puffins entered into a wheel and subsequently landed on puffin breeding slopes. I found tour boats displaced puffins from inshore island waters for approximately 10 minutes after a boat passage. Thus providing boats do not pass by the colony within 10 minutes of each other, my data indicates that 30 tour boat passages in a day would displace puffins from inshore island waters for approximately 5 hours. Inshore island waters are used by Atlantic Puffins for courtship and copulation occurs almost exclusively on the water (Harris 1984, Cramp 1985). In addition, Atlantic Puffins use inshore island waters for loafing and self-maintenance activities (Harris 1984, Cramp 1985). Consequently if boat disturbance prevents puffins from congregating in rafts on inshore island waters for extended periods of time, puffins may be disrupted from performing essential activities relevant to breeding and survival. In contrast, tour boat passages did not normally induce puffins located on breeding slopes to fly-off.

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Chapter IV

Conclusions

4.1 Summary of findings

The impact of the current level of tour boat activity on breeding Common Murres *Uria aalge*, Razorbills *Alca torda*, and Atlantic Puffins *Fratercula arctica* in the Witless Bay Seabird Ecological Reserve was not severe. Except for late in the brooding period, tour boat activity did not normally induce large numbers of alcids to fly-off from breeding cliffs or breeding slopes. Although not consistent with other similar studies (Ahlund & Gotmark 1989, Mikola *et al.* 1994), the disturbance produced by tour boats did not increase Herring Gull *Larus argentatus* or Great Black-backed Gull *L. marinus* predation on alcid eggs or chicks. However, tour boat passages did induce all alcids to engage in alarm behavior regardless of seabird breeding status or breeding season. Of the three alcids studied, Common Murres and Razorbills were the most sensitive to tour boat activity. An important finding from this study was that tour boat passages induced incubating and brooding Razorbills to leave their nesting crevices with eggs and chicks unattended which could negatively impact reproductive success. In addition, tour boat activity displaced alcids from clubs and from inshore island waters. This is significant because alcids gather at these locations to perform crucial self-maintenance and social activities including pair formation and copulating. Thus, tour boat activity may be negatively affecting recruitment of alcids to the colony at Gull Island. My work suggests if the current level of boat activity within the Witless Bay Seabird Ecological Reserve were to increase, local alcid populations would decline over time. This is supported by the findings of Barrett & Vader (1984) who reported high levels of pleasure craft traffic produced a total collapse in Common Murre and Atlantic Puffin populations in southern Norway. As a result, boat operating guidelines near seabird colonies should be implemented in nature reserves to protect alcids.

4.2 Recommendations for tour boat control regulations

1.) I would require that the number of tour boat permits for the Witless Bay Seabird Ecological Reserve remain at the current level and not be increased. I also recommend active law enforcement and fines for tour boats operating illegally in the reserve.

2.) I would require tour boat operators to be permitted one boat passage by the west side of Gull Island per tour. Currently, tour boat operators often pass by the west side of Gull Island twice near the beginning and end of a tour.

3.) Vessels currently approach as close as 25 m to nesting murres. Based on this study, total protection of murres would require tour boats to maintain a distance of 100 m from breeding sites during the incubating and brooding periods. I recommend tour boats should at least maintain a 100 m distance from murre clubs during the incubating period when clubs are most active and from breeding ledges late in the brooding period. Tour boats avoiding breeding ledges late in the brooding period would decrease large murre fly-offs and thus chicks being left unattended.

4.) To protect Common Murres from slow boats, I suggest vessels should travel greater than approximately 7 knots without intermittent stopping or changes in speed past murre breeding sites. My data indicated if boats travel greater than approximately 7 knots, nearly 30% less Common Murres may alarm-bow.

5.) I recommend tour boat activity near puffin colonies should be limited in the pre-laying period to protect puffins on inshore island waters from disturbance. Inshore island waters are of marked importance to puffins early in the breeding season when puffins congregate in rafts near the colony to perform courtship behaviors and to copulate (Cramp 1985). In this way, birds may enter colony almost ready to lay (Cramp 1985).

6.) To protect Razorbills from tour boat activity I suggest tour boats should maintain distances of at least 70 m during the incubating period and 40 m during the brooding period from Razorbill club locations and breeding sites. This study indicates tour boats maintaining these distances would significantly reduce the number of Razorbills flying-off from clubs during tour boat passages.

7.) To protect Common Murres and Razorbills from loud boats, I suggest eliminating human shouting, whistles, horns, or music playing during tour boat passages.

Furthermore, microphone volumes should be minimal while viewing Common Murres and Razorbills, and preferably boat engine noise should be reduced by use of special muffler systems.

8.) I also suggest carefully regulating pleasure craft and kayak activity within the reserve. Currently, vessels other than tour boats are relatively rare in the reserve. However, an increase in pleasure craft or kayak activity should be of concern as these vessel types induced large fly-offs of Common Murres from breeding ledges. Overall, pleasure craft users did not conduct themselves in a manner that was as ecologically responsible as tour boat operators. One pleasure craft user even threw beer bottles at cliff-nesting seabirds. Currrent *Seabird Ecological Reserve Regulations* (Newfoundland Regulation 66/97) do not allow a person to operate a boat within 20 m (motor) or 15 m (no motor) of Gull Island. I recommend these minimum approach distances for motorized and non-motorized vessels to Gull Island be greatly increased, but further data is necessary to develop detailed management guidelines to protect seabirds from these vessel types.

9.) I would prohibit the operation of Personal Watercrafts (PWC's; e.g. Sea Doo, Polaris, Kawasaki Jet Ski) within the Witless Bay Seabird Ecological Reserve. PWC's produce high noise levels and can be operated at very high speeds. On one instance, a PWC operator chased seabirds on the water, and it appeared some birds may have been struck.

4.3 Recommendations for future research

Because few studies have determined the impact of tour boat disturbance on seabirds, there may be a need for further investigations. At Gull Island, it appeared Common Murres may have habituated somewhat to tour boat disturbance. My study was conducted at a seabird colony where tour boats had been operating for approximately 15 years. Thus, it may be important to determine the impact of tour boat disturbance on seabirds that have had little exposure to boat traffic. Moreover since I found tour boats induced seabirds to exhibit alarm behaviors that may be affecting reproductive performance, a study could examine the effect of boat disturbance on seabird productivity. My findings also suggested tour boat activity may be negatively impacting recruitment of seabirds to colonies, but this has yet to be quantified. Further investigations could be undertaken to determine the impact of various vessel types such as kayaks and pleasure crafts on nesting seabirds. In addition, the physiological responses of seabirds to boat disturbance could be researched. For instance, human activity has been shown to increase the heart rates of penguins (Wilson *et al.* 1991, Nimon *et al.* 1995).

Further research may be needed to determine the effect of tour boat activity on Common Murres and Thick-billed Murres (*U. lomvia*) located on Green Island in the Witless Bay Seabird Ecological Reserve. 74,000 pairs of Common Murres currently breed on Green Island (Lock *et al.* 1994), so it is a significant colony to protect from human disturbance. Tour boats passed around Green Island once per tour to view the large numbers of murres. However, these tour boat passages regularly caused Common Murres to fly from clubs near the intertidal zone on Green Island. Consequently, a study could determine at what distance murres first fly from clubs on Green Island due to tour boat disturbance. As a result, tour boat distance guidelines to ensure murre clubs would remain undisturbed during boat excursions could be implemented.

Lastly, a study could be initiated to assess the long-term effects of tour boat activity on seabird populations. As an example, the number of Common Murres on breeding ledges could be counted each breeding season over a period of many years on the west side of Gull Island where tour boat activity predominates and on other sides of Gull Island where there would be no tour boat passages. In this way, the number of breeding murres could be examined in areas of tour boat presence and absence to determine if tour boat activity may be negatively impacting seabird populations.

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