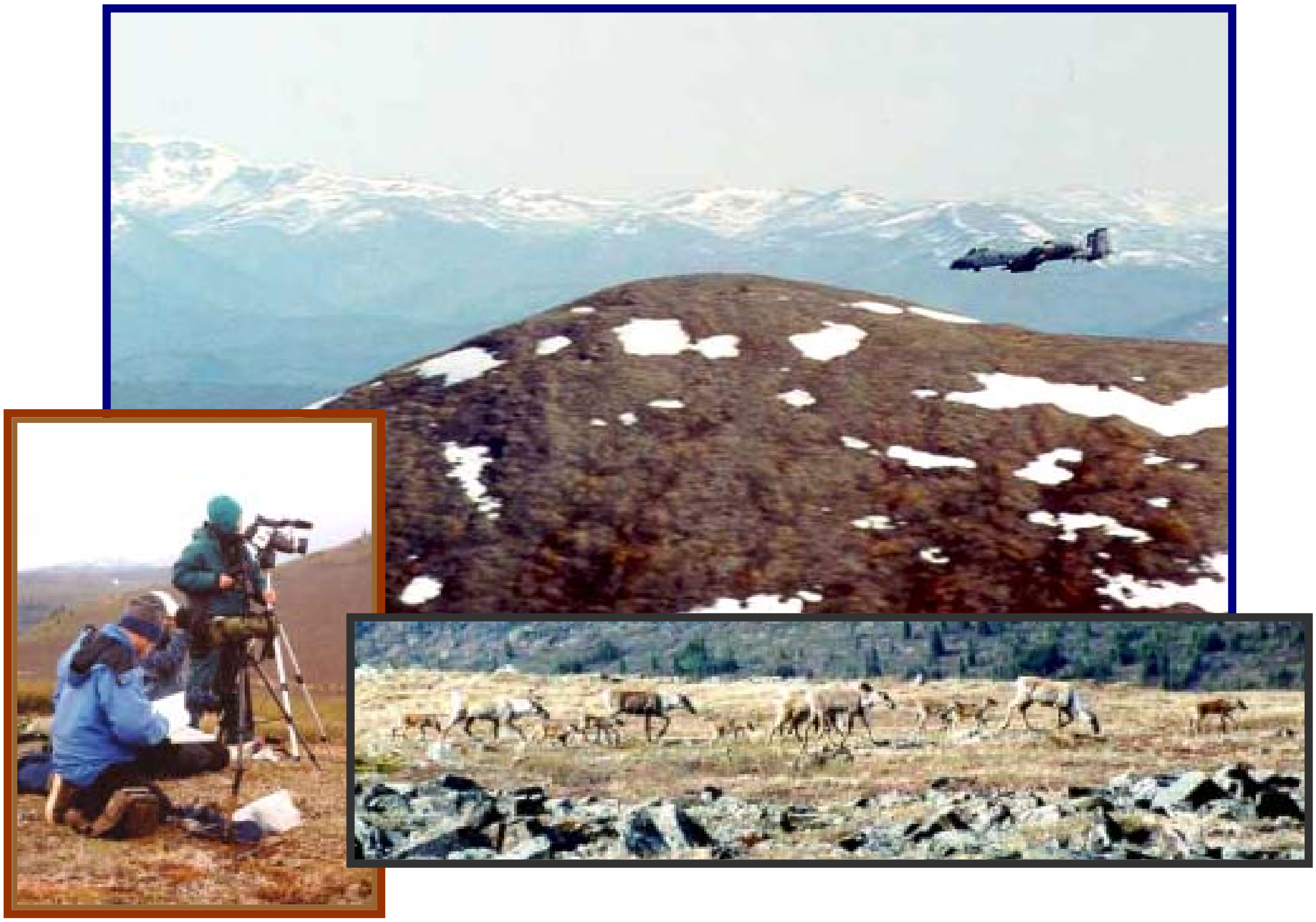
SHORT-TERM IMPACTS OF MILITARY JET OVERFLIGHTS ON THE FORTYMILE CARIBOU HERD DURING THE CALVING SEASON



by

Audrey J Magoun
James P Lawler
Craig L Gardner
Rodney D Boertje
Jay M Ver Hoef

JANUARY 2003

A cooperative study between

ALASKA DEPARTMENT OF FISH AND GAME
and
NATIONAL PARK SERVICE
and
11TH US AIR FORCE

Cite this publication as:

MAGOUN AJ, JP LAWLER, CL GARDNER, RD BOERTJE, AND JM VER HOEF. 2003. Short-term impacts of military jet overflights on the Fortymile caribou herd during the calving season. Alaska Department of Fish and Game. Fairbanks, Alaska.

****

Free copies of this report and other Division of Wildlife Conservation publications are available to the public. Please direct requests to our Publications Specialist or obtain from our website:

Publications Specialist
ADF&G, Division of Wildlife Conservation
PO Box 25526
Juneau, AK 99802-5526

Website: http://www.state.ak.us/adfg/wildlife/wildmain.htm

The Alaska Department of Fish and Game administers all programs and activities free from discrimination based on race, color, national origin, age, sex, religion, marital status, pregnancy, parenthood, or disability. The department administers all programs and activities in compliance with Title VI of the Civil Rights Act of 1964, Section 504 of the Rehabilitation Act of 1973, Title II of the Americans with Disabilities Act of 1990, the Age Discrimination Act of 1975, and Title IX of the Education Amendments of 1972.

If you believe you have been discriminated against in any program, activity, or facility, or if you desire further information please write to ADF&G, PO Box 25526, Juneau, AK 99802-5526; US Fish and Wildlife Service, 4040 N Fairfax Drive, Suite 300 Webb, Arlington, VA 22203 or OEO, US Department of the Interior, Washington DC 20240.

For information on alternative formats for this and other department publications, please contact the department ADA Coordinator at (voice) 907-465-4120, (TDD) 907-465-3646, or (FAX) 907-465-2440.

SUMMARY

The Fortymile caribou herd (FCH) is one of Interior Alaska's most prominent caribou herds. Although the herd presently numbers about 40,000, this estimate is still well below the historically high estimate of over 500,000 caribou made in the 1920s. In 2002 the FCH still occupied less than half of the range it covered during the high population years of the 1920s. In recent years the FCH has been in the news because of Alaska Department of Fish and Game's efforts to increase herd survival and growth in an attempt return the herd to a larger portion of its historical distribution. The National Park Service has an interest in this herd not only for its intrinsic value but also because it is an important component of the Yukon–Charley Rivers National Preserve ecosystem. The US Air Force also has an interest in the FCH because a large portion of its calving and summer range lies beneath heavily used Military Operations Areas (MOA) that are important for flight training.

Previous studies of jet overflights on other herds of caribou have shown relatively mild behavioral responses, but no studies have been conducted during the calving period. In May 2002 a new research project was initiated through a cooperative effort of the Alaska Department of Fish and Game, the National Park Service, and the US Air Force. A team of biologists and technicians from the Alaska Department of Fish and Game and the National Park Service, and 4 forward ground controllers from the US Air Force took to the field in areas just to the east and south of the Yukon–Charley Rivers National Preserve. Field crews observed the behavior of cow caribou and their calves before, during and immediately following low-level military jet overflights. We also monitored movements of radiocollared cow caribou, and survival of their calves. Fieldwork continued through early June.

We concluded that military jet overflights did not cause direct deaths of caribou calves in the FCH during the calving period or result in increased movements of cow–calf pairs over the 24-hour period following exposure to overflights. Short-term responses to overflights were generally mild in comparison to caribou reactions to predators or perceived predators. Caribou responses to jet overflights were variable, but levels of response were generally higher as slant distances decreased and jet speeds increased. Maintaining a floor of 2000 ft (625 m) above ground level (AGL) for all military jet aircraft over the calving grounds would eliminate most of the stronger-level reactions of caribou to military jet aircraft (startle reactions, trotting, and running), especially if speeds for F-15s and F-16s did not exceed 500 knots between 2000 (625 m) and 5000 ft (1562 m) AGL. A-10 jets caused less reaction than F-15s and F16s. Our data indicate that A-10s could operate as low as 1500 ft (469 m) AGL over calving caribou with only mild behavioral responses if the jets maintain low speeds and avoid maneuvers that require changes to higher power settings. Because the F-16 had a relatively high probability of causing stronger reactions in caribou at 1500 ft (469 m) AGL regardless of power settings, these jets should be restricted to elevations >2000 ft (625 m) AGL over the calving grounds if stronger-level reactions are to be minimized.

Although short-term reactions of caribou to jet overflights were relatively mild in this study, we advise against assuming there are no long-term effects on calving caribou from jet overflights. Determining long-term effects of military jet aircraft on caribou will require long-term measurements of physiological responses, movements, and calf survival tied directly to sound exposure under realistic scenarios of military jet training. Technology does not

currently exist for these types of studies. Under the Fortymile Caribou Herd Recovery Plan, and with the current mitigation levels for the calving period, the herd has increased in numbers and expanded its range, suggesting that current jet training (with current mitigation) is not significantly affecting the herd. Because of the political and management interest in the FCH and the international efforts that have been expended in rebuilding the herd and its range into Canada, we recommend a conservative approach to mitigating the effects of military jet overflights. Managers will also need to consider the impacts of overflights on other wildlife species as well as social impacts when considering altitude limitations on military aircraft. Without this information and with the potential for increased military jet training in the Yukon MOA, a conservative approach is advisable.

CONTENTS

FIGURES, TABLES, AND APPENDICES

INTRODUCTION

THE FORTYMILE CARIBOU HERD

The Fortymile caribou herd (FCH) is 1 of 5 international herds shared between Alaska and Yukon, Canada. It has the potential to be the most economically important herd in Interior Alaska and southern Yukon for consumptive and nonconsumptive uses. Like other caribou herds in Alaska, the FCH has displayed major changes in abundance and distribution. During the 1920s it was the largest herd in Alaska and was one of the largest in the world, estimated at 568,000 caribou (Murie 1935). For unknown reasons, the FCH declined during the 1930s to possibly 10,000–20,000 caribou (Skoog 1956). Timing of the subsequent recovery phase is unclear, but by the 1960s the FCH possibly numbered 50,000 (Valkenburg et al. 1994). Between the mid-1960s and 1975, the herd again declined, with a population low during 1973–1975 of 5000–9000 caribou (Davis et al. 1978; Valkenburg and Davis 1989). The FCH began increasing in 1976 and reached an estimated 22,766 caribou by 1990. During 1990–1995 the herd stabilized with an estimated population between 21,884 and 22,558 caribou (Boertje and Gardner 2000). During 1996 and 1997 the herd increased by 4% and 10%, respectively, as pregnancy rates and adult and calf survival improved and harvest declined.

Concurrent with decreased herd size between the mid-1960s and early 1970s, the FCH reduced its range size and changed its seasonal migration patterns. Between 1963 and 2001 the herd no longer crossed the Steese Highway, and between 1973 and 2002 the FCH rarely migrated into Yukon and did not cross the Yukon River (Boertje and Gardner 2000). From the early 1970s through 2000, the herd's total, multi-year range was about 19,300 mi^2 (50,000 km^2), less than 25% of the historic range.

The FCH annually shifts its core calving area. Since 1980 the general area in which these shifts occur encompasses the North Fork and Middle Forks of the Fortymile River, the Goodpaster, Charley, Salcha, and Seventymile Rivers, and Copper, Crescent, and Birch Creeks (Fig 1). Each year, calving distribution is unpredictable and factors influencing selection are not well understood. Furthermore, the FCH has shifted its core calving area up to 100 miles since the early 1960s (Valkenburg and Davis 1986). For example, during 1900–1963 the herd often calved near the Steese Highway, with primary calving often extending west of the Steese Highway.

In July 1994 a Fortymile Caribou Herd Management Planning Team was established to develop management and research plans designed to increase the herd and reestablish the herd's historic range use in both Alaska and the Yukon. The team included subsistence users from Alaska and Yukon, sport hunters, Native villages and corporations, environmental groups, and agency representatives from the Alaska Department of Fish and Game (ADF&G), Bureau of Land Management, US Fish and Wildlife Service, National Park Service (NPS), and Yukon Department of Renewable Resources. The management plan developed by the planning team had substantial public support and was endorsed by Alaska Governor Tony Knowles, the Alaska Board of Game, the Federal Subsistence Board, the Yukon Fish and Wildlife Management Board, and all 3 major Alaskan newspapers. The process was the most publicly scrutinized wildlife program in Alaska during that time.

Since initiation of the Fortymile Caribou Management Plan in 1996, the herd has increased about 4–13% annually. Also, with the crossing of the Yukon River in 2002, and the crossing of the Steese Highway in 2001, the herd is beginning to use historic range not utilized for almost 40 years. There is broad public support for continued conservative herd management to ensure future herd growth. Yukon government regulations do not allow harvest of the herd until it reestablishes traditional migration patterns. The Tr'ondëk Hwëch'in First Nation is currently not exercising their right to hunt the herd and is trying to designate critical habitat within their lands for the herd. In Alaska, hunters continue to support limited harvest opportunity to ensure moderate herd growth, and the mining industry has taken steps to minimize impacts on the herd. The US Air Force (USAF) has restructured jet-training exercises that occur during calving of the FCH.

MILITARY OPERATIONS AREAS

Military Operations Areas (MOA) in Alaska were established in 1976 as Special Use Airspaces designated for nonhazardous military flight training activities such as air combat tactics, formation training, and aerobatics. Since 1976 the expectations of the military and, therefore, expectations of training goals have changed. Concurrent with these changes were changes in weapon and plane technology and changes in the numbers and types of planes being flown in Interior Alaska. In the late 1980s and early 1990s, the USAF initiated several actions that led to a significant increase in training activity in Alaska. All of these changes resulted in different needs for air space. Recognition that the 1976 airspace structure no longer fit the needs of the US military culminated with the completion of an Environmental Impact Statement (EIS) (Department of the Air Force 1995) and the signing of a Record of Decision (ROD) (Department of the Air Force 1997). Among the changes proposed to the existing arrangement and accepted in the ROD were different boundaries for some MOAs, additional MOAs, the addition of supersonic flight to some MOAs, standard floors for some of the supersonic operations in existing MOAs, and higher numbers of aircraft authorized to participate in Major Flying Exercises (MFE). The Final EIS and the ROD included a number of mitigation measures designed to minimize negative impacts on wildlife. The ROD also established committees made up of Air Force and resource agency representatives to monitor the effectiveness of the mitigation measures. Among other needs, these committees recognized the importance of determining the effectiveness of the mitigation measures on caribou and the need to evaluate the impacts of low-level military aircraft on caribou.

The recent calving grounds of the FCH occur within the Yukon MOA (Fig 1) and mitigation measures for the FCH are specific to the calving season. Two sets of mitigation measures have been in place in recent years. During 1998–2000, mitigated airspace extended from the ground to 2000 ft (625 m) above ground level (AGL) and was centered on a 5-nautical mile radius extending outward from a geographical coordinate that represented the approximate center of mass of aggregated caribou on the calving grounds, as determined by ADF&G radiotracking flights. The number of mitigated areas varied between 1 and 4 and they could be separate or overlap. This arrangement was flexible so that dialogue between the ADF&G and the USAF could determine the timing and extent of mitigation, and mitigated areas could be altered on a daily basis. The current mitigation plan, put into place in 2001, mitigates airspace that can be comprised of up to 4 circles with 3-nautical mile radii extending outward from geographical coordinates, representing the approximate centers of mass of aggregated calving caribou. The altitude limit depends on the location of the calving caribou. Aggregations of calving caribou east of longitude 143°45.00'W have a floor of 2000 ft (625 m) AGL. For calving caribou west of this line, the floor is 1500 ft (469 m) AGL because this area is used as an approach to the Stuart Creek Air-to-Ground Weapons Range (R-2205) southwest of the calving grounds. Mitigated airspace remains stationary from 15 to 31 May. From 1 June to 8 July, the mitigation areas typically remain stationary for a minimum of 72 hours. Mitigated areas are updated on 6, 10, 14, and 17 June and may be separate or overlap (Letters of Agreement between the 611th Air Operations Group and ADF&G). For the majority of the year, military aircraft can fly subsonic as low as 100 ft AGL in this area. Supersonic activity is authorized at or above 5000 ft (1562 m) AGL or 12,000 ft mean sea level (MSL), whichever is higher. Details on the projected number of military jet training operations in the Yukon MOA are presented in Appendix A.

OVERFLIGHT IMPACTS ON WILDLIFE

Janssen (1980) identified 3 levels of potential noise effects on wildlife (detailed in Department of the Air Force 1995). Primary effects are direct impacts such as hearing loss, ruptured eardrums, or deafness. Secondary effects include physiological responses, behavior changes, interference with reproduction, and reduced ability to obtain adequate food, water, or cover. Tertiary effects are changes in age and sex ratios, population declines, habitat abandonment, and potential species extinction. In Interior Alaska, maximum noise levels between 73 and 118 decibels (dB) can be expected from routine low-level military jet training operations (Department of the Air Force 1995). Noise events of this magnitude are typically short in duration and are essentially instantaneous events (Department of the Air Force 1992). Wildlife subjected to these types of overflights are unlikely to detect jets until the aircraft is above or past them. Low-altitude military jets, therefore, expose wildlife to very short-term, high-intensity sounds and a noise profile different from civilian helicopters and fixed-wing aircraft (Department of the Air Force 1995); conclusions based on civilian aircraft may be in error when extrapolated to military jet aircraft.

The manner in which an organism responds to aircraft overflights depends on the life-history characteristics of the species as well as habitat and previous exposure to aircraft (NPS 1994). Research efforts on wildlife have documented a variety of physiological and behavioral responses to aircraft overflights (review in NPS 1994), but no studies have definitively documented long-term population effects on caribou. Harrington and Veitch (1992) reported that calf survival in woodland caribou was negatively correlated with level of exposure to military jets near Goose Bay, Labrador and suggested that jet overflights may be compromising herd growth. Davis et al. (1985), on the other hand, concluded that caribou in the Delta caribou herd (DCH) in Alaska were habituated to aircraft overflights, including military jets and civilian aircraft, and showed no evidence of long-term population effects from frequent aircraft activity.

Studies of aircraft overflights on caribou have largely addressed short-term effects of overflights, including acute responses at the time of the overflights and somewhat longer-term (≤10 days) behavioral changes as a consequence of the overflights (Miller and Gunn 1979; Harrington and Veitch 1991, 1992; Murphy et al. 1993; Maier 1996; Maier et al. 1998). Acute responses of caribou in the DCH exposed to military jet overflights were relatively mild; 49% of caribou showed no overt behavioral response, 31% became alert, 6% stood up from a lying posture, and 13% moved in response to the jets (Murphy et al. 1993). However, exposure to jet overflights was correlated with shorter resting bouts in the postcalving and insect seasons and increased daily movements of caribou in the postcalving season (Murphy et al. 1993; Maier 1996; Maier et al. 1998). Harrington and Veitch (1992) proposed that frequent overflights by low-level military jets during the calving and immediate postcalving periods could reduce calf survival as a consequence of startle responses, and subsequent reduced milk intake by calves. Most researchers studying the effects of aircraft overflights on caribou have suggested that female caribou with young calves are more sensitive to aircraft overflights than caribou of other sex and age categories and that mitigation is particularly important in the calving and postcalving seasons (Miller and Gunn 1979; Harrington and Veitch 1991; Murphy et al. 1993; Maier et al. 1998). However, McCourt and Horstman (1974) found that caribou were more reactive to civilian aircraft below 300 ft in the postcalving, winter, and spring migration periods than they were in the calving season.

Past studies of caribou responses to military jet overflights have not been carried out in the calving season using visual observations of cow–calf pairs. Our study examined the impacts of low-level military jet overflights on caribou during the calving season and is the first study conducted during the calving season with a relatively large sample of visual observations of cow–calf pairs exposed to directed military jet overflights.

GOALS AND OBJECTIVES

The goals of this project were to 1) investigate the impacts of low-level military overflight activity on caribou during the calving season and 2) assess the effectiveness of current mitigation measures that are intended to reduce negative impacts to caribou in Interior Alaska MOAs and recommend modifications, if necessary. To achieve these goals we pursued the following objectives: 1) document and model short-term responses of cow caribou during the calving season to low-level military jet aircraft in the Yukon MOA, 2) evaluate caribou calf survival in relation to military jet overflights, 3) examine the effects of military jet aircraft on daily movements of cow caribou during the calving season, and 4) quantify sound levels produced by low-level military jet aircraft during directed overflights.

STUDY AREA

Our study area was eastern Interior Alaska in the Yukon–Tanana Uplands (Fig 2). The most prominent feature of this area is the Yukon River, which flows across the northern portion of the region. Elevations range from 305 m to 2000 m above sea level. Climate is semi-arid continental. At Circle, Alaska, the nearest location for which long-term weather data exists, mean annual precipitation from 1957 to 1997 was 8.2 inches (20.9 cm). Mean daily temperature ranges from 15.6°C in July to -25°C in January (National Weather Service). Topography is rolling forested areas with rugged alpine tundra areas interspersed throughout.

The study area is within the subarctic boreal forest zone. Dominant tree species include black spruce (*Picea mariana*) in low-lying areas, and white spruce (*Picea glauca*), aspen (*Populus tremuloides*), and paper birch (*Betula papyrifera*) in better-drained locations. Above 3300 ft 1000 m, tundra vegetation dominates. Plant species in these alpine areas are typical tundra plants and include dryas (*Dryas* spp.), dwarf willow (*Salix* spp.), and bearberry (*Arctostaphylos* spp.). More detailed descriptions of the physiography and vegetation of this area can be found in Roland (1996), Ducks Unlimited (1998), and Swanson (1999).

Our study area included a portion of the 2002 core calving area of the FCH. During 2002 a sizable portion of the herd calved in an area bound to the north and south, respectively, by latitudes 65°05'N and 64º45'N, and to the east and west, respectively, by longitudes 141º75'W and 143º85'W.

METHODS

Two field crews, each with 4–5 persons, collected data on caribou behavior before, during, and after military jet overflights on the calving grounds of the FCH from 16 May to 5 June 2002. Each crew consisted of a wildlife research biologist, 2 field technicians, and 1 or 2 Air Support Operations Squadron (ASOS) personnel to act as air controllers. In addition, an ADF&G wildlife biologist, a fixed-wing aircraft pilot, and a helicopter pilot were available for support. On the days when jet overflights were scheduled, pilot–biologist crews located concentrations of caribou by radiotracking collared cows and calves. Information gathered on these radiotracking flights included location and approximate size of cow–calf aggregations, occurrence of radiocollared cow–calf pairs in the groups, and potential for ground crews to observe caribou without disturbing them. These reconnaissance flights were done early in the morning, usually between 0700 and 0800 hr. Each field crew was then transported by a Robinson-44 helicopter to an observation site as close to a group of caribou as possible without disturbing it. The distance between the field crew and the caribou was variable depending on the position of the caribou relative to terrain. Crews could observe caribou at relatively close range when the caribou groups were in narrow valleys in hilly terrain; observation sites were located further away in wide valleys or flat terrain.

Once crews were in place, a sound level meter (Larson Davis Model 812 sound level meter, Model 2560 microphone, and Model PRM826B preamp) was positioned at least 640 ft (200 m) from each crew. The Model 812 is a Type 1 sound level meter, indicating that it meets international standards for accuracy, frequency response, and linearity and that these standards are met over a wide range of temperatures and humidity (Larson and Davis 1997). Sound meters were programmed to record A-weighted sound exposure level (SEL) every second. Sound exposure level is the total sound energy measured in a specific time period. A-weighting is a filter that adjusts sound level frequencies similarly to the human ear when exposed to low levels of sound and is most often used to evaluate environmental sounds. Sound meter data presented in this report represent a general picture of the duration and variability of jet sound at the observation sites during the overflights, but do not represent exact sound exposure or peaks that caribou experienced during the overflights because the monitoring equipment was closer to the observers than to the caribou. During almost all sorties, jets made at least one close pass (320–960 ft [100–300 m]) over the sound meter at a speed comparable to the maximum speed during the sortie.

Although we usually knew a day or more in advance when jets would be available to participate in the study, the exact arrival times on any particular day were not known before the jets arrived. Jets (usually in pairs) would arrive in the vicinity of the study area and ASOS personnel on the ground would relay coordinates for overflights by radio to the pilots. Some jet sorties were planned specifically for the study and others occurred incidental to other military training missions in the Yukon MOA. On 2 occasions, more than 1 jet sortie arrived in the study area at the same time so that 2 overflight events involved mixed jet types. The air controllers directed jets to caribou groups that had been targeted for overflights and requested pilots fly over caribou at specified elevations and airspeeds. Direction of passes and maneuvers during overflights were left up to the discretion of pilots and air controllers, giving them the opportunity to use the overflights as training opportunities. Therefore, overflights tested caribou reactions to realistic training scenarios in Interior Alaska MOAs. Pilots avoided the study area when not participating in the research project.

Caribou selected for overflights were filmed using digital movie cameras (Canon XL1 and Canon GL1). A camera was focused on an entire group or a portion of a group if the group was large and relatively close to the camera. The number of caribou filmed during an overflight varied from a single cow–calf pair to 50 or more pairs. Whenever possible, groups were filmed for at least 2 hours before the jets arrived. Often, however, by the time the jets arrived, caribou groups had moved out of sight or into areas where they were difficult to observe and new groups had to be located. In a few instances, groups were filmed for only a few minutes or less before the jets arrived. Filming was continued after overflights for at least 15 minutes after normal behavior resumed or until groups disappeared from sight. Behavior was considered normal if it involved common behaviors observed on the film preceding overflights; bedding (resting), feeding, walking, traveling (alternating walking and trotting but not feeding), and nursing. If more overflights were expected during the day, filming was continued in preparation for the next overflight. Although we sometimes filmed the same group through more than one sortie, quite often the groups differed.

Although the cameras provided the primary means of documenting caribou reactions, a crew member also observed caribou reactions through a spotting scope while another recorded data on standardized forms using the focal animal and scan sampling techniques described by Altmann (1974). A comparison of data collected using cameras vs. direct observations demonstrated that camera data were more accurate and comprehensive. Caribou reactions to overflights could be replayed as often as necessary to reduce observer bias and inaccuracies, and most caribou in the viewfinder could be used for behavioral analysis, considerably increasing sample size. When data were collected by direct observation, observers often could not keep up with the amount of data that needed to be recorded during sorties that had multiple overflights close together. Only the data from the cameras were used in the analysis of short-term caribou reactions to overflights; other information on the data forms was used to crosscheck data verbally recorded on the film (e.g., jet speed and slant angle). Observers recorded weather, distance to caribou from the observation point, frequencies of radiocollared caribou that were in the group or nearby, and other incidental information.

MORTALITY

We compared distances from the nearest jet overflights to locations of dead calves for all radiocollared calves that died during the study on the day of an overflight or the day after. A geographical information system (ArcView GIS 3.2, Environmental Systems Research, Inc. [ESRI], Redlands, California) in conjunction with an ArcView extension (Animal Movement Analyst; Hooge and Eichenlaub 2000) were used to measure distances between location of calf deaths and the nearest overflights. We determined the cause of death for calves when possible.

Daily Movements in Relation to Overflights

As part of a study on mortality of caribou calves in the FCH, approximately 50 radiocollared caribou cows were radiotracked daily during the calving period. Calves of these cows, as well as approximately 25 random calves without collared mothers, were radiocollared as close to birth as possible. We selected about 30 of the radiocollared calves and located them every morning if possible from the time the calves were born until the end of the study period and calculated daily distance moved using ArcView GIS as described above. When selecting groups of caribou for overflights, we tried to target groups that contained at least one of the radiocollared caribou, although this frequently was not possible because of poor sightability. We were also not able to determine exact locations of cow–calf pairs at the time of the overflights. For this reason, we did not statistically analyze the relationship between daily distance moved by radiocollared cow–calf pairs and proximity to overflights, although we present raw data on this relationship. Because we knew the ages of the calves, we were able to examine the relationship between calf age and daily distance moved by cow–calf pairs.

Short-term Reactions of Individual Caribou to Jet Overflights

An overflight was considered a separate event if the sound meter registered a peak ≥60 dBA followed by a drop ≤50 dBA. Most jet activity for which sound meters recorded <70 dBA did not involve passes targeted on the caribou under observation and were not usually close to the caribou; these were not included in data analyses of caribou reactions. However, on a few occasions, jets were far enough from a sound meter during a directed overflight that <70 dBA were recorded on the meter even though the jet passed close to the caribou and probably exceeded 70 dBA at the caribou. In these cases, the passes were also considered overflight events and caribou reactions were included in our analyses. Most events involved more than one peak because most passes involved 2 aircraft separated by less than 15 seconds, and sometimes jets would circle in the area producing multiple peaks ≥70 dBA.

During overflight events, we estimated slant angle and slant distance to caribou groups. The slant angle was the angle at which a jet passed the group at the closest point, estimated from an imaginary horizontal plane where the caribou were standing. Slant distance was the straight-line distance from the jet to the group at the closest point during the pass. The speed of the jet was also recorded at the time of the event; the speed was obtained from the jet pilot or estimated by the air controllers. Other information recorded during the events included direction of the jet passes, types of maneuvers the jets used, and use of afterburners during the pass.

Using videotapes of the jet sorties, we transcribed reactions for as many caribou as possible and stopped recording reactions of a given animal when it could no longer be individually identified on the tape (e.g., when it mixed with a number of other caribou or disappeared from sight). Caribou used in data analyses were identified by a number that included the date and group that they were in when filmed. The same caribou may have been filmed on different days. We defined a caribou event as a particular caribou's reaction to a given event on a given day.

We recorded caribou reactions at least 15 seconds before an event began and until at least 15 seconds after the event ended, unless the caribou was no longer in view. Caribou behaviors recorded during events were noted every 1–4 seconds, depending on how rapidly behavior changed. It was not possible to determine exactly when a caribou first detected the jet or was exposed to peak sound during the event. Changes in the caribou's behavior, therefore, sometimes preceded or followed, by a few seconds, the exact moment when the jet appeared to pass the caribou at the closest point. Using a rule-based system, we ranked caribou reactions into 6 levels according to our subjective determination of the relative amount of energy the activity required (Fancy and White 1985; Fancy 1986) and whether the caribou appeared to be startled during the event.

GROUP RESPONSE TO JET OVERFLIGHTS

From the videotapes, we analyzed overall group behavior of caribou before and after jet sorties. We noted general behavior of the group (resting, feeding, or traveling) in the period (>1 hour if possible) before the jets arrived as well as the behavior just before and after the sortie. We also noted behavioral changes during a more extended period after the sortie (usually >15 min for groups that remained in view). If a combination of behaviors occurred in the group (e.g., bedding and feeding), then the behavior by the majority of animals in the group was listed first (e.g., in the case above, most caribou were bedded). We examined if groups exposed to longer and more intense sorties reacted by changing their activity to one requiring more energy (e.g., changing from bedded to active or feeding to traveling). Length of a sortie was from the time the jets arrived and produced at least 50 dBA on the sound level meter until the last overflight when the sound level dropped below 50 dBA. Intensity of a sortie was measured by the number of peaks of at least 60 dBA that occurred during the sortie as well as the loudest peak that was recorded on the sound meter.

STATISTICAL ANALYSIS

We used SPSS for Windows® (Version 7.0.2, SPSS Inc., Chicago, Illinois) to test hypotheses regarding cow and calf caribou movements. We built a regression model to examine the influence of calf age (during the 3 weeks following birth) on the daily distance moved by cow–calf pairs. Daily distance moved was not available for every pair each day of the sampling period. Because we did not have an equal number of daily distances for each cow–calf pair, we randomly chose one daily distance for each cow–calf pair to include in our regression model (n = 29). Results were assumed to be significant when $P \leq 0.05$.

We used logistic regression (PROC GENMOD, SAS Version 8.02, SAS Institute, Inc. Cary, North Carolina) to examine the relationship of caribou reaction levels to overflight characteristics, specifically jet type (A-10, F-15, and F-16), speed (knots), slant distance (ft), slant angle, caribou group size, and a categorical variable (v) for slant distance relative to 2000 ft (625 m) AGL (v = 0 if slant distance was <2000 ft [625 m] and v = 1 otherwise). Slant distance and speed were divided by 1000, and slant angle and group size were divided by 100 to appropriately scale these variables for inclusion in the models. Results were assumed to be significant when $P \leq 0.05$.

RESULTS

We observed caribou reactions to military jet overflights on 8 days from 16 May to 5 June 2002. Jet aircraft types were A-10, F-16, and F-15. We observed 27 sorties (Table 1) that usually involved 2 jets of the same type; 2 sorties, however, involved mixed jet types when all

4 jets arrived at the same time and alternated overflights on the target caribou. We recorded 179 overflight events for a total of 890 different caribou events.

Sound pictures recorded during overflights are presented in Appendix B and summarized in Table 1. The maximum dBA recorded was 114, produced by an F-16 estimated to be less than 300 ft (94 m) from the sound meter. The speed of this aircraft was not recorded because there were no caribou in view at the time. The same F-16 passing within 300 ft (94 m) of another sound meter and going 475 knots produced a dBA reading of 111. The maximum dBA reading recorded for an F-15 was 113, when the jet was less than 300 ft (94 m) from the meter going 640 knots. For the A-10, the maximum dBA reading was 99, when the jet passed the meter at less than 300 ft (94 m) at 275 knots.

CALVING

Calves were born from 11 May to at least 27 May 2002. Calving began in Independence and Granite Creeks. As the calving period progressed, most of the parturient cows moved down Independence Creek to the south side of the North Fork Fortymile River, and many calves were born in the vicinity of Happy Mountain and Portage Creek. A secondary calving area was from Butte Creek to Mission Creek. During peak calving, most calves were born between Pittsburg Creek and Joseph Creek. Following peak calving, calves were primarily born in Ruby and the Three-finger Charley Creeks (Fig 1). Calves were radiocollared from 13 to 27 May. The peak of calving (median calving date for radiocollared cows) occurred on 19 May. A majority of the radiocollared calves (69%) were born between 18 May and 23 May (Fig 3).

MORTALITY

Of 65 radiocollared calves, 19 died during the study period. Three died on a day with jet overflights, but death occurred before the overflights. Four calves died on the day succeeding a day with overflights; 1 was 4 days old and died 13 miles (20 km) from where overflights occurred, 2 were 5 days old and died 7.5 miles (12 km) and 25 miles (40 km) from overflights, and the last was 10 days old and died 24 miles (38 km) from overflights. The cause of death for these calves was predation; 2 were killed by wolves (*Canis lupus*) and 1 each by a black bear (*Ursus americana*) and a grizzly bear (*Ursus arctos*).

DAILY MOVEMENTS IN RELATION TO OVERFLIGHTS

Radiocollared cows were tracked daily from 11 May until they gave birth and their calves were radiocollared as soon after birth as possible. Radio signals of calves were checked daily to determine if they were still alive but exact locations of the cow–calf pairs were determined for about 50% of the pairs. Daily distance moved by cow–calf pairs was calculated for those days for which we had consecutive-day locations; this distance was a minimum straight-line distance between the daily locations. We calculated both the mean (Fig 4) and the median (Fig 5) daily distance moved by cows before parturition and cow–calf pairs after parturition.

No trend was evident in daily distance moved by cow caribou during the 10 days before they calved, although distance increased just before parturition (Figs 4 and 5). Daily distance moved dropped sharply immediately following parturition and gradually increased during the next 3 weeks. The range of mean daily distances (±*s*) moved by cows with calves that were 1–

5 days old was from 0.8 (±0.20) to 1.7 (±0.40) km (median 0.5–1.4 km); for calves 6–10 days old, 2.3(±0.57)–3.7(±1.36) km (median 1.3–3.3 km); and for calves 11–15 days old, 4.1(±0.89)–6.2(±1.12) km (median 3.3–4.4 km). For calves16–20 days old, mean daily distance moved was more variable and ranged from 3.6 (±0.57) to 11.6 (±3.94) km (median 3.6–7.2 km). Our study ended on 5 June, when the oldest calf in the radiocollared cow–calf pairs was 24 days old (n = 29).

Daily distance moved by cow–calf pairs tended to increase as calves got older (r^2 = 0.106, F = 3.196, P = 0.085). Upon examination of this data set, it became apparent that one data point had an inordinate influence on the regression model (i.e., it was 4 times greater than any other movement in our data set). A reanalysis of the data without this outlier (n = 28) resulted in a much stronger relationship of daily distance moved to calf age (r^2 =0.262, F = 9.215, P = 0.005).

SHORT-TERM REACTIONS OF INDIVIDUAL CARIBOU TO JET OVERFLIGHTS

We recorded 14 different caribou behaviors (Table 2) during 890 caribou events when we reviewed the videotapes of jet sorties. We categorized caribou responses into 6 reaction levels (Table 3) based on a caribou's behavior before, during, and immediately following (≤15 sec) the overflight. Using a logistic regression model, we examined the level of reaction in each caribou event to the following variables: group size, jet type, jet speed, slant angle, and slant distance. All independent variables contributed significantly to the model at one or more caribou reaction levels (Table 4). Group size had only a minimal effect and tended to be inversely correlated with reaction level. Slant angle had a larger effect than group size; the more directly overhead the jets were, the higher the probability that caribou would respond at a higher reaction level. Slant distance, jet speed, and jet type had substantial impact on the reaction level of caribou.

Of the 890 different caribou events, 169 (19%) occurred at or above slant distances of 2000 ft (625 m), 87 (10%) from 1500–1999 ft (469–625 m), 133 (15%) from 1000–1499 ft (312–468 m), 364 (41%) from 500–999 ft (156–312 m), and 137 (15%) below 500 ft (156 m). The shortest slant distance recorded was 100 ft (31 m) by an A-10. The fastest speed recorded was 640 knots by an F-15. The fastest speed for an F-16 was 520 knots and for an A-10, 350 knots.

Of the 890 caribou events, 636 reactions (71%) occurred at lower response levels (levels 1, 2, and 3) and 254 (29%) at higher levels (levels 4, 5, and 6). Lower-level responses occurred throughout the range of slant distances, from 100 (31 m) to ≥2000 ft (625 m), and the number of lower-level responses outnumbered the higher levels within each slant distance range (Table 5). Taking into consideration the distribution of caribou events among the different combinations of slant distances and speeds (Fig 6), higher-level responses occurred disproportionately less at slant distances ≥2000 ft (625 m) and disproportionately more at slant distances between 500 and 1000 ft (156–312 m) (Fig 7). In contrast, lower-level responses were more evenly distributed across the different combinations of slant distances and speeds (Fig 8). At <500 ft (156 m) no difference was evident.

At observed maximum jet speeds and minimum slant distances for each jet type, logistic regression models indicated that the probability of getting a reaction from a caribou >level 1 was 75% for the A-10. The probability decreased considerably when lower-level responses were grouped together (i.e., 40% at >level 2 but only 8% at >level 5) (Fig 9). A comparable analysis for the F-15 (Fig 10) indicated that the probability of getting a reaction at >level 1 to >level 3 remained high (90% to 73%, respectively), but dropped considerably at reactions of >level 4 (38%) and >level 5 (47%). For the F-15 at a low slant distance and high speed, unlike the A-10, the probability of getting higher-level reactions from caribou did not fall below 38%. For the F-16 at low slant distance and high speed, the probability of getting higher-level reactions did not decrease over the range of possible reactions, with the probability of a reaction at >level 5 being only slightly less (70%) than the probability of a reaction at >level 1 (81%) (Fig 11). Considering all jet types at slant distances ≥2000 ft and minimum observed speeds, the probability of getting a reaction at >level 3 was less than 10%.

While holding group size and slant angle constant (i.e., an overhead pass on a group of 30 caribou), we calculated the probability of getting caribou reactions at the 3 highest levels at different slant distances and jet speeds for each jet type (Tables 6–8). For the A-10 at 1500 ft (469 m), there is less than a 10% chance of getting a reaction >level 3 if jets maintain speeds of 240 knots. The results are quite different for the F-15 and F-16. At 1500 ft (469 m), the probability of a >level 3 reaction at the slowest observed speeds was 19% for the F-15 and 24% for the F-16.

No level 6 reactions (i.e., reactions that usually involved running or extended trotting; see Table 3) were detected for any jet type when the slant distance was ≥2000 ft (625 m). The probability of getting a level 6 reaction from a caribou with an A-10 overflight was quite low, <10% even at the most extreme flight parameters that we observed for this jet type (100 ft [31 m] and 350 knots); the probability of either a level 5 or level 6 reaction was still <15%. In contrast, even at 1500 ft (469 m) and the slowest speeds, the probability of either a level 5 or level 6 reaction for the F-15 and F-16 is almost always >15% (the only exception is the F-15 flying at 400 knots) and the probability becomes much higher at the extreme flight parameters for these jet types (38–70%) (Tables 6–8).

Individual caribou in the same group differed in their reactions to the same overflight, with some caribou reacting at lower levels (i.e., 1, 2, or 3) and others reacting at higher levels (i.e., 4, 5, or 6). Of 127 events in which we recorded reactions by more than one caribou, 42% of the events had mixed reactions (i.e., <level 4 and ≥level 4). Of those events with mixed reactions, 65% of the caribou reacted at lower levels and 35% at higher levels. Mixed reactions were more common in larger groups. The mean group size for which we recorded mixed reactions to the same event was 92 (median = 50; mode = 200; *n* = 56) and for those without mixed reactions, 33 (median = 12; mode = 12; *n* = 72).

Distribution of reaction levels differed depending on whether caribou were bedded or active before the overflight (Table 9). Of 263 caribou events in which the caribou were bedded before the event, 82% of the caribou responded at the lower levels, with 75% at level 1; of 627 caribou events in which the caribou were active before the event, 74% responded at the lower levels, but only 40% were at level 1. Considering only data with slant distances of 1000–1499 ft (312–468 m), the proportion of higher-level reactions increased by 5–10% for both bedded and active categories. However, at slant distances of 100–499 ft (31–156 m), bedded caribou reacted in the same proportions as they did when all slant distances were considered, indicating that most bedded caribou that were going to react to an overflight had already done so by the time jets were directed this close.

Group Response to Jet Overflights

Of 27 groups that were exposed to jet sorties, 13 changed from one behavior to another that required more energy, 10 remained the same, and 4 changed behavior to one that required less energy (Table 10). For groups that increased energy output, mean duration of sorties (19.2 min) and mean number of peaks per sortie (8.9) were less than for those groups that remained the same or decreased energy output (21.6 min and 9.2 peaks, respectively). Even considering cumulative exposure (multiple sorties that occurred <2 hr apart), there was no evidence that duration of sorties or number of peaks caused changes in behavior that required increased energy output; duration was 28.8 vs. 35.3 minutes for groups with increased output vs. those without, respectively, and number of peaks was 12.8 vs. 15.2, respectively. Mean dBAs recorded during the sorties for both groups differed by only 0.5 dBAs.

DISCUSSION

Mortality

There is no evidence that caribou calves died as a direct result of jet overflights in our study. No calves among 62 radiocollared cow–calf pairs were found dead near the location of an overflight, either on the day of the overflight or on the following day. We observed no abandonment of calves or panic responses that would lead to trampling of calves in response to overflights. Startle reactions and running that we observed in response to overflights lasted 15 seconds or less in most instances; longer bouts of running that we observed appeared to be in response to predators or other perceived dangers and were not related to overflights. Although calves would sometimes engage in bursts of play behavior at the time of an overflight (Miller and Gunn 1981), the duration of this behavior was similar to other spontaneous bouts of play that we observed when there were no overflights. By approximately 6 months after birth, 61% of the radiocollared calves were still alive, and of the 11 cow–calf pairs that were known to have been overflown by military jet aircraft at distances <2 km, 82% were still alive (including 3 that were known to have been overflown at <1 km). However, we do not know the total exposure or intensity of exposure for cow–calf pairs during the calving season in our study area. Directed overflights occurred on only 8 days during the study and mitigation levels in place during the calving season should have prevented jet overflights at <2000 ft (625 m) during this period in our study area.

Harrington and Veitch (1992) concluded that calf survival of woodland caribou in a military jet training area near Goose Bay, Labrador was negatively correlated with exposure to low-level jet overflights. The authors estimated that some caribou had as many as 4.5 overflights at <1 km in each 24-hour period during their study, although some had none. They suggested that startle reactions produced by close jet overflights in their study area could have interfered with lactation and led to lower calf survival, but they did not observe most overflights during the calving season or measure physiological responses. We observed cows nursing calves during 24 overflight events (both as the jets passed by and in the 15 sec after a pass); 13 nursing bouts occurred during overflights in which cows responded to overflights at lower reaction levels and 11 when responses were at higher reaction levels, most of which included startle responses. We do not know if calves obtained milk during the nursing bouts.

Harrington and Veitch (1992) suggested that jet overflights in their study area could be occurring at levels where impacts on calf mortality are interfering with population growth. However, the conclusions of Harrington and Veitch (1991) on the effects of jet overflights on caribou calf survival should be considered speculative, because their data set had a number of apparent limitations. Only 11 cow–calf pairs were followed during their 2-year study; of these, 6 calves died. Moreover, the authors did not directly observe jet overflights of cow–calf pairs during the calving and postcalving periods, so they could not know for certain if jets were close enough to cause startle responses, which was the basis of their hypothesis for lower survival of calves (i.e., that startle responses affect lactation thereby predisposing exposed calves to higher mortality throughout the lactation period, but particularly during the calving period and the beginning of the postcalving period). Field-truthing of directed jet overflights in their study, however, indicated that the mean distance of jets from target coordinates was 720 ± 838 ft (225 ± 262 m). We found that the probability of a startle response (>level 3) at 1500 ft (469 m) was 9–49% depending on jet type and speed (Tables 6–8). However, our data also show that even at slant distances of 100–200 ft (31–62 m), there is a 27–77% probability that caribou would not react with startle responses, depending on jet type and speed. To account for the inherent error in the location of remotely-monitored (satellite telemetry) caribou, Harrington and Veitch (1992) included in their analyses any overflight that they assumed was within 1 km of target animals; jet flight paths were reported by the pilots. Actual slant distances and speeds that the cow–calf pairs were exposed to during their study were not known. We found that pilots in our study were not able to accurately (i.e., <500 ft [156 m] slant distance) target the caribou for which they had coordinates without repeated directions from air controllers on the ground, especially in hilly terrain. We also watched caribou easily travel >1 km in less than a few minutes, so unless coordinates from satellite locations were obtained very shortly before overflights, targeted caribou may not have been within 1 km of the reported jet flight path. Timing of satellite locations and jet overflights were not reported. Finally, the authors did not identify proximate causes of calf mortality or examine other factors that could have led to calf deaths. The authors recognized that predation pressure could have been disproportionately distributed in their study area (wolves and black bears were relatively common), but they did not report on the distribution of radiocollared cow–calf pairs in relation to predator distribution and abundance or discuss predation on calves.

DAILY MOVEMENTS IN RELATION TO OVERFLIGHTS

Daily movement patterns of cow caribou just before and during the calving period in our study area were similar to those reported for parturient cow caribou in the Porcupine caribou herd (PCH), where military jet overflights do not occur (Griffith et al. 2002). Rates of movement for cows with newborn calves in our study were slightly less than that reported for the PCH. Median straight-line daily distance for calves in the first week after birth was 0.8 and 1.6 miles (1.3 and 2.5 km) for FCH and PCH calves, respectively; in the second week, daily distance moved was 2.1 and 3.1 miles (3.4 and 5.0 km), respectively. By the end of June, PCH calves moved approximately 9.4–12.5 miles/day (15–20 km/day); our study ended

5 June, but we suspect that movement rates continued to increase through June for FCH caribou as well, because the pattern of movement before and during calving was similar in the 2 studies.

Cows with very young calves (<5-days old) moved the least and there was very little variability in the daily distance that they moved (Figs 4 and 5). On 20 May, we observed a cow–calf pair when the calf was 1-day old; there were no jet overflights that day. The pair was still in the same place the following day and was exposed to 3 2-jet sorties (1 sortie each by A-10s, F15s, and F-16s) in a 2-hour period. The total number of sound peaks (≥60 dBA) recorded on the nearby sound meter was 35 for the day; 20 were ≥80 dBA and 9 were ≥90 dBA. The maximum reading was 106 dBA. The pair did not move away from the location during the sorties and was <0.6 miles (<1 km) from the site the next day when the calf was captured with the use of a Robinson helicopter, radiocollared, and released. The cow–calf pair was still <0.6 miles(<1 km) from the calf capture location the next day. Daily distances moved by the pair in those 4 days were within the normal range for undisturbed calves of that age, and daily movement did not exceed 2.8 miles (4.5 km) until the calf was 14 days old. The calf was still alive 6 months later. Daily distance moved was not a useful measurement by which to gauge the impact of jets (or radiocollaring operations) on this cow–calf pair.

Daily distance moved by cow–calf pairs during our study were significantly affected by calf age but we could not test the effects of overflight proximity on daily distance moved for most cow–calf pairs due to small sample size. Murphy et al. (1993) concluded that daily distance moved by caribou during the postcalving period (6–17 Jun) in the DCH was affected by military jet overflights. Using a regression model, Murphy et al. (1993) concluded that the loudest overflight of the day was the best predictor for daily distance moved for postcalving caribou; however, they did not account for calf age. Moreover, SEL was estimated for an unreported proportion of the cow–calf pairs (rather than directly measured) using a noise prediction program that required, among other variables, an estimate of slant range (i.e., slant distance), but some of the pairs for which slant range was estimated were not directly observed. The authors acknowledge that slant ranges calculated for animals not observed (based on telemetry fixes) could have had poor temporal correspondence with overflights.

We did not compare daily distance moved to sound variables because we could not be certain of sound exposure for radiocollared cow–calf pairs. We have data for 3 radiocollared cow–calf pairs that were located on a day following jet sorties during which they were <0.6 miles (<1 km) from the jets and sound meters registered ≥85 dBA. They were accompanied by calves that were 1, 2, and 12 days old on the days following the overflights, and the cow–calf pairs moved 0.25, 1.25, and 3.4 miles (0.4, 2.0, and 5.5 km), respectively, in the 24-hour period following the overflights. The mean daily distance moved by cows accompanied by 1-, 2-, and 12-day-old calves in our study was 0.5 miles (0.8 km; $n = 22$), 1.1 miles (1.7 km; $n = 11$), and 3.7 miles (5.9 km; $n = 20$), respectively. Our limited data do not support the hypothesis that exposure to jet overflights increases daily distance moved by cow–calf pairs, at least during the first 12 days after birth. Other researchers also have not been able to show a relationship between jet overflights and daily distance moved by caribou (Harrington and Veitch 1991).

Murphy et al. (1993) concluded that a 10 dBA increase in maximum noise exposure for the day was associated with a 3.0 mile (4.8 km) increase in distance moved for postcalving caribou in the DCH. It is unlikely that this relationship applied to cow–calf pairs in our study (at least in the first 2 weeks after birth), because an increase in decibels during overflights from 85 dBA to 105 dBA would mean an increase in daily movements of cow–calf pairs of 6.0 miles (9.6 km) or a total movement of about 6.2–8.8 miles (10–14 km) in the 24-hour period after an overflight; these are relatively large movements for cow–calf pairs in the 2-week period after birth. Movements of this distance occurred for only 10 of 213 recorded daily distances (<5%); of the 10, only 5 movements occurred within 24 hours after an overflight, and only 1 of these overflights occurred within 1.25 miles (2 km) of a cow–calf pair (the others occurred at 5.6–21.2 miles [9–34 km]). This cow–calf pair moved 6.8 miles (10.8 km) in <24 hours following an overflight that occurred 0.9 miles (1.5 km) away. The maximum sound level recorded on the sound meters during the overflights that day was 112, but there is no way to know for certain if the cow–calf pair was subjected to that sound level, because the location of the pair in relation to the jet flight path was not known.

There were 16 instances when we documented overflights ≤1.25 miles (≤2 km) of radiocollared cow–calf pairs. Of the 16, 8 cow–calf pairs moved more than the mean for pairs with calves of that age in the 24 hours after the overflight and 8 moved less. Of the 8 that moved more, only one moved >3.0 miles (>4.8 km) more than the mean distance for calves of that age (the one mentioned above). Of those that moved less than 3.0 miles (4.8 km), the distance was only 1.2 mi (1.9 km) more than the mean. Maier et al. (1998), referring to the same study as Murphy et al. (1993), stated that increased movement observed during the postcalving period in response to jet overflights was only an additional 1.6 miles/day (2.5 km/day) and concluded that the increased movement was of low energetic cost because of the generally low energetic costs of locomotion for caribou (Fancy and White 1987). However, for newborn calves ≤5 days old, traveling this distance could be energetically costly because mean distances moved for calves in this age bracket is <1.25 miles (<2 km). Moreover, any increase in movements by newborn calves potentially increases their exposure to predators.

Murphy et al. (1993) and Maier et al. (1998) do not report how many of the radiocollared caribou cows in their study were accompanied by calves and did not consider calf age in the analyses of their data. Because most calves are born over a 2-week period in the DCH (Valkenburg et al. 2002), calf age in their sample could have varied by as much as 14 days. Age of calves was an important factor affecting the movements of cow–calf pairs in our study, at least during the calving period, and was probably important in the postcalving period as well based on the pattern of movements for cow–calf pairs in the PCH (Griffith et al. 2002). Calf age should be considered when analyzing data on movements for cow–calf pairs, at least during calving and postcalving seasons.

Short-term Reactions of Caribou to Jet Overflights

Short-term behavioral responses to jet overflights were similar to those reported by other researchers (Harrington and Veitch 1991; Murphy et al. 1993). We avoided terms such as mild, moderate, and severe (McCourt and Horstman 1974; Miller and Gunn 1979) for describing individual caribou reactions to overflights because these terms are subjective and imply a quantifiable stress level. For the same reason, we caution the reader that our designations for reaction levels (levels 1–6, Table 3) do not necessarily represent increasingly stressful reactions or reflect greater physiological impacts. However, we are confident that reactions we observed at levels 1, 2, and 3 (i.e., lower-level responses) involved less energy and fewer startle responses (Table 3) than reactions at levels 4, 5, and 6 (i.e., higher-level responses). For this reason, our presentation of data on caribou reactions to jet overflights reflect our subjective differentiation between these 2 general levels of response.

Lower-level responses were distributed throughout the entire range of slant distances and jet speeds that we observed (Fig 8), but higher-level responses were much more common below 1000 ft (310 m) and occurred more commonly at higher speeds (Fig 7). The slower-flying A-10 had less impact than the faster F-15 and F-16. The distribution of caribou reactions across the range of slant distances and speeds indicates that there is much individual variability in the way caribou react to jet overflights, but as jets get lower and speed increases, higher-level responses from caribou can be expected to occur more frequently.

Logistic regression models indicated that the level of caribou response to overflights was inversely related to group size, contrary to what other researchers have reported for caribou disturbed by turbo-helicopters (Miller and Gunn 1979) or fixed-winged aircraft (McCourt and Horstman 1974). In our study caribou in smaller groups were more likely to react at higher levels than caribou in larger groups, even though larger groups had a higher probability of having at least a small number of more reactive caribou.

Although short-term movements of caribou in response to jet overflights have been used to quantify response of caribou to overflights (Harrington and Veitch 1991), we chose not to measure short-term movements for 2 reasons. From videotape, it was not possible to consistently measure distance moved, even in body lengths as described by Harrington and Veitch (1991), because caribou were not always moving across the viewing screen; i.e., distance for animals moving diagonally or directly away from the camera, or towards it, could not be measured. Generally, distances moved are short, so errors in measurement could significantly affect data analysis; Harrington and Veitch (1991) reported a median distance of only 8 body lengths 38–51 feet (12–16 m). Moreover, there was potential for biasing the data because some caribou moved out of sight before returning to “normal” behavior and these were most likely to be caribou reacting at higher response levels.

Responses of caribou to jet overflights in our study were mild compared to reactions in response to predators or perceived predators that we observed during the study. Other researchers have documented relatively mild short-term responses of caribou to military jet overflights and other types of aircraft disturbance, but they point out that short-term responses potentially lead to long-term population consequences (Harrington and Veitch 1992; Maier 1996). However, there are no studies that directly measure energetic or physiological costs to caribou from repeated exposures to jet overflights. We cannot conclude, therefore, that the reactions to jet overflights that we observed during the calving season on the FCH are detrimental to the overall health of the herd. Moreover, caribou on the calving grounds of the FCH have had opportunity to habituate to the presence of jets similarly to caribou in the DCH (Davis et al. 1985). Caribou in our study area usually showed little interest in the jets except when the jets were quite low and fast. Harrington and Veitch (1991) state that caribou, regardless of habituation, will respond with a startle reflex when exposed to a sudden, intense noise as is characteristic of low, fast military jets.

Caribou responded differently to A-10 jets compared to F-15s and F-16s (Tables 6–8). For the A-10, there was less than a 5% chance of getting higher-level responses from caribou when jets were ≥2000 ft (625 m) AGL, regardless of speed; even at 1500 ft (469 m) AGL, A-10s at slow speeds caused few higher-level responses. In contrast, even at ≥2000 ft (625 m) AGL, F-15 and F-16 jets caused higher-level responses from caribou more than 10% of the time when flying at speeds of 500 knots or more. At high speeds, higher-level responses of caribou were sometimes observed at slant distances up to 5000 ft (1562 m) AGL. At 1500 ft (469 m) AGL, caribou responded to the F-15s and F16s with high-level reactions more than 20% of the time at all speeds.

GROUP RESPONSE TO JET OVERFLIGHTS

There was little evidence to suggest that groups of cow–calf pairs undertook movements away from areas where sorties occurred after jets left. In fact, cows sometimes bedded down during or immediately after the sorties ended. Even for the 13 groups that showed increased movement after the sorties, it was not clear that the sorties were the cause of the movements. We believe that other factors such as predators or perceived predators and behavior of a group before jets arrived affected group behavior during overflights. For example, in 3 instances, caribou groups were observed running when the sortie was over; in 1 case, they may have been running from a grizzly bear that had been chasing caribou before the sortie, and in another case, we suspected that the caribou group had been disturbed by the observers just before the overflight. In the third case, we could not discern what made the caribou run because, although the running started in the middle of the sortie, it was not initiated during or immediately following a jet pass, and the running continued on and off throughout the sortie without obvious relationship to when jets were present. On a number of other occasions when we knew caribou were not aware of us, we watched the caribou bunch together, run, and turn to look behind them when we could detect no predators and no jets were present.

Perhaps one of the most important factors affecting how a group of caribou reacts to jet overflights is their activity before the jets arrive. Harrington and Veitch (1991) found that behavior prior to an overflight was significantly correlated with level of response by caribou in their study. Caribou have cycles of rest and activity that have been described by a number of authors (Boertje 1985; Russell et al. 1993; Maier et al. 1998). Maier et al. (1998) reported that resting bouts numbered 3.5–4.2 per day and active bouts 3.8–4.8 per day for caribou that were not subjected to overflights. The mean length of resting bouts was 1.4–3.8 hours and for active bouts 2.3–4.6 hours. We also differentiated between 3 broad categories of behavior when caribou were active: “stationary feeding”, “feeding while moving” (usually at a walk but sometimes interspersed with trotting), and “traveling” (a combination of walking and trotting and sometimes even bursts of running, but no feeding). A lengthy resting bout was often followed by the cow standing, nursing, and then traveling or feeding while walking. Traveling was often preceded by feeding and was never followed by a resting bout without feeding, usually stationary feeding. When young calves were present, bouts of stationary feeding were sometimes interspersed with resting bouts and cow–calf pairs might spend many hours in the same place. Resting bouts were sometimes briefly interrupted with standing and stretching and then bedding again nearby.

When caribou reacted to jet overflights by changing activity, it was often not possible to tell if the activity change would have occurred even if the jets had not arrived, at least without some indication of how long the caribou had been engaged in the preceding activity. Thirteen groups responded to jet sorties by changing to a new activity after the jets were gone that was different from the activity before jets arrived. Eleven of these groups engaged in activities that required more energy (in the other 2 cases, the groups ran and disappeared from view during one of the overflights so we could not determine their activity at the end of the sortie), but 14 groups did not change activities or changed to one requiring less energy. We observed no cases of caribou disturbed by jets at the beginning of a resting bout that did not resume resting after the jets left, usually within 20 minutes, even if they initially responded to overflights by feeding or traveling. Likewise, caribou that were beginning to feed and were disturbed by jets resumed feeding after the jets left. However, in many instances for individual caribou, short-term responses to jet overflights probably ended resting or feeding bouts prematurely, but we were not able to determine if daily resting time overall was affected by overflights. Maier et al. (1998) found that caribou exposed to jet overflights in the postcalving period in the DCH had a mean daily resting time that was less than that of caribou not exposed to overflights; consequently, mean daily time active was greater and most of the active time was spent feeding (Murphy et al. 1991). We observed that caribou either did not appreciably change their activity or readily returned to their preexposure activity when overflown by jets in the FCH during the calving period. If daily resting times were reduced for caribou in our study, the reduced rest may be within the physiological tolerances for the caribou given the relatively low level of jet activity over the calving grounds and the current growth rate of the FCH. However, appreciable increases in numbers, duration, and intensity of jet overflights, perhaps at the levels observed by Harrington and Veitch (1991) in Labrador, could conceivably cause significant and detrimental interruptions in activity cycles and reduced resting or feeding times with biological consequences for the herd.

Finally, overflights could have an indirect impact on the response of caribou groups by predisposing them to react to disturbance. For example, in one case a group of caribou exposed to a very loud overflight (113 dBA at the sound meter) showed little initial reaction and cows continued to feed in place for about 90 seconds after the jet had passed. Suddenly, the whole group began to run and was joined by other groups, all running and trotting for several minutes, and finally walking out of sight. Upon reviewing the videotape, it became apparent that the group movement was initiated by a cow that had noticed something uphill of the group and out of the viewfinder of the camera. This cow turned and ran downhill as another cow from further uphill ran into view from the direction the first one had been watching. While the overflight did not immediately instigate movement of the group, ultimately it may have been responsible for the group response by startling a caribou that was higher up on the hill and closer to the jet's path. Cows that feed while their calves are bedded down will often wander some distance from their calves, and we have observed them running to their calves when overflights were particularly close; the reaction sometimes happened after the jets were gone. The sudden running by caribou on the edge of a group will frequently initiate running by the whole group, until the caribou determine whether or not they are being pursued by a predator. We noticed that caribou that reacted to the presence of a perceived predator prior to the arrival of jets sometimes appeared more reactive to jet overflights. This apparent heightened sensitivity to disturbance caused by preexposure to a different disturbance could intensify the effects of jet overflights on caribou in areas where caribou undergo frequent disturbance from other agents.

CONCLUSIONS

We concluded that military jet overflights did not cause deaths of caribou calves in the FCH during the calving period or increase the movements of cow–calf pairs over the 24-hour period following exposure to overflights. Short-term responses to overflights were generally mild in comparison to caribou reactions to predators or perceived predators. Caribou responses to jet overflights were variable, but levels of response were generally higher as slant distances decreased and jet speeds increased. In the current study involving A-10, F-15, and F-16 aircraft, flights above 2000 ft AGL did not produce >level 3 reactions (startle reactions, trotting, and running), especially if speeds for F-15s and F-16s did not exceed 500 knots between 2000 (625 m) and 5000 ft (1562 m) AGL. A-10 jets caused less reactions than F-15s and F16s. Our data indicate that A-10s could operate as low as 1500 ft (469 m) AGL over calving caribou with only mild behavioral responses if the jets maintain low speed and avoid maneuvers that require changes to higher power settings. Because the F-16 had a relatively high probability of causing >level 3 reactions in caribou at 1500 ft (469 m) AGL regardless of power settings, these jets should be restricted to elevations ≥2000 ft (625 m) AGL over the calving grounds if >level 3 reactions are to be minimized during the calving period.

Although short-term reactions of caribou to jet overflights were relatively mild in this study, we advise against assuming there are no long-term effects on calving caribou from jet overflights. Determining long-term effects of military jet aircraft on caribou will require long-term measurements of physiological responses, movements, and calf survival tied directly to sound exposure under realistic scenarios of military jet training; the technology for these types of studies are not adequately developed at this time. Under the Fortymile Caribou Herd Recovery Plan and with the current mitigation levels for the calving period, the herd has increased in numbers and expanded its range, suggesting that current mitigation levels are allowing for herd recovery, at least under the environmental conditions that have existed since the recovery began. Because of the political and management interest in the FCH and the international efforts that have been expended in rebuilding the herd and expanding its range into Canada, we recommend a conservative approach to mitigating the effects of military jet overflights. Managers will also need to consider the impacts of overflights on other wildlife species as well as social impacts when considering altitudinal limitations on military aircraft. Without this information and with the potential for increased military jet training in the Yukon MOA, a conservative approach is advisable at least until management goals for the herd have been realized.

ACKNOWLEDGMENTS

Funding and support for this project came from the United States Air Force through the 11 AF Resource Protection Council, and the committees for Resource Protection/Mitigation and Research and Monitoring. Field support was provided by the Alaska Department of Fish and Game and the National Park Service. We thank J Hostman, USAF, who was instrumental in getting this project underway. We thank G Rolf and the 611th Air Operations Squadron for facilitating communication between biologists in the field and the participating 3rd Wing, 168 Air Refueling Wing, and 354 Fighter Wing flying squadrons. This project would not have been possible without the participation of the USAF pilots who generously accommodated our overflight requests into their training schedules. Expert air control, often under difficult conditions, was provided by 3rd Air Support Operations Squadron personnel D Aldrich, M Batts, B Grimm, S Kurdziolek, T Magdich, K Parson, B Peña, J Pennington, E Rankin, and A Thweatt. We benefited while in the field from the efforts and input from biological technicians T Ball, P Del Vecchio, D Nigro, N Pfeiffer, and T Seaton and pilots T Cambier, A Einer, M Terwilliger, and P Zaczkowski. We thank P Valkenburg, DD James, LG Adams, RA Winfree, and JAK Maier for critical review of this manuscript.

LITERATURE CITED

ALTMANN J. 1974. Observational study of behaviour sampling methods. *Behavior* 49:227–265.

BOERTJE RD. 1985. Seasonal activity of the Denali caribou herd, Alaska. *Rangifer* 5:32–42.

BOERTJE RD AND CL GARDNER. 2000. The Fortymile caribou herd: novel proposed management and relevant biology, 1992–1997. Proceedings of the eighth North American caribou workshop, Whitehorse, Yukon, Canada, 20–24 April 1998. *Rangifer* Special Issue 12:17–37.

DAVIS JL, RT SHIDELER, AND RE LERESCHE. 1978. Fortymile caribou herd studies. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Final Report. Projects W-17-6 and W-17-7. Juneau, Alaska.

DAVIS JL, P VALKENBURG, AND RD BOERTJE. 1985. Disturbance and the Delta caribou herd. Pages 2–6 *in* AM Martell and DE Russell, editors. Proceedings of the first North American caribou workshop, Whitehorse Y.T., 1983. Canadian Wildlife Service Publication, Ottawa.

DEPARTMENT OF THE AIR FORCE. 1992. Environmental Assessment of the expansion and upgrade of military training routes, Alaska. Elmendorf Air Force Base, Alaska.

DEPARTMENT OF THE AIR FORCE. 1997. Final Environmental Impact Statement, Alaska Military Operation Areas, Record of Decision. Eleventh Air Force, Elmendorf Air Force Base, Alaska.

DUCKS UNLIMITED, INC. 1998. Yukon–Charley/Black River/40-mile earth cover classification. Users guide. Ducks unlimited project number AK-0024-22-002. BLM agreement number 1422-D910-A4-0205.

FANCY SG. 1986. Daily energy budgets of caribou: a simulation approach. PhD Thesis. University of Alaska Fairbanks, Fairbanks, Alaska.

FANCY SG AND RG WHITE. 1985. Incremental cost of activity. Pages 143–159 *in* RJ Hudson and RG White, editors. Bioenergetics of wild herbivores. CRC Press, Inc. Boca Raton, Florida.

FANCY SG AND RG WHITE. 1987. Energy expenditures for locomotion by barren-ground caribou. *Canadian Journal of Zoology* 65:122–128.

GRIFFITH B, DC DOUGLAS, NE WALSH, DD YOUNG, TR MCCABE, DE RUSSELL, RG WHITE, RD CAMERON, AND KR WHITTEN. 2002. The Porcupine Caribou Herd. Pages 8–37 *in*

DC Douglas, PE Reynolds, and EB Rhode, editors. Arctic Refuge coastal plain terrestrial wildlife research summaries. US Geological Survey, Biological Resources Division, Biological Science Report USGS/BRD/BSR-2002-0001.

HARRINGTON FH AND AM VEITCH. 1991. Short-term impacts of low-level jet fighter training on caribou in Labrador. *Arctic* 44(4):318–327.

HARRINGTON FH AND AM VEITCH. 1992. Calving success of woodland caribou exposed to low-level jet fighter overflights. *Arctic* 45(3):213–218.

HOOGE PN AND B EICHENLAUB. 2000. Animal Movement Extension to ArcView. Version 2.0. Alaska Science Center–Biological Science Office, US Geological Survey, Anchorage, Alaska.

JANSSEN R. 1980. Future scientific activities in effects of noise on animals. American Speech-Language-Hearing Association Report Number 10.

LARSON AND DAVIS. 1997. Model 812 sound-level meter user manual. Larson•Davis, Incorporated. Provo, Utah.

LAWLER JP AND TL HAYNES. 1998. *Civilian Use and Military Overflight Activity in Selected Alaskan Military Operations Areas*. National Park Service Report YUCH-98-05.

MAIER JAK. 1996. Ecological and physiological aspects of caribou activity and responses to aircraft overflights. PhD Thesis. University of Alaska Fairbanks, Fairbanks, Alaska.

MAIER JAK, SM MURPHY, RG WHITE, AND MD SMITH. 1998. Responses of caribou to overflights by low-altitude jet aircraft. *Journal of Wildlife Management* 62(2):752–766.

MCCOURT KH AND LP HORSTMAN. 1974. The reaction of barren-ground caribou to aircraft. Chapter 1.1–36 in *The reaction of some mammals to aircraft and compressor station noise disturbance*, edited by RD Jakimchuk. Renewable Resources Consulting Services, Ltd. and Canadian Arctic Gas Study, Ltd. Biological Report Series. Volume 23.

MILLER FL AND A GUNN. 1981. Play by Peary caribou claves before, during, and after helicopter harassment. *Canadian Journal of Zoology* 59:823–827.

MILLER FL AND A. GUNN. 1979. Responses of Peary caribou and muskoxen to helicopter harassment. Canadian Wildlife Service Occasional Paper 40, Ottawa.

MURIE OJ. 1935. Alaska–Yukon caribou. North Am Fauna No. 54. US Department of Agriculture, Washington, DC.

MURPHY SM, CL CRANOR, AND RG WHITE. 1991. Behavioral responses of Delta Herd caribou to low-level, subsonic jet aircraft overflights. Pages 418–421 *in* CE Butler and SP Mahoney, editors. Proceedings fourth North American caribou workshop. St. John's, Newfoundland, 1989.

MURPHY SM, MD SMITH, RG WHITE, JA KITCHENS, BA KUGLER, AND DS BARBER. 1993. Behavioral responses of caribou to low-altitude jet aircraft. AL/OE-TR-1994-0117. National Technical Information Service, Springfield, Virginia.

NATIONAL PARK SERVICE. 1994. Report to the congress: report on the effects of aircraft overflights on the National Park System. US Department of the Interior, National response to public law 100-91, the National Parks Overflights Act of 1987.

ROLAND CA. 1996. The floristics and community ecology of extrazonal steppe in the Yukon and Kolyma river drainages. MS Thesis. University of Alaska Fairbanks, Fairbanks, Alaska.

RUSSELL DE, AM MARTELL, AND WAC NIXON. 1993. Range ecology of the Porcupine caribou herd in Canada. *Rangifer* Special Issue 8.

SKOOG RO. 1956. Range, movements, population, and food habits of the Steese–Fortymile caribou herd. MS Thesis, University of Alaska Fairbanks.

SWANSON DK. 1999. Ecological units of Yukon–Charley Rivers National Preserve, Alaska. NPS report YUCH-99-001. Preserve files, Yukon–Charley Rivers National Preserve.

VALKENBURG P AND JL DAVIS. 1986. Calving distribution of Alaska's Steese–Fortymile caribou herd: a case of infidelity? *Rangifer* Special Issue 1:315–324.

VALKENBURG P AND JL DAVIS. 1989. Status, movements, range use patterns, and limiting factors of the Fortymile caribou herd. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Final Report. Project W-23-1. Juneau, Alaska.

VALKENBURG P, DG KELLEYHOUSE, JL DAVIS, AND JM VER HOEF. 1994. Case history of the Fortymile caribou herd, 1920–1990. *Rangifer* 14:11–22.

VALKENBURG P, MA KEECH, RA SELLERS, RW TOBEY, AND BD DALE. 2002 (In press). Investigation of regulating and limiting factors in the Delta caribou herd. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Final Research Report. Grants W-24-5 and W-27-1 through W-27-5. Juneau, Alaska.

APPROVED BY:

____

Patrick Valkenburg
Research Coordinator
Division of Wildlife Conservation

____

Wayne L Regelin, Director
Division of Wildlife Conservation
Alaska Department of Fish and Game

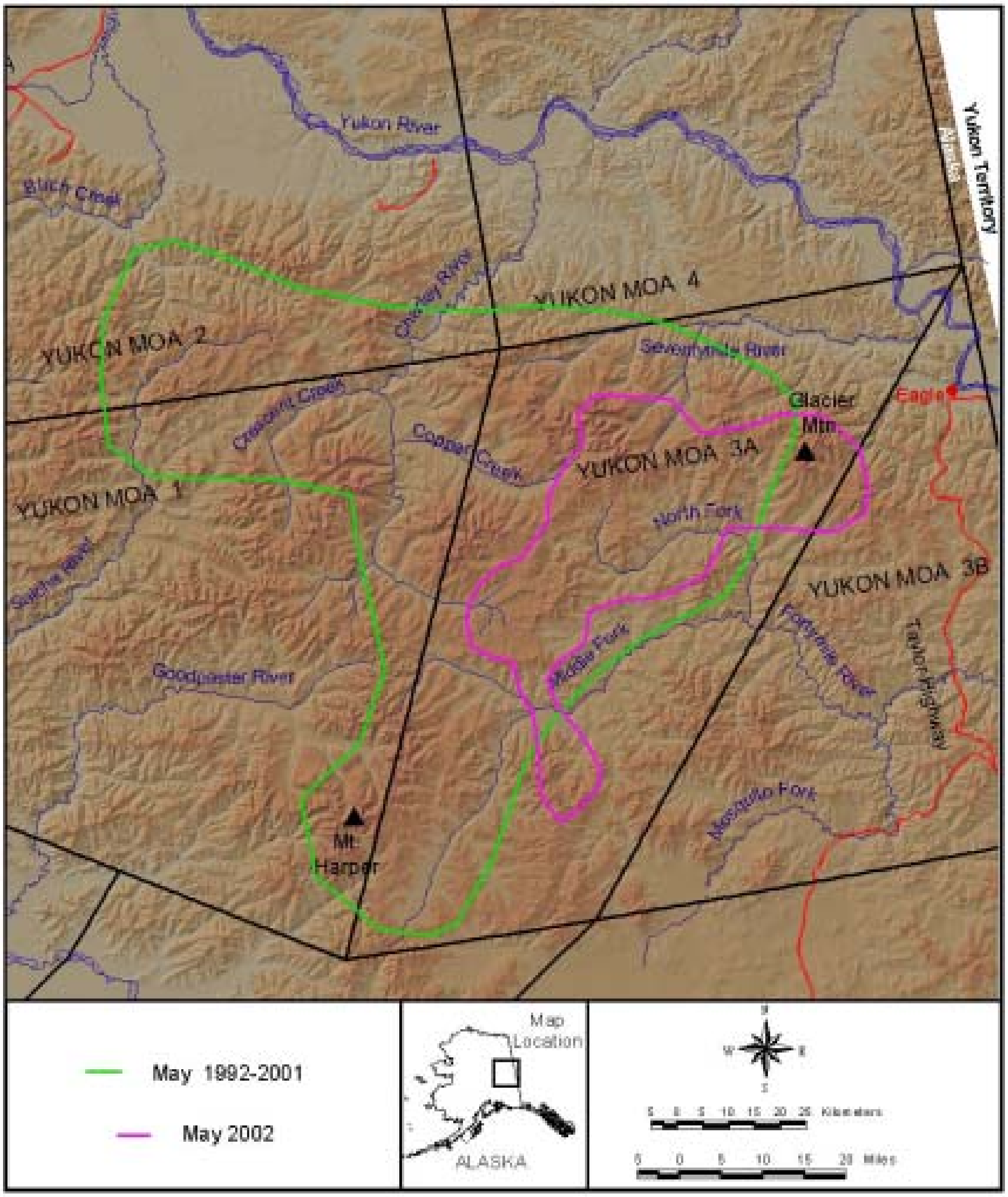


FIGURE 1 Calving areas of the Fortymile caribou herd in the Yukon–Tanana Uplands, Alaska from 1992 to 2002

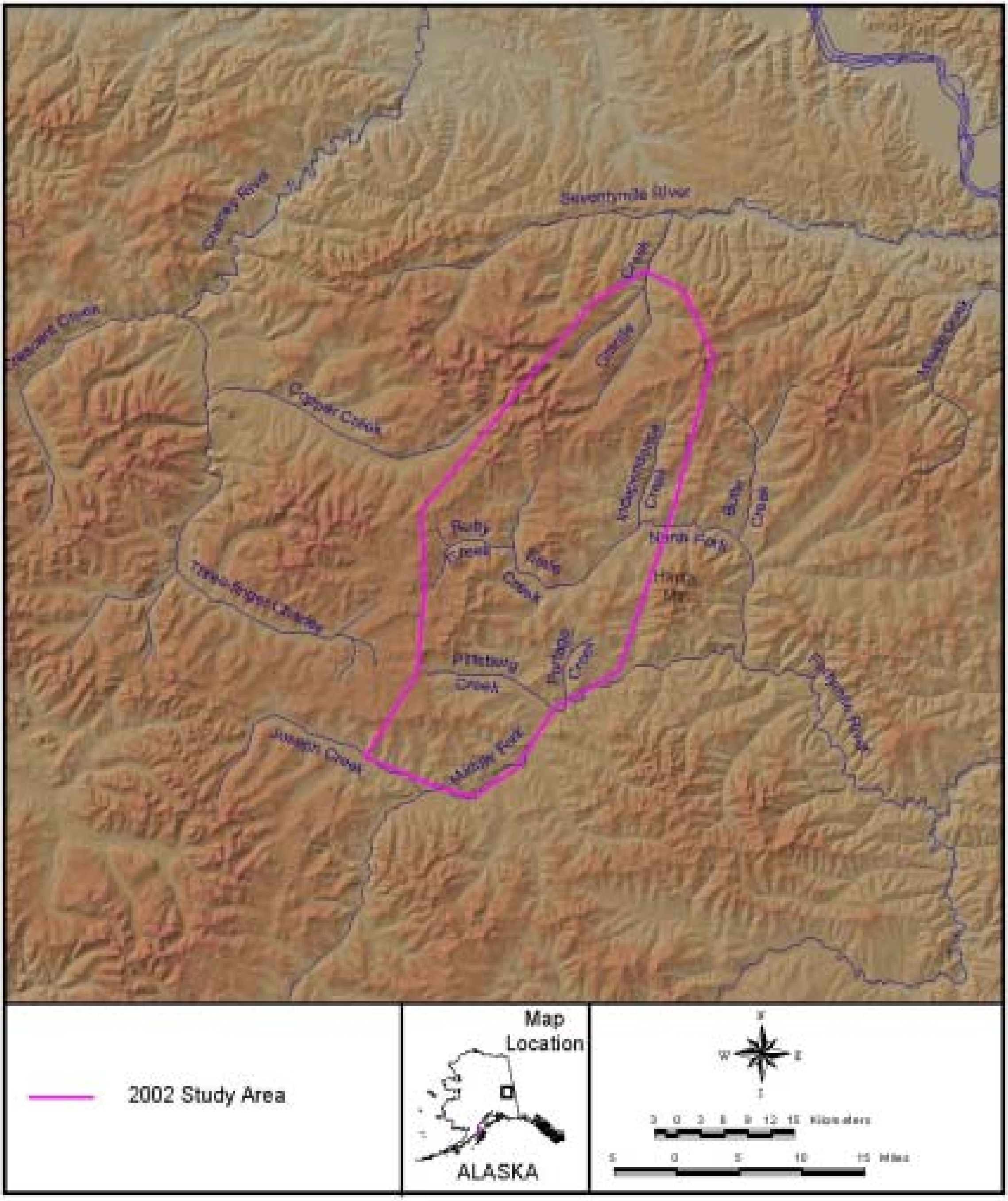


FIGURE 2 Study area where we observed military jet overflights, FCH calving area, 2002

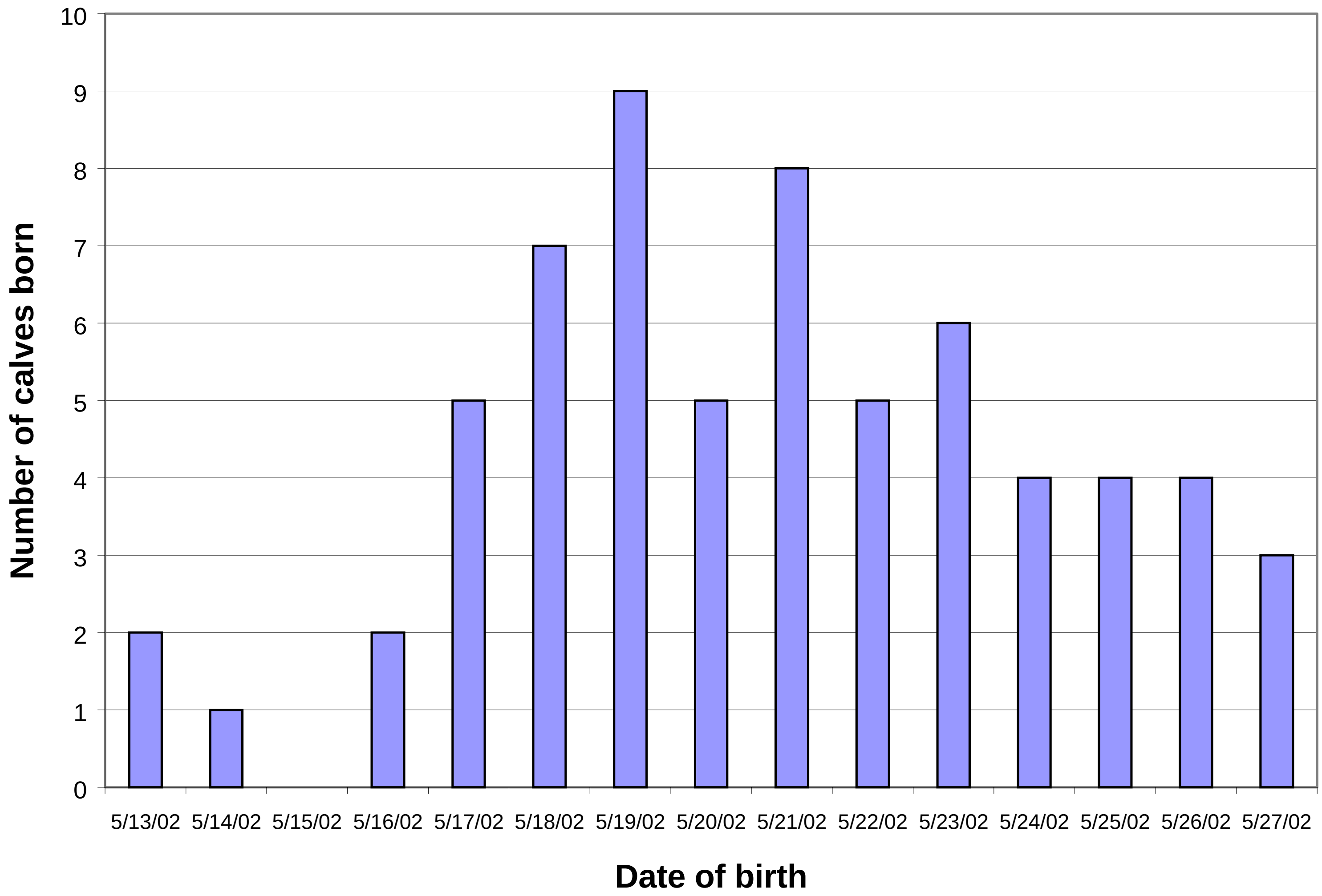


FIGURE 3 Birth dates of radiocollared caribou calves in the Fortymile caribou herd in 2002

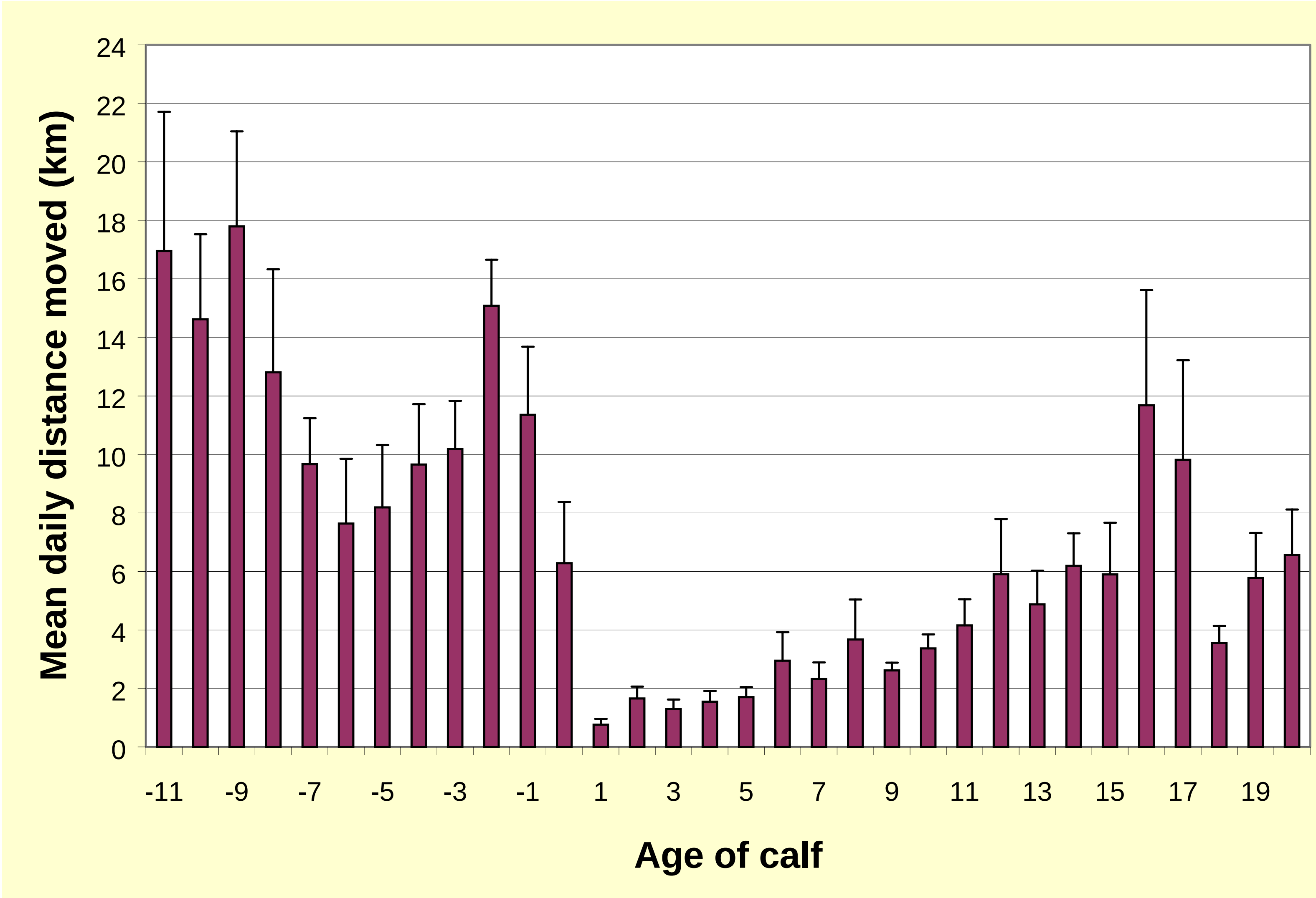


FIGURE 4 Mean daily distances (straight-line) moved by caribou cow–calf pairs in the Fortymile caribou herd during the 2002 calving season

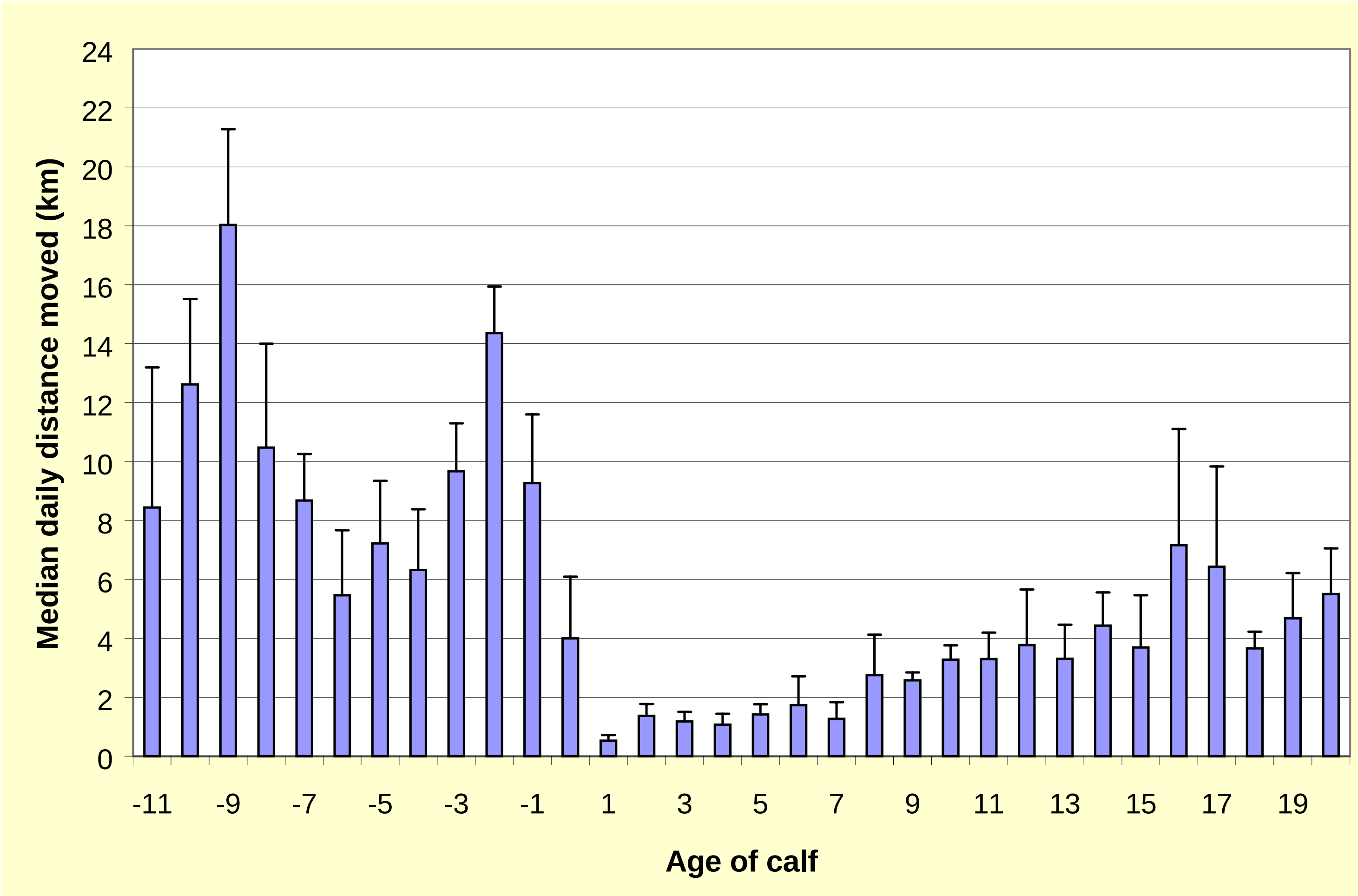


FIGURE 5 Median daily distances (straight-line) moved and standard errors by caribou cow–calf pairs in the Fortymile caribou herd during the 2002 calving season

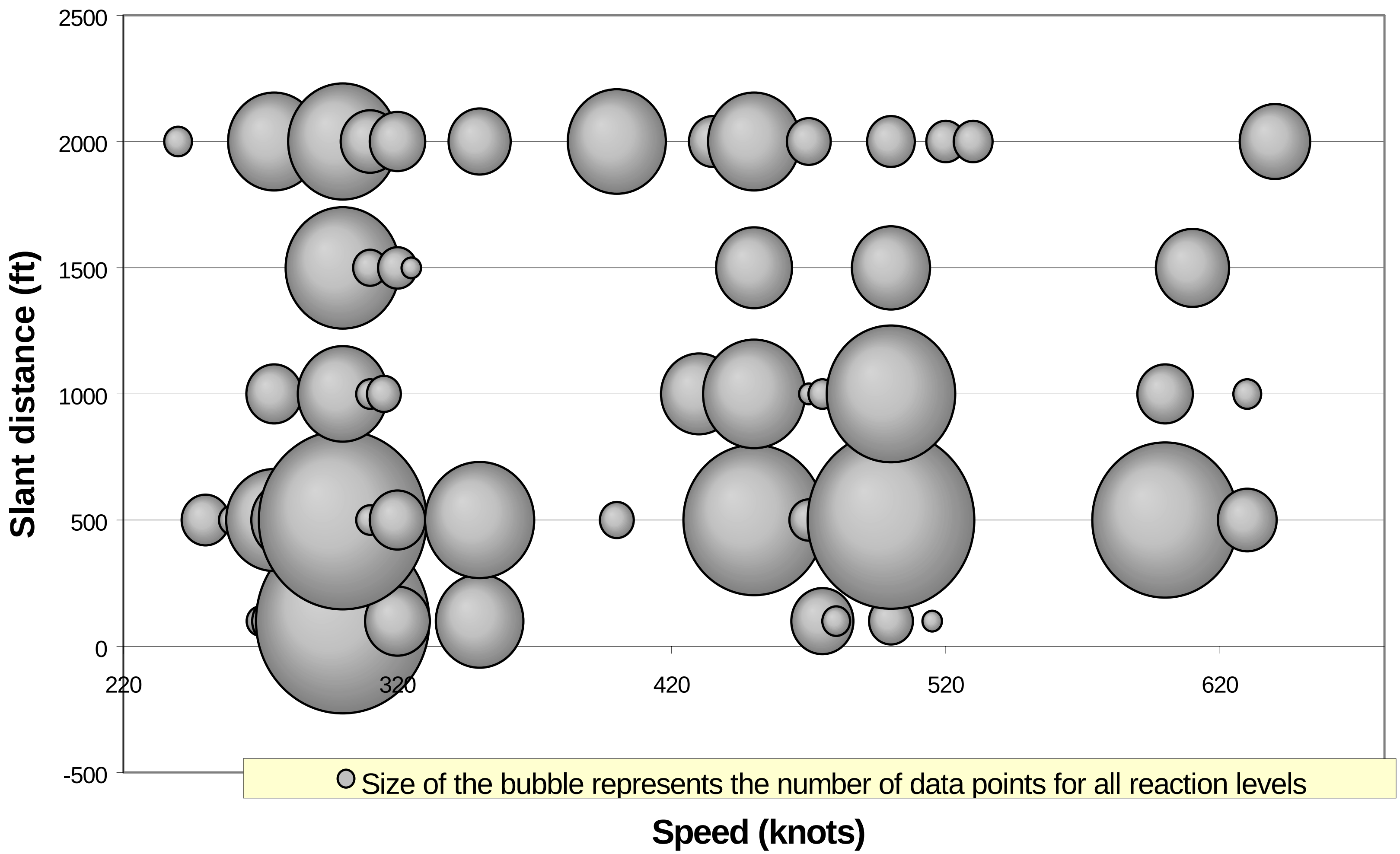


FIGURE 6 Distribution of 890 military jet overflight events by slant distance and jet speed used in the analysis of caribou reactions to jet overflights over the Fortymile caribou herd during the 2002 calving season

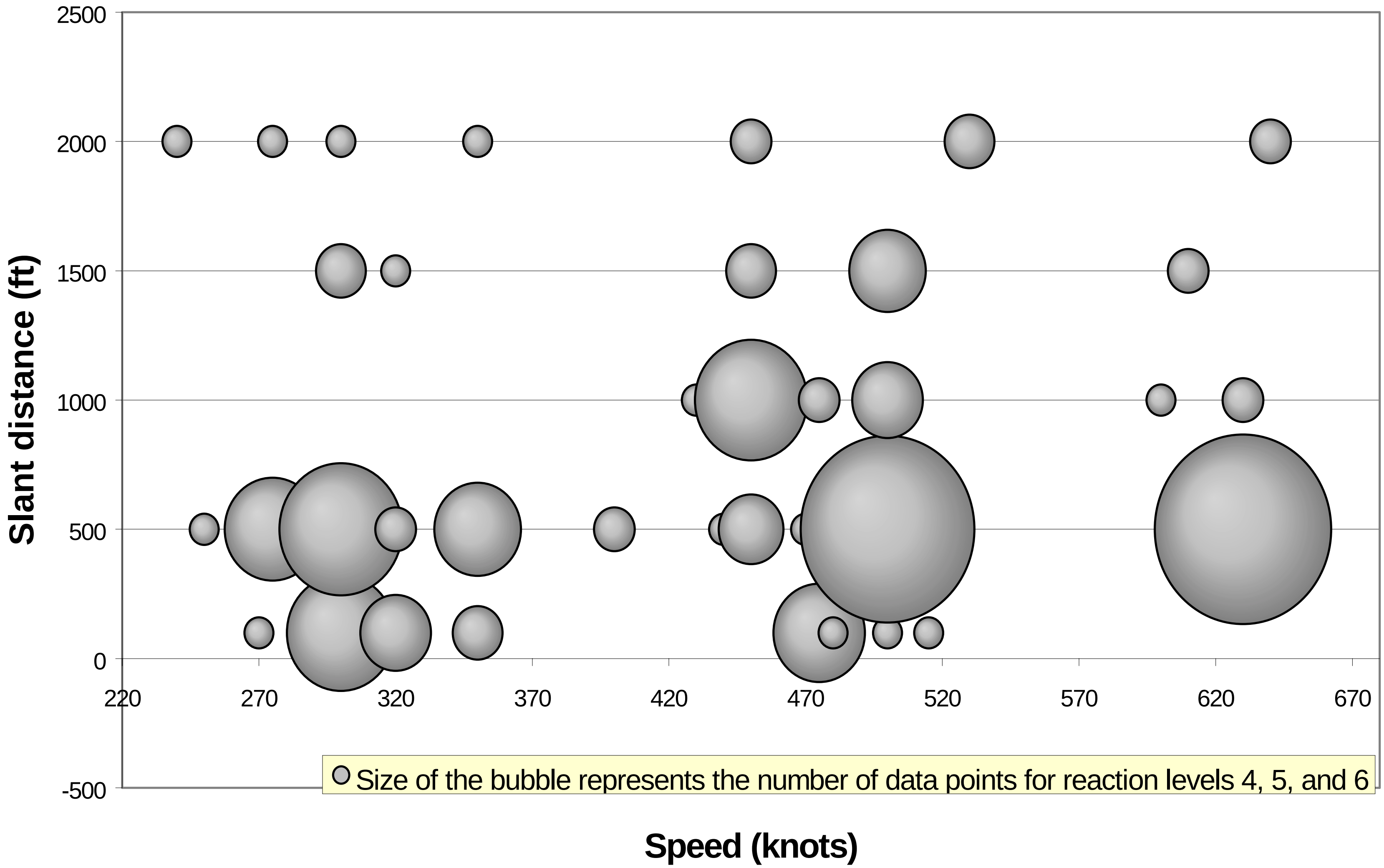


FIGURE 7 Distribution of 254 higher-level responses (levels 4, 5, and 6) of caribou to military jet overflights over the Fortymile caribou herd during the 2002 calving season

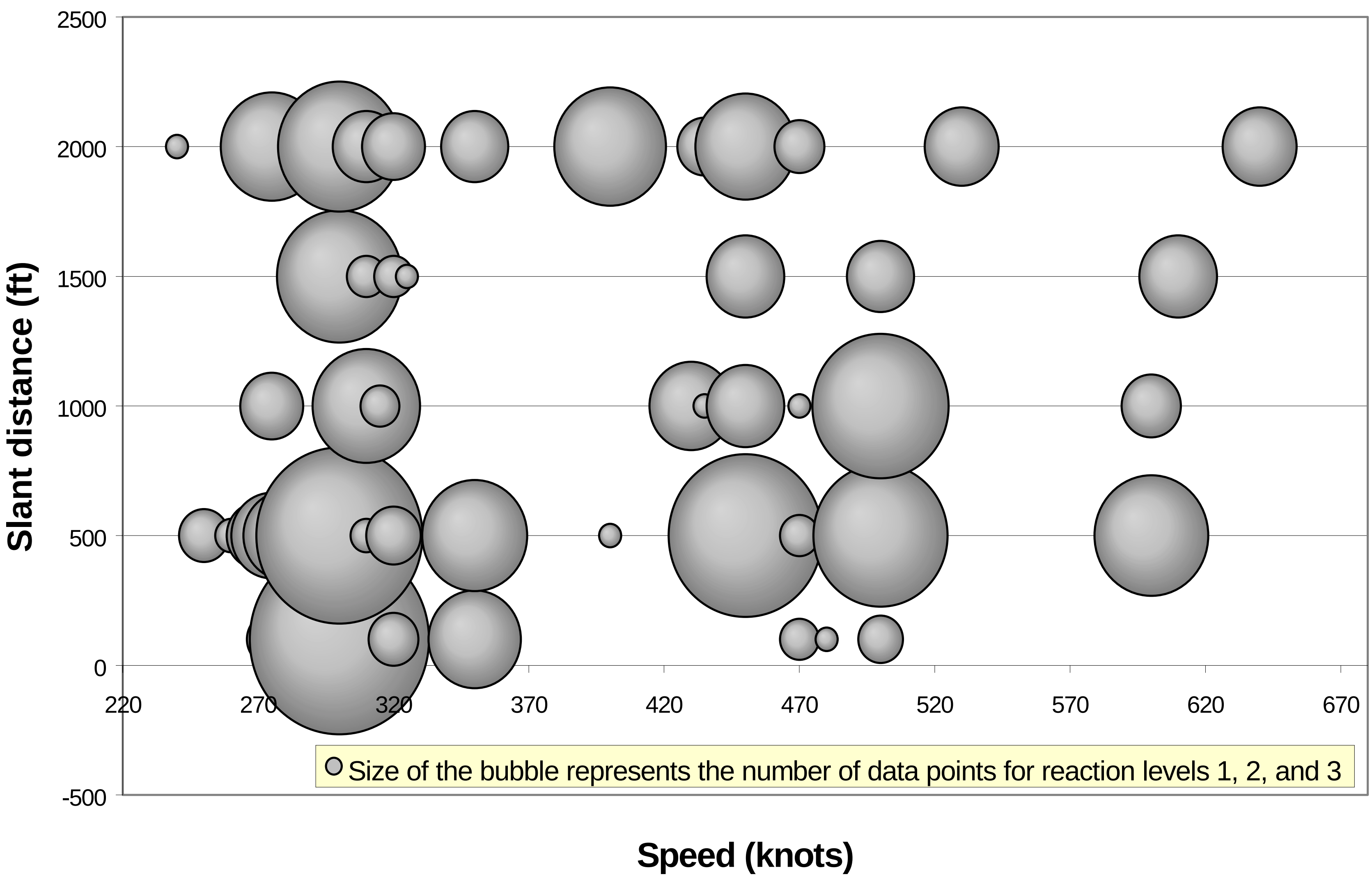


FIGURE 8 Distribution of 636 lower-level responses (levels 1, 2, and 3) of caribou to military jet overflights over the Fortymile caribou herd during the 2002 calving season

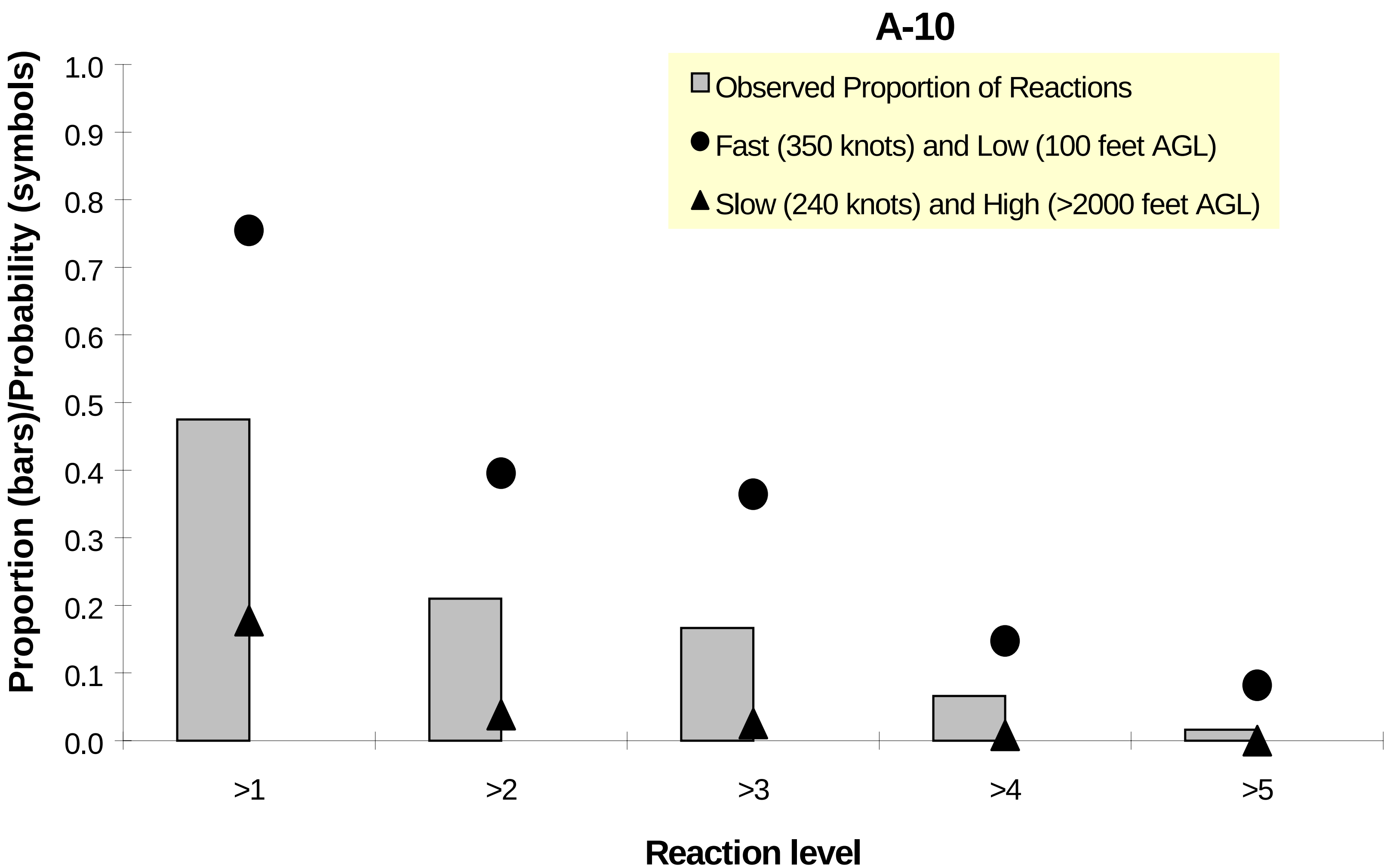


FIGURE 9 Probability of caribou cows (assumed group size of 30) responding at increasingly higher reaction levels to overflights of A-10 jets at observed maximum jet speed and minimum slant distance and at observed minimum jet speed and maximum slant distance, determined by logistic regression models based on observed reactions during directed jet overflights over the Fortymile caribou herd during the 2002 calving season

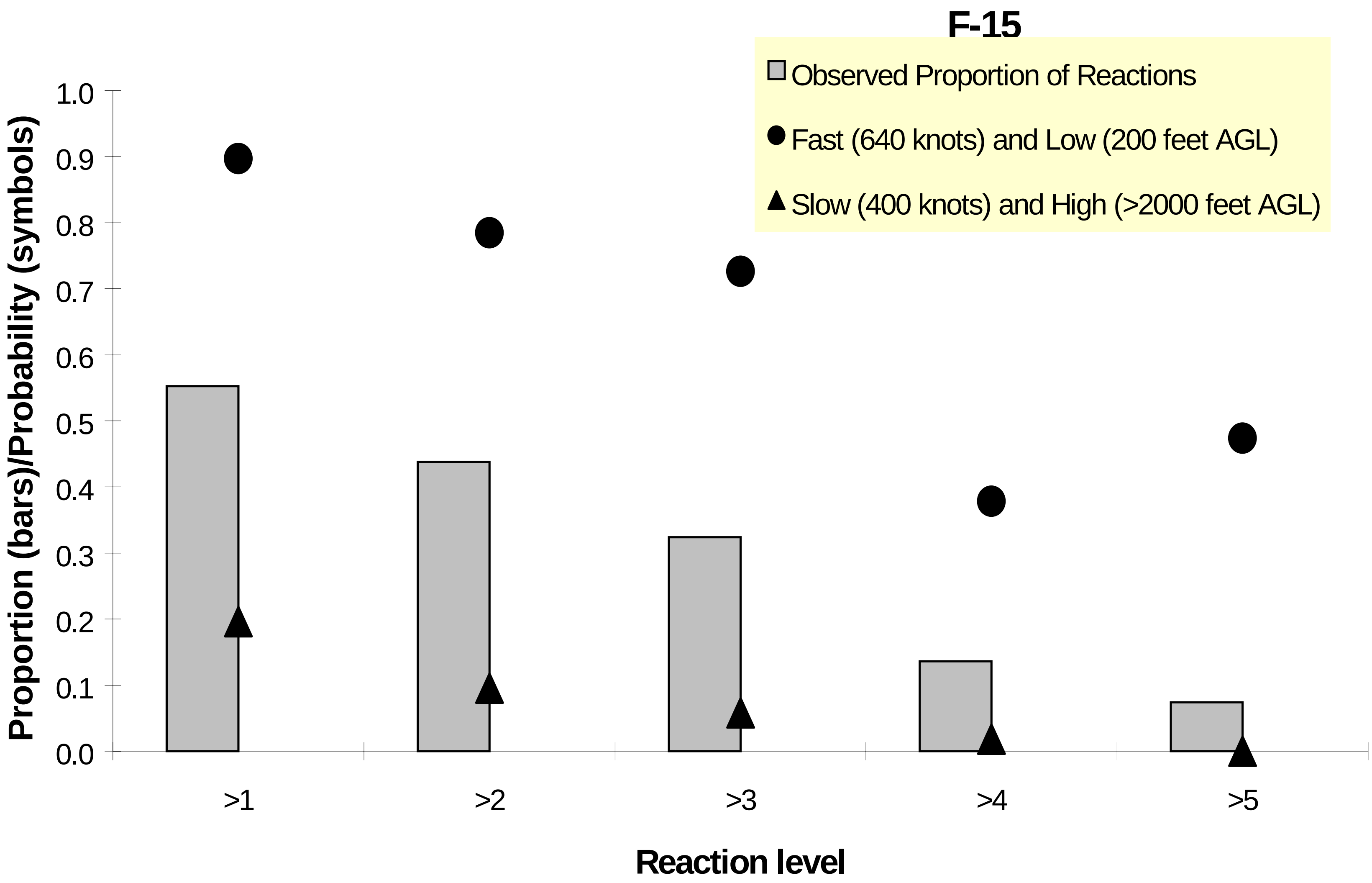


FIGURE 10 Probability of caribou cows (assumed group size of 30) responding at increasingly higher reaction levels to overflights of F-15 jets at observed maximum jet speed and minimum slant distance and at observed minimum jet speed and maximum slant distance, determined by logistic regression models based on observed reactions during directed jet overflights over the Fortymile caribou herd during the 2002 calving season

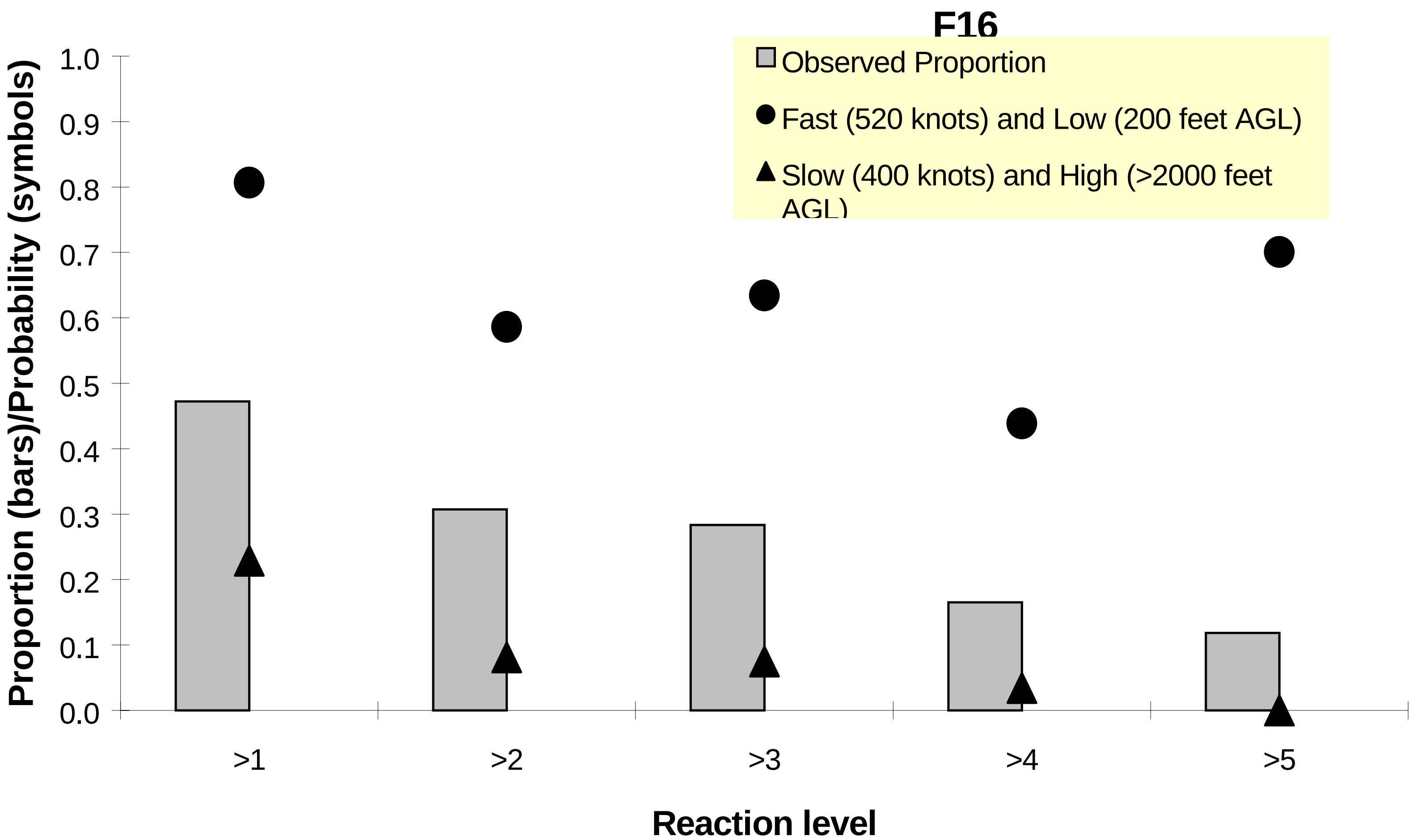


FIGURE 11 Probability of caribou cows (assumed group size of 30) responding at increasingly higher reaction levels to overflights of F-16 jets at observed maximum jet speed and minimum slant distance and at observed minimum jet speed and maximum slant distance, determined by logistic regression models based on observed reactions during directed jet overflights over the Fortymile caribou herd during the 2002 calving season

TABLE 1 Characteristics of military jet sorties used in the analysis of caribou reactions to jet overflights during the calving season of the Fortymile caribou herd, 16 May–5 June 2002

Date	Crew	Sortie	Jet	Duration of sortie (min)	No. peaks[a]	Mean time between peaks	Mean width of peaks[b] (sec)	Highest dBA	Mean dBA of peaks	Number of peaks 60s	70s	80s	90s	100s
16 May	AA	164723	A-10	24.5	10	77	78	99	85	1	3	1	5	0
16 May	JT	100847	A-10	26.9	9	150	46	79	70	5	4	0	0	0
16 May	JT	140056	A-10	31.4	16	72	50	96	77	5	4	5	2	0
21 May	AA	110044	A-10	17.0	12	24	63	83	66	5	4	3	0	0
21 May	JT	110029	A-10	17.0	8	67	69	86	75	2	4	2	0	0
22 May	JT	165225	A-10	22.8	9	103	60	82	72	3	5	1	0	0
23 May	AA	104912	A-10	1.6	2	35	30	86	80	0	1	1	0	0
23 May	JT	105312	A-10	7.2	5	32	60	86	79	1	0	4	0	0
28 May	JT	164637	A-10	10.3	8	39	43	87	70	5	1	2	0	0
5 Jun	AT	110647	A-10	11.0	7	55	47	90	75	3	2	1	1	0
5 Jun	AT	133038	A-10	32.7	15	81	55	94	79	4	4	3	4	0
5 Jun	JA	132045	A-10	39.0	18	81	51	95	82	2	4	7	5	0
$\bar{x}$				20.1	9.9	68.0	55.0	88.6	76.0					
21 May	AA	113643	F-15	42.1	19	64	72	100	84	2	4	5	7	1
21 May	JT	113148	F-15	41.3	22	54	61	106	82	6	3	5	6	2
4 Jun	AT	110907	F-15	47.0	15	122	74	111	82	3	7	1	1	3
4 Jun	AT	131124	F-15	22.9	11	81	51	97	74	7	0	1	3	0
4 Jun	JA	132559	F-15	23.0	11	45	85	112	82	3	2	3	1	2
$\bar{x}$				35.3	15.6	73.3	61.0	105.2	80.8					
16 May	AA	152144	F-16	18.3	8	99	50	111	83	2	2	0	1	2
16 May	JT	152142	F-16	15.8	6	144	38	114	87	2	0	0	3	1
21 May	AA	105254	F-16	6.8	5	60	32	86	78	0	2	2	0	0
21 May	JT	104718	F-16	7.8	5	49	55	92	89	0	0	4	1	0
22 May	JT	171736	F-16	7.8	5	49	54	91	88	0	0	3	2	0
4 Jun	AT	120100	F-16	20.2	7	155	41	90	70	4	2	0	1	0
4 Jun	JA	115311	F-16	23.9	12	74	52	92	77	3	6	1	2	0
5 Jun	AT	120245	F-16	12.7	5	127	50	102	98	0	0	0	3	0
$\bar{x}$				14.1	6.6	94.5	47.7	97.3	83.8					

Date	Crew	Sortie	Jet	Duration of sortie (min)	No. peaks[a]	Mean time between peaks	Mean width of peaks[b] (sec)	Highest dBA	Mean dBA of peaks	Number of peaks				
										60s	70s	80s	90s	100s
30 May	AT	120753	Mixed (F-15, A-10)	37.2	12	133	64	102	79	3	5	1	2	1
30 May	JA	122013	Mixed (F-15, A-10)	36.9	13	143	38	113	78	5	4	1	1	2
$\bar{x}$				37.0	12.5	138.2	51.0	107.5	78.5					

[a] A peak was the highest decibel reading after the sound level exceeded 50 decibels and before it dropped below 50 decibels.
[b] The width of a peak was the time from when the sound level reached 50 decibels until it dropped to 50 decibels again.

TABLE 2 Caribou behaviors observed during a study of the short-term impact of military jet overflights on the Fortymile caribou herd during the calving season, 16 May–5 June 2002

Behavior
Startle (full body movement)
Head up
Bedded
Bedded but alert
Turning to touch the calf while bedded
Eating snow
Feeding
Pawing
Running
Standing
Turning to touch the calf while standing
Standing and nursing
Trotting
Walking

TABLE 3 Descriptions of reactions of caribou to military jet overflights on caribou in the Fortymile caribou herd during the calving season, 16 May–5 June 2002

Level	Description	Examples
1	No change in behavior detected during the overflight or a mild change in behavior that was not obviously in response to the overflight.	Moving the head around, taking a few steps while feeding, turning toward the calf while nursing, stopping briefly while walking or feeding.
2	Mild change in behavior that occurred temporarily in response to the overflight but did not involve an appreciable increase in energy expenditure over the activity already in progress at the time of the overflight.	Lifting the head up while bedded, feeding, or walking; stopping to stand with head up for a few seconds; walking a few extra steps while feeding; trotting for a few seconds while traveling (traveling = alternating walking and trotting but no feeding).
3	Behavioral change from one activity to another but with only a mild increase in energy expenditure and no obvious startle reaction.	Changing from feeding to standing or walking in response to the overflight; standing up from bedding >5 seconds after the jets have passed by and then feeding; changing from walking to trotting as long as trotting had occurred before the jets arrived in the area.
4	Reactions involving a change in activity and movement of the caribou's entire body in response to the overflight; does not involve trotting more than a few seconds; a startle response that involved movement of the entire body.	Startle reaction when the jets passed by and then resumption of previous behavior; getting up slowly from a bedded position after the sound of the jets had receded but within 2–5 seconds after the overflight; changing from walking to trotting at the time of the overflight as long as trotting had not occurred before the overflight and did not continue for 5 seconds or more; a bedded or standing cow which turned to touch the calf as the jet was passing over as long as it was not nursing at the time (this behavior while nursing is common but is uncommon in other circumstances); standing alert for more than 5 seconds while the jets are in the vicinity regardless of behavior before the overflight; changing from feeding to standing or walking for at least 5 seconds without a startle reaction or trotting for less than 5 seconds.
5	Reactions that involved rising from a bedded position at the time of the overflight or a startle reaction while feeding or walking that ended in trotting.	Rising slowly from a bedded position just as the jets passed by and walking, standing, or feeding (if standing occurs, it lasts less than 5 seconds); changing from feeding to walking and trotting with a startle or head up response as the jets passed by (trotting did not last more than 5 seconds); jumping up from bedding, then nursing or feeding.
6	Reactions that usually included extended trotting or running; startled jumps from a bedded position followed by alert standing, trotting, or running.	Jumping up from a bedded position when the jet passed by then trotting or standing for at least 5 seconds and/or running; running even briefly in response to the overflight regardless of behavior before the overflight; trotting for at least 5 seconds in response to the overflight if the caribou had not been trotting before the overflight and had not resumed feeding for at least 15 seconds after the overflight.

TABLE 4 Results of logistic regression models[a] showing the relationship of group size, jet type, jet speed, slant distance, and slant angle to the level of response by cow caribou in the Fortymile caribou herd to military jet overflights during the 2002 calving season

	Dependent variable = reaction levels[b]									
Independent variables	>1		>2		>3		>4		>5	
	Coefficient	χ^2	Coefficient	χ^2	Coefficient	χ^2	Coefficient	χ^2	Coefficient	χ^2
Intercept	-2.444[a]	9.32	-2.8363[a]	11.68	-2.3227[a]	6.79	-1.8222	2.19	0.0997	0.00
Group size[c]	-0.0009	0.78	0.0011	1.00	-0.0011	0.79	-0.0022	1.72	-0.0097[a]	13.06
Jet (A-10)	0.9301[a]	7.14	0.2418	0.42	-0.1944	0.24	-1.0054	3.44	-3.0587[a]	14.48
Jet (A-15)	-0.1974	0.71	0.1761	0.50	-0.2730	1.11	-0.6309[a]	3.83	-1.1752[a]	6.98
Jet (A-16)	0.000	--	0.000	--	0.000	--	0.000	--	0.000	--
Speed (knots)[d]	7.8063[a]	24.36	6.4245[a]	16.34	5.8285[a]	11.81	3.1746	1.91	1.8202	0.32
v[e]	-1.8907[a]	57.02	-2.1630[a]	45.50	-2.5217[a]	44.04	-2.7856[a]	18.16	-26.4917	0.00
(1-v)*slant distance[d]	-0.9397[a]	19.85	-0.7890[a]	10.52	-0.7865[a]	9.23	-0.3801	1.19	-0.9756	3.18
(1-v)*slant angle[c]	-0.1237	0.12	-0.4815	1.45	-0.6122	2.08	-1.4747[a]	5.58	-2.9287[a]	8.39

[a] Indicates that the coefficient is statistically significant at ≤0.05 level.
[b] Reaction levels are described in Table 3.
[c] Group size and slant angle were divided by 100 to scale this variable for analysis.
[d] Speed and slant distance were divided by 1000 to scale this variable for analysis.
[e] v is a dummy variable. $v = 0$ if slant distance less than 2000 ft and $v = 1$ otherwise.

TABLE 5 Distribution of reaction levels among slant distance categories for caribou in the Fortymile caribou herd responding to low-level military jet overflights during the calving season, 16 May–5 June 2002

	Reaction levels								
Slant distance	1	2	3	1+2+3	4	5	6	4+5+6	Total
>1999	24	59	59	142	14	13	0	27	169
1500–1999	0	42	15	57	16	14	0	30	87
1000–1499	8	26	46	80	42	11	0	53	133
500–999	54	114	60	228	72	23	41	136	364
100–499	7	109	13	129	5	3	0	8	137
Total	93	350	193	636	149	64	41	254	890
%				0.71				0.29	

TABLE 6 Probability of caribou in the Fortymile caribou herd reacting to overflights by A-10 jets at levels >3, >4, and >5 for different combinations of slant distances and jet speeds based on logistic regression models from data collected during the calving season 2002

Speed	Slant distance[a] (ft)						
(knots)	2000	1500	1000	700	500	200	100
A-10 Prob >3[b]							
240	0.026	0.091	0.130	0.159	0.181	0.218	0.232
270	0.030	0.107	0.151	0.183	0.208	0.250	0.265
300	0.036	0.125	0.174	0.211	0.238	0.284	0.300
330	0.042	0.145	0.201	0.241	0.271	0.321	0.338
350	0.047	0.160	0.220	0.263	0.295	0.346	0.364
A-10 Prob >4[b]							
240	0.008	0.067	0.080	0.088	0.095	0.105	0.109
270	0.009	0.073	0.087	0.096	0.103	0.114	0.118
300	0.009	0.080	0.095	0.105	0.112	0.124	0.129
330	0.010	0.087	0.103	0.114	0.122	0.135	0.140
350	0.011	0.092	0.109	0.121	0.129	0.143	0.147
A-10 Prob >5[b]							
240	0.000	0.018	0.029	0.039	0.047	0.062	0.068
270	0.000	0.019	0.031	0.041	0.049	0.065	0.071
300	0.000	0.020	0.033	0.043	0.052	0.068	0.075
330	0.000	0.021	0.034	0.045	0.055	0.072	0.079
350	0.000	0.022	0.036	0.047	0.057	0.074	0.081

[a] Straight-line distance from caribou to jet.
[b] Group size = 30; angle held constant at 0° (i.e., from vertical).

TABLE 7 Probability of caribou in the Fortymile caribou herd reacting to overflights by F-15 jets at levels >3, >4, and >5 for different combinations of slant distances and jet speeds based on logistic regression models from data collected during the calving season 2002

Speed	Slant distance (ft)					
(knots)	2000	1500	1000	700	500	200
*F-15 Prob >3**						
400	0.058	0.191	0.259	0.307	0.341	0.396
450	0.076	0.240	0.319	0.372	0.409	0.467
500	0.099	0.297	0.385	0.442	0.481	0.540
550	0.129	0.361	0.456	0.515	0.554	0.611
600	0.165	0.431	0.529	0.587	0.624	0.678
640	0.200	0.489	0.586	0.642	0.677	0.726
*F-15 Prob >4**						
400	0.019	0.148	0.173	0.190	0.202	0.221
450	0.022	0.169	0.197	0.216	0.229	0.250
500	0.025	0.192	0.223	0.244	0.258	0.280
550	0.030	0.218	0.252	0.274	0.290	0.314
600	0.034	0.246	0.283	0.307	0.323	0.349
640	0.039	0.270	0.310	0.334	0.352	0.378
*F-15 Prob >5**						
400	0.000	0.140	0.210	0.262	0.302	0.367
450	0.000	0.152	0.225	0.280	0.321	0.388
500	0.000	0.164	0.242	0.299	0.342	0.410
550	0.000	0.176	0.259	0.319	0.362	0.432
600	0.000	0.190	0.277	0.339	0.384	0.455
640	0.000	0.202	0.291	0.355	0.401	0.473

*Group size = 30; Angle = 0° from vertical.

TABLE 8 Probability of caribou in the Fortymile caribou herd reacting to overflights by F-16 jets at levels >3, >4, and >5 for different combinations of slant distances and jet speeds based on logistic regression models from data collected during the calving season 2002

Speed	Slant distance (ft)					
(knots)	2000	1500	1000	700	500	200
*F-16 Prob >3**						
400	0.075	0.237	0.315	0.368	0.405	0.463
430	0.088	0.270	0.354	0.409	0.448	0.506
460	0.103	0.305	0.395	0.452	0.491	0.550
490	0.120	0.344	0.437	0.496	0.535	0.593
520	0.140	0.384	0.480	0.539	0.578	0.634
*F-16 Prob >4**						
400	0.034	0.245	0.282	0.306	0.322	0.348
430	0.038	0.263	0.302	0.327	0.343	0.370
460	0.041	0.282	0.322	0.348	0.365	0.392
490	0.045	0.302	0.344	0.370	0.388	0.415
520	0.049	0.323	0.365	0.392	0.410	0.438
*F-16 Prob >5**						
400	0.000	0.346	0.462	0.535	0.583	0.652
430	0.000	0.358	0.476	0.549	0.597	0.665
460	0.000	0.371	0.490	0.562	0.610	0.677
490	0.000	0.384	0.503	0.576	0.623	0.689
520	0.000	0.396	0.517	0.589	0.635	0.700

*Group size = 30; Angle = 0° from vertical.

TABLE 9 Distribution of caribou reaction levels relative to slant distances from military jets during the 2002 calving season of the Fortymile caribou herd, depending on whether the caribou were bedded or active at the beginning of overflights

	All slant distances		<1500 ft		<1000 ft		<500 ft	
	n	%	*n*	%	*n*	%	*n*	%
Bedded to Active								
Level 6	11	0.04	11	0.07	6	0.04	1	0.02
Level 5	19	0.07	13	0.08	13	0.09	1	0.02
Level 4	18	0.07	16	0.10	15	0.11	5	0.12
Level 3	5	0.02	2	0.01	2	0.01	1	0.02
Level 2	13	0.05	13	0.08	12	0.09	6	0.15
Level 1	197	0.75	106	0.66	89	0.65	27	0.66
Total	263		161		137		41	
Active to Active								
Level 6	35	0.06	34	0.07	30	0.08	12	0.13
Level 5	29	0.05	26	0.06	19	0.05	6	0.06
Level 4	100	0.16	87	0.19	77	0.22	12	0.13
Level 3	54	0.09	46	0.10	36	0.10	2	0.02
Level 2	158	0.25	119	0.26	102	0.28	35	0.38
Level 1	251	0.40	154	0.33	94	0.26	26	0.28
Total	627		466		358		93	
Active to Bedded								
Level 6	0	0.00	0	0.00	0	0.00	0	0.00
Level 5	0	0.00	0	0.00	0	0.00	0	0.00
Level 4	0	0.00	0	0.00	0	0.00	0	0.00
Level 3	0	0.00	0	0.00	0	0.00	0	0.00
Level 2	3	0.27	3	0.43	2	0.33	1	1.00
Level 1	8	0.73	4	0.57	4	0.67	0	0.00
Total	11		7		6		1	

TABLE 10 Group response[a] of caribou in the Fortymile caribou herd to military jet sorties during the 2002 calving season

Group	Sortie	Jet	Duration (min)	Number of peaks	Maximum peak	Cumulative duration (min)	Cumulative number of peaks	Behavior in the period before sortie	Behavior at start of sortie	Behavior at end of sortie	Group behavior after sortie	Energy increase
AA5161	152144	F-16	18.3	8	111	18.3	8	F	F	R[b]	RO	Yes
AA5162	164723	A-10	24.5	10	99	42.8	18	F	F	B	B	No
AA5211	105254	F-16	6.7	5	86	6.7	5	Unk	F/Tr	Tr	Tr	Yes
AA5212	110044	A-10	17.0	12	83	23.7	17	B	B	B	B	No
AA5213	113643	F-15	42.1	19	100	65.7	31	B+F	B+F	F/Tr	F/Tr	Yes
AA5231	104912	A-10	1.6	2	86	1.6	2	B	B	F/Tr	F/Tr	Yes
AT5301	120753	Mix	37.2	12	102	37.2	12	B+F	B+F	F/Tr	F+B	Yes
AT6041	110907	F-15	47.0	15	111	47.0	15	B-N-Tr	F	F	F	No
AT6042	120100	F-16	20.2	7	90	67.2	22	F	F	F	F	No
AT6043	131124	F-15	22.9	11	97	90.1	33	F/Tr	F/Tr	Tr/R	Tr/R	Yes
AT6051	110647	A-10	11.0	7	90	11.0	7	B+F	B+F	F+B	F+B	Yes
AT6052	120245	F-16	12.7	5	102	23.7	12	F/Tr	F	F/Tr	F/Tr	Yes
AT6053	133038	A-10	38.3	15	94	62.0	27	F+B	F+B	F+B	F+B	No
JA5301	122013	Mix	29.0	10	113	29.0	10	B+F	F	Tr[c]	Tr	Yes
JA5302	122013	Mix	7.9	3	100	36.9	13	B+F	B+F	B+F	B+F	No
JA6041	115311	F-16	23.9	12	92	23.9	12	B	F/Tr	F/Tr	F/Tr	No
JA6042	132559	F-15	23.0	11	112	46.9	23	Tr	Tr	F/Tr	F/Tr	No
JA6051	132045	A-10	38.3	18	95	38.3	18	B+F/Tr+F	B+F	F/Tr	F/Tr	Yes
JT5161	100847	A-10	26.9	9	79	26.9	9	B+F	B+F	B	B	No
JT5162	140056	A-10	12.0	6	82	12.0	6	F	F	R[b]	RO	Yes
JT5163	140056	A-10	19.4	10	96	31.4	16	F	F	F	F	No
JT5164	152142	F-16	15.8	6	114	47.2	22	Tr	Tr	Tr[d]	Tr	No
JT5211	104718	F-16	7.8	5	92	7.8	5	B	B	B	B	No
JT5221	165225	A-10	22.8	9	82	22.8	9	B	B	B	B	No
JT5222	171736	F-16	7.8	5	91	30.6	14	B	B	F	F	Yes
JT5231	105312	A-10	7.2	5	86	7.2	5	F	F	B	B	No
JT5281	164637	A-10	10.3	8	87	10.3	8	B	B	Tr[e]	Tr	Yes

[a] Behaviors: F = Feeding; B = Bedding; R = Running; RO = Ran out of sight; Tr = Traveling; N = Nursing.
[b] Running not associated with an overflight.
[c] Initiation of traveling began suddenly about 1.5 min after the last overflight.
[d] Caribou may have been moving away from a grizzly bear.
[e] Traveling to catch up to other cows after long rest; stayed bedded throughout overflights.

APPENDIX A A summary of military flying activity in the air space above the Fortymile caribou herd (*Source*: Lawler and Haynes 1998)

A SUMMARY OF MILITARY FLYING IN INTERIOR ALASKA

Military aircraft in all Military Operations Areas (MOA) may be involved in routine flying exercises or more complex Major Flying Exercises (MFE). Historical funding allocations would typically constrain routine training exercises to an average of 240 days per year and these days can be distributed throughout the year. Included in this 240 days is a maximum of 60 days of MFEs. These 60 days of MFEs can be distributed over 6 exercises a year. Aircraft taking part in training exercises may come from the various US military services or their allies (Dept. of the Air Force 1995).

MFEs typically occur Monday through Friday, 8 a.m. through 6 p.m. but are most concentrated 2 hours before and 2 hours after noon. Training on weekends may also occur, on average of two weekends per 3-month period. In general, one MFE is to take place between February and April, four MFEs between May and August, and one MFE between October and November. A typical MFE will last for 10 days but can last for as many as 15. Up to 100 aircraft a day can be involved in an MFE with each aircraft flying up to 2 sorties (take-off, flight, and landing) per day for a total of 200 MFE sorties per day (EIS executive summary 1995). No MFEs are to be conducted during September, December, or January, or during the week prior to or the week after the 4th of July. Routine training typically occurs at reduced levels during Thanksgiving and Christmas. There is a minimum interval of 2 weeks between MFEs (Dept. of the Air Force 1995).

The 60 days of MFEs also include a maximum of two nighttime exercises for a maximum of 30 days of nighttime MFEs annually. These nighttime MFEs mainly occur in February/March and October/November. During the nighttime MFEs, aircraft can take-off from Eielson and Elmendorf Air Force Bases (AFB) as late as 10:00 p.m. and can land as late as 11:00 p.m. Night MFEs are limited to 10% of the daily MFEs and average 20 sorties per night (Dept. of the Air Force 1995).

MILITARY FLIGHT EXERCISE DESCRIPTIONS AND DATES

COPE THUNDER is the largest flying exercise that occurs in Alaska and may be held in conjunction with Northern Edge, a combined services exercise. There are normally four each year and they last approximately 2 weeks each. These exercises emphasize large force employment of aircraft and use all the MOAs and restricted areas in the Alaska Interior. Air activity typically occurs during two, three-hour blocks per day, and unless bad weather forces cancellation of flying on a weekday, Cope Thunder flying occurs Monday through Friday. There are normally between 40 and 60 fighter-type aircraft supported by 4 to 7 tankers and 1 to 2 AWACs in the designated airspace during the designated times. Sometimes, 4 to 8 C-130s are also in the airspace. It is important to emphasize the air to air combat flying occurs during 2 50-minute (sometimes longer) windows per day and MOA use is mostly confined to the Yukons 1, 2, 3A, and 4 MOAs. The majority of the flying below 5000’ AGL occurs in these same 2 50-minute windows per day and is predominantly completed in the Yukon 1, 2, 3A Low, and 4, Birch, and

Buffalo MOAs as well as the 3 air-to-ground weapon ranges (bombing ranges). An average sorties time below 10,000 feet MSL would typically not exceed 30 minutes. This is based on a 10–20 minute flight time from takeoff to arrival at the MOA, 10–15 minutes spent at high altitude receiving gas from a tanker or marshaling of forces, and 20–30 minutes for descent and run-in to the target areas in the bombing ranges, followed by climbing back to high altitude for recovery to Eielson AFB and Elmendorf AFB.

NORTHERN EDGE is a joint service exercise that primarily emphasizes ground troop activities. Northern Edge is typically held in conjunction with a Cope Thunder. Aerial activity that supports this exercise includes transport aircraft (C-130s and C-141s) near the beginning and end, and some low flying "close air support" fighter activity. Most activity takes place on or near Army lands underlying the Yukon 1, Buffalo, Eielson, and Birch MOAs, and the 3 air-to-ground weapon ranges.

INITIAL READINESS RESPONSE EXERCISE (IRRE) tests a wing's capability to deploy to a simulated overseas forward operating location within a specified time and to then generate a certain number of aircraft sorties. The acronym "IRRI" stands for "Initial Readiness Response Inspection." It is the same as an IRRE except that inspectors from the major command's headquarters (i.e., HQ Pacific Air Force (PACAF)) are on hand to evaluate. Neither an IRRE nor an IRRI change the local flying schedule drastically. Some aircraft will take off and fly a long, circuitous high-altitude route simulating a deployment to a remote location.

COMBAT EMPLOYMENT READINESS EXERCISES (CERE) tests a wing's capability to generate sorties during simulated combat conditions and simulates the wing as being deployed to an overseas forward operating base. A "CERI" is the same as a "CERE" except it is an inspection evaluated by the headquarters' inspectors. CEREs and CERIs increase the local flying by increasing the tempo of operations, but not the overall sortie numbers (CERE sorties come at the expense of routine sorties). A typical scenario would use daily training numbers of aircraft flying 4 launches per day, instead of the normal 2. CEREs and CERIs may be conducted independently, but normally occur immediately after IRREs and IRRIs. With the exception of the Yukon 3B and 5 MOAs, any and all the MOAs and air-to ground weapon ranges may be utilized.

DISTANT FRONTIER is a deployment training activity involving the British Royal Air Force (RAF) with support of Alaskan units hosting the RAF. It occurs between iterative Cope Thunder exercises. The local flying will increase very little if at all during this period. With the exception of Yukon 3B and 5 MOAs, any and all the MOAs and air-to-ground weapon ranges may be utilized.

AMALGAM WARRIOR is an exercise run by the Alaska Region of the North American Aerospace Defense (NORAD) Command. The MOAs rarely see use by the participants and local flying does not significantly increase. This exercise tests the air sovereignty mission of the Alaska NORAD region forces. Fighter aircraft are scrambled from Elmendorf AFB, King Salmon, or Galena airports to intercept unidentified intruders of

Alaskan airspace. Airspace used for the exercise is usually at high altitudes (>10,000' MSL) and over the ocean.

ROUTINE TRAINING for Elmendorf AFB fighter aircraft currently averages approximately 45 aircraft per day during 2 launch periods, Monday through Friday. Eielson AFB averages 40 aircraft per day during 2 launch periods.

**Source*: Capt. Tim Petrishen, 611th Air Operations Group Airspace Manager. 1998.

The final EIS (1995) estimated the projected number of aircraft, the number of sorties flown by these aircraft, and the altitudes flown by these aircraft within individual MOAs on an annual basis. These values were derived from typical use patterns and represent estimates of the maximum use of these airspaces. At present, no historical record is systematically kept of the actual number of aircraft participating in particular training exercises in MOAs within Interior Alaska (Capt. Tim Petrishen, personal communication).

THE YUKON MOA

Yukon 1

The final EIS (1995) projected daily military aircraft operations in the Yukon 1 MOA to be 18 aircraft operations per day in a routine flying day and 206 aircraft operations per day during MFE training. Supersonic activity in this MOA is authorized at or above 5000 feet AGL or 12,000 MSL, whichever is higher. Yukon 1 has a floor of 100 AGL (Federal Aviation Administration 1995). Flight activity in the Yukon 1 MOA includes daily training and MFEs. Planes participate in air combat training, fighter intercept training, basic fighter maneuvers, and low altitude fighter operations (Federal Aviation Administration 1995).

Mitigated MOA boundaries that were adopted with the FAA Aeronautical Study 95-AAL-042NR and the ROD (1995) place an exclusion area over the Charlie River from 15 April to 15 September. This area extends from the surface to 2000 feet AGL 2 NM either side of the river centerline. The Cirque Lakes Dall sheep lambing area also falls within this MOA. This area is a flight exclusion area from 10 May through 15 June from the surface to 5000 feet AGL. One mitigation measure put in place by the Air Force was moving the southern boundary of this MOA to avoid the lower Salcha River. The upper Salcha River was then divided into 2 mitigated areas. The uppermost section excludes turbojet and turbofan aircraft from the surface to 5000 feet MSL and all other military aircraft are excluded from the surface to 1000 feet AGL 2 NM either side of the Salcha River from 1 through 20 September. The lower section of the upper Salcha excludes all military aircraft from the surface to 1000 feet AGL year around and turbojet and turbofan aircraft are excluded from the surface to 5000 MSL from 1 through 20 September for 2 NM either side of the Salcha River (11 AF Noise/Flight Sensitive Areas List, 21 July 1997).

Yukon 2

Military overflight activity in the Yukon 2 MOA is most concentrated near the juncture of the Yukon 1, 2 and 3 MOAs. The floor of this MOA is 100 feet AGL. Supersonic activity is authorized at or above 5000 AGL or 12,000 MSL, whichever is higher (Federal Aviation Administration 1995). The final EIS (1995) projected daily military aircraft operations in the

Yukon 2 MOA to be 12 aircraft operations per day in a routine flying day and 201 aircraft operations per day during MFE training. Flight activity in the Yukon 2 MOA includes daily training and MFEs. Planes participate in air combat training, fighter intercept training, basic fighter maneuvers, and low altitude air combat operations (Federal Aviation Administration 1995).

Airspace within this MOA that is excluded (Federal Aviation Administration 1995; ROD 1995) includes a corridor on either side of the Steese Highway from ground level to 2000 feet AGL (see Appendix A for latitude and longitude coordinates). Military aircraft are also excluded from the ground surface to 1500 AGL within a 3 NM radius of the airports found at Ben Creek, Central, Circle, Circle Hot Springs, and Coal Creek. (11 AF Noise/Flight Sensitive Areas List, 21 July 1997; Appendix A). Within a 10 NM radius of the communities of Central and Circle Hot Springs, no supersonic flight is permitted from the ground surface to 35,000 MSL. All military flight is restricted to elevations above 10,000 MSL over these communities (see Appendix A for latitude and longitude coordinates). Over the community of circle, there is a no fly zone from the surface to 6000 MSL within a 2-mile radius (11 AF Noise/Flight Sensitive Areas List, 21 July 1997).

All the above restrictions apply year around. Seasonal restrictions occur along the Yukon and the Charley Rivers. From 15 April through 31 August, from the ground surface to 2000 AGL 2 miles either side of these rivers is a “no fly” zone (11 AF Noise/Flight Sensitive Areas List, 21 July 1997).

Yukon 3

The ROD (1995) projected the number of aircraft to be using the Yukon 3 MOA during a routine flying day to be 8 aircraft and during a MFE to be 166 aircraft. Activity in this MOA is most concentrated along the western edge. The Yukon 3 MOA is split into 3 separate MOAs. Yukon 3 High has a floor of 10,000 feet AGL and overlies the Yukon 3A Low MOA. Yukon 3A Low and 3B Low are divided by a line that runs from the northeast corner of this MOA to the intersection with the northeast corner of the Buffalo MOA. Yukon 3A Low is the western portion of this MOA and has a floor 100 feet AGL. Yukon 3B Low, the eastern portion has a floor of 2000 feet AGL and is only used during MFEs. Supersonic activity is authorized in the Yukon 3 High MOA but not in the Yukon 3A Low or 3B High MOAs (Federal Aviation Administration 1995). Planes participate in air combat training, fighter intercept training, basic fighter maneuvers, and low altitude air combat operations (Federal Aviation Administration 1995).

Seasonal restrictions occur along the Yukon and the Charley Rivers. From 15 April through 31 August, from the ground surface to 2000 AGL 2 miles either side of these rivers is a “no fly” zone (11 AF Noise/Flight Sensitive Areas List, 21 July 1997).

Yukon 4 MOA

The ROD (1995) projected the number of aircraft operating within the Yukon 4 MOA to be 7 on routine flying days and 164 on an MFE day. The floor of this MOA is 100 feet AGL and supersonic flight is restricted to 5000 AGL or 12,000 feet MSL, whichever is higher. Aircraft in this airspace engage in air combat training, fighter intercept training, basic fighter maneuvers, and low altitude fighter operations. This airspace is used for both routine flying exercises as well as MFEs (Federal Aviation Administration 1995). Activity in this MOA is most concentrated in the southwest corner.

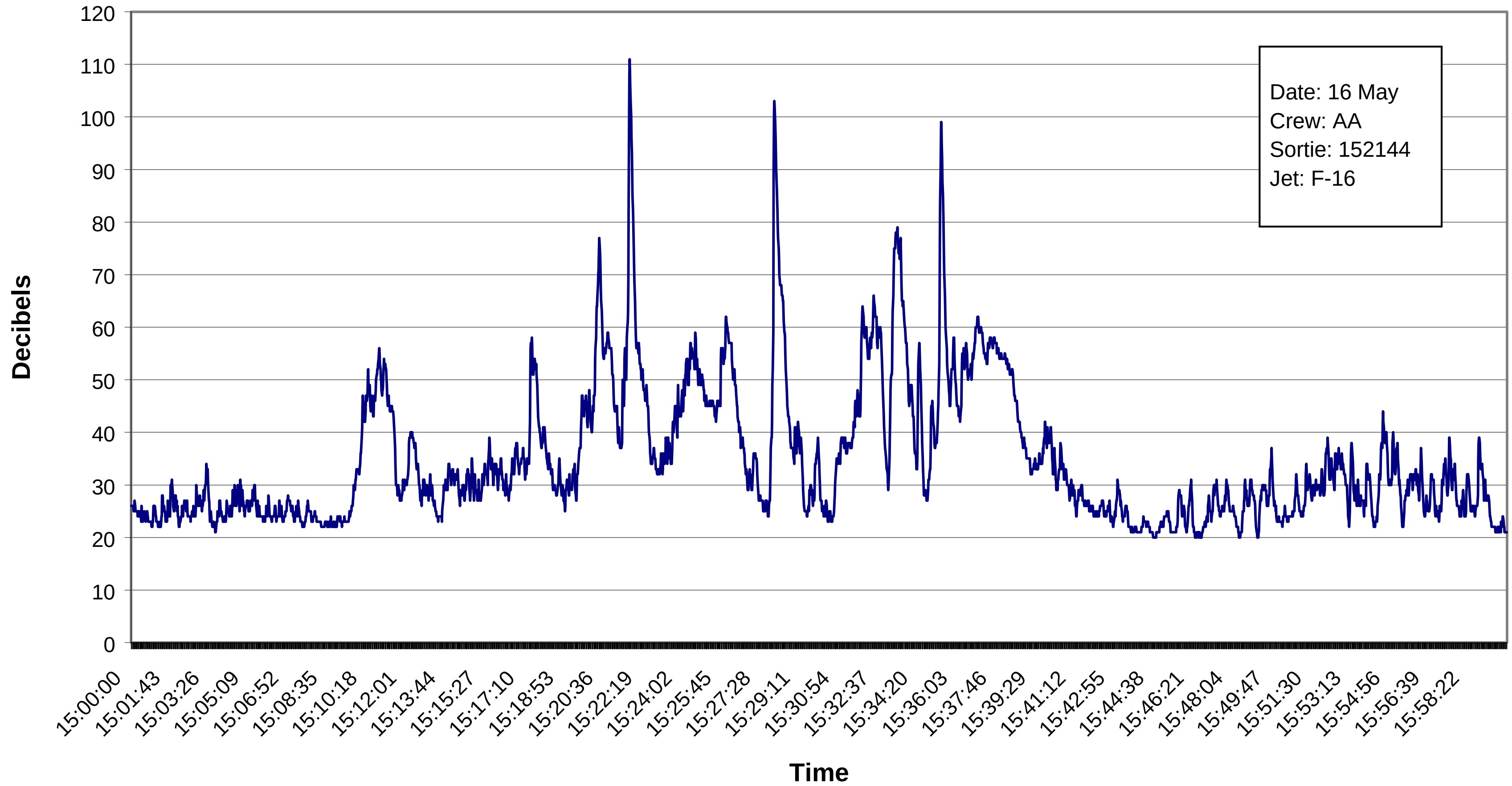
Seasonal restrictions along the Yukon and the Charley Rivers apply. From 15 April through 31 August, from the ground surface to 2000 AGL 2 miles either side of these rivers is a “no fly” zone (11 AF Noise/Flight Sensitive Areas List, 21 July 1997).

References

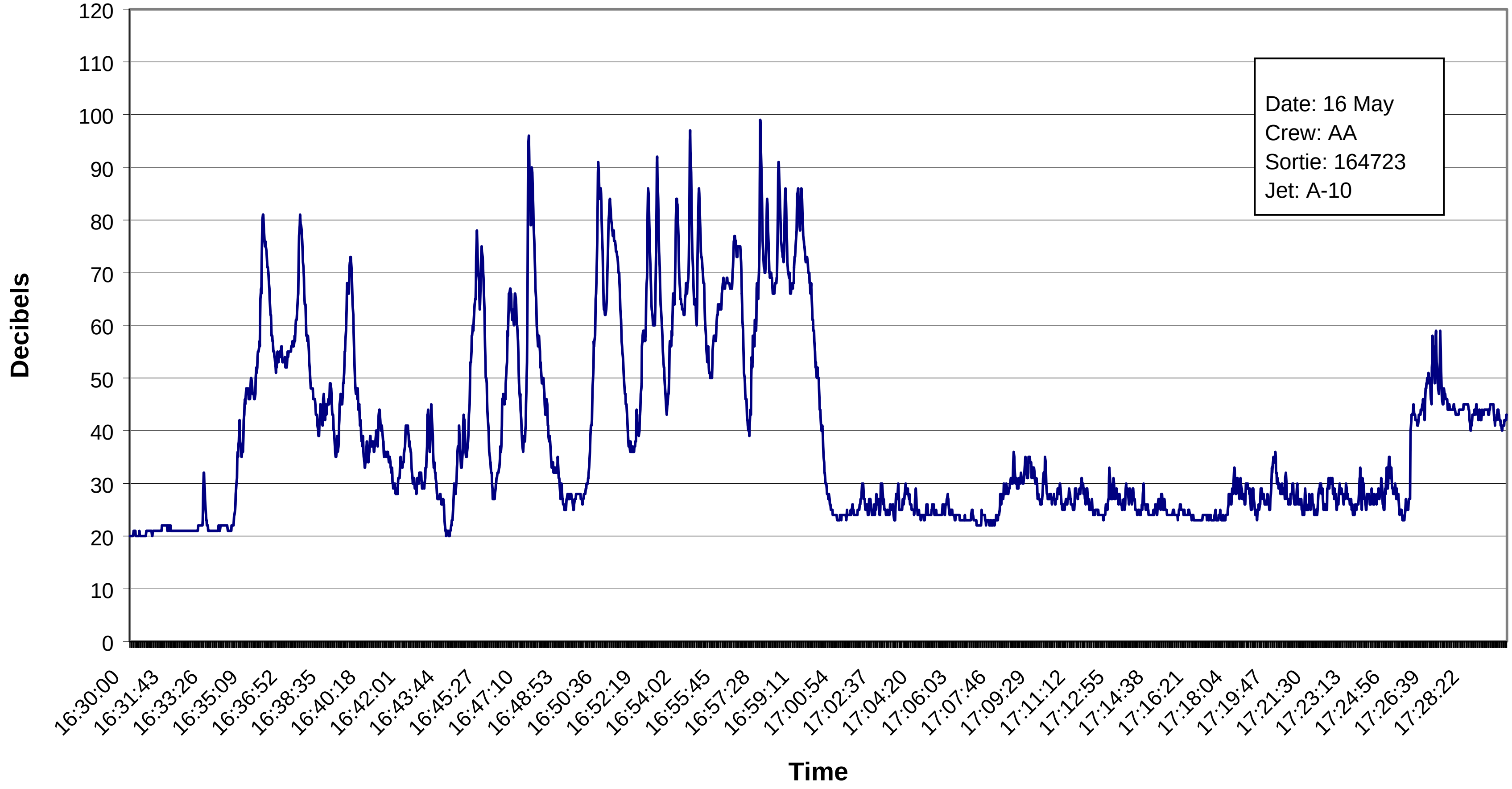
DEPARTMENT OF THE AIR FORCE. 1995. Final Environmental Impact Statement, Alaska Military Operation Areas. Eleventh Air Force, Elmendorf Air Force Base, Alaska.

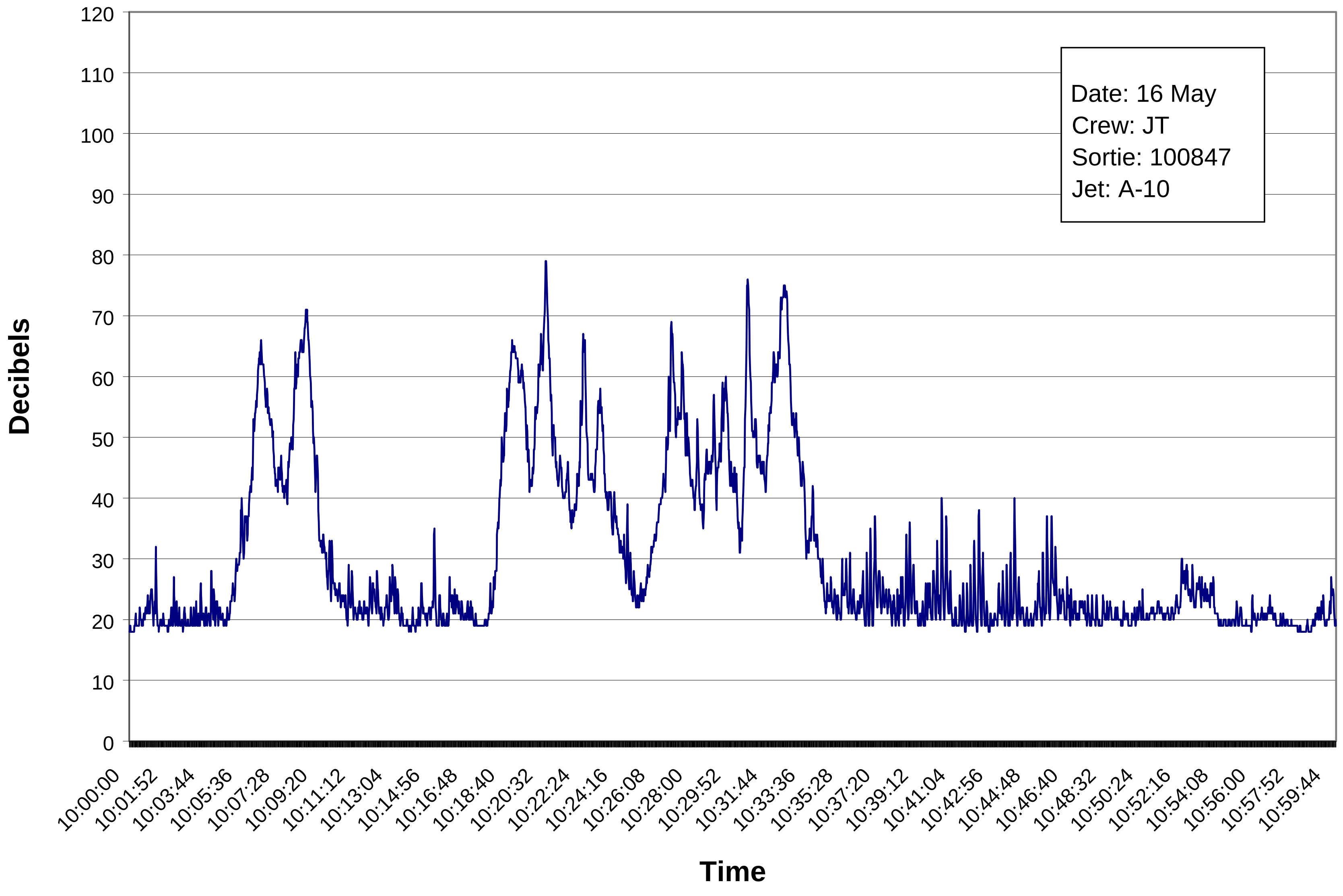
FEDERAL AVIATION ADMINISTRATION. 1995. Notice to Establish Special Use Airspace Military Operations Areas. Aeronautical Study No. 95-AAL-042NR. Anchorage, Alaska.

APPENDIX B Graphs of A-weighted decibel readings at 1 second intervals on Larson Davis Model 812 sound level meters during military jet sorties over the calving grounds of the Fortymile caribou herd in the 2002 calving season



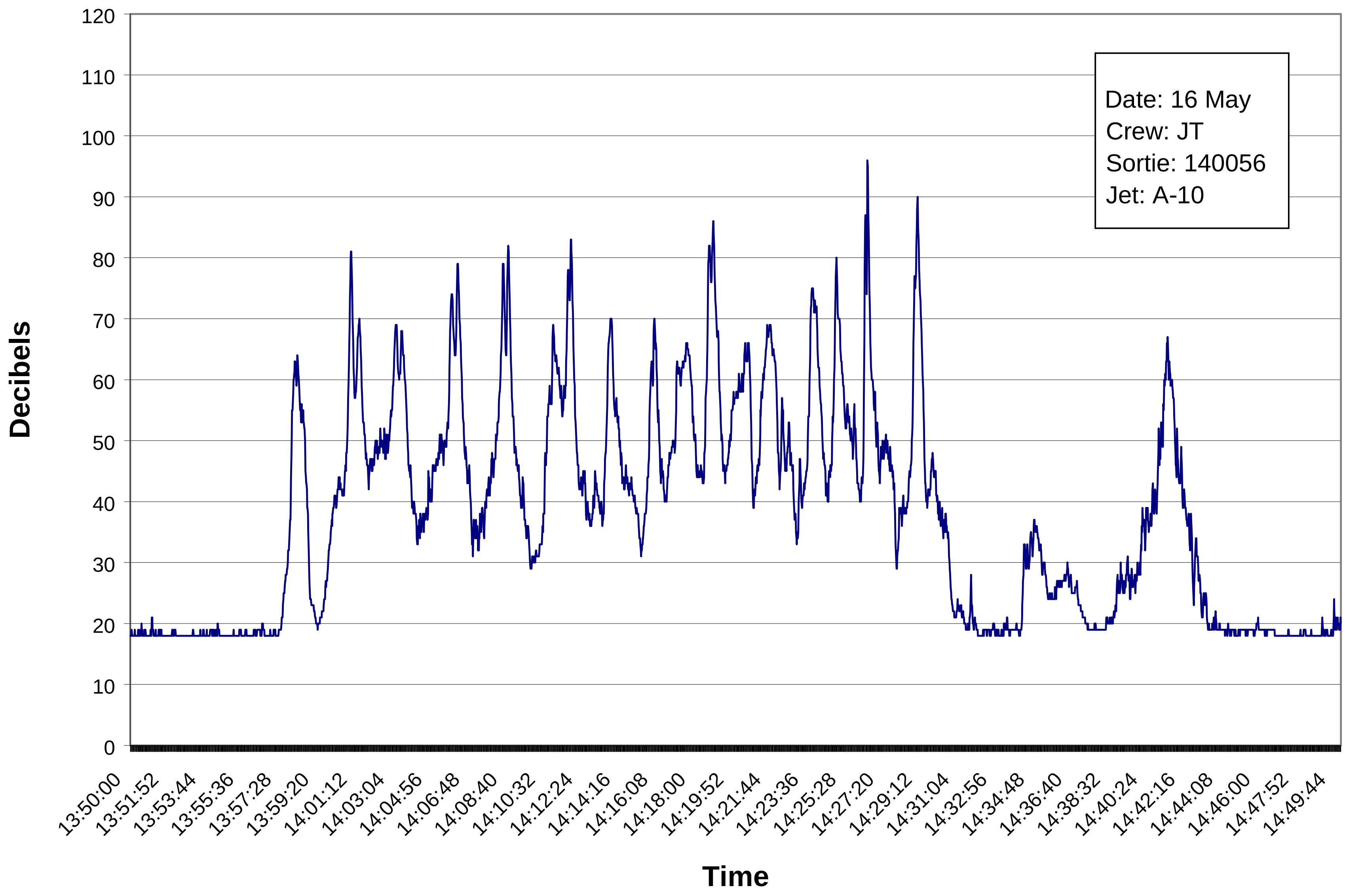
APPENDIX B (Cont'd)



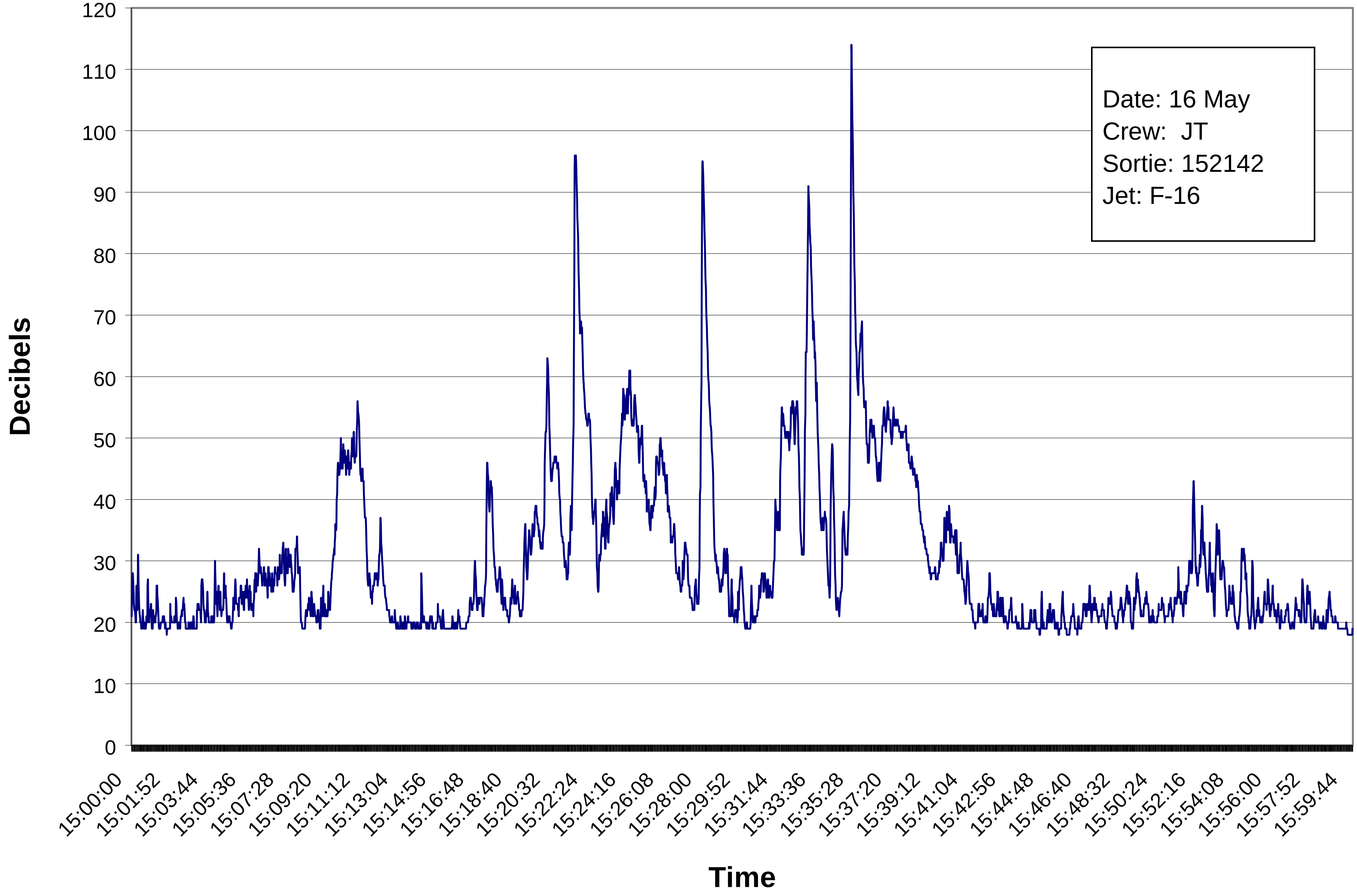


Date: 16 May
Crew: JT
Sortie: 100847
Jet: A-10
Decibels
Time
120
110
100
90
80
70
60
50
40
30
20
10
0
10:00:00
10:01:52
10:03:44
10:05:36
10:07:28
10:09:20
10:11:12
10:13:04
10:14:56
10:16:48
10:18:40
10:20:32
10:22:24
10:24:16
10:26:08
10:28:00
10:29:52
10:31:44
10:33:36
10:35:28
10:37:20
10:39:12
10:41:04
10:42:56
10:44:48
10:46:40
10:48:32
10:50:24
10:52:16
10:54:08
10:56:00
10:57:52
10:59:44

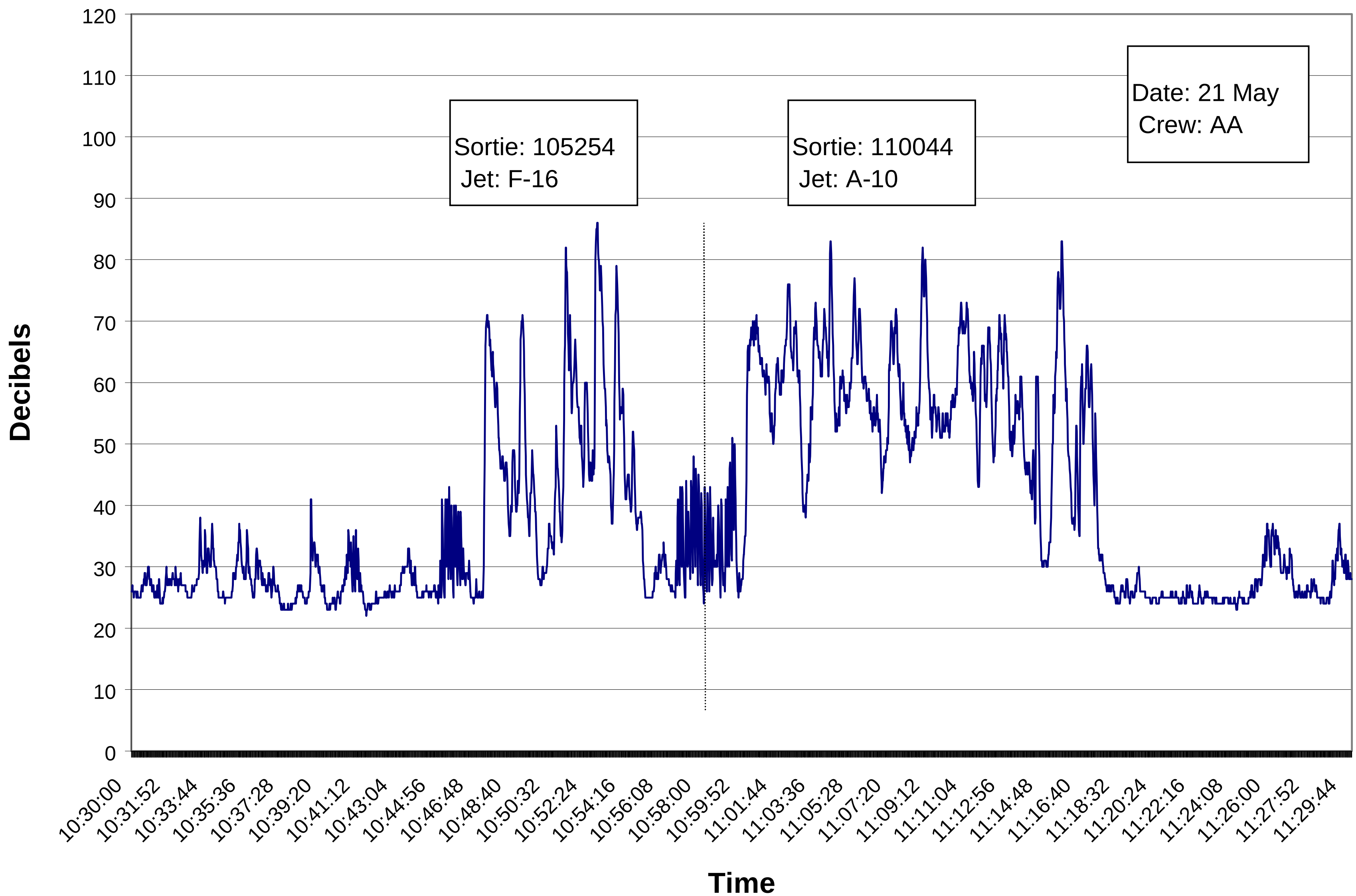
APPENDIX B (Cont'd)



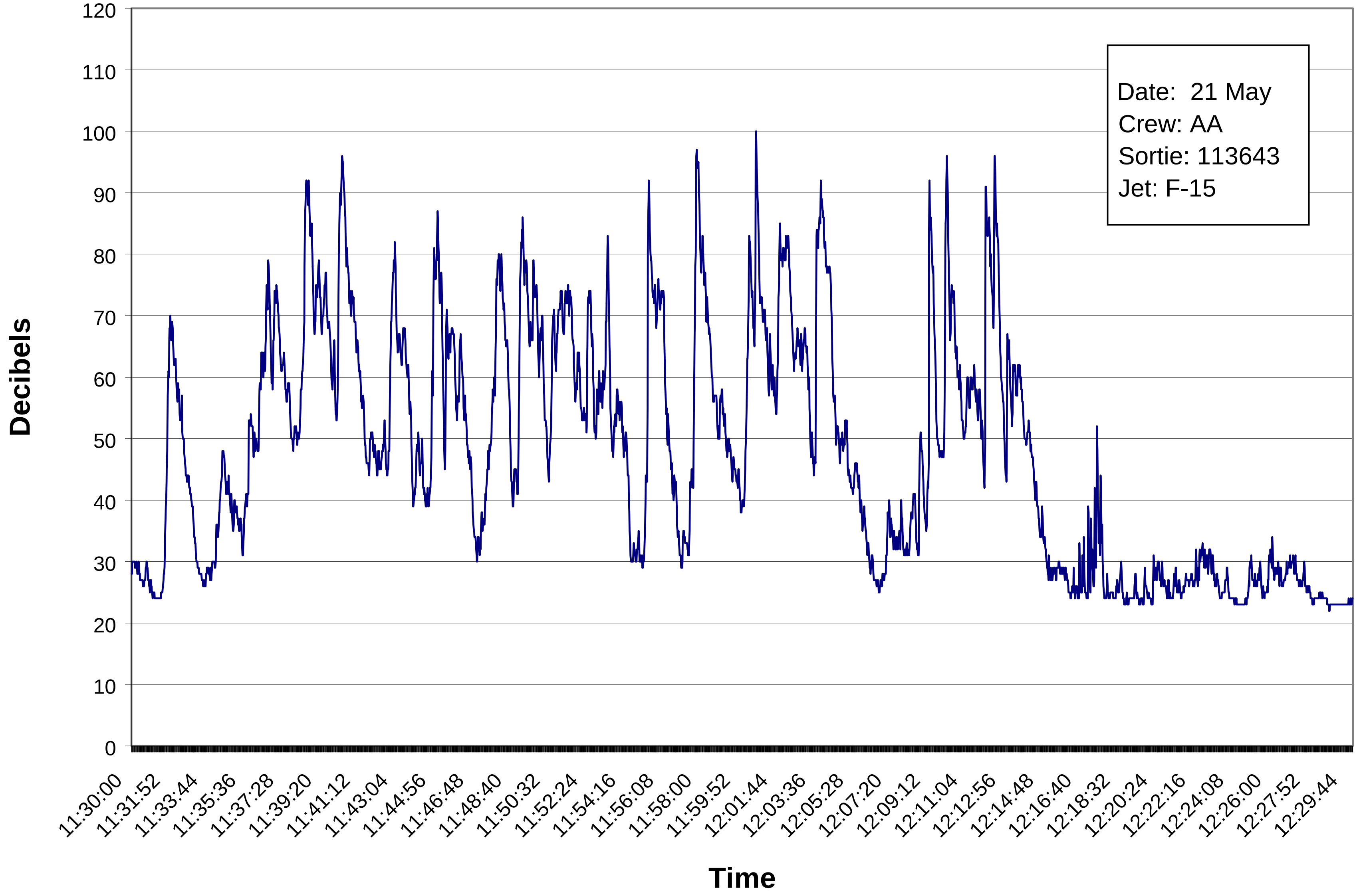
APPENDIX B (Cont'd)



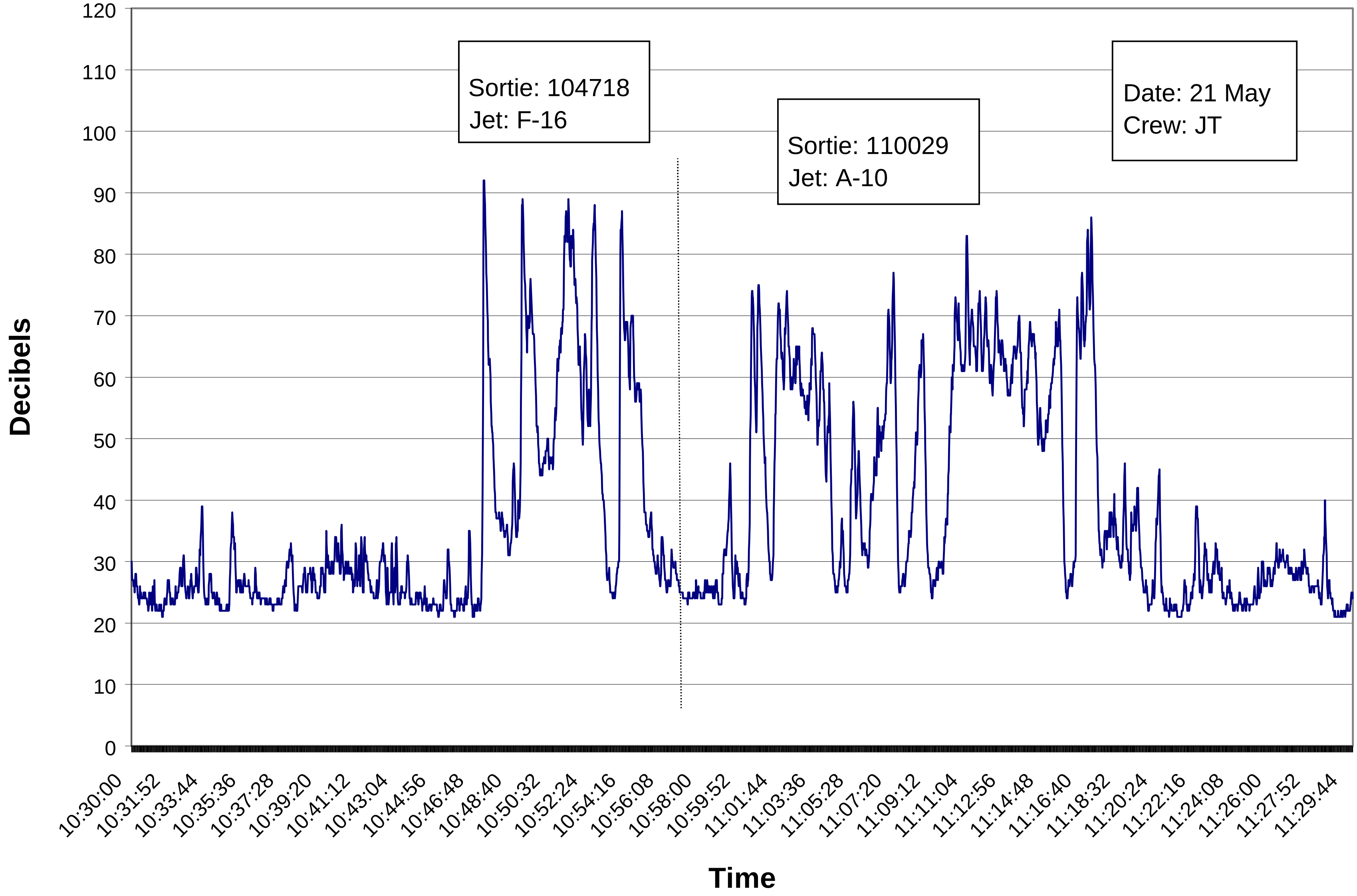
APPENDIX B (Cont'd)



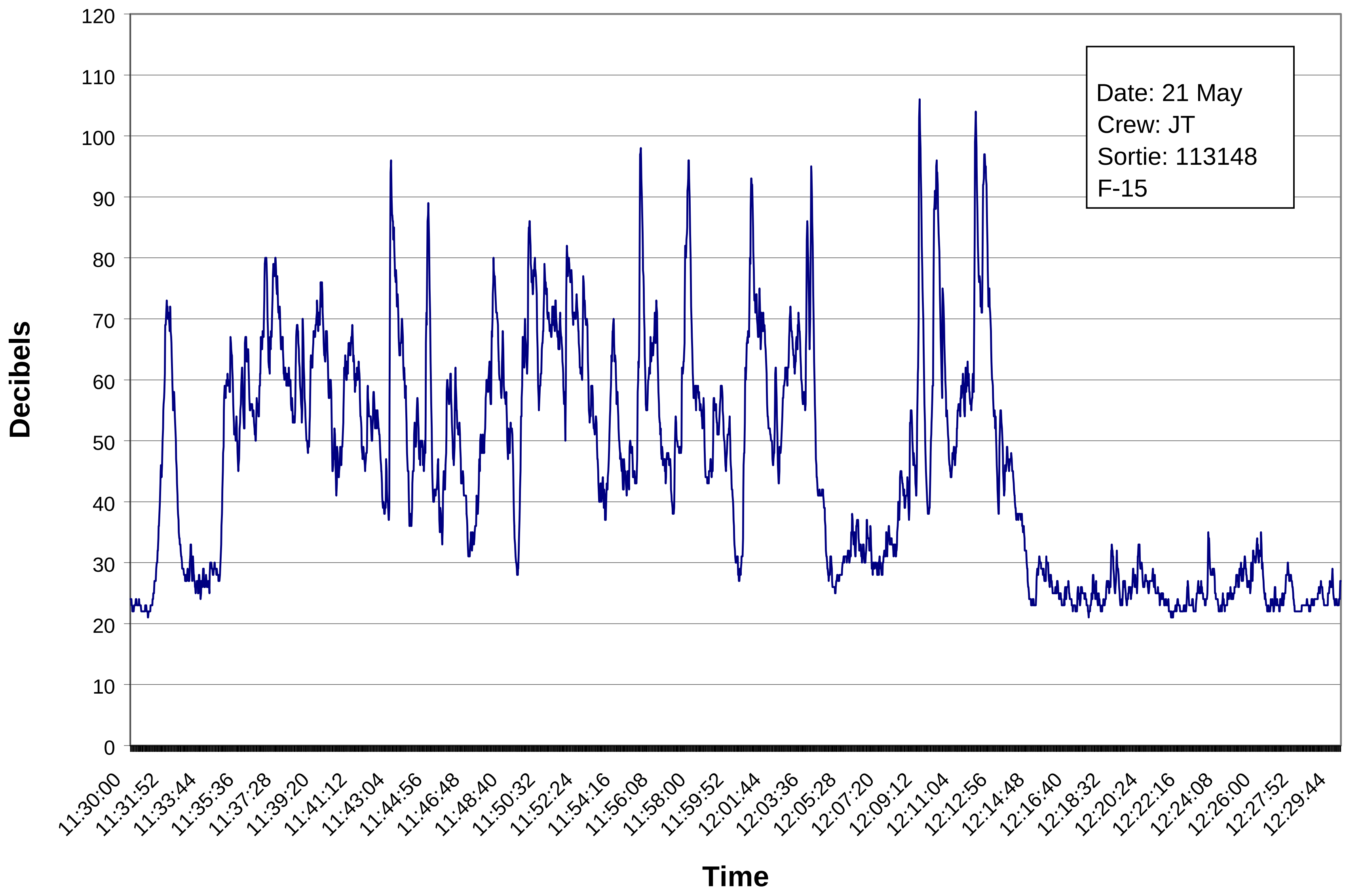
APPENDIX B (Cont'd)



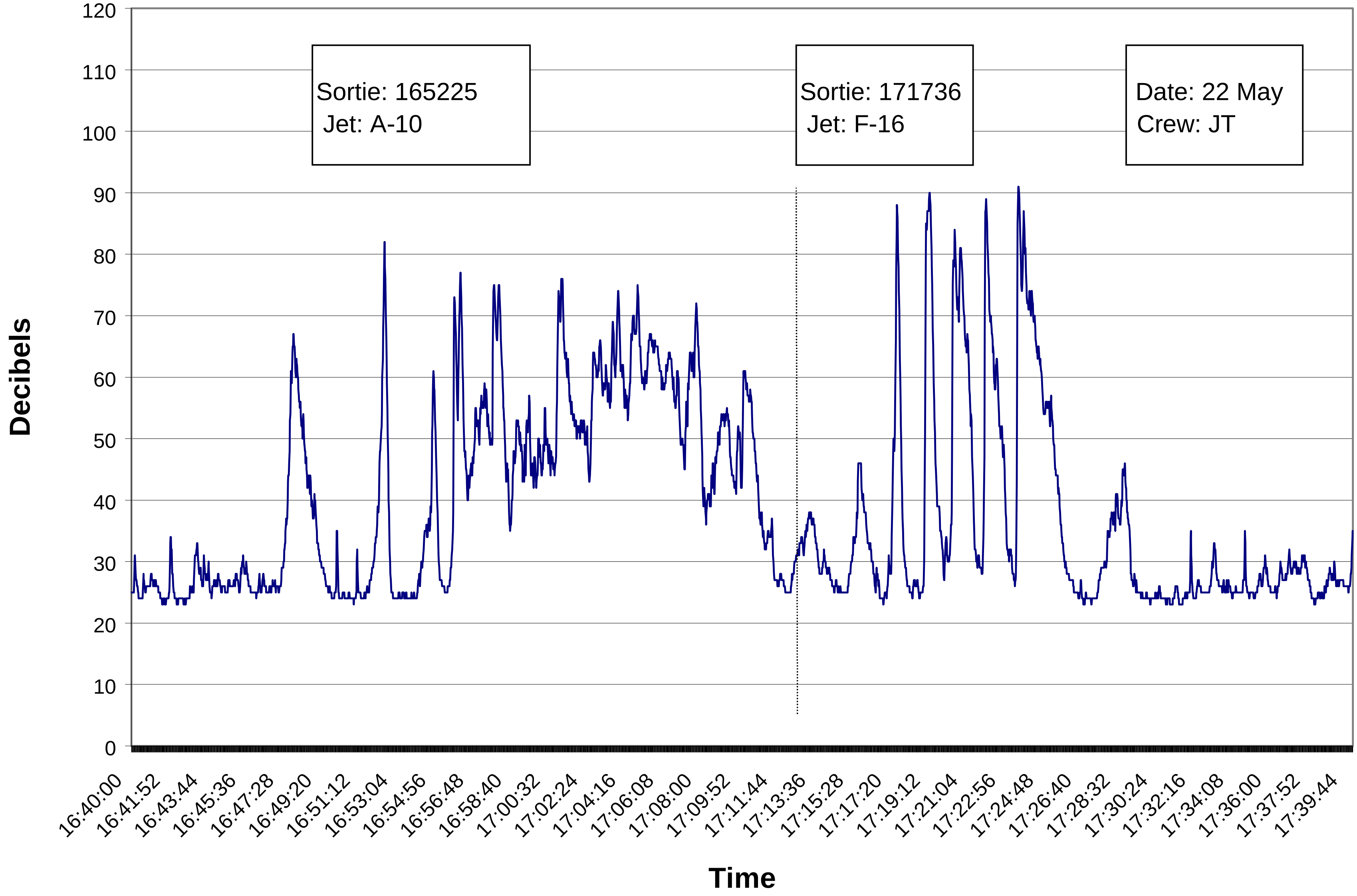
APPENDIX B (Cont'd)



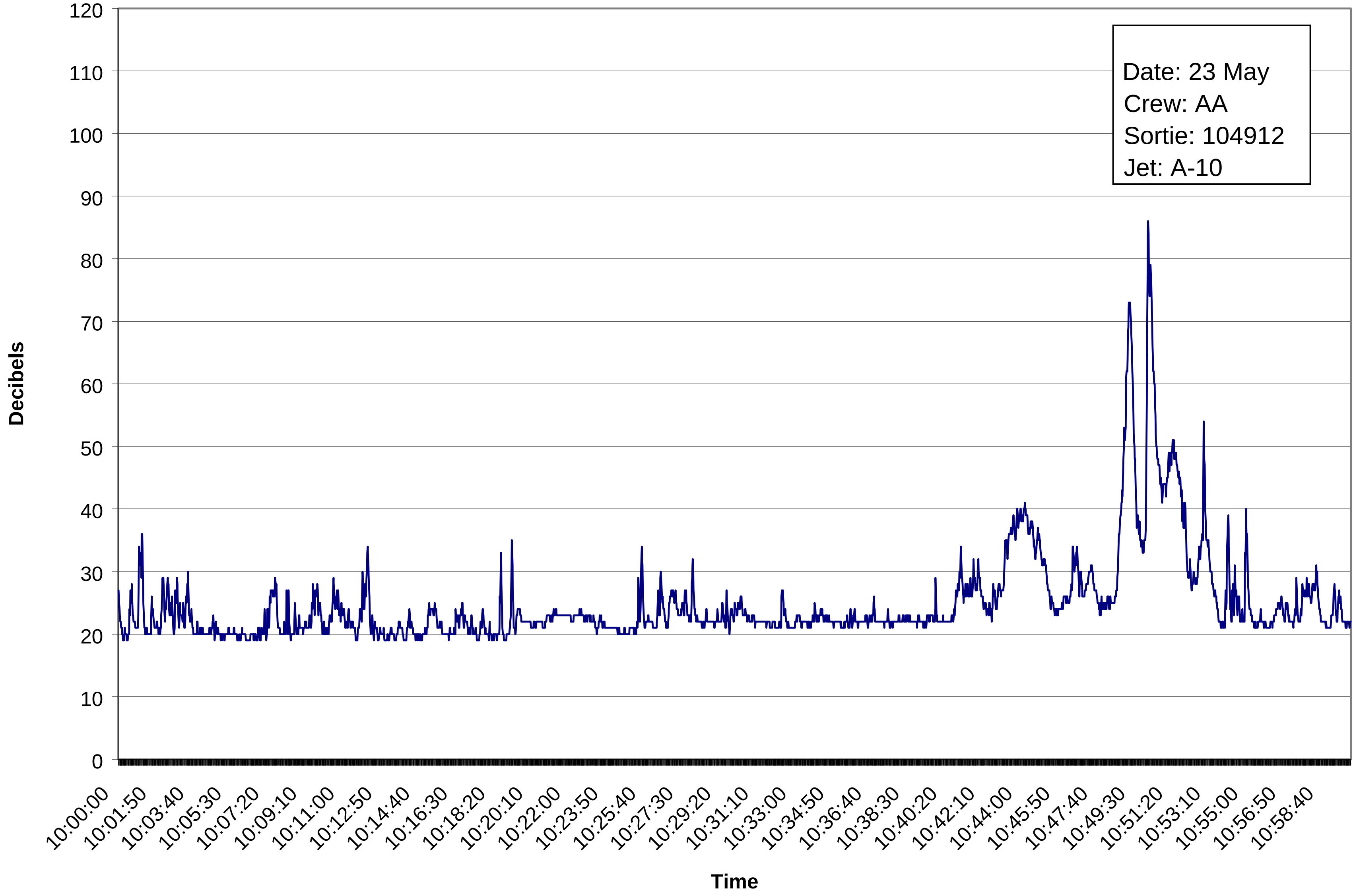
APPENDIX B (Cont'd)



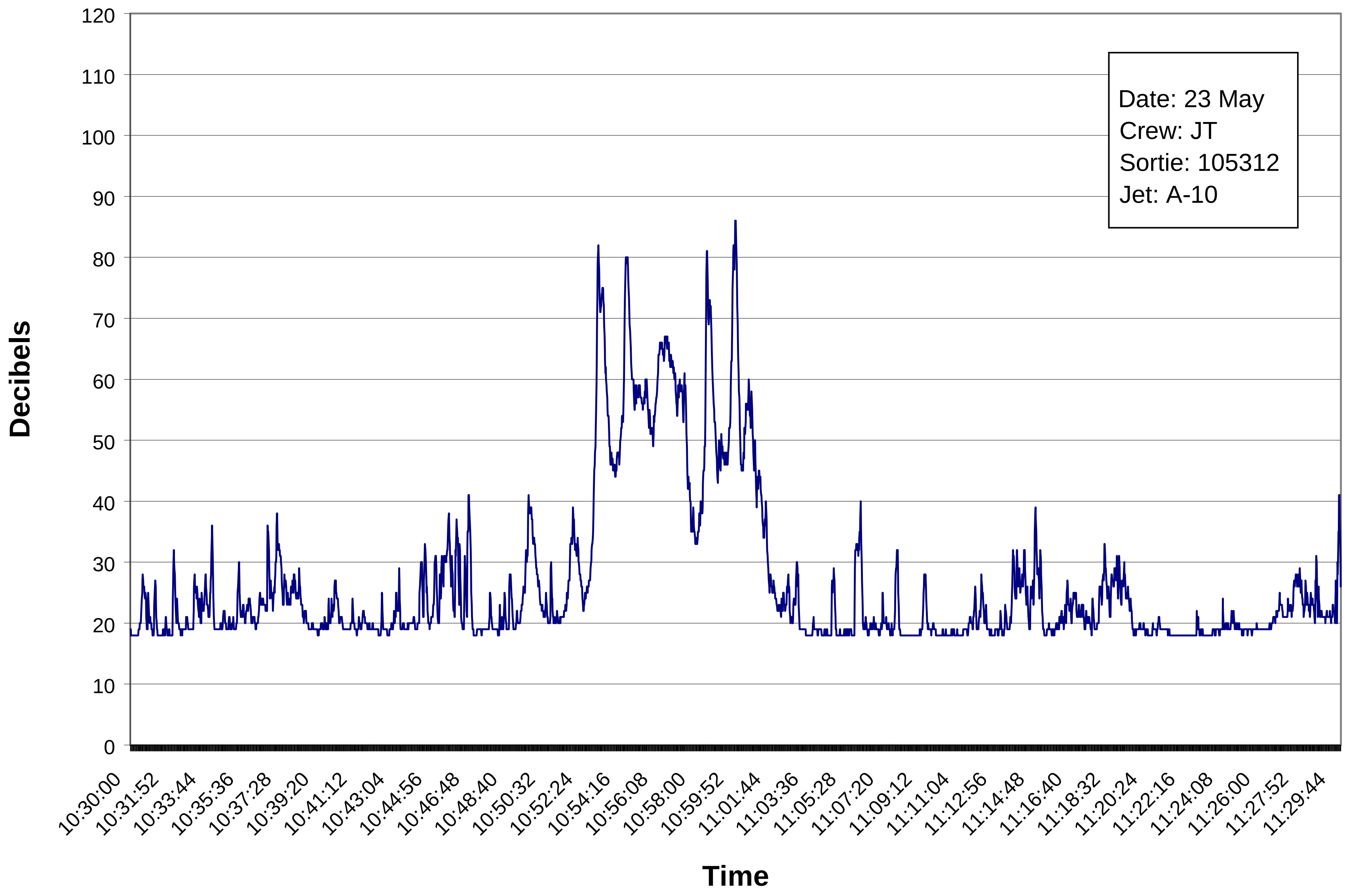
APPENDIX B (Cont'd)



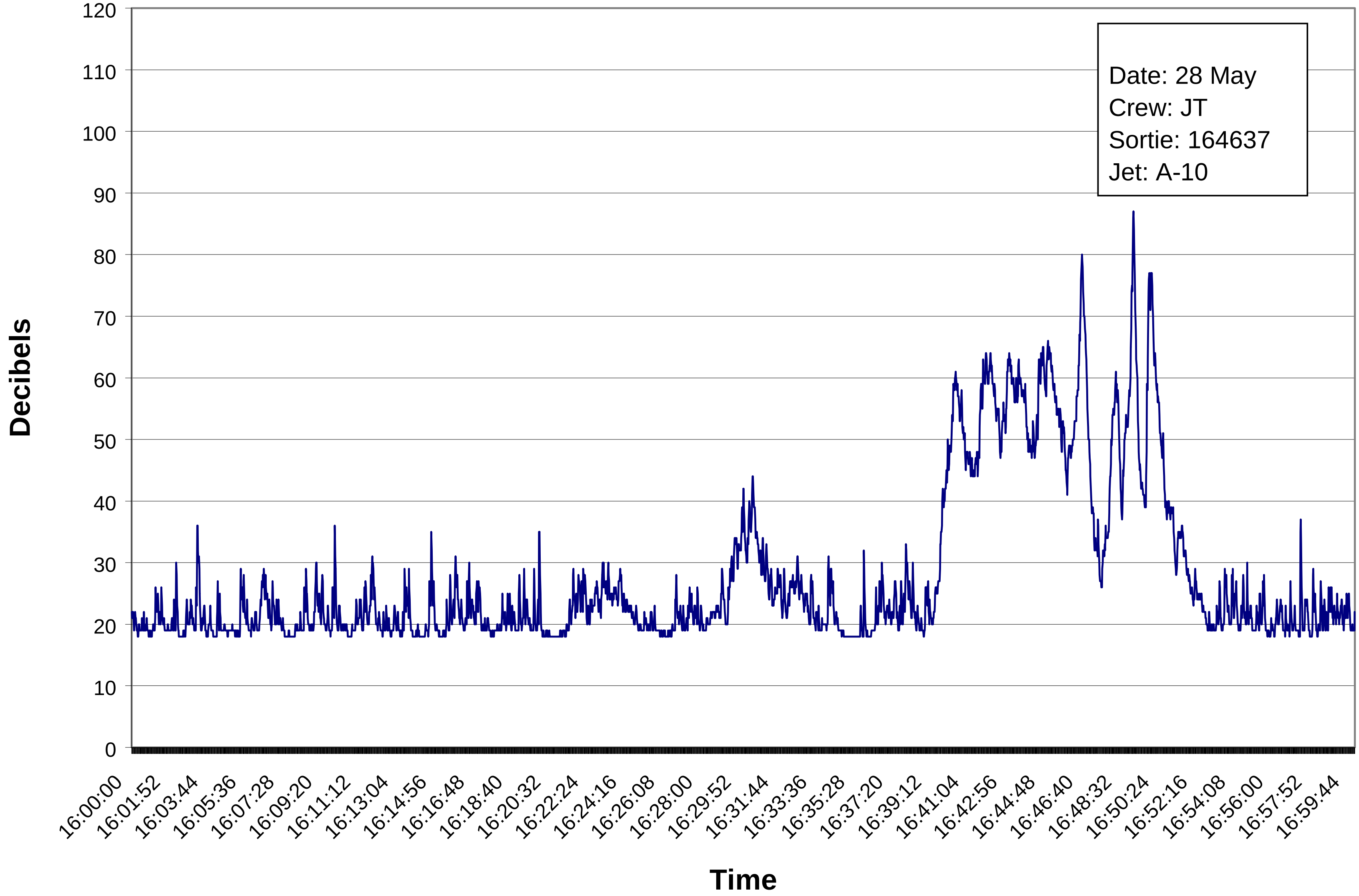
APPENDIX B (Cont'd)

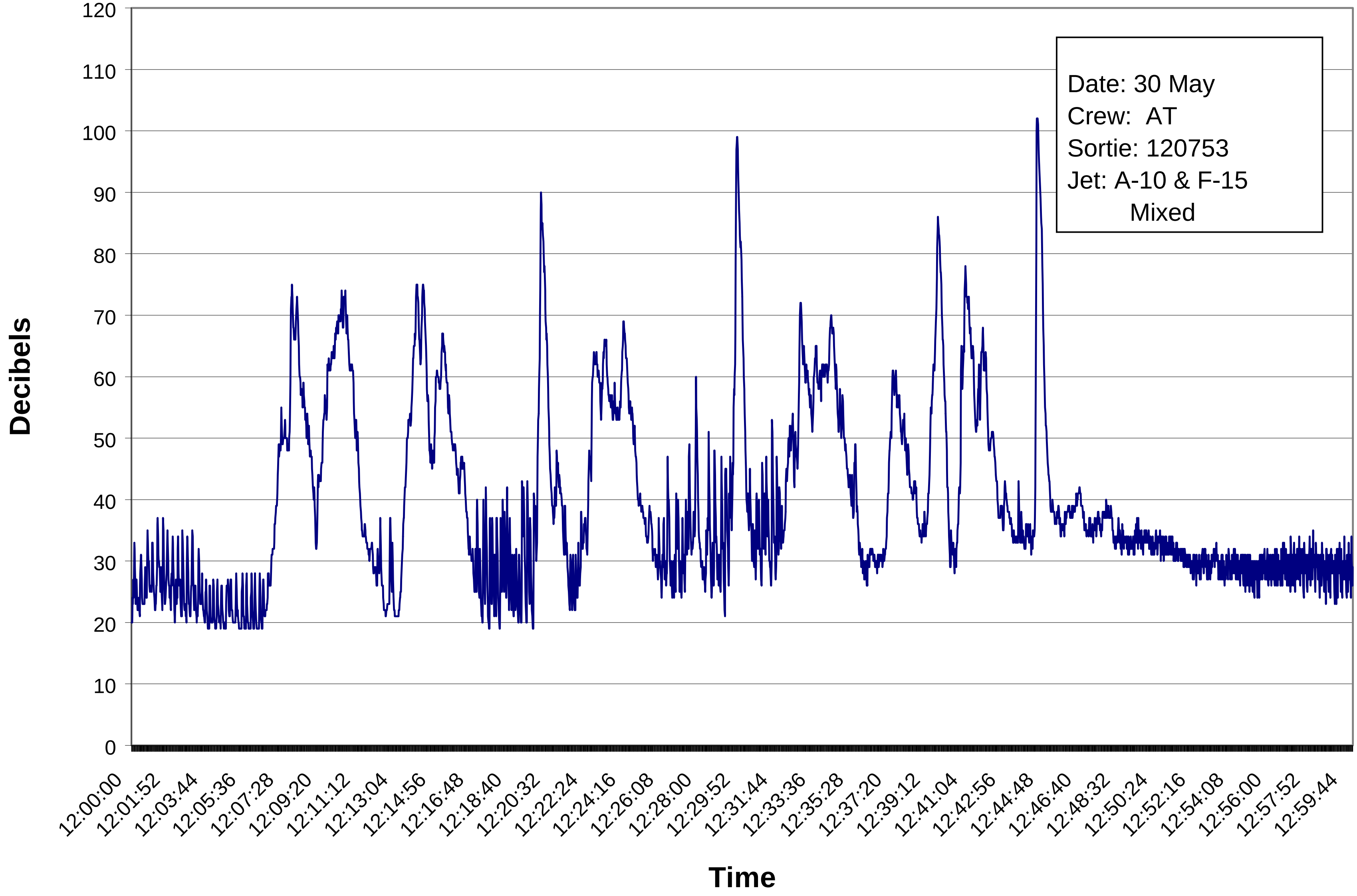


APPENDIX B (Cont'd)

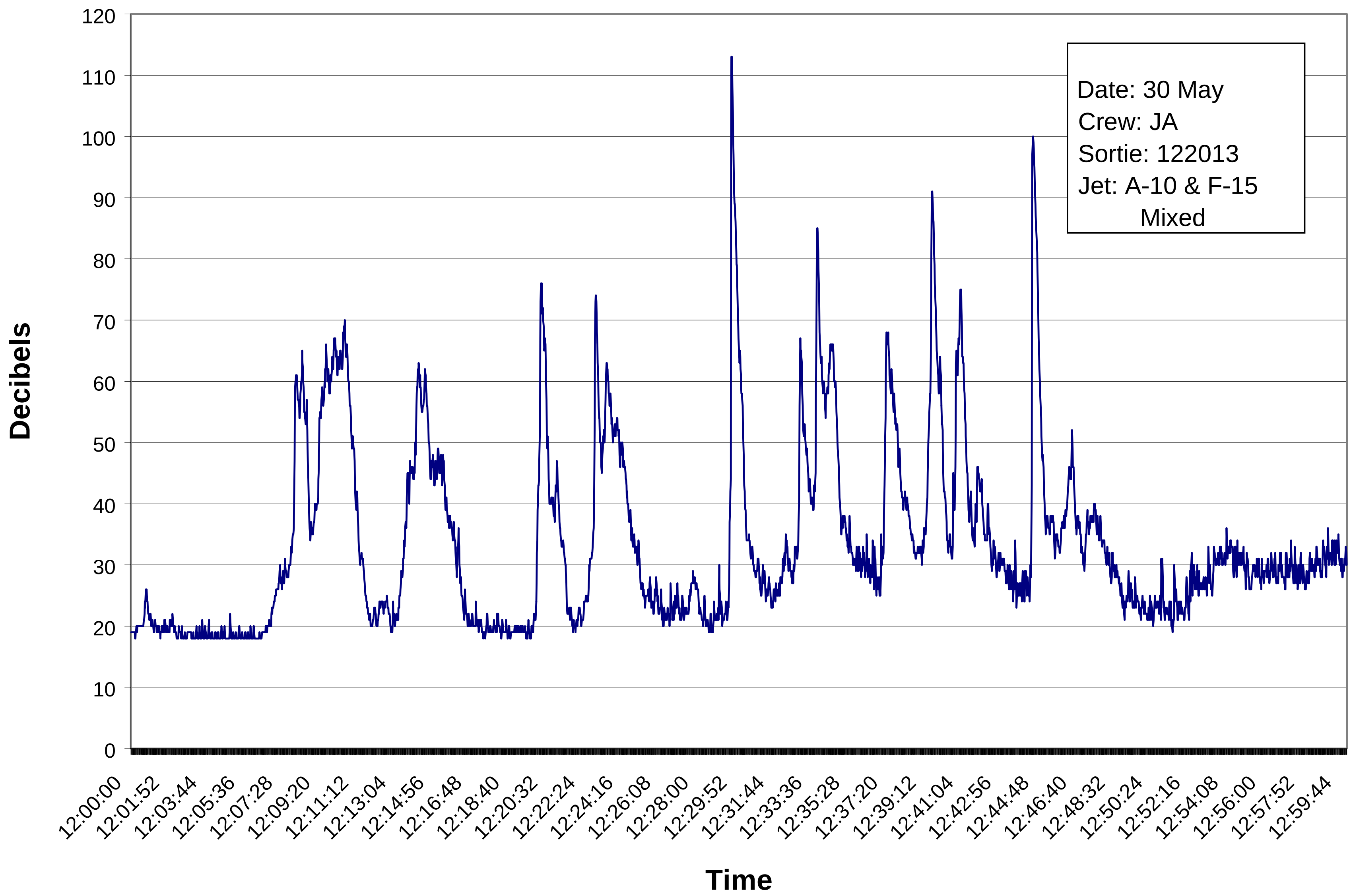


APPENDIX B (Cont'd)

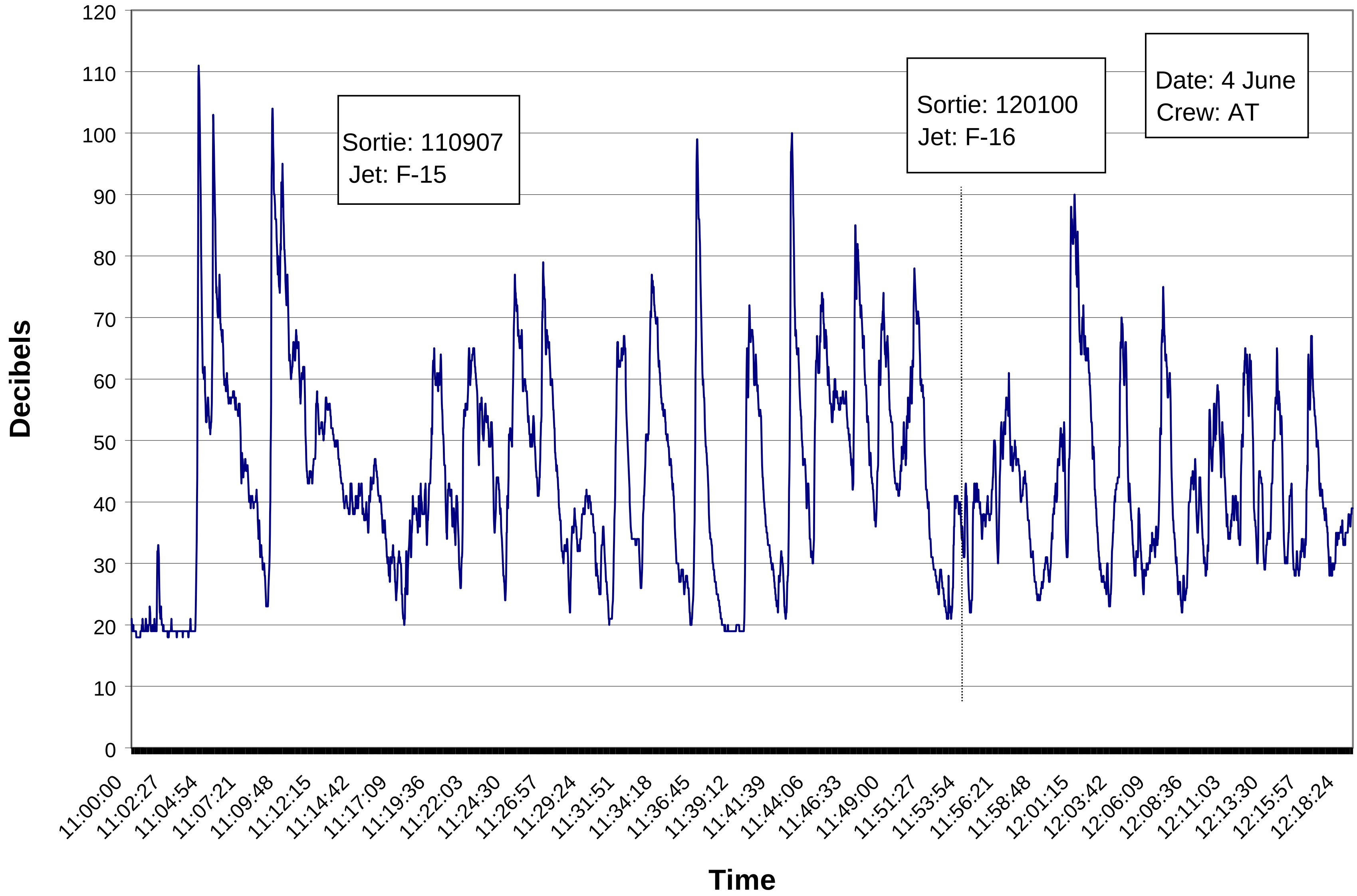



120
110
100
90
80
70
60
50
40
30
20
10
0
Decibels
Date: 30 May
Crew: AT
Sortie: 120753
Jet: A-10 & F-15
Mixed
12:00:00
12:01:52
12:03:44
12:05:36
12:07:28
12:09:20
12:11:12
12:13:04
12:14:56
12:16:48
12:18:40
12:20:32
12:22:24
12:24:16
12:26:08
12:28:00
12:29:52
12:31:44
12:33:36
12:35:28
12:37:20
12:39:12
12:41:04
12:42:56
12:44:48
12:46:40
12:48:32
12:50:24
12:52:16
12:54:08
12:56:00
12:57:52
12:59:44
Time

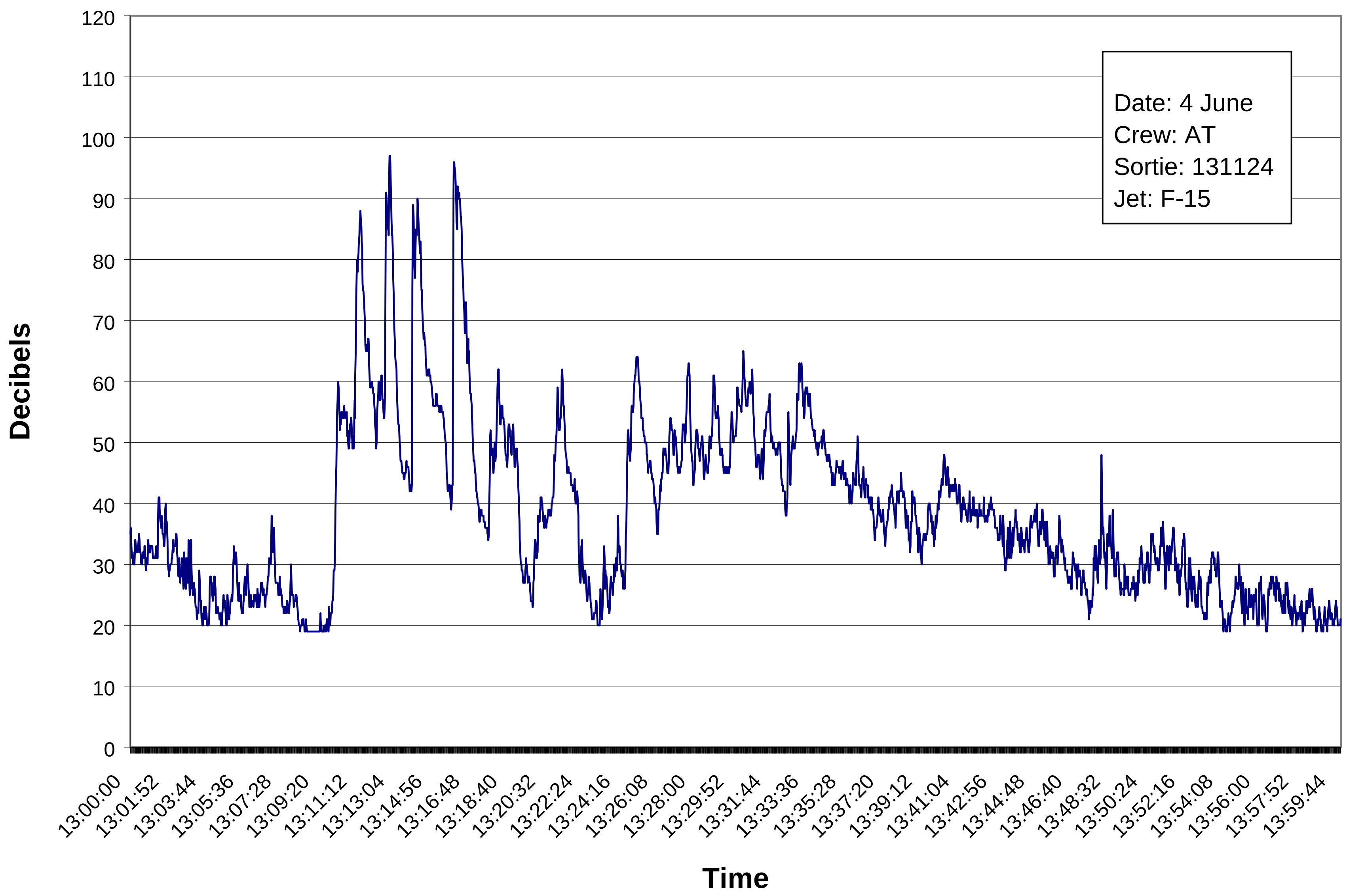
APPENDIX B (Cont'd)

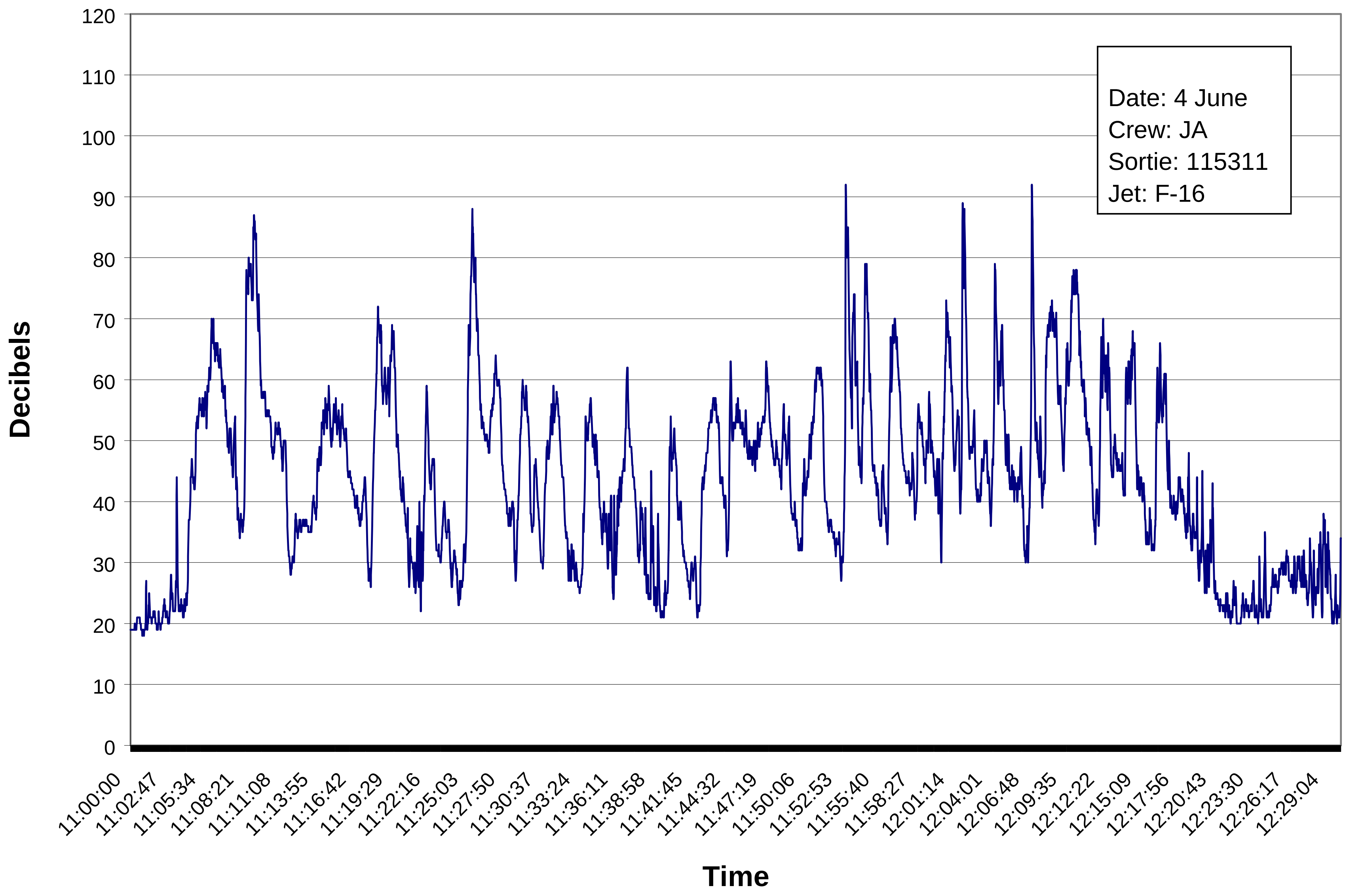


APPENDIX B (Cont'd)

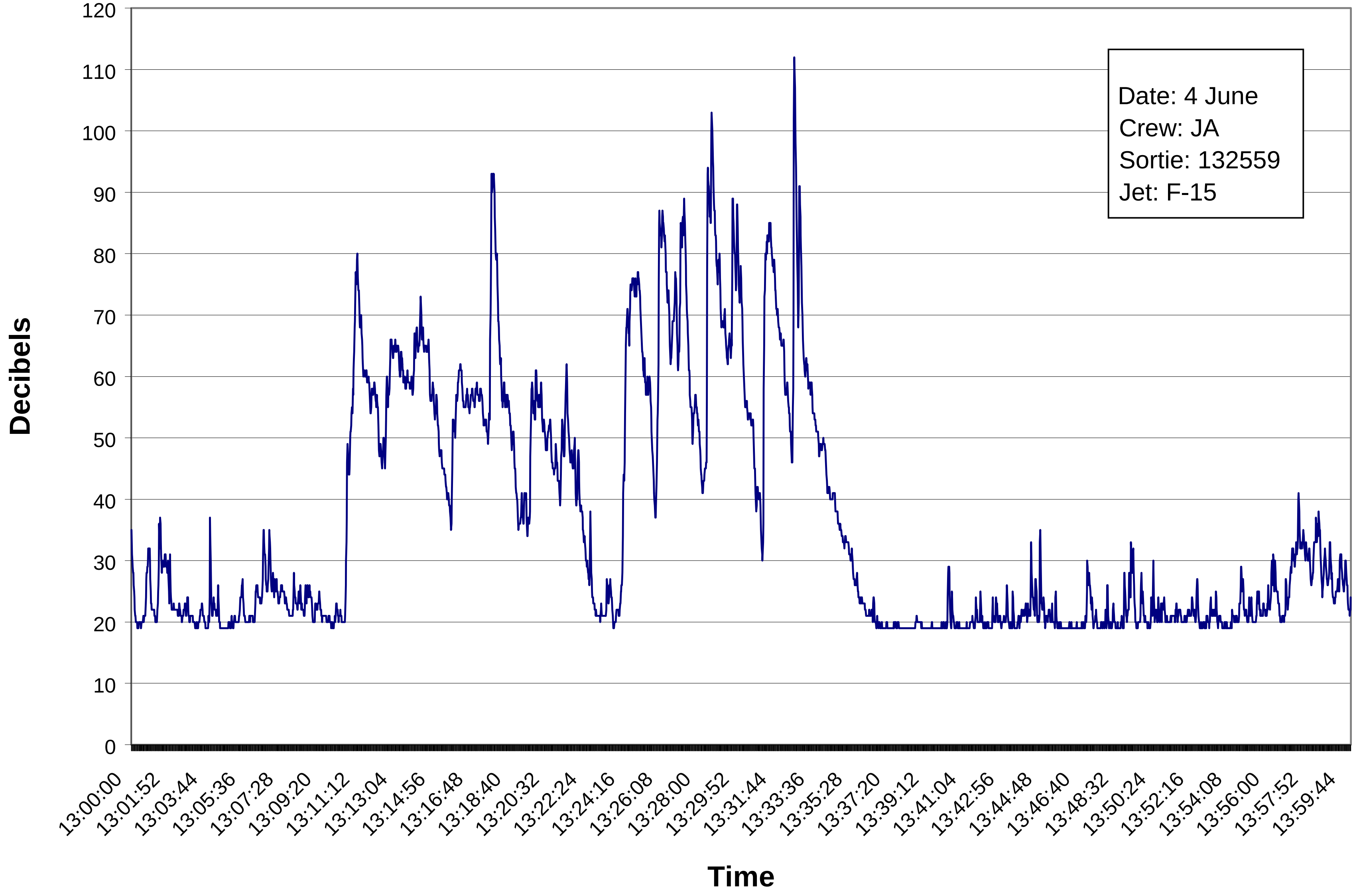


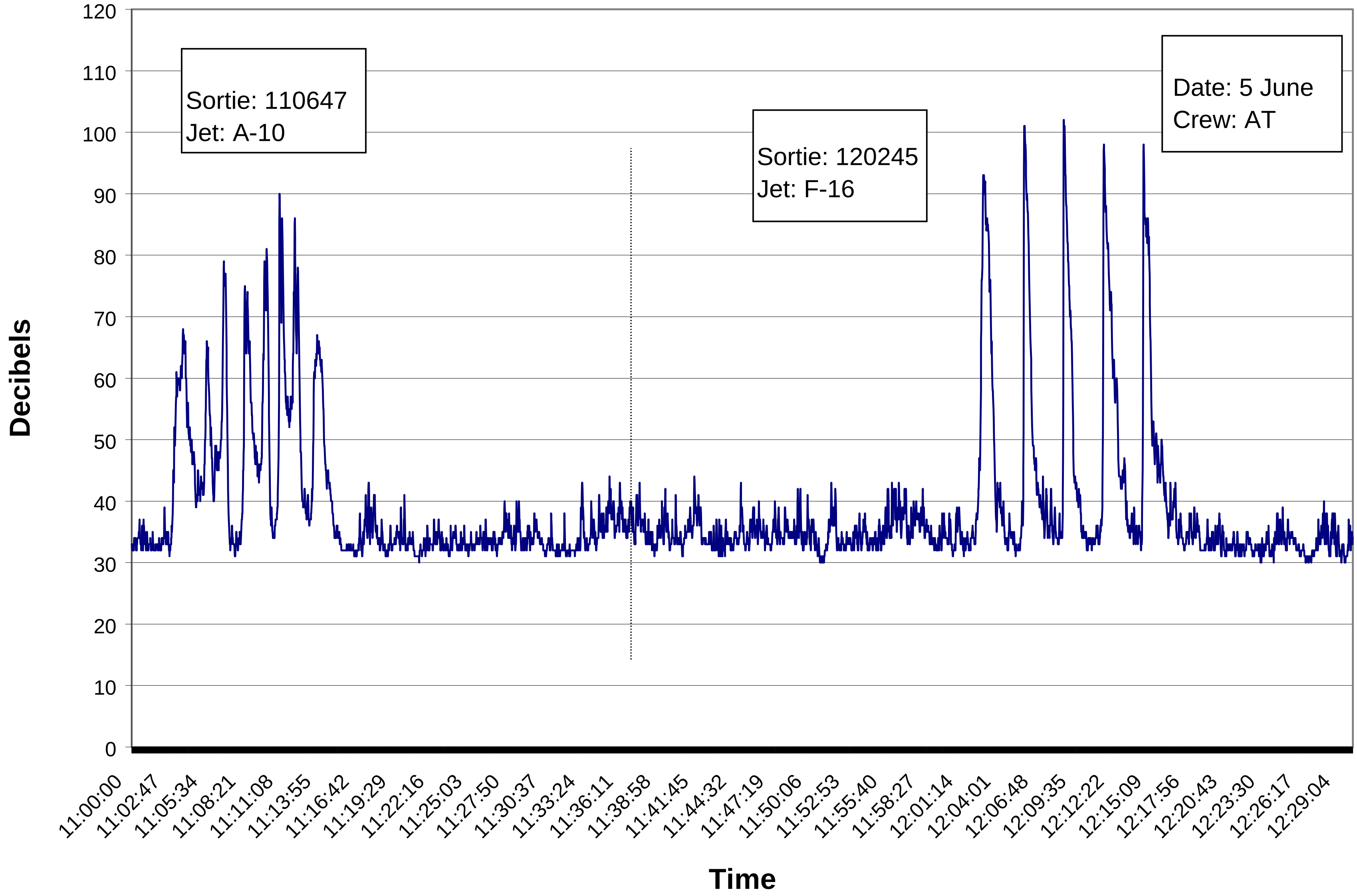
APPENDIX B (Cont'd)




Date: 4 June
Crew: JA
Sortie: 115311
Jet: F-16
Decibels
0
10
20
30
40
50
60
70
80
90
100
110
120
Time
11:00:00
11:02:47
11:05:34
11:08:21
11:11:08
11:13:55
11:16:42
11:19:29
11:22:16
11:25:03
11:27:50
11:30:37
11:33:24
11:36:11
11:38:58
11:41:45
11:44:32
11:47:19
11:50:06
11:52:53
11:55:40
11:58:27
12:01:14
12:04:01
12:06:48
12:09:35
12:12:22
12:15:09
12:17:56
12:20:43
12:23:30
12:26:17
12:29:04

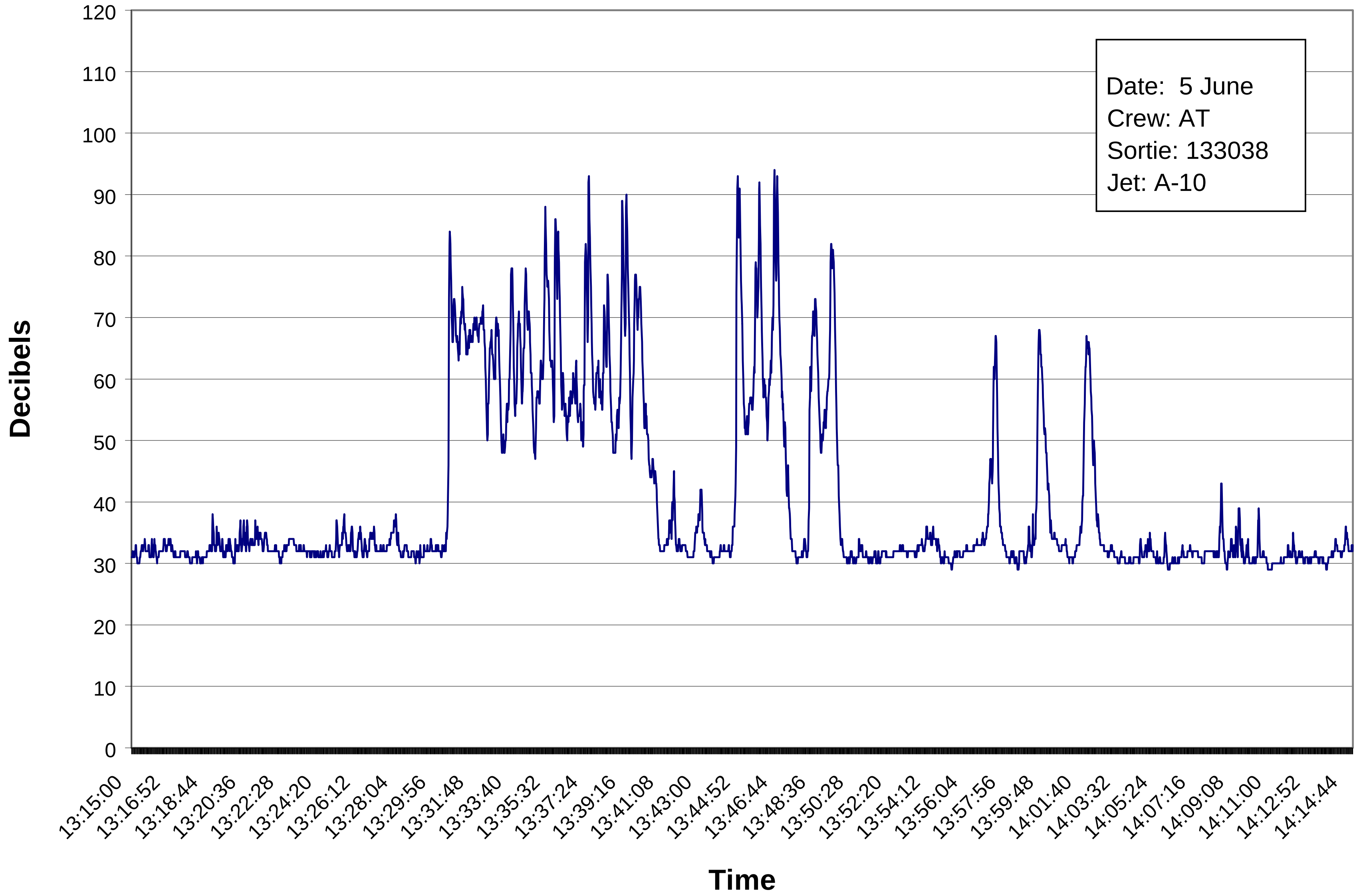
APPENDIX B (Cont'd)





Sortie: 110647
Jet: A-10
Sortie: 120245
Jet: F-16
Date: 5 June
Crew: AT
Decibels
120
110
100
90
80
70
60
50
40
30
20
10
0
11:00:00
11:02:47
11:05:34
11:08:21
11:11:08
11:13:55
11:16:42
11:19:29
11:22:16
11:25:03
11:27:50
11:30:37
11:33:24
11:36:11
11:38:58
11:41:45
11:44:32
11:47:19
11:50:06
11:52:53
11:55:40
11:58:27
12:01:14
12:04:01
12:06:48
12:09:35
12:12:22
12:15:09
12:17:56
12:20:43
12:23:30
12:26:17
12:29:04
Time

APPENDIX B (Cont'd)



APPENDIX B (Cont'd)