ASSESSING NOCTURNAL BIRD AND BAT MIGRATION PATTERNS ON THE CAPE MAY PENINSULA USING MARINE RADAR: POTENTIAL EFFECTS OF A SUSPENSION BRIDGE SPANNING MIDDLE THOROUGHFARE, CAPE MAY COUNTY, NEW JERSEY

FINAL REPORT

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EXECUTIVE SUMMARY

- This report presents results of a study whose primary goal was to quantify nocturnal bird and bat movement patterns during peak migration periods in the coastal region of Cape May County, New Jersey. The project was initiated to support decisions regarding construction of a replacement bridge across Middle Thoroughfare that connects the mainland to the southern end of Seven-Mile Island. Specifically, our objectives were to (1) quantify nightly and seasonal passage patterns in birds/bats flying through the three study areas, (2) quantify altitudinal distributions of bird/bat movements and determine what proportions occur in different altitudinal strata, (3) determine flight directions of bird/bat targets and (4) investigate how meteorological conditions may affect movement density/rates, altitudinal distributions and flight directions.

- The study was conducted during the spring (47 nights, 15 Apr - 31 May) and fall (122 nights, 1 Aug - 30 Nov) of 2005. We used a dual marine radar system configured to collect data on the passage magnitude, altitude and flight direction of birds and bats. The radar system was located at Atlantic Cape Fisheries, along the western shore of Middle Thoroughfare. The radars sampled the air space out to one nautical mile in horizontal range and 0.75 nautical miles in vertical range. During the fall 2005 period, various problems (e.g., radar malfunction, loss of power) fog resulted in data loss on eight nights. Heavy and persistent fog caused data contamination that could not be effectively removed on another five nights. Thus, only 109 nights of data were included in our summaries and statistical analyses for the fall period.

- We found that average nightly target (i.e., birds, bats) passage was significantly greater in fall (2070.51 ± SE 242.69) compared with spring ($\bar{x}$ = 1,313.17 ± SE 171.23, $F_{1,154}$ = 4.41, P = 0.04), although passage rates (90/km/hr in spring, 116.16 targets/km/hr in fall) were not statistically different. In both seasons, passage was highly variable among nights we sampled. In spring, the sum of the sample means for the entire season (i.e., average targets detected during each 10 minute sample, summed for over an entire night then across the entire season) was nearly 62,000. Peak periods of passage in spring occurred around the middle of April and again in the middle of May. In fall, the sum of the sample means across the entire season was nearly 233,000. Peak migration episodes occurred throughout September and then again from the middle of October into early November.

- Passage rates observed during our study were generally lower than reported in several other studies conducted in the northeast (150-200 targets/km/hr). However, most studies we reviewed for comparison conducted radar observations for considerably shorter periods during a given season than our Cape May study. Generally, other studies focus on what is assumed to be the peak of migration movement for a given season (e.g., September and October during fall migration. Additionally, many of the studies we reviewed began their radar observations approximately one hour after sunset and continued for approximately six hours, far less than the average number of hours/night we made radar observations (i.e., $\bar{x}$ = 14 hrs in spring, $\bar{x}$ = 16.3 hours in fall).

- Differences in nightly and seasonal radar observation periods are noteworthy and must be accounted for when comparing target passage rate estimates among studies. Target passage rate estimates that include significant sampling during seasonal and nightly non-peak periods of migration, as in our study, likely are lower than those reported from studies with markedly fewer hours of observation and that focused on peak migration periods. Additionally, extending nightly and sampling periods (i.e., pre sunset to post sunrise) can provide insight into times of day when bird and bats are most vulnerable (e.g., during take off and landing).

- Nightly temporal patterns in passage were similar in spring and fall. That is, we observed a marked increase in detected targets during the first hour after sunset. Target detection increased rapidly afterward and peaked 2-3 hours after sunset. Detections then gradually declined in subsequent hours until sunrise the following morning.

- The proportion of targets detected in the 0-100 m arl and the 101-200 m strata were highly variable during spring and fall data collection period. The proportion of targets detected in the 0-100 m arl stratum was significantly greater in spring ($\bar{x}$ = 0.23, 10,716 total targets) compared with fall ($\bar{x}$ = 0.06, 9,324 total targets). Similarly, the proportion of targets detected in the 101-200 m arl stratum was significantly greater in spring ($\bar{x}$ = 0.22, total 13,879 targets) compared with fall ($\bar{x}$ = 0.14, 29,109 targets). The proportion of targets we detected flying at or below 100 m in spring was greater than those reported by other radar studies we reviewed. Conversely, the proportion we detected in this altitudinal strata during fall was among the lowest reported. Across both seasons we detected more than 62,000 targets flying at or below 200 m.

- Problems with extensive ground clutter hampered our ability to generate hourly and nightly mean vectors (directional tendency) and vector lengths (r, strength of directional tendency) because of too few samples. Given this, we calculated a mean vector and vector length for each season. Flight directions of targets were primarily northeasterly for the spring migration study period. In fall, target flew primarily in a southwesterly direction. Directional tendencies were statistically significant for both seasons.

- Our results suggest that synoptic (i.e., regional-scale) weather patterns are important determinants of variation in the flight dynamics and behavior patterns we observed. Pressure systems (i.e., highs, lows) and frontal boundaries that produced winds that would vector birds and bats toward their seasonally appropriate goals (i.e., northerly in spring, southerly in fall) resulted in greater numbers of detected targets, on average, than when these conditions were not occurring. Similarly, we detected greater numbers of targets in the two lowest altitudinal strata we considered ((i.e., $\leq$ 100 m, >100 m and $\leq$ 200 m) when regional-scale weather patterns were favorable for passage.

- *A priori*, we identified what we believed were three weather variable groups that migrating birds and bats likely respond to: (1) cloud condition, visibility and precipitation, (2) temperature, dew point and barometirc pressure (mb) and (3) wind speed and direction. Because wind direction is a circular variable and thus problematic

when used in linear statistical analyses, we used tailwind/headwind vector (THV). This metric combines wind direction relative to an individual's assumed directional goal with wind speed to produce a single, non circular variable. We also considered side wind vectors (SWV), which is the calculated wind vector along an axis perpendicular to assumed direction of migration.

- Using an information theoretic approach to model selection, we found that in spring, THV/SWV models had the strongest support as determinants of passage magnitude and the proportion of detected targets occurring in the two lowest altitudinal strata we considered (i.e., $\leq$ 100 m, >100 m and $\leq$ 200 m). Our analyses suggest that when winds blew in the direction of the assumed migration goal and from the east (i.e., positive THV and SWV values), migration passage increased. For flight altitude, the proportion of targets detected at or below 100 m increased when winds became more opposing (i.e., negative THV and SWV values).

- In fall, "cloud cover/precipitation" and "cloud ceiling/visibility," models performed best and equally well as determinants of target passage and the proportion of targets detected in the $\leq$ 100 m stratum. Parameter estimates suggest that target passage increased when cloud cover was low, precipitation was absent, cloud ceiling was high and visibility was good. These characteristics typically are apparent after the passage of a cold front, which also accompanied by northerly or westerly winds. Conversely, decreases in cloud ceiling and increases in cloud cover (i.e., the only significant parameters) resulted in greater proportions of targets detected in the $\leq$ 100 m stratum.

- Differences between spring and fall results with respect to the importance of wind conditions may be related to the need for individuals to arrive on the breeding grounds (i.e., spring migration) in good energetic condition to improve reproductive output. This would put a premium on selecting wind conditions that would vector an individual towards its goal using the least amount of energy (i.e., tailwinds blowing from the appropriate direction). This requirement is not in effect during southbound passage to the wintering grounds. Additionally, the fall passage period includes a large proportion of naive migrants (i.e., recently hatched birds) making their first trip south. Naive migrants may respond less effectively to weather conditions conducive to migration.

- Despite some limitations, we believe this study was successful in documenting key elements of bird and bat flight dynamics and behavior during their north and southbound migrations through the southern end of Cape May Peninsula. We believe the results reported here will prove useful in future decisions about the type of bridge to be constructed across Middle Thoroughfare and for the development of wind resources in the region. Furthermore, our results shed light on meteorological conditions that modify flight dynamics and behavior and suggest when birds and bats may be at greatest risk from collision with tall structures along their migration routes.

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1.0 INTRODUCTION

Over the last two decades, construction of tall structures (e.g., digital television towers, wind turbines, cellular phone towers) the penetrate the lower strata of the atmosphere (i.e., up to 1000 feet) has increased at a rapid rate (Shire et al. 2000, National Research Council 2007). Demands for improved communications capabilities and alternative energy has spurred this growth, not only in the number of tall structures, but their overall height.

Several studies have documented that significant bird mortality at tall communication towers (Crawford, 1981, Kemper 1996) and the USFWS estimates that between four and five million birds are killed each year (Manville 2000). Studies conducted at wind power projects in different regions, sited in different habitat types and with varying configurations indicate that the potential for collision incidents between aerial vertebrate biota (i.e., birds, bats) and wind turbines exists (e.g., Orloff and Flannery 1992, Johnson et al. 2002, Kerns and Kerlinger 2004, Fiedler et al. 2007, *cf* citations in Arnett et al. 2008) to varying degrees, but most frequently involves nocturnally migrating passerines and bats (Kunz et al. 2008). Other structures that penetrate the air space used by aerial vertebrates, such as buildings and power lines also are known to cause mortality during episodic migration events (*cf* citations in Erickson et al. 2005 regarding bird mortality).

In 2005, New Jersey Audubon Society undertook a project to assess flight dynamics and movement patterns of aerial vertebrates during spring and fall migration periods. The intent of this work was to provide information that could be used to support the selection of a bridge design planned for construction in southern Cape May County, New Jersey. The bridge would span Middle Thoroughfare, a waterway approximately 300 m wide that separates the mainland of Cape May Peninsula from the southern end of Seven-Mile Island. Two bridge designs under consideration were: (1) Cable-stayed type. This design would require two support stanchions that rise approximately 100 m above water level and includes approximately 100, one-foot diameter cables emanating from the stanchions to support the road bed. (2) Segmental type. This design would require 16 or more stanchions to support the road bed, which would rise approximately 30 m above water level.

Environmental concerns over the bridge's design were focused primarily on the potential affect the cable-stayed bridge's stanchions and network of cables might have on migrating birds and bats. The southern region of New Jersey, especially the Cape May Peninsula, is widely recognized as one of the most important migration corridors in the northeast for birds during passage between northern latitude breeding grounds and non breeding areas in the subtropical and tropical Americas. Similar to other tall structures such as wind turbines, guy-wired communication towers or tall buildings, a cable-stayed bridge might impede movement of birds and bats and this could result in collisions. The following report describes the study conducted by New Jersey Audubon Society and analysis results, followed by a discussion of those results in the context of collision risk.

2.0 GOALS AND OBJECTIVES

The goal of this project was to understand bird and bat movement patterns on the Cape May Peninsula. The project was initiated to provide data and analyses that could be used to assess the potential affects of a tall structure (i.e., a cable-stayed bridge) on birds and bats during passage migration through the lower Cape May Peninsula. Specifically, our objectives were to (1) quantify nightly and seasonal density and passage rate patterns in birds/bats flying through study areas, (2) quantify altitudinal distributions of bird/bat movements and determine what proportions occur in different altitudinal strata (e.g., 0-100 m, 101-200 m), (3) determine flight directions of bird/bat targets and (4) investigate how meteorological conditions may affect movement density/rates, altitudinal distributions and flight directions.

3.0 METHODS

3.1 *Data collection protocol*

We used two 25 kW Furuno X-band marine radars (frequency = 9410 GHz, wavelength = 3 cm, model # FAR2127BB, Furuno Electric Company, Nishinomiya, Japan) operating simultaneously (Fig. 1) to monitor various aspects of bird and bat flight behavior and dynamics. Each radar was fitted with a standard 6.5' open array antenna, which produces a fan-shaped electromagnetic beam 1.23° x 20°.

One radar unit operated with the antenna rotating in the horizontal plane or "surveillance" mode , describing a 360° arc every 2.5 seconds. Data collected in this mode provided counts of target passage and estimates of target flight direction and velocity (Fig. 2). The second radar's antenna rotated in the vertical plane (Fig. 1). This is accomplished by mounting the antenna turning unit perpendicular to the ground. In this mode, the radar monitors the altitudinal distribution of targets and passage density/rates. The antenna sweeps from the eastern to the western horizons, describing a 180° arc above radar level (arl), 20° wide (Fig. 3). To avoid spurious target propagation, the radar does not transmit when the antenna is pointing toward the ground. We anticipated that the radar's orientation (i.e., facing north, antenna sweeping east to west) would maximize the number of target detections along the predominantly north/south axis of bird migration.

The radars' pulse lengths can be set from 0.07 - 1.2 μsec and detection ranges from 0.125 - 96 nautical miles (nm). For both radars we used a 0.15 μsec pulse length. Short pulse lengths provide better target resolution and more accurate location and distance estimates. Similarly, short detection ranges result in improved resolution of small passerine or bat-sized targets. Data collected during previous studies suggested that small target detection drops off markedly between 0.75 and 1.0 nm from the radar. Given this, we set the radar's detection range to 0.75 nm for the vertically oriented radar and 1.0 nm for the radar oriented horizontally. The radars we used feature color-coded target representation that indicates return signal strength. This allows for discrimination of weak reflectors that could be insects. The radar units are also equipped with integrated global positioning systems (GPS) and target tracking features that allows us to determine each target's coordinates and quantify target flight directions.

Each radar's processor unit was connected directly to a computer equipped with a PCI frame grabber circuit board. Using proprietary scheduling software, we automatically captured a user-defined number of consecutive radar sweeps as bitmap image files (Fig. 4) at any interval and for any period. Typically we collected five consecutive radar sweep images every 10 min, from approximately two hours before sunset to two hours after sunrise the next morning (~420 images/night/radar). We chose 10 min intervals because this insured total turnover of targets between samples. If target's minimum air speed was 20 mph, then it would take 6 min to cross the widest part of our sample area (i.e., two nautical miles).

3.2 *Study site and data collection time frame*

We collected data on Cape May Peninsula at the Atlantic Cape Fisheries, located along the western shore of Middle Thoroughfare (38°57.5'N 74°52.5'W, Fig. 5). Approximately 20 tractor trailers, numerous buildings, several dozen commercial fishing boats and the Garden State Parkway were within the horizontally oriented (i.e., surveillance) radar's field of view (Fig. 6A). Additionally, the U.S. Coast Guard's Loran navigational tower and its >50 transmission and guy wires at the southern end of "Seven Mile Island" were in the radar's sweep area. All these objects obstructed and reflected energy transmitted by the radar operating in "surveillance" mode creating extensive ground clutter and intermittent spurious propagation. To ameliorate these problems we built a radar fence before the beginning of the fall data collection period to obstruct transmission and reception of radar's electromagnetic energy below the scanning horizon. This reduced ground clutter and unwanted propagation but did not eliminate it completely (Fig. 6B). Eventually, however, we removed the fence because we believed it was interfering with the overall detection of targets by the horizontally-oriented radar.

Data collection began approximately two hours before sunset and continued to approximately two hours after sunrise the following morning. We selected this time interval to document dusk and pre dawn movements of birds to and from foraging areas, the onset of nocturnal migration events and the full temporal pattern of those events. During spring 2005 we collected data on 57 nights from 5 Apr - 31 May. However, data capture from 5-14 April was restricted to the first 3-4 hours after sunset because of problems with the data collection software provided with the PCI frame grabber circuit board. These problems limited the number of radar images captured to 50 during nightly sessions and consequently these data were not used in analyses. In consultation with Foresight Imaging, the PCI board's manufacturer, we made major modifications to the software to rectify the problem. Afterwards, three consecutive data images were collected every 10 min from 15 Apr - 15 May. For the remainder of the spring we collected five consecutive images during each 10 min sample period. All results reported herein are based on data collected 15 Apr - 31 May. In fall 2005, we collected five images every ten minutes from 1 Aug - 30 Nov. Data were not collected on three nights because of power failure and on five nights because of radar malfunction.

3.3 *Data Processing and Analysis*

In spring 2005, we reviewed 656 hrs ($\bar{x}$ = 14.0 hr/night, Table 1, ~14,500 images/radar) and 1890 hrs in fall ($\bar{x}$ = 16.30 hr/night, Table 2, ~56,000/radar in fall) to determine occurrences of bird/bat movement episodes and identify precipitation events, insect contamination or any other

unwanted propagation. Precipitation and insects typically have distinct characteristics that allow trained observers to distinguish them from bird and bat targets. Data images with precipitation, insect contamination or any other unwanted propagation were removed from subsequent data analyses either using data processing software developed by NJAS or by manually removing images from data set before analyses. In extreme cases, we removed entire nights of data from analysis. Specifically, data collected from 21-25 August were not used in any analyses reported here because of persistent contamination from fog (Table 2). This coupled with mechanical problems (see previous paragraph) meant that only 109 nights of data were analyzed.

3.3.1 Vertically-oriented radar

Using image processing software developed by New Jersey Audubon Society staff, we extracted target information from all data images collected with the vertically-oriented radar during fall 2005. The integrated image processing software:

1. Identifies the sample area (Fig. 7A) and creates a template (Fig. 7B) to remove stationary radar reflectors (i.e., ground clutter, main bang,).
2. Removes targets with low signal strength likely to be insects (i.e., based on color value).
3. Smooths the data and locates and marks the centroid of each discrete target that remains
4. Exports a text file that includes information on every target's signal strength and its position (i.e., the distance of its centroid) in the *X*- and *Y*-planes relative to the radar's position
5. Outputs a bitmap image showing the transformed data with marked targets (Fig. 8). This last feature allows us to review the data processing output to identify possible spurious targets and manually remove them from the data analysis step.

Using an analysis software program developed by NJAS staff, we summarized passage density/rate information and altitudinal distribution (i.e., target position in the *Y*-plane relative to radar's position) for 10 min and hourly intervals. The program also has a threshold feature that allowed us to filter out data with unusually high target counts, typically indicating rain. The software's output includes the total number of targets detected in each image and the mean number of targets detected in each three- or five-image sample.

The results of analyses reported here are based on the average for each three- or five-image sampling bout. These values are summed for the entire night's data collection (sum of the sample means, SSM) to generate a passage estimate. We believe SSM is a more accurate assessment for the number of targets crossing through the study area because it minimizes the effect of enumerating the same targets multiple times during a single sampling bout. Analyses to quantify variation in target counts in successive images in a sampling bout indicated that coefficients of variation (CV) were very low (< 2%).

The software also quantifies the number of targets detected in discrete altitudinal bins (e.g., 100 m). It also has a threshold feature that allows us to filter out data with unusually high target counts, typically indicating precipitation or insect contamination. The threshold used, number of images exceeding the threshold and number of images used in the analysis also are part of the program's output.

We used one-way analysis of variance (ANOVA, Zar 2003) to investigate between-season differences in targets detected and proportion of targets detected in different altitudinal strata (below 100 m, below 200 m and between 100 and 200 m). We used linear regression to investigate relationships between nightly targets detected and the proportion of targets detected in the two lowest altitudinal strata (i.e., 0-100 m, 101-200 m). In all analyses involving proportions we used arcsine transformations (Zar 2003) to meet assumptions of normality.

3.3.2 Horizontally-oriented radar

We used NJAS-developed software to calculate target directions from images collected with the horizontally-oriented radar (see Fig. 4 example). The program requires that the end of a target's trail and the target (in that order) be marked manually using the computer's mouse and cursor (Fig. 9). The program outputs the position of the trail's tail and the target and from these calculates the target's direction of movement. We analyzed one image for each hour of each night data were collected. Problems with extensive ground clutter hampered our ability to generate hourly and nightly mean vectors (directional tendency) and vector lengths (r, strength of directional tendency) because of too few samples. Given this, we calculated a mean vector and vector length for each season and evaluated statistical significance using Rayleigh's Z test (Zar 2003).

3.4 *Weather patterns and bird/bat flight dynamics*

3.4.1 Synoptic weather

We used National Weather Service (NWS) surface weather maps (Fig. 10) generated at 0000 Greewich Mean Time (GMT, 2000 Eastern Standard Time) to determine the position of synoptic weather systems (i.e., large scale atmospheric condition) relative to the study area. In this analysis we used Cape May peninsula. The position of the reference location was then plotted on a generalized synoptic weather map (Fig. 11, after Richardson 1976, Lank 1983). For statistical purposes, we defined five synoptic regions on the synoptic map based on geostrophic wind patterns (Table 3). We used one-way Likelihood Ratio χ^2 tests (Zar 2003) to determine if nightly target passage and target altitudes in spring and fall were significantly different under the five synoptic weather conditions.

Additionally, we used two-way Likelihood Ratio χ^2 tests (Zar 2003) to investigate whether season-specific proportions of targets detected under each of the five synoptic conditions during or the proportion of targets flying in the two lowest altitudinal strata (i.e., $\leq$ 100 m arl and 101-200 m arl) were significantly different than the proportional occurrence of synoptic weather conditions. For example, if target movement patterns were related to synoptic weather patterns, then we would expect that the proportion of targets detected (i.e., relative to all targets detected during a specific season) across the five synoptic weather conditions would be statistically different than the proportional occurrence of the five synoptic weather conditions. We would infer from this result that movement patterns occurred disproportionately under certain synoptic conditions relative the occurrence of those conditions.

3.4.2 Local weather

For all analyses, we used local climatological data for Cape May County Airport, NJ (39° 0.57.5'N, 74° 54.88'W), purchased from the NWS National Climatic Data Center web site

(http://www.ncdc.noaa.gov/oa/ncdc.html). We selected this station because of its proximity to our study site (~4.1 miles) and its consistent data availability during the study period.

We used Generalized Linear Models (GLM) to investigate relationships between several weather variables (Table 3) and bird/bat flight dynamics response variables (i.e., migration magnitude, altitude, flight direction). *A priori*, we identified what we believed were three weather variable groups that migrating birds and bats likely respond to: (1) cloud cover, ceiling, visibility and precipitation, (2) dry bulb temperature (C°), dry bulb dew point (C°) and barometirc pressure (mb) and (3) wind speed and direction (see Table 4 for descriptions of each variable). Given the difficulty using circular data (e.g., wind azimuths) in linear statistical analyses (Mardia and Jupp (2000) we calculated headwind/tailwind vectors (THV) and sidewind vectors (i.e., SWV, vectors perpendicular to the assumed direction of migration) using an equation proposed by Piersma and Jukema (1990):

$$THV = W\cos\alpha + \sqrt{\{A^2 - (W\sin\alpha)^2\}} - A,$$

where W is the wind velocity, A is the bird's air velocity, and α is the difference between wind direction and the assumed direction of migration ± 180° (see Appendix 1 for derivation of equation). Using wind vectors effectively resolves the circular variable, wind azimuth, into its rectangular components (i.e., cosine and sine), and incorporates wind speed. Thus, this conversion provides a way to examine the entire affect of wind on migratory behavior. This particular wind vector equation assesses wind conditions relative to the assumed axis of migration. Based on our analyses of flight directions detected by radar during this study, we used "northeast" (i.e., 45°) as the assumed direction of migration in spring and "southwest" (i.e., 225°) in fall. In our analyses we also considered assumed migration directions of "north" (i.e., 0°) in spring and "south" (i.e., 180°) in fall. The combination of THV and SWV for each pair of assumed migration directions (i.e., NE-SW, N-S) were modeled separately to see which performed better at capturing variance in bird/bat flight dynamics response variables.

Prior to GLM procedures, we conducted Pearson's product moment correlation analyses (Zar 2003) to identify weather variables in each grouping that might be intercorrelated. When variables exhibited correlation coefficients greater or equal to 0.5 (i.e., positive or negative) they were not included together in the same model. *Post hoc*, we took an information-theoretic approach (Burnham and Anderson 2002) to evaluate model performance among the multiple models we tested. Models performance was evaluated using Akaike Information Criteria (AIC_c, corrected for small sample sizes). We inferred that models with the lowest AIC_c and that exhibited ΔAIC_c values > 2 compared to the next lowest model AIC_c values to be the best performing.

3.5 *Statistical analysis*

Prior to statistical analyses, response and predictor variables were evaluated to determine if they met assumptions of parametric tests being employed. If assumptions were not met, data were transformed or non parametric tests were used. Based on these assessments we used arcsine transformations to normalize variables represented as proportions (e.g., proportion of targets

detected in various altitudinal strata). We used the log transformation to normalize the response variable representing nightly number of targets detected. Although we present results of statistical analyses that used transformed variables, we present summary statistics (e.g., means, standard errors) for response variables in their untransformed state in textual, tabular and graphical accounts, unless otherwise indicated. All standard statistical analyses were performed using SAS® 9.1 (SAS Institute, Inc. 2004) and SYSTAT® 11.0 (SYSTAT Software, Inc. 2004). Statistical tests involving directional data (i.e., flight direction) were performed using Orianna 2.02© (Kovach Computing Services 2007). Results of statistical tests were considered significant at $\alpha \leq 0.05$.

4.0 RESULTS

4.1 *Target passage*

4.1.1 Spring

1. We detected 242,927 targets during the 47 nights we collected data between 15 April and 31 May (Table 5).
   a. "Sum of the sample means" (SSM) for spring totaled 61,719 targets ($\bar{x}$ = 1313.17 ± SE 171.23, Table 5).
   b. This translated into an average passage rate of 90.23 ± SE 11.62 targets/km/hour during 488 hours of observation (range = 4.71 - 398.16 targets/km/hr)
   c. The median for SSM was 963 targets.
   d. Counts exceeding 2487 targets (i.e., mean + 1 SD) occurred only six times during the season (Table 5).
2. The number of targets detected nightly (i.e., SSM) was highly variable across the season (Fig. 12A). This finding was expected given the variable nature of seasonably favorable meteorological conditions on which migration typically depends.
   a. When averaged over the entire season, nightly temporal variation (i.e., hourly changes) in SSM target counts and proportions showed a distinct pattern (Fig. 12B).
   b. Target counts were moderately high in the first 2 hours before sunset (sunset time = 2000 EDT, 4 hours before midnight), which corresponds to approximately -6 hours before midnight (i.e., "0" on all graphs where time appears on the "X" axis).
   c. Target counts increased markedly ~4 hours before midnight (i.e., ~2 hours after sunset).
   d. Peak counts were attained ~3 hours before midnight and generally were maintained through the first hour after midnight.
   e. Detected target numbers began to decline approximately two hours after midnight and continued until reaching their lowest levels approximately 1 hour after sunrise the following morning.

4.1.2 Fall

1. We detected 1,156,790 targets during the 109 nights we collected data between 1 August and 30 November (Table 6).

a. "Sum of the sample means" (SSM) for fall totaled 225,686 targets ($\bar{x}$ = 2070.51 ± SE 242.69, Table 6).
b. This translated into an average passage rate of 118.33 ± SE 13.17 targets/km/hour during 1891 hours of observation (range = 0 - 686.62 targets/km/hr).
c. The median for SSM was 1122 targets.
d. Counts exceeding 4711 targets (i.e., mean + 1 SD) occurred only 16 times during the season (Table 6).

2. The number of targets detected nightly (i.e., SSM) was highly variable across the season (Fig. 13A). Again, this finding was expected given the variable nature of seasonably favorable meteorological conditions on which migration typically depends.
   a. When averaged over the entire season, nightly temporal variation (i.e., hourly changes) in SSM target counts and proportions showed a distinct pattern (Fig. 13B).
   b. Target counts started relatively low during the first 2-3 hours of the sampling period (i.e., pre sunset), which corresponds to approximately -7 hours before midnight (i.e., "0" on all graphs where time appears on the "X" axis).
   c. They increased markedly ~6 hours before midnight (i.e., ~1 hour after sunset) and continued to increase for several hours.
   d. Peak counts were attained ~1 hours before midnight and generally were maintained through the first hour after midnight.
   e. Target numbers began to decline approximately two hours after midnight and continued until reaching their lowest levels approximately 2 hours after sunrise the following morning, when the sampling period ended.

4.1.3 <u>Comparison between spring and fall flight characteristics</u>

1. SSM was significantly greater in fall ($\bar{x}$ = 2137.09) compared with spring ($\bar{x}$ = 1313.17, $F_{1,154}$ = 4.41, P = 0.04).
2. Target passage rates were not significantly different between seasons (spring: $\bar{x}$ = 90.23/km/hr, fall: $\bar{x}$ = 116.16/km/hr, $F_{1,154}$ = 1.47, P = 0.23)

4.2 *Flight altitude*

4.2.1 <u>Spring</u>

1. The number of targets detected nightly in the 0-100 m and 101-200 m strata was highly variable across the season (Fig. 14A, see Appendix 2 for target counts of all strata).
   a. When we averaged across the entire season, the 101-200 m arl (i.e., above radar level), stratum had the highest overall proportion of targets detected and proportions declined asymptotically up to 1400 m arl (Fig. 14B).
   b. Proportions of targets detected in the 0-100 m and the 101-200 m arl strata were 0.16 (~10,716 targets) and 0.22 (~13,879 targets) respectively (Table 5, Fig. 14B) of the total detected targets.
   c. Furthermore, targets detected within 300 m arl accounted for over 57% of all targets detected (36,304 targets, Table 5).

2. When averaged over the entire season, nightly temporal variation (i.e., hourly changes) in the proportions of targets detected in the 0-100 m and the 101-200 m arl strata showed distinct patterns (Fig. 15A).
   a. Proportions appeared highest (~0.40) in the early hours of the nightly sampling period, from about 1-2 hours before sunset until about 1-2 hours after sunset.
   b. The proportion declined sharply afterwards, and continued at comparatively low levels (~0.20) until about 4 hours before the sampling period ended.
   c. The hourly temporal pattern for targets detected in the 101-200 m stratum was distinctly different from the one apparent for the 0-100 m stratum (Fig. 15A).
   d. The proportion was lowest during the first hour of sampling, then increased and remained relatively constant (~0.20-0.25) throughout the nightly sampling period until the last hour, when the proportion increased sharply
3. When averaged across the entire season, nightly temporal variation in the number of targets detected in the 0-100 m and 101-200 m arl showed distinct patterns (Fig. 15B).
   a. For the 0-100 m stratum, number of targets were highest during the first hour of the nightly sampling period (i.e., before sunset), then decreased by ~50% and remained relatively constant until sunrise.
   b. Average hourly target counts in 101-200 m stratum followed a pattern similar to hourly counts for all altitudinal strata (see Fig. 12B).
      i. Counts were relatively low during the pre sunset hours then rose steadily until two hours before midnight
      ii. Counts leveled off and remained steady until ~1 hour after midnight, when average hourly counts declined steadily until sunrise.
4. It is important to note that averaging or summing over an entire season masks the variability evident in these metrics within a given night and among nights. Appendix 3 shows hourly temporal patterns in passage (Figure A), altitudinal distribution (Figure B) and the proportion and number of targets in the 0-100 m and 101-200 m strata (Figure C and D) for each night of data.
5. We conducted regression analyses to investigate relationships between nightly target passage and the proportion of targets detected in the two lowest altitudinal strata (i.e., 0-100 m, 101-200 m).
   a. Analysis suggested a significant inverse correlation between nightly passage intensity (ln transformed) and the proportion (arcsine transformed) of targets detected in the 0-100 m stratum ($F_{1,45} = 14.65$, $P = 0.0004$, $R^2 = 0.25$, Fig. 15C)
   b. Analysis indicated a non significant inverse correlation between nightly passage intensity (ln transformed) and the proportion (arcsine transformed) of targets detected in the 101-200 m stratum ($F_{1,45} = 1.97$, $P < 0.17$, $R^2 = 0.04$, Fig. 15C).

4.2.2 Fall

1. The number of targets detected nightly in the 0-100 m and 101-200 m strata was highly variable across the season (Fig. 16A, see Appendix 4 for target counts of all strata).
   a. When we averaged across the entire season, the 301-400 m and 401-500 m arl strata had the highest overall proportion of targets detected (~15% in each stratum) and proportions declined asymptotically up to 1400 m arl (Fig. 16B).

b. Proportions of targets detected in the 0-100 m and the 101-200 m arl strata were 0.04 (~9,324 targets) and 0.13 (~29,109 targets) respectively (Table 6, Fig. 16B) of the total detected targets.

c. Targets detected within 300 m arl accounted for over 27% of all targets detected (64,915 targets, Table 6).

2. When averaged over the entire season, nightly temporal variation (i.e., hourly changes) in the proportions of targets detected in the 0-100 m and the 101-200 m arl strata showed distinct patterns (Fig. 17A).

   a. Proportions appeared highest (~0.07-0.09) in the early hours of the nightly sampling period, from about 1-2 hours before sunset until about 1-2 hours after sunset.

   b. The proportion declined afterwards, and continued at comparatively low levels (~0.05-0.06) until about 4 hours before the sampling period ended, at which time proportions increased to levels similar to the early hours of the sampling period.

   c. The hourly temporal pattern for targets detected in the 101-200 m stratum was distinctly different from the one apparent for the 0-100 m stratum (Fig. 17A).

   d. The proportion was high during the first two hours of sampling (i.e., pre sunset, ~0.20)

   e. Afterwards, the proportion decreased dramatically to ~0.14 and this persisted until sunrise, when proportions returned to pre sunset levels.

3. When averaged across the entire season, nightly temporal variation in the number of targets detected in the 0-100 m and 101-200 m arl showed distinct patterns (Fig. 17B).

   a. For the 0-100 m stratum, number of targets were relatively low and remained constant throughout the nightly sampling period.

   b. Average hourly target counts in 101-200 m stratum followed a pattern similar to hourly counts for all altitudinal strata (see Fig. 13B).

      i. Target counts started relatively low during the first 2-3 hours of the sampling period (i.e., pre sunset), which corresponds to approximately -7 hours before midnight (i.e., "0" on all graphs where time appears on the "X" axis).

      ii. They began to increase ~6 hours before midnight (i.e., ~1 hour after sunset) and continued to increase for several hours, reaching an initial plateau at about 4 hours before midnight.

   c. Peak counts were attained ~1 hour after midnight and target numbers began to decline approximately incrementally until reaching their lowest levels approximately 2 hours after sunrise the following morning, when the sampling period ended.

4. It is important to note that averaging or summing over an entire season masks the variability evident in these metrics within a given night and among nights. Appendix 5 shows hourly temporal patterns in passage (Figure A), altitudinal distribution (Figure B) and the proportion and number of targets in the 0-100 m and 101-200 m strata (Figure C and D) for each night's of data.

5. We conducted regression analyses to investigate relationships between nightly target passage and the proportion of targets detected in the two lowest altitudinal strata (i.e., 0-100 m, 101-200 m).

a. Analysis suggested a significant inverse correlation between nightly passage intensity (ln transformed) and the proportion (arcsine transformed) of targets detected in the 0-100 m stratum ($F_{1,107} = 15.02$, $P = 0.0002$, $R^2 = 0.12$, Fig. 17C)

b. Analysis indicated a non significant inverse correlation between nightly passage intensity (ln transformed) and the proportion (arcsine transformed) of targets detected in the 101-200 m stratum ($F_{1,107} = 6.63$, $P < 0.01$, $R^2 = 0.06$, Fig. 17C).

4.2.3 Comparison between spring and fall flight characteristics

1. The proportion of targets detected in the 0-100 m arl stratum was significantly greater in spring ($\bar{x} = 0.23$) compared with fall ($\bar{x} = 0.06$, $F_{1,154} = 96.80$, $P < 0.0001$. Note: analysis conducted with arc sin transformed data).
2. The proportion of targets detected in the 101-200 m arl stratum was significantly greater in spring ($\bar{x} = 0.22$) compared with fall ($\bar{x} = 0.14$, $F_{1,154} = 33.38$, $P < 0.0001$. Note: analysis conducted with arc sin transformed data).

4.3 *Flight direction (horizontally-oriented radar)*

Problems with extensive ground clutter hampered our ability to generate hourly and nightly mean vectors (directional tendency) and vector lengths (r, strength of directional tendency) because of too few samples. Given this, we calculated a mean vector and vector length for each season.

4.3.1 Spring

1. We identified 302 target tracks during the 47 days of data collection ($\bar{x} = 6.42 \pm$ SD 3.66, range = 0-13).
2. Target tracks from the entire spring season showed significant directional tendency to the NNE (Fig. 18A).
   a. Mean vector = 26°
   b. Vector length = 0.63
   c. Rayleigh's $Z_{302} = 119.26$, $P < 0.0001$

4.3.2 Fall

1. We identified 1172 target tracks during the 109 days of data collection ($\bar{x} = 10.74 \pm$ SD 6.74, range = 0-22).
2. Target tracks from the entire fall season showed significant directional tendency to the WSW (Fig. 18B)
   a. Mean vector = 240°
   b. Vector length = 0.47
   c. Rayleigh's $Z_{1172} = 176.31$, $P < 0.0001$

4.4 *Synoptic weather patterns and bird/bat flight dynamics*

4.4.1 Spring

1. We found significant differences among mean targets (i.e., sum of the sample means averaged over each synoptic condition) across synoptic weather conditions ($\chi^2 = 15.19$, df = 4, $P = 0.004$), mean proportion of targets detected in the 0-100 m ($\chi^2 = 23.00$, df = 4, $P = 0.0001$) and 101-200 m strata ($\chi^2 = 15.58$, df = 4, $P = 0.004$).

2. Additionally, using Log Likelihood Ratio χ^2 tests, we found that proportional occurrences of mean targets (i.e., sum of the sample means averaged over each synoptic condition), and targets detected in the 0-100 m and 101-200 m strata averaged across each of the five synoptic weather conditions, differed significantly from the proportional occurrence of each synoptic weather condition (mean target count: $\chi^2 = 27.31$, df = 4, $P < 0.0001$, mean targets 0-100 m: $\chi^2 = 32.99$, df = 4, $P < 0.0001$, mean targets 101-200 m: $\chi^2 = 28.36$, df = 4, $P < 0.0001$).
   a. For example, nearly 59% of all targets were detected during synoptic weather conditions "1" and "5" (Table 7), which produce southerly or calm winds respectively. These conditions only occurred on 32% of the days we sampled (Table 9).
   b. Conversely, synoptic conditions "2", "3", and "4" accounted for 68% of days we sampled but only 42% of all targets we detected were done so under these conditions (Table 7).
3. We did not have enough flight direction data across all synoptic conditions to assess relationships.

4.4.2 Fall

1. We found significant differences among mean targets (i.e., sum of the sample means averaged over each synoptic condition) across synoptic weather conditions ($\chi^2 = 33.20$, df = 4, $P = 0.0001$), mean proportion of targets detected in the 0-100 m ($\chi^2 = 2.50$, df = 4, $P = 0.64$) and 101-200 m strata ($\chi^2 = 19.74$, df = 4, $P = 0.0006$).
2. Using Log Likelihood Ratio χ^2 tests, we found that proportional occurrences of mean targets (i.e., sum of the sample means averaged over each synoptic condition), and targets detected in the 0-100 m and 101-200 m strata averaged across each of the five synoptic weather conditions, differed significantly from the proportional occurrence of each synoptic weather condition (mean target count: $\chi^2 = 15.19$, df = 4, $P = 0.004$, mean targets 0-100 m: $\chi^2 = 15.18$, df = 4, $P = 0.004$, mean targets 101-200 m: $\chi^2 = 13.30$, df = 4, $P = 0.01$).
   a. For example, 84% of all targets were detected during synoptic weather conditions "2" , "3" and "5" (Table 7) that typically produce northerly winds (i.e., conditions "2" and "3") or calm winds (i.e., synoptic condition "5"). These conditions only occurred on 34% of the days we sampled (Table 7).
   b. Conversely, synoptic condition "1" accounted for 35% of days we sampled but only 7% of the targets we recorded were done under these conditions (Table 7)
3. We did not have enough flight direction data across all synoptic conditions to assess relationships.

4.5 *Local weather patterns and bird/bat flight dynamics*

4.5.1 Spring

1. Results of Pearson's product moment correlation analyses are presented in Table 8.
   a. Because pair-wise correlations between indices of "cloud cover"and "cloud ceiling, and between "visibility" and "precipitation" all exceeded 0.5, we restructured this *a priori* weather variable grouping.

i. "Cloud cover" was paired with "precipitation"
ii. "Cloud ceiling" was paired with "visibility"

b. Resulting models used to evaluate effects of local weather conditions on target passage (sum of nightly sample means) and altitude (proportion $\leq$ 100 m, proportion 100 > and $\leq$ 200 m) were: (1) Julian day [base model], (2) tailwind/headwind vector-north, side-wind vector-north (THV-N, SWV-N), (3) tailwind/headwind vector-northeast, side-wind vector-northeast (THV-NE, SWV-NE), (4) dry bulb temperature (C°), dry bulb dew point temperature (C°) and barometric pressure (millibars), (5) cloud cover and precipitation, and (6) cloud ceiling and visibility.

2. Model selection procedures indicated that wind vector models (i.e., THV-NE/SWV-NE, THV-N, SWV-N) performed better than all other models in explaining variation in all three flight dynamics/behavior response variables (Table 11).

a. Target passage

i. The THV-NE/SWV-NE model had a weight (w_i) of 0.89 and a ΔAIC_c of 4.5 compared with the next-best performing model (THV-N/SWV-N) (Table 10). These results indicate strong support for this being the best model.

ii. The THV-NE/SWV-NE model explained 36% (i.e., r^2) of the variation inherent in nightly target passage (Table 10).

iii. The parameter estimate for THV-NE variable (Table 11) was positive and significant ($P = 0.0001$), suggesting that when winds were blowing toward the migration goal (i.e., northeast, when winds were more southwesterly), target passage increased.

iv. The parameter estimate for SWV-NE variable (Table 11) was positive and significant ($P = 0.02$), suggesting that when winds were more southeasterly, target passage increased.

b. Proportion targets $\leq$ 100 m

i. The THV-NE/SWV-NE model had a weight (w_i) of 0.87 and a ΔAIC_c of 3.8 compared with the next-best performing model (THV-N/SWV-N)(Table 10). These results indicate strong support for this being the best model.

ii. The THV-NE/SWV-NE model explained 52% (i.e., r^2) of the variation inherent in the proportion of targets detected in the 0-100 m stratum (Table 10).

iii. The parameter estimate for THV-NE variable (Table 11) was negative and significant ($P < 0.0001$), suggesting that when winds were blowing away from the migration goal (i.e., southwest or headwinds, when winds were more northeasterly), the proportion of targets detected $\leq$ 100 m increased.

iv. The parameter estimate for SWV-NE variable (Table 11) was negative and significant ($P = 0.01$), suggesting that when winds were more northwesterly, the proportion of targets detected $\leq$ 100 m increased.

c. Proportion targets > 100 m and ≤ 200 m

i. THV-NE/SWV-NE and THV-N/SWV-N models had the lowest AIC_c. However, the ΔAIC_c value between the two was 0.02, suggesting they performed equally well (Table 10). ΔAIC_c between these and the next-best performing model temperature, barometric pressure) was ≥ to 3.8 (Table 10). The models had weights (w_i) of 0.46 and 0.42 (Table 10), respectively, indicating equally strong support for these being the best models.

ii. Each model explained 20% (i.e., r^2) of the variation inherent in the proportion of targets detected in the 0-100 m stratum (Table 10).

iii. The parameter estimate for the THV-NE variable was significant (P = 0.005, Table 11) and positive and significant ($P < 0.0001$), suggesting that when winds were blowing toward the migration goal (i.e., northeast, when winds were more southwesterly), the proportion of targets detected in the 101-200 m stratum increased.

iv. The parameter estimate for the SWV-N variable was significant (P = 0.005, Table 11) and negative, suggesting that when winds were more northeasterly, the proportion of targets detected in the 101-200 m stratum increased.

4.5.2 Fall

1. Results of Pearson's product moment correlation analyses are given in Table 9.

a. Because pair-wise correlations between indices of "dry bulb temperature" and "dry bulb dewpoint" exceeded 0.5, we eliminated the latter from this *a priori* grouping that also included "barometric pressure."

b. Because pair-wise correlations between indices of "cloud cover"and "cloud ceiling," and between "visibility" and "precipitation" all exceeded 0.5, we restructured this *a priori* weather variable grouping.

i. "Cloud cover" was paired with "precipitation"

ii. "Cloud ceiling" was paired with "visibility"

c. Resulting models used to evaluate effects of local weather conditions on target passage (sum of nightly sample means) and altitude (proportion ≤ 100 m, proportion 100 > and ≤ 200 m) were: (1) Julian day [base model], (2) tailwind/headwind vector-north, side-wind vector-north (THV-N, SWV-N), (3) tailwind/headwind vector-northeast, side-wind vector-northeast (THV-NE, SWV-NE), (4) dry bulb temperature (C°) and barometric pressure (millibars), (5) cloud cover and precipitation, and (6) cloud ceiling and visibility.

2. Model selection procedures indicated that the two "sky condition" models (i.e., cloud cover/precipitation and cloud ceiling/visibility) performed better than other models in explaining variation in target passage and the proportion of targets detected in the lowest altitudinal stratum (≤ 100 m).

a. Target passage

i. The two "sky condition" models had the lowest AIC_c values but were within 1.7 units of each other (Table 12). However, the "cloud

cover/precipitation" model had a greater overall weight ($w_{i,}$) compared with the "cloud ceiling/visibility" model (0.70 versus 0.29)

ii. The "cloud cover/precipitation" model explained 25% of the variation in target passage while the "cloud ceiling/visibility" model explained 23%.

iii. In the "cloud cover/precipitation" model, only the "precipitation" variable was significant ($P < 0.0001$) and appeared to underlie the model's performance. A positive parameter estimate indicated that target passage increased when "precipitation" was "zero" (Table 13) .

iv. In the "cloud ceiling/visibility" model, both parameters were significant ($P = 0.0005$, $P = 0.009$, respectively). Both parameter estimates were positive, suggesting that when either cloud ceiling or visibility increased, target passage also increased.

b. Proportion targets $\leq$ 100 m

i. The two "sky condition" models had the lowest AIC_c values but were within 0.7 units of each other (Table 12). The "cloud ceiling/visibility" model had a greater overall weight ($w_{i,}$) compared with the "cloud cover/precipitation" model (0.42 versus 0.30)

ii. However, both two models were relatively weak predictors of variation in the proportion of targets detected in the lowest altitudinal stratum ($r^2 =$ 0.04 in each case, Table 12) .

iii. "Cloud ceiling" was the only significant parameter ($P = 0.04$, Table 13) in either of the two models. In this case, the estimate was negative (Table 13), suggesting that as cloud ceiling decreased in height, the proportion of targets detected at or below 100 m increased.

iv. "Cloud cover" was marginally significant ($P = 0.08$, Table 13). The estimate for this parameter was positive (Table 13), suggesting that as the percent of the sky occluded by clouds increased, so did the number of targets detected at or below 100 m.

c. Proportion targets > 100 m and $\leq$ 200 m

i. Although the "base" model, "julian day" had the lowest AIC_c value, it was within two units of the "temperature/barometric pressure" model suggesting that the two models performed similarly. However, the "julian day" model had a much higher weight compared with the "temperature/barometric pressure" model ($w_i = 0.71$ versus $w_i = 0.26$, Table 12).

ii. Additionally, both models explained a similar amount of the variation ($r^2 =$ 0.14) in the proportion of targets detected in this altitudinal stratum

iii. The parameter estimate for "julian day" was significant ($P < 0.0001$) and positive, indicating that as the season progressed, the proportion of targets detected in this stratum increased (Table 13)

iv. For the "temperature/barometric pressure" model, only temperature was significant ($P < 0.0001$). The estimate for this parameter was negative, suggesting that lower temperatures resulted in a higher proportion of targets detected in this stratum.

5.0 DISCUSSION

Indices of bird and bat flight dynamics (e.g., passage magnitude, altitude of flight, speed and direction) are critical for evaluating the potential risk that tall structures (e.g., wind turbines, communication towers, buildings, bridges) pose to aerial vertebrate biota. Regulatory agencies, natural resource managers and developers require this information to compare relative risk of constructed tall structures, especially when they are proposed for areas known to have high bird or bat passage and activity rates. Additionally, stakeholders require information about other locations so that comparisons among sites can be made and characteristics of the specific site slated for development can be evaluated in a relevant context.

However, several caveats must be stated when evaluating results of this or other similar studies. Because our sampling was limited to single spring and fall seasons, caution should be exercised when extending our results to longer time frames. Interannual variability in temporal patterns of avian migration is well documented (*cf* citations in Alerstam 1990, Berthold 1996). Similarly, caution is advised before applying inferences from this study to other areas or physiographic regions. Our radars were configured to sample relatively small volumes of space compared to the extent that migration likely occurs in the mid Atlantic coastal region.

Our inability to distinguish between birds and bats during radar monitoring, or distinguish among species in each of these taxa, also is important to note. Air speeds of several avian taxa (e.g., passerines) overlap with those reported for bats (i.e., ~6 m^{-s}, cf Larkin 1991, Bruderer and Boldt 2001, Kunz and Fenton 2003). Consequently, we could not determine the relative contribution of birds or bats in spatial or temporal patterns we observed. Future studies focused on flight dynamics and behavior of migrating birds and bats in the region must include tasks that provide this type of information. To reflect our uncertainty about the identity of aerial vertebrates in our radar data, we refer to entities detected by the radars as "targets," throughout this report. This is a widely used term in radar parlance for any object detected by a radar.

Additionally, we use the term "target" rather than "individual" or "flock" because the number of birds or bats represented as single entities by the radar was unknown. Some studies report the ability to distinguish small, medium, large and flock-like targets by evaluating their relative size. This approach is problematic because inherent physical properties of radar affect the amount of energy reflected by a detected object, the basis by which target size would be evaluated. Distance between target and radar, a target's orientation relative to the radar and the location of a target in the radar beam (i.e., central versus peripheral) are among several characteristics that affect the amount of energy a target reflects. These characteristics influence target detection simultaneously, so can seriously confound target size classifications. Given these difficulties, we classified all aerial vertebrate detections as single targets. Thus, enumerations of passage we report are likely underestimates of the total number of birds and bats passing through our study sites.

In the following "Discussion" sections, we compare our results to those reported in other marine radar studies, primarily related to the development of wind resources. We believe these are relevant for comparison with this study as they represent situations where risk evaluation is

related to birds and bats encountering tall structures (i.e., wind turbines), which are currently within the height range (300-400 feet) of the cable-stayed bridge support structures proposed for the Middle Thoroughfare Bridge project. However, caution should be used when interpreting differences between this and other studies because of inherent differences in equipment, data collection procedures and analytical approaches.

Many of the studies cited in this report used a single 12 kW X-band radar with the antenna rotating parallel to the ground (i.e., what we refer to in this report as "horizontal" orientation). Data collected with the radar in this orientation are used to estimate target passage rates and flight direction. This single unit is periodically rotated 90° so that the antenna spins perpendicular to the ground (i.e., what we refer to in this report as "vertical" orientation). Data collected with the radar in this orientation are used to estimate target altitudes. In this study, we used two 25 kW X-band radars operating simultaneously as described in the "Methods" section. Our radars were more powerful and thus likely to detect more targets compared with 12 kW models. Importantly, we used the data collected with the radar in the "vertical" orientation to estimate target passage indices as well as flight altitude. Given the inherent properties of the radar systems used in most of these studies, we believe that data collected with the vertically-oriented radar provide the best estimates of target passage.

Typically, the studies we cite for comparison use manual methods to estimate the number, altitude and flight direction of targets detected by their radar. These methods may be subject to observer biases, especially because studies are conducted at night and for many consecutive hours. Additionally, most studies do not archive the image data produced by their radars. In these cases, investigators are unable to conduct quality control assessments of their data. In contrast, we used automated image data collection and algorithm-based data processing and target quantifying) which allows for standardized assessment of target movement indices (i.e., passage, altitude and direction) and data quality control.

5.1 *Target passage*

Passage rates observed during our study (i.e., 90/km/hr in spring, 116/were generally lower than reported in several other studies conducted in the northeast (150-200 targets/km/hr, e.g., Plissner et al. 2006, Mabee et al. 2005, Cooper et al. 2004a, 2004b) and the northwest U.S. (Mabee and Cooper 2004). However, the studies we cite for comparison conducted radar observations for shorter periods during a given season compared to our Cape May study (i.e., 47 in spring, 109 in fall). Our reviews of relevant literature suggested that most studies focus on what is assumed to be the peak of migration movement for a given season. For example, two different studies conducted in northern New York during fall migration covered only two month periods in September and October (Mabee et al. 2005) or from mid August through mid October (Kerns et al. 2007), while a study from western New York was conducted for only 30 days in September and October (Cooper et al. 2004b).

Additionally, many of the studies we reviewed began their radar observations approximately one hour after sunset and continued for approximately six hours (Cooper et al. 2004a, b, Mabee et al. 2004, 2005, 2006, Plissner et al. 2006), far less than the average number of hours/night we made

radar observations (i.e., $\bar{x}$ = 14 hrs in spring, $\bar{x}$ = 16.3 hours in fall). Nightly data collection in these studies again appear focused on what is assumed to be the peak of nocturnal migration period. Although some studies did conduct radar observations from sunset to sunrise the next morning (e.g., Kerns et al. 2007), we are unaware of any published study that included two hour periods before sunset and after sunrise as was done in our study.

Differences in nightly and seasonal radar observation periods are noteworthy and must be accounted for when comparing target passage rate estimates among studies. Estimates that include significant sampling during seasonal and nightly non-peak periods of migration, as in our study, likely are lower than those reported in studies with markedly fewer hours of observation focused on peak migration periods. Additionally, extending nightly sampling periods (i.e., pre sunset to post sunrise) provided insight into times of day when bird and bats are most vulnerable (i.e., during take off and landing, Richardson 2000). We believe that broader temporal coverage is essential to a comprehensive understanding of how tall structures might affect bird and bat flight dynamics and behavior.

Although using target passage rates as an index of migration magnitude allows for comparisons among studies, they can be misleading. This is especially true when differences in data collection methods (e.g., hours of radar operation) are not fully explored. Furthermore, target passage rates as a measure of migration magnitude can obfuscate what is likely the more important metric for assessing collision risk, that is, the total number of birds and bats exposed to the tall structure in question.

Target passage was markedly greater in fall than spring although our passage rates were not significantly different, which was likely caused by high nightly variability in migration. Fall avian migration events typically include large numbers of juveniles, which could explain the seasonal differences we observed. Seasonal differences may have been related in part to greater bat activity during the post breeding season (i.e., August and September) compared to other times of year (Arnett et al. 2008, Horn et al. 2008). Seasonal differences in passage indices generated from marine radar data have been reported widely (*cf* studies listed in Kerns et al. 2007, Table 7, p. 31) and whether spring or fall exhibits greater numbers of migrants depends primarily on the location under consideration.

We found that temporal patterns in nightly movement were distinct, predictable and generally consistent with those reported for nocturnal landbird migration (Gauthreaux 1971, Åkesson et al. 1996). That is, migrants ascend rapidly within the first hour after sunset, numbers increase markedly and peak approximately 2-4 hours after sunset and then decline gradually until the following morning. Åkesson et al. (1996) suggest that various bird species make nocturnal migration ascents at different times relative to sunset and civil twilight, which could result in the 2-3 hour interval to reach peak numbers that we observed. Horn et al. (2008) and Reynolds (2006) suggest that bats in West Virginia and New York, respectively, exhibit similar within-night activity patterns as reported for birds, but whether this behavior is widespread is unclear because data are lacking.

However, it is important to note that we detected sizable numbers of targets during the two hours prior to sunset. Movements during this period were likely birds flying to roosting areas or bats beginning nightly foraging bouts. We also detected a rapid increase in movement just after sunrise in fall. This could have been related to birds moving from roosting areas to begin foraging or the morning flight of nocturnally migrating passerines that may be reorienting after a night of migration, which is well documented (Wiedner et al. 1992).

5.2 *Flight altitude*

Determining flight altitudes in nocturnally active birds and bats is an essential element in assessing the potential affects of tall structures on aerial vertebrates. Most investigators working on environmental impact assessments of tall structures, such as wind turbines, limit their evaluation of potential risk to the altitudinal strata immediately associated with a wind turbine's rotor swept area. However, expanding the range considered as "risky" may provide improved insight into the broader extent of potential impacts. Birds are known to alter their altitude in changing wind fields (Able 1970, Alerstam 1985, Gauthreaux 1991, Bruderer et al. 1995), in response to meteorological conditions (e.g., cloud cover, Able 1970) and to topography and land forms (Bruderer 1978, Williams et al. 2001).

On average, 23% and 6% of all targets we detected in spring and fall respectively, flew at or below 100 m above radar level (arl). The proportion of targets we detected flying in this altitudinal stratum in spring was greater than those reported by radar studies at proposed or operational wind power projects in the eastern U.S. (*cf* Table 7 in Kerns et al. 2007). Conversely, the proportion we detected in fall was among the lowest reported (*cf* Table 7 in Kerns et al. 2007). Based on our minimum estimates of target passage, this means that more than 20,000 birds and bats flew at altitudes that put them at risk of encountering a structure at least 100 m tall. Nightly averages for targets detected in the 101-200 m arl stratum (i.e., 22% and 14% in spring and fall respectively) suggest that more than 43,000 targets were detected in this stratum.

Average hourly variation in altitude appeared to follow a similar pattern in spring and fall. Proportions of targets at the lowest altitudes were highest during the first two hours before and after sunset, then declined afterwards. They gradually rose as sunrise approached and were highest in the morning, during the hour preceding and immediately after sunrise. This temporal pattern is effectively the opposite of the one we observed for target passage magnitude (i.e., low numbers early, increasing to peak around 2-3 hours after sunset, then declining gradually). These two data sets and our analysis on the correlation between passage magnitude and altitude suggest several important relationships. As nocturnal activity commences, and again as it wanes, the proportion of birds and bats flying at low altitudes is highest, but this is also the time when fewer individuals are aloft. Conversely, during periods of high target detection, proportions of birds and bats flying at low altitudes are lowest.

These relationships were alluded to in radar studies of bird migration in New England (Nisbet 1963), the Gulf of Mexico (Able 1970) and apparent in a study conducted in the mid Atlantic Appalachian Mt.region (Mizrahi et al. 2008). They are important to consider when evaluating

the risk of collision with tall structures. Although the thesis that nocturnal migrants may be at greatest risk of collision during ascent and descent has been suggested (e.g., Richardson 2000), the greatest number of individuals may be exposed to risk during the peak periods of migration, as was the case in our study. Using proportions of targets detected in various altitudinal strata allows for comparison among studies, however, they can be misleading. In our study, numerically greater numbers of individuals were detected in those lowest strata during the nightly peak of movement, although the proportion of individuals in these strata, relative to the total, were lowest. Again, the total number of birds and bats exposed to the tall structure in question, is likely the more important measure of risk.

5.3 *Flight orientation*

Mechanisms used by migrating birds to find their way between breeding and wintering grounds have been studied extensively (*cf* citations in Gauthreaux 1980, Alerstam 1990, Berthold 1991). "Pilotage," the use of visible features in the landscape as a guide (e.g., coastlines, rivers, mountain ranges), is often associated with diurnal migrants (Kerlinger 1989, Alerstam 1990, Berthold 1991), although some nocturnal migrants also exhibit this behavior (Bingman et al. 1982). On the other hand, "orientation," the use of an environmental cue or cues that provide directional information (e.g., celestial rotation, Earth's magnetic inclination) appears to be more prevalent in nocturnal migrants (e.g., some passerines, shorebirds).

Two questions frequently asked about the flight behavior of nocturnal migrants are "do they use topographic features," and if so "do their flight paths parallel topographic contours." These are increasingly relevant conservation questions because of recent pressure to develop coastal regions in the eastern U.S. Targets detected during our study flew primarily in a northeasterly direction in spring southwesterly in fall. These predominant flight paths are approximately parallel to the southwest/northeast orientation of the mid Atlantic coast where our study was conducted. In a study conducted in the mid Atlantic Appalachian Mt. region (Mizrahi et al. 2008), mean vectors suggested that bird and bat targets traveled primarily northwest in the spring and southeast in fall. Mabee et al. (2006) reported that the mean vector for targets they detected in fall at their "central" site during their study in the mid Atlantic Appalachian Mt. region was southerly ($\bar{x}$ = 184°), while mean flight direction of targets detected in the Virginia Highlands was 204° (Plissner et al. 2006).

Differences among these studies could have been related to local topography. Although birds and bats flying at lower elevations or through mountain passes in the mid Atlantic Appalachian Mts. may alter their flight behavior when they encounter ridge lines (Williams et al. 2001), they do not encounter these kinds of obstacles as they travel through the coastal plain regions of the mid Atlantic. Differences could also be related to annual variation in prevailing weather patterns or to species composition. In fall, south-southeasterly vectors are typical of migrating birds that winter in the Neotropics, while southwest is the principal direction of avian migrants wintering in North America (Drury and Keith 1962, Williams et al. 1977). Although the relative abundance of specific species differs between the two regions, the general composition is similar, with each region supporting similar migration guilds (i.e., short, medium and long-distance).

5.4 *Weather effects on target flight dynamics*

The affect of weather conditions, both synoptic and local scale, on bird migration have been well documented (Lack 1960, *cf* citations Richardson 1978, Alerstam 1979, Richardson 1990a). Evaluating how specific factors (e.g., wind speed and direction, temperature, pressure, cloud cover, ceiling, visibility) modify flight behavior is essential for determining when aerial vertebrates are at greatest risk of colliding with structures that penetrate their airspace.

5.4.1 Synoptic weather patterns and bird/bat flight dynamics

Our results suggest that synoptic weather patterns producing seasonally appropriate wind conditions for vectoring individuals toward their intended goal are important predictors of passage events. Birds can reduce energetic costs significantly by migrating under favorable winds (i.e., tailwinds, Gauthreaux 1991, Piersma and van de Sant 1992, Liechti et al. 2000), thus large migration events are coincidental with these conditions (Richardson 1972, 1974, Able 1973 Blokpoel and Gauthier 1974, Pyle et al. 1993, Williams et al. 2001).

At temperate latitudes in spring, this generally means southerly winds prevalent after the passage of a warm front and on the western side of a high pressure system, or in the light and variable winds near the center of high pressure areas (*cf* citations in Richardson 1978, 1990a, Alerstam 1990). We found significant differences in passage under the five synoptic conditions we considered. Nearly 60% of targets we detected were done so when weather patterns produced prevailing southerly winds, or when winds were generally calm. Additionally, we detected a disproportionately greater number of targets when pressure systems produced southerly winds or calm conditions relative to the occurrence of these conditions. This suggests that birds, and possibly bats, were selective about the conditions under which they were actively migrating.

In fall, the largest migration events typically occur after the passage of a cold front or when the western portion of a low pressure system is positioned north and east of the region in question (*cf* citations in Richardson 1978, 1990a, Alerstam 1990). Rising barometric pressure, clearing skies and northwesterly and northeasterly winds are usually associated with these synoptic conditions. Our results were consistent with this widespread pattern. We detected significantly greater target numbers when these synoptic conditions affected the mid Atlantic coastal region. Similar to spring, the proportion of targets (i.e., of the total targets detected) we detected under these conditions were significantly different than their overall occurrence, suggesting that aerial vertebrates respond specifically to the occurrence of meso scale weather conditions that are favorable for fall passage.

The effects of prevailing pressure systems on flight altitude were similar to those we found on passage magnitude. Generally, more low-flying targets were detected when synoptic weather conditions were seasonally favorable than when they were not. Furthermore, in both spring and fall, the proportion of targets detected in the two lowest strata were greater under favorable conditions than we would expect based on the frequency that these conditions occurred.

5.4.2 Local weather patterns and bird/bat flight dynamics

Among the various meteorological conditions evaluated for their affect on the timing, magnitude, altitude and flight paths in migrating birds, wind has been repeatedly identified as the principal driver (Nisbet and Drury 1968, Alerstam 1978, 1979, Richardson 1978, 1990a, 1990b, Pyle et al. 1993, Butler et al. 1997, Liechti and Bruderer 1998, Weber et al. 1998, Åkesson and Hedenström 2000, Williams et al. 2001, Erni et al. 2002). Results from our study are consistent with this premise.

Among the models we evaluated, those that included tailwind/headwind vector (THV) and sidewind vector (SWV) were clearly the strongest determinates of passage magnitude in spring, although the model set that assumed the migration goal to be toward the northeast was clearly the best performing. Target detections covaried positively with THV-NE, indicating that when winds were blowing toward the migration goal, targets detections increased. These results suggest that the timing of major migration events is in part determined by the occurrence of favorable winds.

The affects of wind conditions on migration altitudes in birds are well documented (*cf* citations in Alerstam 1979, Richardson 1990a). They tend to fly at higher altitudes under following or tail wind conditions (i.e., winds blowing toward the bird's goal) and at lower altitudes in opposing or head wind conditions (i.e., wind blowing away from the bird's goal). Wind speeds are typically lower at lower altitudes, so individuals migrating under head wind conditions can reduce energy costs by reducing flight height.

Our modeling efforts suggest that in spring, tailwind/headwind vectors had a significant negative effect on flight altitudes for targets detected in the lowest 100 m above ground level. That is, targets occurred in greater proportion at low altitudes as winds vectors became more negative (i.e., headwinds), which could result from either winds becoming more opposing or higher wind speeds of slightly opposing winds.

In fall, "cloud cover/precipitation" and "cloud ceiling/visibility," models performed best and equally well as determinants of target passage. Parameter estimates suggest that target passage increased when cloud cover was low, precipitation was not apparent, cloud ceiling was high and visibility was good. These characteristics typically are apparent after the passage of a cold front, which also accompanied by northerly or westerly winds. Our analyses of relationships between migration magnitude and synoptic weather conditions suggest that the passage of cold fronts in fall resulted in greater numbers of targets detected.

The same two models also performed best and equally well at predicting targets detected in the 0-100 m stratum, although they were relatively weak determinants. Here, decreases in cloud ceiling and increases in cloud cover (i.e., the only significant parameters) resulted in greater numbers of targets detected in this stratum. Generally, these conditions are apparent as a storm approaches and our results suggest that birds and bats may be at greatest risk from colliding with tall structures during these periods. The "Base" model (i.e., day only) and the "temperature/barometric pressure" model were similarly good predictors of targets detected in

the 101-200 m stratum. Our results suggest that as the season progressed and, in a related way, temperatures decreased, proportions of targets detected in this stratum increased.

The differences between spring and fall results with respect to the importance of wind conditions may be related to the need for individuals to arrive on the breeding grounds in good energetic condition to improve reproductive output (Sandberg 1996, Sandberg and Moore 1996). This would put a premium on selecting wind conditions that would vector an individual towards its goal using the least amount of energy (i.e., tailwinds blowing from the appropriate direction). This need is not in effect during southbound passage to the wintering grounds. Additionally, the fall passage period includes a large proportion of naive migrants making their first trip south. As much as 85-95% of individuals found along the Atlantic Coast during fall migration are young of the year (i.e., hatched during that summer's breeding season, *cf* citations in Ralph 1981, Mizrahi unpublished data from Two-Mile Beach, Cape May County, NJ). Naive migrants may respond less effectively to weather conditions conducive to migration.

Climatological conditions in part appear to underlie the evolution of migration in bats (Fleming and Ebby 2003), however, their proximate affect on variability in migration patterns is not well described. Given that migrating bats face similar ecological and physiological constraints (e.g., energy conservation) of prolonged flight, it is likely they respond in similar ways to weather conditions that favor transport between migration goals. More work in this area is needed to improve our understanding of when migrating bats are at greatest risk from colliding with tall structures that penetrate the atmosphere.

6.0 CONCLUSIONS

Despite some limitations, we believe our project was successful in documenting key elements of bird and bat flight dynamics and behavior during their north and southbound migrations through the mid Atlantic coastal region. More specifically, the results reported here will prove useful in assessing the potential impacts of a cable-stayed bridge in lower Cape May County and future assessments of potential impacts of tall structures in the region.

Clearly, our results suggest that the movement of aerial vertebrates through the study area was substantial. The flight altitudes of many thousands of birds and bats could have resulted in their encountering structures 100-200 m in height. Whether those encounters would have resulted in collisions is an open question that is rarely addressed in these kinds of studies. Our results also shed light on meteorological conditions that modify flight dynamics and behavior and suggest weather patterns that might affect when birds and bats may be at greatest risk from collision with tall structures they encounter during daily movements or along their migration routes.

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Table 1. Data collection dates, start/end times, sunset/sunrise times and survey hours for marine radar study conducted on 47 days during spring 2005 in Cape May County New Jersey. Data were collected during 656 hours (mean = 13.96 hours/night). Start and end times, and sunrise and sunset times are given in Eastern Daylight Time.

Date	Start time	End time	*Sunset*	Sunrise (following *morning*	Data collection hours
04/15/05	1734	0754	1937	0621	15.23
04/16/05	1804	0745	1938	0620	14.43
04/17/05	1913	0743	1939	0618	13.22
04/18/05	1741	0741	1940	0617	14.68
04/19/05	1742	0743	1941	0616	14.73
04/20/05	1745	0745	1942	0614	14.75
04/21/05	1740	0741	1943	0613	14.70
04/22/05	1743	0743	1943	0611	14.72
04/23/05	2400	0740	1944	0610	8.33
04/24/05	1757	1747	1945	0609	8.62
04/25/05	1744	0744	1946	0607	14.73
04/26/05	1746	0746	1947	0606	14.77
04/27/05	1826	0737	1948	0605	13.80
04/28/05	1905	0746	1949	0604	13.45
04/29/05	1908	0738	1950	0602	13.13
04/30/05	1749	0739	1951	0601	14.48
05/01/05	1753	0743	1952	0600	14.55
05/02/05	1753	0734	1953	0559	14.25
05/03/05	1753	0734	1954	0558	14.25
05/04/05	1755	0735	1955	0557	14.25
05/05/05	1752	0732	1956	0555	14.20
05/06/05	1750	0741	1957	0554	14.53
05/07/05	1816	0742	1958	0553	14.13
05/08/05	1755	0736	1959	0552	14.28
05/09/05	1752	0733	2000	0551	14.23
05/10/05	1758	0738	2001	0550	14.30
05/11/05	1804	0735	2002	0549	14.10
05/12/05	1802	0733	2003	0548	14.07
05/13/05	1801	0732	2004	0547	14.05
05/14/05	1802	0733	2004	0547	14.07
05/15/05	1812	0732	2005	0546	13.87
05/16/05	1803	0734	2006	0545	14.08
05/17/05	1800	0731	2007	0544	14.03
05/18/05	1800	0740	2008	0543	14.33
05/19/05	1807	0737	2009	0542	14.12
05/20/05	1832	0733	2010	0542	13.57
05/21/05	1804	0735	2011	0541	14.10
05/22/05	1806	0717	2011	0540	13.47
05/23/05	1806	0736	2012	0540	14.10
05/24/05	1808	0739	2013	0539	14.17
05/25/05	1807	0738	2014	0539	14.15
05/26/05	1807	0738	2015	0538	14.15
05/27/05	1812	0743	2015	0537	14.23
05/28/05	1814	0745	2016	0537	14.27
05/29/05	1815	0746	2017	0536	14.28
05/30/05	1845	0745	2018	0536	13.75
05/31/05	1815	0746	2018	0536	14.28
Total					**656.00**
Mean					**13.96**

Table 2. Data collection dates, start/end times, sunset/sunrise times and survey hours for marine radar study conducted on 122 nights during fall 2005 in Cape May County New Jersey. Data were collected during 1858 hours (mean = 16.3 hours/night). Start and end times, and sunrise and sunset times are given in Eastern Daylight Time through 29 Oct. Afterward they are given in Eastern Standard Time.

Date	Start	End	Sunset	Sunrise	Data collection hours	Comments
08/01/05	1903	0803	2010	0601	13.1	
08/02/05	1818	0809	2009	0602	14.0	
08/03/05	1830	0801	2008	0603	13.5	
08/04/05	1802	0753	2007	0604	14.7	
08/05/05	1806	0807	2006	0605	14.1	
08/06/05	1803	0803	2005	0606	14.1	
08/07/05	1758	0809	2004	0607	14.3	
08/08/05	1757	0808	2003	0607	14.3	
08/09/05	1800	0811	2002	0608	14.4	
08/10/05	1756	0817	2000	0609	14.6	
08/11/05	1756	0817	1959	0610	14.6	
08/12/05	1756	0817	1958	0611	14.6	
08/13/05	1821	0821	1957	0612	14.4	
08/14/05	1756	0817	1955	0613	14.6	
08/15/05	1757	0818	1954	0614	14.7	
08/16/05	2048	0819	1953	0615	11.8	
08/17/05	1754	0815	1951	0616	14.6	
08/18/05	1852	0823	1950	0617	13.9	
08/19/05	1743	0823	1949	0617	15.1	
08/20/05	1902	0823	1947	0618	13.7	
08/21/05	1836	0818	1946	0619	14.0	Data not used. Contamination from fog
08/22/05	1851	0822	1944	0620	13.9	Data not used. Contamination from fog
08/23/05	1921	0823	1943	0621	13.4	Data not used. Contamination from fog
08/24/05	1738	0828	1941	0622	15.3	Data not used. Contamination from fog
08/25/05	1734	0825	1940	0623	15.3	Data not used. Contamination from fog
08/26/05	1737	0828	1939	0624	15.3	
08/27/05	1729	0830	1937	0625	15.5	
08/28/05	1831	0832	1936	0626	14.6	
08/29/05	1805	0836	1934	0627	15.1	
08/30/05	1730	0831	1933	0627	15.5	
08/31/05	1723	0833	1931	0628	15.7	
09/01/05	1739	0830	1929	0629	15.4	
09/02/05	1732	0833	1928	0629	15.6	
09/03/05	1723	0834	1926	0630	15.8	
09/04/05	1725	0836	1925	0631	15.8	
09/05/05	NA	NA	1923	0632	0.0	No data. Radar malfunctioning
09/06/05	NA	NA	1922	0633	0.0	No data. Radar malfunctioning
09/07/05	NA	NA	1920	0634	0.0	No data. Radar malfunctioning
09/08/05	NA	NA	1919	0635	0.0	No data. Radar malfunctioning
09/09/05	1710	0841	1917	0636	16.2	
09/10/05	1727	0838	1915	0636	15.8	
09/11/05	1756	0837	1914	0637	15.3	
09/12/05	NA	NA	1912	0638	0.0	No data. Power failure
09/13/05	1709	0840	1911	0639	16.2	
09/14/05	1704	0845	1909	0640	16.4	
09/15/05	1736	0847	1907	0641	16.0	
09/16/05	1754	0845	1906	0642	15.6	
09/17/05	1656	0847	1904	0643	16.6	
09/18/05	1706	0847	1903	0644	16.5	
09/19/05	1700	0831	1901	0644	16.0	
09/20/05	1734	0845	1859	0645	15.9	
09/21/05	1850	0851	1858	0646	14.9	
09/22/05	1655	0856	1856	0647	17.0	
09/23/05	1655	0906	1855	0648	16.3	
09/24/05	1656	0857	1853	0649	17.0	
09/25/05	1658	0859	1851	0650	17.0	
09/26/05	1708	0859	1850	0651	16.8	
09/27/05	1659	0900	1848	0652	16.0	

Table 2. Continued.

09/28/05	1642	0852	1847	0653	17.0	
09/29/05	1652	0854	1845	0654	16.9	
09/30/05	1723	0854	1843	0655	16.4	
10/01/05	1645	0856	1842	0656	17.1	
10/02/05	1646	0858	1840	0657	17.2	
10/03/05	1712	0903	1839	0658	15.9	
10/04/05	1741	0905	1837	0659	15.5	
10/05/05	1628	0855	1836	0700	17.4	
10/06/05	1750	0901	1834	0701	15.2	
10/07/05	1633	0904	1832	0702	16.6	
10/08/05	1714	0905	1831	0703	15.9	
10/09/05	1716	0906	1829	0704	15.9	
10/10/05	1730	0911	1828	0705	15.9	
10/11/05	1725	0906	1826	0706	15.8	
10/12/05	1738	0909	1825	0707	15.7	
10/13/05	1630	0821	1823	0708	16.2	
10/14/05	NA	NA	1822	0709	0.0	No data. Power failure
10/15/05	1636	0825	1821	0710	16.2	
10/16/05	1619	0900	1819	0711	16.7	
10/17/05	1622	0343	1818	0712	12.1	
10/18/05	1706	0913	1816	0713	16.3	
10/19/05	1656	0913	1815	0714	16.5	
10/20/05	1607	0908	1814	0715	17.2	
10/21/05	1703	0924	1812	0716	16.8	
10/22/05	NA	NA	1811	0717	0.0	No data. Water in radar unit
10/23/05	NA	NA	1810	0718	0.0	No data. Radar under repair (see 10/21)
10/24/05	1604	2354	1808	0719	11.7	
10/25/05	1602	0923	1807	0720	17.7	
10/26/05	1719	0920	1806	0721	16.4	
10/27/05	1654	0925	1804	0723	16.9	
10/28/05	1608	0929	1803	0724	17.8	
10/29/05	1724	0935	1802	0725	16.8	
10/30/05	1542	0833	1701	0626	16.4	
10/31/05	1455	0826	1700	0627	18.0	
11/01/05	1501	0832	1659	0628	18.1	
11/02/05	1610	0831	1657	0629	16.9	
11/03/05	1531	0832	1656	0630	17.6	
11/04/05	1553	0834	1655	0631	17.3	
11/05/05	1444	0835	1654	0632	18.4	
11/06/05	1445	0837	1653	0634	18.5	
11/07/05	1607	0838	1652	0635	17.2	
11/08/05	1451	0842	1651	0636	18.6	
11/09/05	1457	0838	1650	0637	18.3	
11/10/05	1448	0840	1649	0638	18.5	
11/11/05	1525	0846	1649	0639	18.1	
11/12/05	1447	0848	1648	0640	18.8	
11/13/05	1449	0840	1647	0641	18.5	
11/14/05	1515	0847	1646	0642	18.3	
11/15/05	1446	0847	1645	0644	18.8	
11/16/05	1445	0847	1645	0645	18.8	
11/17/05	1446	0847	1644	0646	18.8	
11/18/05	1444	0846	1643	0647	18.8	
11/19/05	1436	0847	1643	0648	19.0	
11/20/05	1437	0849	1642	0649	19.0	
11/21/05	1452	0853	1641	0650	18.9	
11/22/05	1454	0855	1641	0651	18.9	
11/23/05	1435	0856	1640	0652	19.3	
11/24/05	1431	0853	1640	0653	19.3	
11/25/05	1433	0854	1639	0654	19.3	
11/26/05	1653	0856	1639	0655	17.0	
11/27/05	1434	0856	1639	0656	19.3	
11/28/05	1438	0900	1638	0657	18.4	
11/29/05	1440	0901	1638	0658	18.4	
11/30/05	1439	0900	1638	0659	18.4	
0122	0114					
Total					**1858**	
Mean					**16.30**	

Table 3. Synoptic weather classifications based on geostrophic wind circulation patterns (after Richardson 1976, Lank 1983).

Class	Description
1	Southerly winds, from southeast to west, except immediately following a cold front.
2	Northwesterly winds, from west to north.
3	Northeasterly winds, from north to southeast.
4	The center of a low pressure system and the area immediately around a cold front
5	Calm weather at the center of a high pressure system or in poorly organized areas south of a stationary front.

Table 4. Types of data used in analyses to investigate relationships between local weather conditions and bird and bat flight dynamics (e.g., migration magnitude, altitude, direction) observed in mid Atlantic Appalachian Mountain region during spring and fall 2006.

1	Cloud cover (% of sky covered by clouds or fog).
2	Ceiling (vertical visibility estimated in kilometers
3	Horizontal visibility (estimated in kilometers).
4	Precipation (drizzle, rain, snow; classified as 0 [No] or 1 [Yes])
5	Temperature (in degrees Celsius)
6	Dew point temperature (in degrees Celsius)
7	Barometric pressure (in millibars)
8	Wind direction (in degrees, measured as direction from which winds originate
9	Wind speed (in m/s)
10	Tailwind/Headwind vector (calculated wind vector along an axis parallel to assumed direction of migration goal [i.e., S ↔ N, SW ↔ NE]. Tailwinds have positive values and headwinds have negative values [see Appendix 1 for equation used in calculation]).
11	Sidewind vector (calculated wind vector along an axis perpendicular to assumed direction of migration goal [i.e., S ↔ N, SW ↔ NE]. Sidewind vectors have positive values from the east in spring and from the west in fall [calculations are similar to those shown in Appendix 1]).

Table 5. Results of marine radar image analyses for data were collected on 47 days during spring 2005 along Middle Thoroughfare, Cape May County, New Jersey. "Threshold" refers to the setting used to filter out image data that contain precipitation. "Data images used," (i.e., to quantify passage and altitudinal distribution), "Data images rejected" and the "Proportion rejected" show the results of the thresholdong process. "Total targets" are the number of birds/bats detected in all images collected. "Sum of the sample means" refers to the target count averaged over the five successive images that constitute a sample (i.e., every 10 minutes from sunset to sunrise the following morning). These values are summed for the entire night's data collection to generate a passage estimate. "Target detection rate" represents the number of targets detected per kilometer of passage front per hour. We also present the proportion and number of targets detected within the three lowest altitudinal strata (i.e., 100, 200, 300 m).

Date	Threshold	Data images used	Data images rejected	Proportion rejected	Total targets	Sum of the sample means	Target detection rate	Proportion of targets <=100 m	Number of targets <=100 m	Proportion of targets 101-200 m	Number of targets 101-200 m	Proportion of targets 201 -300 m	Number of targets 201-300 m
041505	60	261	0	0.00	3,393	1,130	73.40	0.53	602.13	0.15	164.85	0.03	33.30
041605	50	249	0	0.00	2,901	963	62.84	0.57	548.39	0.12	112.20	0.03	33.53
041705	65	228	0	0.00	5,587	1,863	122.49	0.33	605.88	0.29	542.19	0.11	202.41
041805	65	255	0	0.00	6,564	2,189	144.58	0.26	569.26	0.24	521.24	0.19	418.19
041905	125	255	0	0.00	11,297	3,767	249.96	0.19	715.25	0.24	902.99	0.20	768.94
042005	125	255	0	0.00	10,496	3,497	233.84	0.23	798.95	0.25	886.24	0.20	698.67
042105	75	255	0	0.00	5,396	1,794	120.52	0.13	240.71	0.31	564.20	0.19	336.79
042205	25	106	149	0.58	1,334	508	34.34	0.45	228.10	0.10	49.51	0.05	23.23
042305	50	141	0	0.00	1,558	520	44.92	0.20	102.46	0.21	110.14	0.08	40.72
042405	100	216	36	0.14	2,884	955	79.79	0.25	243.39	0.20	194.38	0.09	84.11
042505	85	255	0	0.00	7,207	2,404	165.36	0.10	237.50	0.20	491.67	0.20	482.33
042605	60	183	72	0.28	4,283	1,428	98.70	0.13	185.04	0.18	263.06	0.28	398.43
042705	85	240	0	0.00	2,711	906	62.92	0.36	323.17	0.18	165.09	0.10	91.57
042805	60	231	0	0.00	2,626	874	60.99	0.27	240.30	0.21	182.39	0.25	214.67
042905	70	113	115	0.50	3,957	1,338	94.13	0.13	171.43	0.19	251.91	0.21	277.61
043005	85	93	159	0.63	3,720	1,242	87.81	0.13	159.59	0.17	215.35	0.20	251.40
050105	50	252	0	0.00	3,053	1,015	72.11	0.15	152.60	0.34	345.43	0.18	178.53
050205	50	195	54	0.22	1,726	574	37.29	0.23	131.69	0.39	224.15	0.15	88.13
050305	50	249	0	0.00	4,564	1,517	98.99	0.09	132.62	0.21	316.76	0.27	415.48
050405	60	249	0	0.00	4,507	1,501	98.39	0.09	128.55	0.18	273.42	0.17	255.11
050505	30	249	0	0.00	1,024	340	22.46	0.10	32.54	0.21	70.72	0.20	66.74
050605	25	66	186	0.74	215	71	4.71	0.38	26.75	0.22	15.52	0.13	9.25
050705	50	243	0	0.00	3,190	1,063	70.86	0.12	122.63	0.21	218.93	0.21	226.93
050805	50	252	0	0.00	3,718	1,239	82.98	0.15	191.62	0.38	476.21	0.20	246.93
050905	50	415	0	0.00	4,597	923	62.10	0.13	121.88	0.33	305.39	0.15	133.92
051005	60	415	0	0.00	7,197	1,437	97.14	0.07	103.23	0.09	125.99	0.18	257.97
051105	100	410	0	0.00	16,189	3,237	219.85	0.09	276.33	0.36	1172.91	0.24	761.81
051205	35	410	0	0.00	2,686	539	36.78	0.26	140.07	0.24	129.03	0.20	108.16
051305	50	410	0	0.00	5,472	1,099	75.35	0.10	110.26	0.16	171.52	0.19	207.27
051405	400	410	0	0.00	29,049	5,807	398.16	0.08	458.38	0.19	1094.47	0.20	1164.04
051505	100	175	230	0.57	4,289	855	58.90	0.30	252.57	0.24	208.32	0.11	92.90
051605	50	410	0	0.00	4,647	930	64.38	0.20	188.52	0.34	317.40	0.17	155.70
051705	125	410	0	0.00	15,624	3,123	217.23	0.07	211.88	0.19	581.07	0.22	698.00
051805	125	415	0	0.00	20,224	4,045	282.73	0.13	508.83	0.19	785.64	0.21	843.24
051905	20	172	238	0.58	1,185	264	18.54	0.31	81.54	0.26	69.51	0.14	36.98

Table 5. Continued

052005	45	315	80	0.20	2,707	541	38.06	0.66	356.14	0.17	90.53	0.10	55.56
052105	55	395	15	0.04	5,046	1,006	71.12	0.04	42.86	0.12	119.42	0.20	203.95
052205	65	315	95	0.23	2,564	510	36.17	0.07	36.40	0.13	65.44	0.26	131.88
052305	25	395	15	0.04	825	162	11.51	0.21	33.97	0.15	23.56	0.23	36.52
052405	20	356	54	0.13	778	161	11.50	0.72	116.71	0.09	13.87	0.06	9.73
052505	25	155	255	0.62	670	130	9.30	0.65	84.40	0.15	19.01	0.12	16.10
052605	75	410	0	0.00	5,711	1,144	82.22	0.09	101.56	0.17	197.51	0.21	240.78
052705	50	410	0	0.00	4,214	843	60.79	0.21	177.24	0.36	306.87	0.16	133.63
052805	50	410	0	0.00	2,382	476	34.38	0.29	140.28	0.32	150.87	0.16	74.54
052905	50	410	0	0.00	4,266	853	61.93	0.19	164.56	0.25	216.75	0.30	253.94
053005	50	345	50	0.13	2,786	555	40.36	0.10	55.18	0.15	85.86	0.26	144.43
053105	50	410	0	0.00	1,908	381	27.71	0.17	63.10	0.18	69.89	0.27	104.04
Totals					**242,927**	**61,719**		**0.16**	**10716.46**	**0.22**	**13879.39**	**0.19**	**11708.07**
Means					**5168.66**	**1313.17**	**90.23**	**0.23**	**228.01**	**0.22**	**295.31**	**0.18**	**249.11**

Table 6. Results of marine radar image analyses for data collected on 109 nights during fall 2005 along Middle Thoroughfare, Cape May County, New Jersey. Radar malfunction, power loss and meteorological conditions resulted in data not being analyzed for 13 of the 122 nights during the study period. "Threshold" refers to the setting used to filter out image data that contain precipitation. "Data images used," (i.e., to quantify passage and altitudinal distribution), "Data images rejected" and the "Proportion rejected" show the results of the thresholdong process. "Total targets" are the number of birds/bats detected in all images collected. "Sum of the sample means" refers to the target count averaged over the five successive images that constitute a sample (i.e., every 10 minutes from sunset to sunrise the following morning). These values are summed for the entire night's data collection to generate a passage estimate. "Target detection rate" represents the number of targets detected per kilometer of passage front per hour. We also present the proportion and number of targets detected within the three lowest altitudinal strata (i.e., 100, 200, 300 m).

Date	Threshold	Data images used	Data images rejected	Proportion rejected	Total targets	Sum of the sample means	Target detection rate	Proportion of targets <=100 m	Number of targets <=100 m	Proportion of targets 101-200 m	Number of targets 101-200 m	Proportion of targets 201 -300 m	Number of targets 201-300 m
080105	150	395	0	0.00	2,793	556	40.57	0.34	188.12	0.09	47.58	0.08	46.58
080205	150	420	0	0.00	6,966	1,387	100.70	0.03	43.01	0.12	164.27	0.13	182.19
080305	150	410	0	0.00	4,959	989	71.44	0.04	37.89	0.10	103.31	0.15	147.98
080405	150	420	0	0.00	2,569	513	36.87	0.05	26.96	0.08	40.54	0.13	68.49
080505	25	365	60	0.14	2,242	467	33.40	0.06	29.37	0.13	58.53	0.13	60.41
080605	150	425	0	0.00	4,680	935	66.54	0.06	52.74	0.10	90.30	0.11	101.49
080705	175	430	0	0.00	2,977	599	42.42	0.04	25.15	0.09	52.92	0.12	74.65
080805	100	365	65	0.15	1,658	333	23.54	0.10	31.93	0.12	41.57	0.15	49.61
080905	22	295	135	0.31	1,231	247	17.38	0.22	54.18	0.15	36.52	0.10	24.48
081005	150	435	0	0.00	6,511	1,302	91.01	0.30	392.54	0.25	331.95	0.07	87.59
081105	150	435	0	0.00	5,697	1,145	79.65	0.06	70.95	0.11	127.83	0.13	146.11
081205	150	435	0	0.00	3,186	637	44.10	0.05	30.99	0.11	70.98	0.18	112.36
081305	150	425	0	0.00	6,564	1,313	90.46	0.27	355.45	0.26	337.65	0.09	114.02
081405	50	414	21	0.05	6,581	1,326	90.77	0.04	51.18	0.12	153.53	0.14	184.36
081505	100	405	30	0.07	13,394	2,680	182.60	0.02	56.83	0.09	245.31	0.14	377.77
081605	50	143	207	0.59	2,774	572	38.79	0.03	17.94	0.12	66.81	0.14	82.69
081705	330	435	0	0.00	17,470	3,493	235.39	0.04	145.76	0.09	331.31	0.09	319.91
081805	80	327	83	0.20	12,110	2,458	164.87	0.04	107.58	0.09	220.83	0.06	152.64
081905	25	327	118	0.27	2,731	574	38.44	0.06	33.63	0.09	52.33	0.07	37.62
082005	175	405	0	0.00	9,198	1,841	122.53	0.02	34.63	0.13	230.18	0.11	205.76
082605	150	450	0	0.00	4,057	811	52.37	0.05	41.58	0.05	39.38	0.08	64.37
082705	25	418	37	0.08	1,686	362	23.23	0.04	13.53	0.11	40.15	0.11	38.65
082805	150	425	0	0.00	2,350	470	30.03	0.05	25.00	0.08	37.60	0.09	43.80
082905	150	440	0	0.00	1,500	300	19.06	0.06	18.80	0.07	19.80	0.10	30.20
083005	100	445	10	0.02	2,744	548	34.76	0.03	14.78	0.04	20.37	0.07	36.75
083105	25	246	214	0.47	2,737	806	50.83	0.08	62.72	0.07	57.72	0.10	77.74
090105	450	450	0	0.00	35,514	7,105	445.44	0.04	308.90	0.09	628.19	0.11	794.85
090205	350	455	0	0.00	28,587	5,719	358.03	0.06	319.69	0.09	519.95	0.12	705.40
090305	100	411	49	0.11	20,063	4,367	271.81	0.04	161.51	0.10	428.80	0.12	545.25
090405	150	455	5	0.01	13,300	2,663	165.04	0.02	58.27	0.06	161.58	0.09	230.06
090905	300	470	0	0.00	33,249	6,648	401.64	0.07	440.08	0.09	586.04	0.09	579.24
091005	250	460	0	0.00	11,786	2,355	141.88	0.06	134.07	0.11	253.56	0.09	220.79
091105	150	445	0	0.00	7,269	1,451	87.05	0.04	55.29	0.05	70.66	0.05	76.05
091305	225	470	0	0.00	6,573	1,313	78.34	0.02	29.56	0.04	53.14	0.08	98.48
091405	100	475	0	0.00	516	99	5.88	0.19	18.61	0.18	17.46	0.10	9.98
091505	100	460	0	0.00	1,397	280	16.55	0.06	16.23	0.10	27.46	0.08	21.85

Table 6. Continued.

091605	70	364	86	0.19	7,554	1,520	89.33	0.04	56.94	0.11	163.99	0.12	183.51
091705	200	415	55	0.12	27,129	5,425	317.54	0.03	163.78	0.11	596.91	0.13	689.50
091805	450	475	0	0.00	36,302	7,257	422.48	0.00	35.38	0.04	324.85	0.06	452.99
091905	100	455	15	0.03	10,598	2,122	122.71	0.02	45.85	0.05	115.13	0.10	214.44
092005	50	330	130	0.28	7,717	1,627	93.58	0.01	24.03	0.08	132.82	0.05	88.34
092105	325	425	0	0.00	13,407	2,678	153.42	0.01	22.97	0.07	186.96	0.07	177.97
092205	150	485	0	0.00	4,999	1,000	56.99	0.00	4.40	0.05	48.61	0.11	108.42
092305	70	276	214	0.44	7,614	1,704	96.72	0.01	22.16	0.10	168.52	0.10	169.64
092405	100	475	10	0.02	7,803	1,562	88.20	0.03	48.04	0.18	286.86	0.12	189.77
092505	150	485	0	0.00	1,783	353	19.83	0.01	4.16	0.06	22.37	0.08	27.92
092605	28	363	117	0.24	2,946	610	34.13	0.01	5.38	0.05	28.57	0.05	29.61
092705	375	485	0	0.00	26,915	5,385	299.76	0.02	102.24	0.11	610.23	0.09	506.99
092805	150	495	0	0.00	3,521	706	39.15	0.01	5.41	0.04	28.47	0.06	44.31
092905	175	490	0	0.00	9,339	1,864	102.83	0.02	29.54	0.09	176.24	0.09	166.46
093005	225	470	0	0.00	6,917	1,385	76.02	0.02	23.23	0.08	116.53	0.06	78.09
100105	150	490	0	0.00	7,084	1,416	77.43	0.05	76.76	0.09	132.92	0.07	94.35
100205	150	490	0	0.00	5,651	1,122	61.04	0.11	118.14	0.17	192.79	0.14	152.88
100305	30	317	163	0.34	3,860	826	44.77	0.16	129.68	0.25	204.57	0.12	95.65
100405	150	465	0	0.00	4,913	980	52.85	0.08	80.99	0.21	203.26	0.15	151.40
100505	150	490	10	0.02	3,132	627	36.40	0.08	48.25	0.13	82.08	0.10	61.86
100605	17	436	24	0.05	1,324	271	15.65	0.21	56.29	0.10	27.02	0.05	12.69
100705	25	39	461	0.92	272	58	3.33	0.21	12.37	0.24	13.86	0.28	16.42
100805	25	280	200	0.42	2,585	597	34.16	0.04	22.86	0.08	46.65	0.15	91.22
100905	125	470	10	0.02	8,237	1,645	93.62	0.07	121.02	0.27	451.94	0.23	372.86
101005	25	276	199	0.42	3,779	851	48.24	0.09	75.44	0.32	270.91	0.16	139.17
101105	35	325	150	0.32	4,040	866	48.84	0.17	145.12	0.27	229.58	0.22	191.21
101205	25	15	455	0.97	178	35	1.97	0.22	7.87	0.44	15.53	0.12	4.33
101305	20	204	276	0.58	1,527	335	18.72	0.09	28.96	0.40	132.95	0.09	28.74
101505	150	480	0	0.00	12,686	2,535	140.57	0.12	313.93	0.20	517.75	0.14	344.70
101605	150	505	0	0.00	5,074	1,012	55.83	0.20	205.63	0.24	238.54	0.12	125.05
101705	200	344	0	0.00	23,543	4,709	258.79	0.04	180.22	0.12	580.05	0.10	448.44
101805	250	490	0	0.00	26,007	5,203	284.50	0.07	373.11	0.22	1,142.55	0.21	1,094.94
101905	125	495	0	0.00	15,532	3,105	169.14	0.02	55.57	0.07	231.90	0.11	349.84
102005	600	415	100	0.19	53,927	10,788	585.43	0.01	77.02	0.15	1,641.20	0.14	1,497.76
102105	25	84	411	0.83	769	202	10.91	0.10	20.49	0.22	45.44	0.11	22.85
102405	25	5	235	0.98	0	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
102505	17	173	351	0.67	1,731	373	19.82	0.02	8.40	0.06	20.69	0.03	12.28
102605	275	485	0	0.00	42,398	8,481	448.96	0.02	195.83	0.17	1,412.43	0.11	909.35
102705	350	500	0	0.00	28,635	5,728	301.01	0.03	197.83	0.15	837.35	0.13	739.93
102805	375	515	0	0.00	65,377	13,077	684.70	0.02	255.43	0.11	1,378.37	0.11	1,501.18
102905	150	490	0	0.00	13,370	2,677	139.66	0.08	216.04	0.24	640.32	0.11	297.13
103005	300	530	0	0.00	20,701	4,143	215.36	0.03	113.68	0.10	423.09	0.08	345.23
103105	225	530	0	0.00	13,117	2,624	135.91	0.06	168.64	0.15	400.69	0.12	323.47
110105	60	515	15	0.03	6,960	1,389	71.68	0.01	17.36	0.12	161.05	0.08	112.76
110205	375	494	0	0.00	66,837	13,368	686.62	0.01	158.81	0.11	1,432.46	0.14	1,825.28
110305	150	515	0	0.00	3,483	704	36.03	0.01	9.90	0.11	75.39	0.11	79.64
110405	150	505	0	0.00	3,571	714	36.41	0.03	21.39	0.12	86.98	0.09	65.38
110505	60	510	30	0.06	6,402	1,279	65.00	0.02	21.58	0.13	169.01	0.11	141.45

Table 6. Continued.

110605	150	540	0	0.00	5,172	1,034	52.24	0.02	20.99	0.09	91.56	0.12	126.35
110705	175	500	0	0.00	21,181	4,234	213.16	0.01	26.99	0.08	341.42	0.10	416.38
110805	300	480	60	0.11	28,952	5,789	290.44	0.04	237.34	0.17	989.96	0.13	766.81
110905	25	393	142	0.27	4,538	962	48.10	0.06	59.36	0.23	219.83	0.18	174.04
111005	200	540	0	0.00	19,346	3,869	192.77	0.05	185.79	0.28	1,072.14	0.16	606.77
111105	175	525	0	0.00	24,778	4,956	246.35	0.02	110.41	0.10	507.24	0.10	482.64
111205	150	545	0	0.00	2,704	540	26.75	0.04	21.57	0.15	83.08	0.08	42.54
111305	150	540	0	0.00	2,894	577	28.49	0.04	22.53	0.20	115.24	0.15	83.74
111405	300	530	0	0.00	20,623	4,120	202.70	0.02	85.10	0.10	406.95	0.10	403.55
111505	150	540	5	0.01	2,516	508	24.85	0.03	16.96	0.19	95.50	0.11	56.94
111605	50	328	217	0.40	3,397	698	34.07	0.07	51.37	0.24	168.28	0.16	108.29
111705	50	541	4	0.01	8,158	1,637	79.63	0.07	115.78	0.26	433.23	0.14	230.96
111805	150	545	0	0.00	13,924	2,790	135.26	0.03	91.57	0.16	446.63	0.11	316.59
111905	150	550	0	0.00	2,545	505	24.43	0.07	35.52	0.17	84.33	0.10	49.41
112005	150	550	0	0.00	3,178	633	30.52	0.02	14.94	0.10	64.73	0.08	52.19
112105	25	15	530	0.97	33	7	0.34	0.00	0.00	0.15	1.06	0.21	1.48
112205	35	519	26	0.05	3,373	677	32.46	0.11	75.47	0.27	182.25	0.15	102.76
112305	15	435	120	0.22	2,273	489	23.37	0.09	43.89	0.25	121.98	0.16	77.45
112405	25	528	22	0.04	2,784	587	27.99	0.10	59.88	0.19	113.86	0.19	109.22
112505	50	555	0	0.00	5,873	1,176	55.88	0.06	66.08	0.15	181.42	0.11	134.36
112605	50	555	0	0.00	3,017	599	28.40	0.05	27.20	0.17	100.46	0.18	106.42
112705	25	496	59	0.11	1,957	414	19.59	0.09	38.92	0.24	99.64	0.17	68.75
112805	50	555	0	0.00	3,284	657	30.98	0.08	52.22	0.19	123.84	0.32	212.46
112905	50	235	320	0.58	2,592	519	24.42	0.16	82.90	0.32	165.59	0.21	109.53
113005	75	555	0	0.00	10,531	2,107	98.93	0.05	112.04	0.17	361.54	0.12	261.70
Totals					**1,120,488**	**225,686**		**0.04**	**9,288.38**	**0.13**	**28,784.27**	**0.12**	**26,028.89**
Means					**10,280**	**2,070.51**	**118.33**	**0.06**	**85.21**	**0.14**	**264.08**	**0.12**	**238.80**

Table 7. Relationships between the propotional occurrence of synoptic weather conditions and movement pattern response variables (i.e., total targets, targets detected in the 0-100 m arl and 101-200 m arl strata).

Season	Synoptic Class	Number of nights	Proportion of total	Mean* targets detected	Proportion of total	Mean* targets detected 0-100 m	Proportion of total	Mean* targets detected 101-200 m	Proportion of total
Spring									
	1	12	0.2553	1916.33	0.2638	316.23	0.2443	439.27	0.2681
	2	9	0.1915	1025.44	0.1412	137.43	0.1061	241.19	0.1472
	3	13	0.2766	918.31	0.1264	199.36	0.1540	175.39	0.1071
	4	10	0.2128	1048.90	0.1444	166.88	0.1289	258.62	0.1579
	5	3	0.0638	2355.67	0.3243	474.79	0.3667	523.72	0.3197
Fall									
	1	38	0.3519	788.34	0.0762	94.32	0.2354	284.62	0.2367
	2	36	0.3333	3462.89	0.3346	85.43	0.2133	268.28	0.2231
	3	20	0.1852	2344.95	0.2266	84.01	0.2097	297.19	0.2471
	4	8	0.0741	822.25	0.0794	55.69	0.1390	112.22	0.0933
	5	6	0.0556	2931.33	0.2832	81.15	0.2026	240.28	0.1998

*Average for each synoptic condition

Table 8. Results of Pearson's product moment correlation analyses evaluating spring 2005 weather variables considered for use in General Linear Model procedures and multiple model inference analyses. Matrix values represent pairwise correlation coefficients. Bolded values are correlation coefficients that exceed the 0.50 threshhold we use to determine which variables cannot occur together in modeling analyses.

Season	Date	Cloud cover	Cloud ceiling	Visibility	Precipitation	Temperature	Dew point	Barometric pressure	Tailwind/ Headwind Vector-N	Tailwind/ Headwind Vector-NE	Sidewind Vector-N	Sidewind Vector-NE
Date	1.00											
Cloud cover	0.11	1.00										
Cloud ceiling	-0.06	**-0.83**	1.00									
Visibility	-0.08	-0.21	0.38	1.00								
Precipitation	0.03	0.23	-0.40	**-0.81**	1.00							
Temperature	0.28	-0.14	0.27	0.22	-0.24	1.00						
Dew point	**0.55**	0.25	-0.29	-0.06	0.06	0.40	1.00					
Barometric pressure	-0.15	-0.37	0.38	-0.02	0.03	-0.32	-0.48	1.00				
Tailwind/ Headwind Vector-N	-0.14	-0.19	0.22	0.41	-0.43	0.12	0.24	-0.03	1.00			
Tailwind/ Headwind Vector-NE	0.02	-0.10	0.27	**0.53**	-0.38	**0.52**	0.19	-0.29	**0.58**	1.00		
Sidewind Vector-N	-0.08	-0.11	0.01	-0.21	0.02	**-0.50**	-0.08	0.40	0.17	**-0.65**	1.00	
Sidewind Vector-NE	-0.17	-0.25	0.20	0.23	-0.33	-0.20	0.11	0.21	**0.83**	0.06	**0.67**	1.00

Table 9. Results of Pearson's product moment correlation analyses evaluating fall 2005 weather variables considered for use in General Linear Model procedures and multiple model inference analyses. Matrix values represent pairwise correlation coefficients. Bolded values are correlation coefficients that exceed the 0.50 threshhold we use to determine which variables cannot occur together in modeling analyses.

Season	Date	Cloud cover	Cloud ceiling	Visibility	Precipitation	Temperature	Dew point	Barometric pressure	Tailwind/ Headwind Vector-N	Tailwind/ Headwind Vector-NE	Sidewind Vector-N	Sidewind Vector-NE
Date	1											
Cloud cover	0.05512	1										
Cloud ceiling	0.0529	**-0.7797**	1									
Visibility	0.19768	-0.2585	0.38847	1								
Precipitation	-0.06698	0.25291	-0.45035	**-0.62962**	1							
Temperature	**-0.83967**	-0.1125	-0.01007	-0.19638	0.02386	1						
Dew point	**-0.76713**	0.16954	-0.34395	-0.39799	0.22875	**0.87899**	1					
Barometric pressure	0.00846	-0.1785	0.18687	0.12109	-0.14072	-0.05118	-0.12408	1				
Tailwind/ Headwind Vector-N	0.05557	0.20637	-0.15927	-0.04001	0.01662	-0.31222	-0.27181	0.08233	1			
Tailwind/ Headwind Vector-NE	-0.17497	0.23484	-0.28043	-0.17463	0.11151	0.00282	0.14394	0.33156	**0.70573**	1		
Sidewind Vector-N	0.17566	-0.2132	0.33816	0.23436	-0.17237	-0.25967	-0.47973	-0.30482	0.08533	-0.57293	1	
Sidewind Vector-NE	0.21879	-0.0072	0.12293	0.17014	-0.11563	-0.41562	**-0.5468**	-0.22527	**0.61088**	-0.09313	**0.81257**	1

Table 10. Results from multiple model inference procedures used to evaluate the effects of local meteorological conditions on target passage (sum-nightly sample means, [log transformed]) and altitude (i.e., proportion <100 m, proportion >100 m and <=200 m, arcsine transformed) in spring 2005. Models with the lowest AIC values (corrected for small sample sizes [AIC_c]) and that are at least two units smaller (ΔAIC_c) than the model with the next lowest AIC_c value are considered the best performing (bold).

Response Variable	Model	k*	(-)2 Log-Likelihood	AIC_c	ΔAIC_c	w_i	r^2
Sum-nightly sample means	Base model (Julian Day Only)	3	-94.7209	-88.1628	11.6	0.00	0.14
	THV[a], SWV[b]: North	4	-104.213	-95.2609	4.5	0.09	0.30
	THV[a], SWV[b]: Northeast	**4**	**-108.685**	**-99.7329**	**0.0**	**0.89**	**0.36**
	Temperature, Barometric pressure	4	-95.3698	-83.9064	15.8	0.00	0.15
	Cloud cover, precipitation	4	-95.6235	-86.6712	13.1	0.00	0.16
	Cloud ceiling, visibility	4	-100.638	-91.6852	8.0	0.02	0.24
Proportion <=100 m	Base model (Julian Day Only)	3	-154.997	-148.439	31.7	0.00	0.01
	THV[a], SWV[b]: North	4	-185.254	-176.302	3.8	0.13	0.48
	THV[a], SWV[b]: Northeast	**4**	**-189.088**	**-180.136**	**0.0**	**0.87**	**0.52**
	Temperature, barometric pressure	4	-157.963	-146.499	33.6	0.00	0.07
	Cloud cover, precipitation	4	-160.53	-151.578	28.6	0.00	0.12
	Cloud ceiling, visibility	4	-165.937	-156.984	23.2	0.00	0.22
Proportion >100 & <=200 m	Base model (Julian Day Only)	3	-220.739	-214.181	8.0	0.01	0.00
	THV[a], SWV[b]: North	**4**	**-231.004**	**-222.051**	**0.2**	**0.42**	**0.20**
	THV[a], SWV[b]: Northeast	**4**	**-231.162**	**-222.209**	**0.0**	**0.46**	**0.20**
	Temperature, barometric pressure	4	-229.71	-218.247	4.0	0.06	0.18
	Cloud cover, precipitation	4	-224.878	-215.926	6.3	0.02	0.09
	Cloud ceiling, visibility	4	-225.282	-216.33	5.9	0.02	0.10

* The number of estimable parameters in the model including intercept and error term.

[a]THV=Tailwind/Headwind Vector,

[b]SWV=Sidewind Vector

Table 11. Parameter estimates for factors related to flight dynamics observed during spring 2005 radar sampling. Estimates derived from the best fitting models depicted in Table 11.

Variable	Mean number of Targets			Proportion of targets ≤ 100m			Proportion of targets 101-200m		
	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*
Base model (Julian Day Only)	-	-	-	-	-	-	-	-	-
Tailwind/headwind vector-North	-	-	-	-	-	-	0.0024	0.0031	0.44
Sidewind vector-North	-	-	-	-	-	-	**-0.0111**	**0.0034**	**0.002**
Tailwind/headwind vector-Northeast	**0.0579**	**0.0135**	**0.0001**	**-0.0359**	**0.0058**	**<0.0001**	**0.0120**	**0.0037**	**0.005**
Sidewind vector-Northeast	**0.0262**	**0.0111**	**0.02**	**-0.0125**	**0.0048**	**0.01**	0.0050	0.0030	0.10
Temperature	-	-	-	-	-	-	-	-	-
Dew point	-	-	-	-	-	-	-	-	-
Barometric pressure	-	-	-	-	-	-	-	-	-
Cloud cover	-	-	-	-	-	-	-	-	-
Precipitation	-	-	-	-	-	-	-	-	-
Cloud ceiling	-	-	-	-	-	-	-	-	-
Visibility	-	-	-	-	-	-	-	-	-

Table 12. Results from multiple model inference procedures used to evaluate the effects of local meteorological conditions on target passage (sum-nightly sample means, [log transformed]) and altitude (i.e., proportion <100 m, proportion >100 m and <=200 m, arcsine transformed) in fall 2005. Models with the lowest AIC values (corrected for small sample sizes [AICc]) and that are at least two units smaller (DAICc) than the model with the next lowest AICc value are considered the best performing (bold).

Response Variable	Model	k*	(-)2 Log-Likelihood	AIC_c	ΔAIC_c	w_i	r^2
Sum-nightly sample means	Base model (Julian Day Only)	3	-114.601	-106.216	29.9	0.00	0.01
	THV[a], SWV[b]: North	4	-132.763	-124.378	11.7	0.00	0.16
	THV[a], SWV[b]: Northeast	4	-130.868	-122.483	13.6	0.00	0.15
	Temperature, Barometric pressure	4	-116.41	-108.025	28.1	0.00	0.02
	Cloud cover, precipitation	**4**	**-144.473**	**-136.089**	**0.0**	**0.70**	**0.25**
	Cloud ceiling, visibility	**4**	**-142.726**	**-134.341**	**1.7**	**0.29**	**0.23**
Proportion <=100 m	Base model (Julian Day Only)	3	-471.489	-463.105	2.7	0.11	0.02
	THV[a], SWV[b]: North	4	-469.798	-461.414	4.4	0.05	0.00
	THV[a], SWV[b]: Northeast	4	-469.791	-461.406	4.4	0.05	0.00
	Temperature, Barometric pressure	4	-470.581	-462.197	3.6	0.07	0.01
	Cloud cover, precipitation	**4**	**-473.526**	**-465.142**	**0.7**	**0.30**	**0.04**
	Cloud ceiling, visibility	**4**	**-474.192**	**-465.807**	**0.0**	**0.42**	**0.04**
Proportion >100 & <=200 m	**Base model (Julian Day Only)**	**3**	**-492.683**	**-486.454**	**0.0**	**0.71**	**0.14**
	THV[a], SWV[b]: North	4	-482.851	-474.466	12.0	0.00	0.06
	THV[a], SWV[b]: Northeast	4	-482.881	-474.497	12.0	0.00	0.06
	Temperature, Barometric pressure	**4**	**-492.85**	**-484.465**	**2.0**	**0.26**	**0.14**
	Cloud cover, precipitation	4	-487.166	-478.782	7.7	0.02	0.10
	Cloud ceiling, visibility	4	-483.419	-475.035	11.4	0.00	0.07

* The number of estimable parameters in the model including intercept and error term.

[a]*THV=Tailwind/Headwind Vector,*

[b]SWV=Sidewind Vector

Table 13. Parameter estimates for factors related to flight dynamics observed during fall 2005 radar sampling. Estimates derived from the best fitting models depicted in Table 12.

Variable	Mean number of Targets			Proportion of targets ≤ 100m			Proportion of targets 101-200m		
	Estimate	SE	*P*	Estimate	SE	*P*	Estimate	SE	*P*
Base model (Julian Day Only)	-	-	-	-	-	-	0.0012	**0.0003**	**<0.0001**
Tailwind/headwind vector-North	-	-	-	-	-	-	-	-	-
Sidewind vector-North	-	-	-	-	-	-	-	-	-
Tailwind/headwind vector-Northeast	-	-	-	-	-	-	-	-	-
Sidewind vector-Northeast	-	-	-	-	-	-	-	-	-
Temperature (dry bulb, C°)	-	-	-	-	-	-	**-0.0062**	**0.0015**	**<0.0001**
Barometric pressure (millibars)	-	-	-	-	-	-	-0.0010	0.0014	0.48
Cloud cover	-0.1397	0.1005	0.17	0.0395	0.0222	0.08	-	-	-
Precipitation	**0.8877**	**0.1718**	**<0.0001**	-0.0175	0.0380	0.65	-	-	-
Cloud ceiling	**0.0001**	**0.0000**	**0.0005**	**-0.00002**	**0.00001**	**0.04**	-	-	-
Visibility	**0.0628**	**0.0237**	**0.009**	0.0008	0.0052	0.88	-	-	-

Figure 1. Dual radar system with horizontally and vertically oriented antennas that operate simultaneously. This system allows for data collection on passage (horizontal and vertical), altitude (vertical) and flight direction (horizontal).

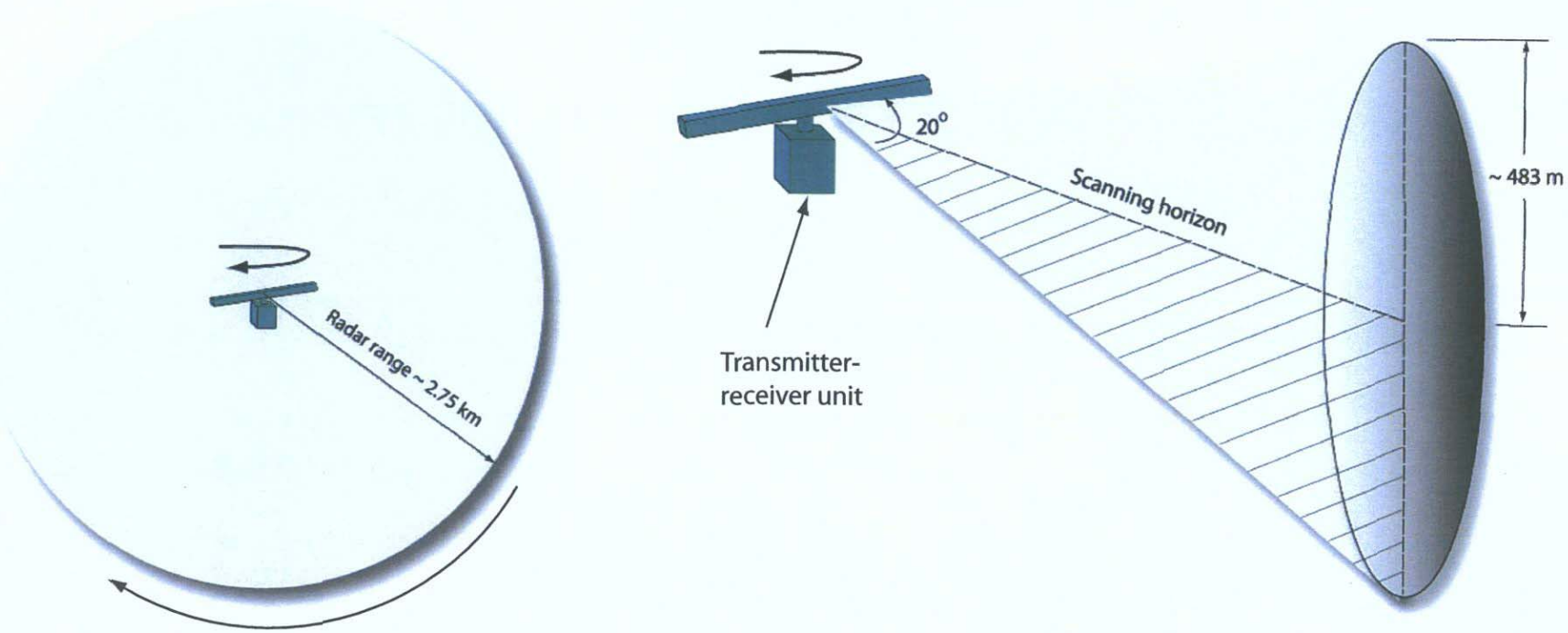


Figure 2. Graphic representation of scanning operation of horizontally-oriented radar. In this orientation, the antenna rotates in a plane parallel to the ground resulting in a 360° scan with a that samples 10° above and below the scanning horizon. With the radar's range set to 1 nautical mile (1.85 km, 6076 ft) which is the effective detection range for small passerines with 25 kW radar) it samples up to 483 m arl (above radar level) and ~4.0 km3 of air space. Data collected in "horizontal" scanning mode can be used to estimate (1) target flight direction and speed and (2) target passage magnitude.

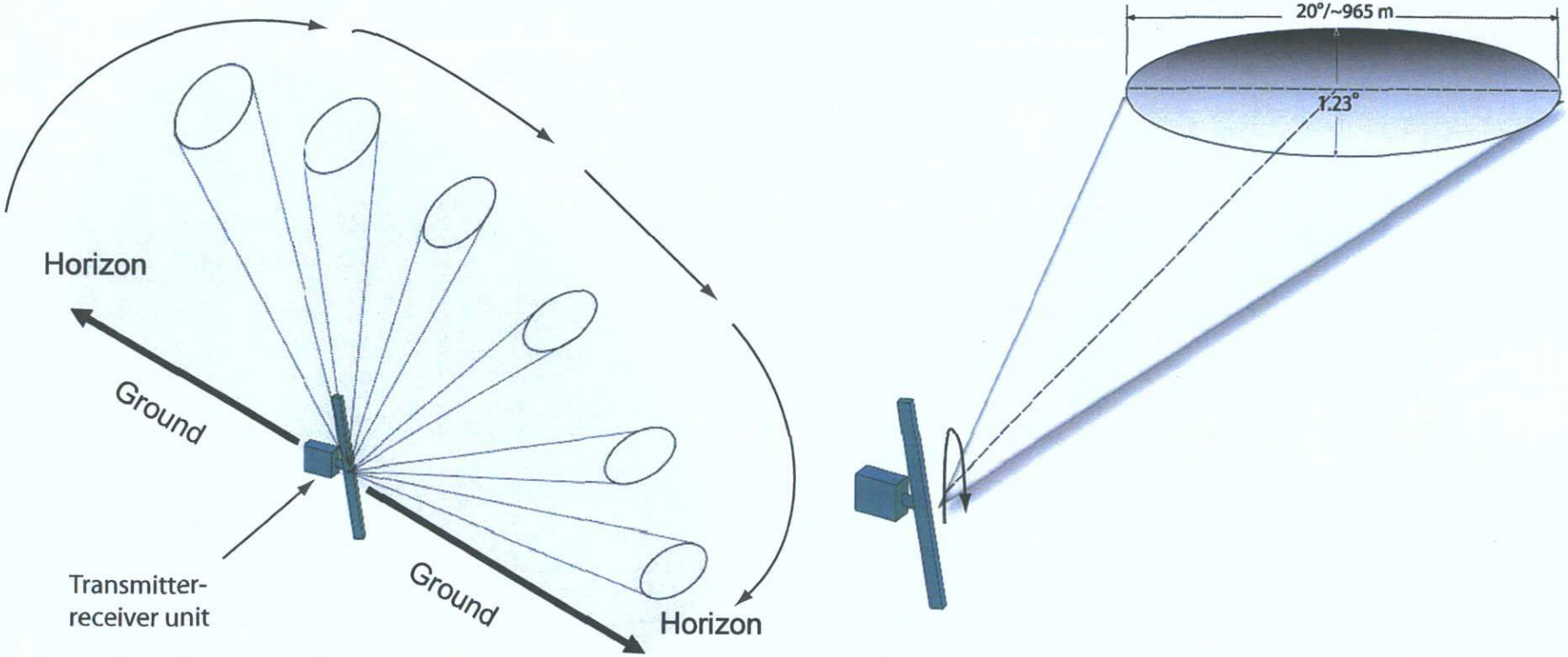


Figure 3. Graphical depiction of scanning operation of vertically-oriented radar. In this orientation, the transmitter-receiver unit is mounted perpendicular to the ground so that the radar antenna's rotation results in a 180°, horizon-to-horizon scan (radar does not transmit when antenna is oriented groundward). When the radar's range is set to 0.75 nm (1.4 km, 4557 ft) it samples ~0.98 km3 of air space. Data collected in "vertical" scanning mode can be used to estimate (1) target altitude and (2) target passage magnitude.

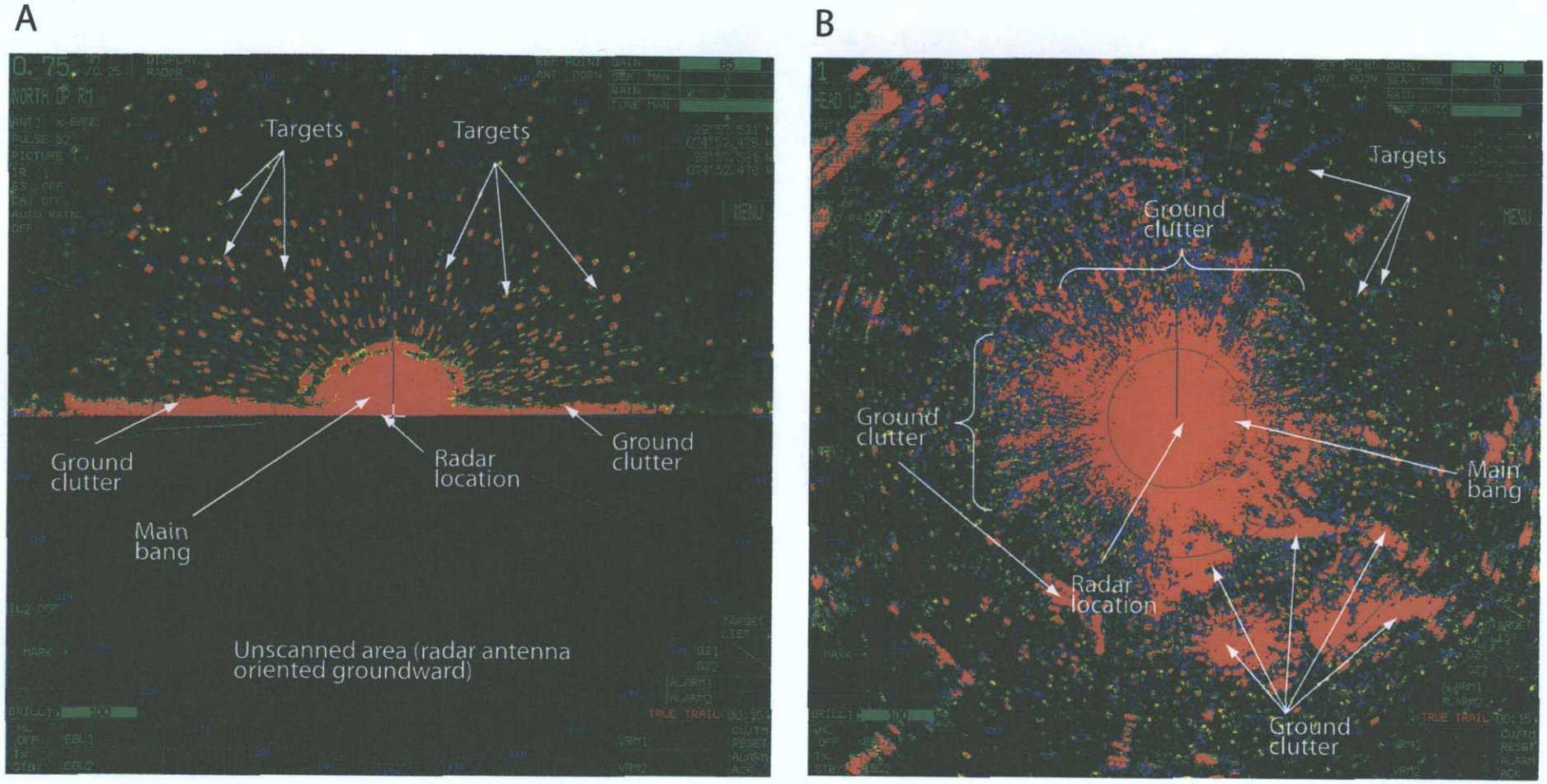


Figure 4. (A) Data images from vertically-oriented and (B) horizontally-oriented radars collected on 20 October 2005, at ~2357 EDT. Radar displays targets using an RGB color scale to represent 29 reflectance levels (i.e., amount of energy reflected by target).

Greens → Yellows → Reds = low → moderate → high reflectance values.

Target tracking (shown in blue) can be used to estimate target velocity and flight direction. Circular areas of red at the center of each data image is referred to as the "main bang." The main bang is an inherent property of all radars representing the radar's noise range and thus occludes target detection in this region. Irregularly shaped red areas, referred to as ground clutter, are typically large, stationary features (e.g., buildings, mountains, trees) in the radar's field of view that reflect electromagnetic energy. Similar to the main bang region, these features occlude target detection.

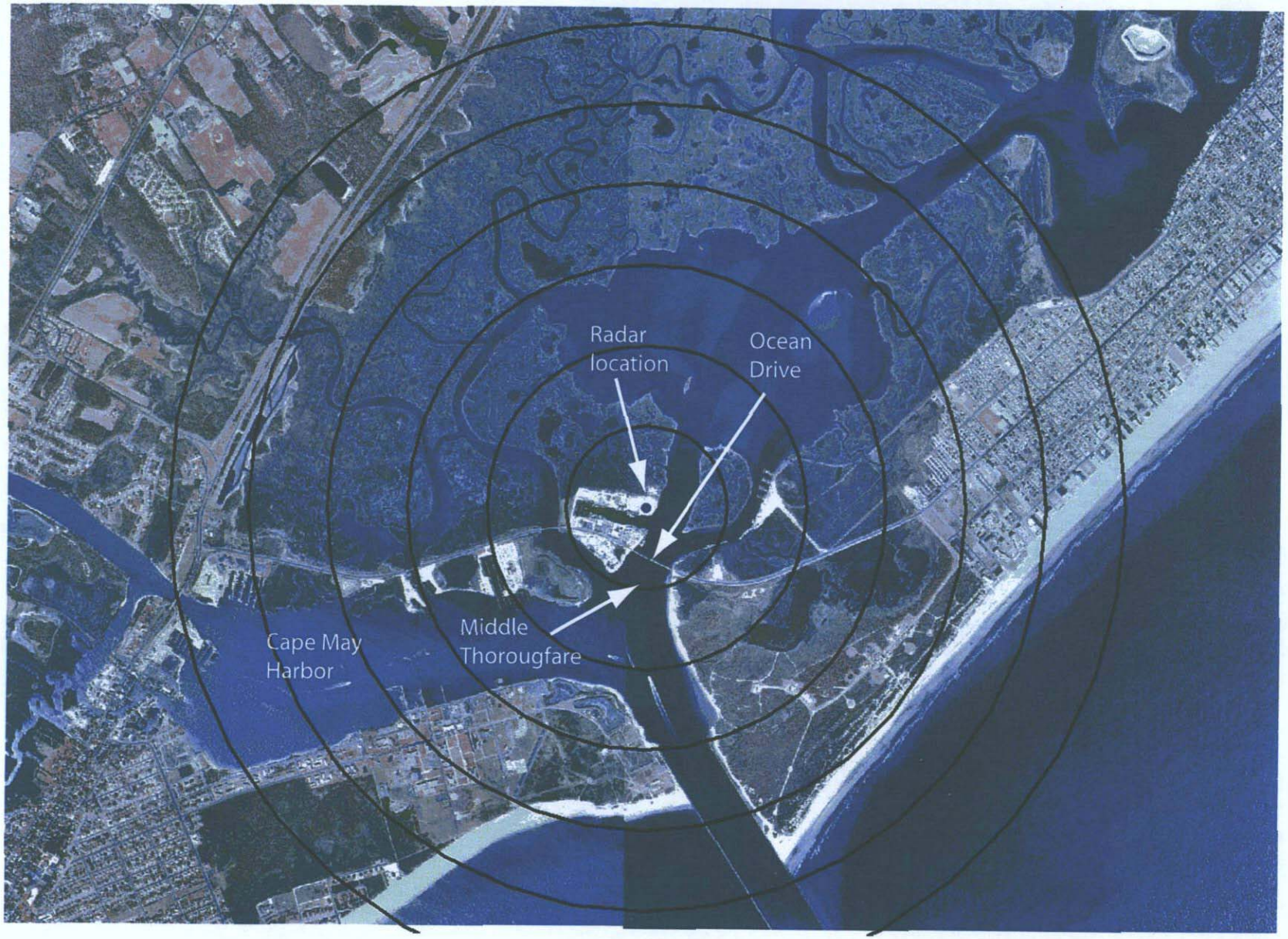
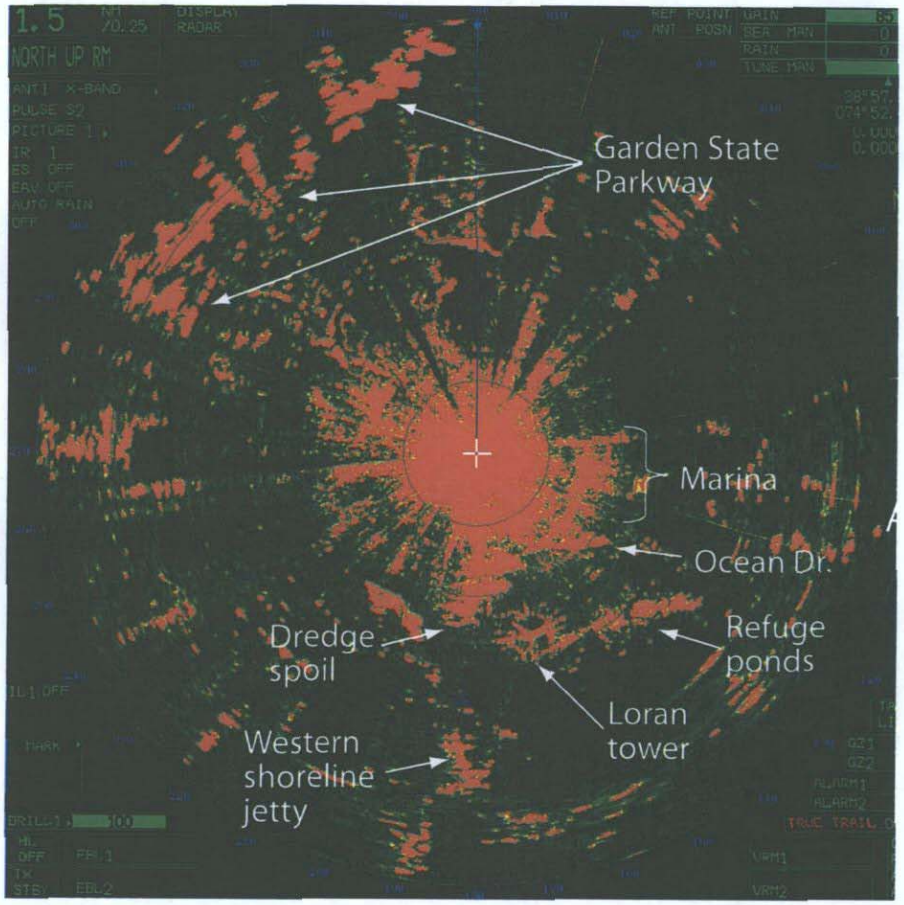


Figure 5. Study site on Cape May Peninsula at the Atlantic Cape Fisheries. The radar was located along the western shore of Middle Thoroughfare waterway. Middle Thoroughfare separates the southern end of Seven Mile Island (right) and Cape Island (left). Concentric circles are 0.25 nautical miles apart.

A



B

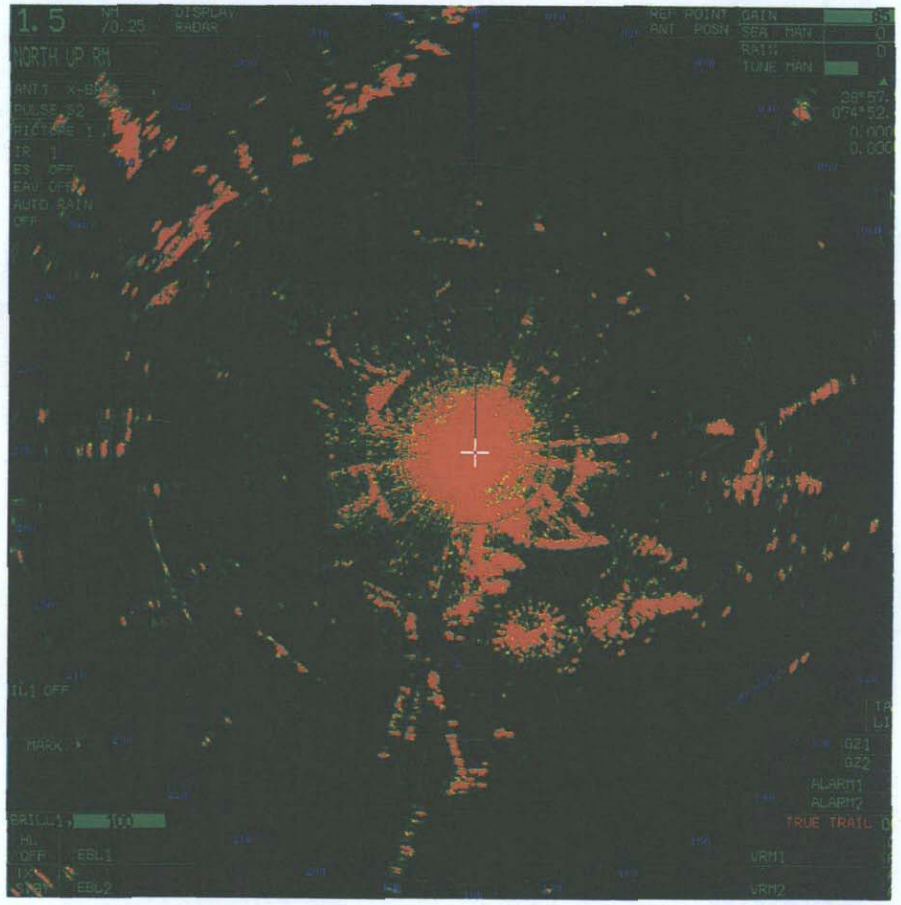
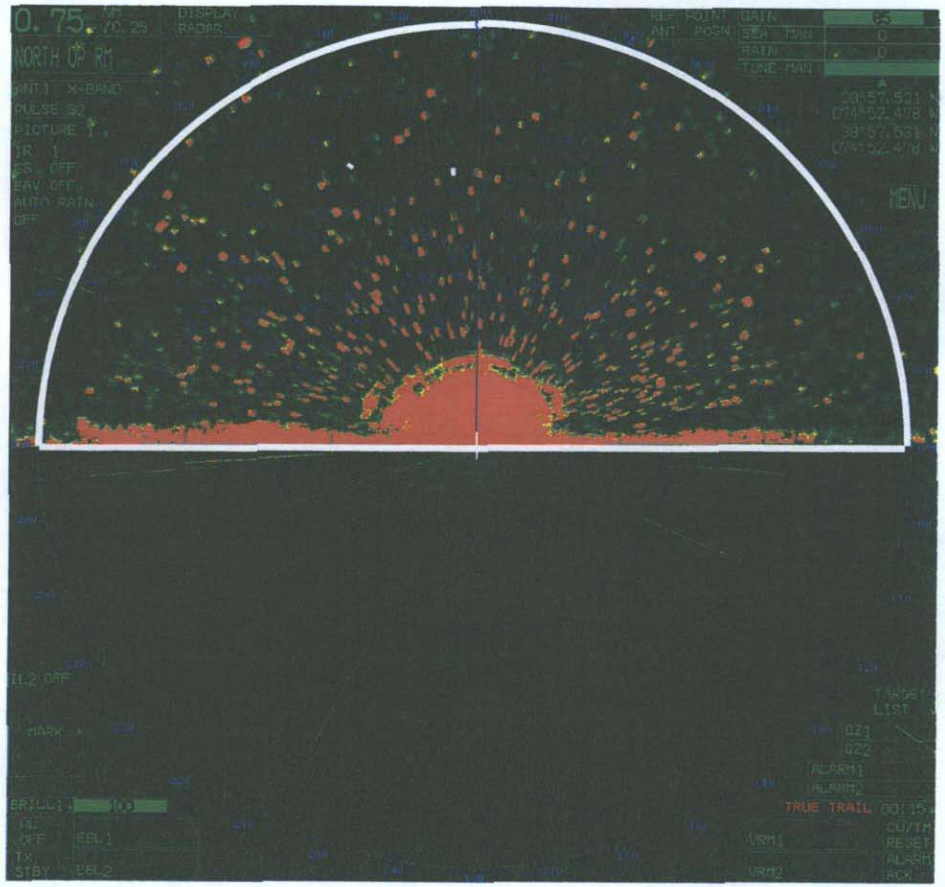


Figure 6. (A) Data image collected with the horizontally-oriented radar (i.e., surveillance) showing major areas of ground clutter (red areas). The ground clutter is produced by various reflective structures in the radar's field of view. Red spokes emanating from the image's central area result from large amounts of equipment (>20 tractor trailers) on the study that are reflecting the radar's electromagnetic energy. (B) Data image after radar fence was installed to reduce the amount of electromagnetic energy transmitted and received below the radar's scanning horizon. The radar fence reduced but did not completely eliminate the ground clutter problem.

A



B

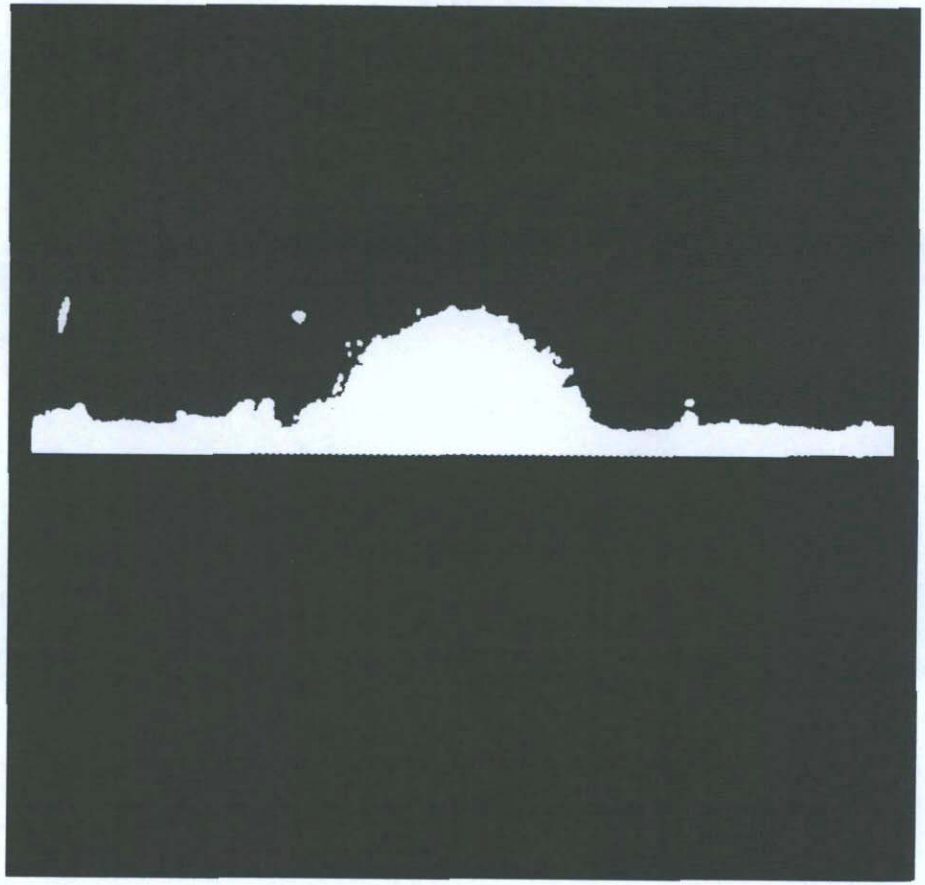


Figure 7. (A) Data image from vertically oriented radar collected on 20 Oct 2005, 2357 EST. Thick white line graphically represents how NJAS's integrated image processing software defines the sample area. (B) Template generated by NJAS's integrated image processing software for vertically -oriented data collected 20 October 2005. Template performs as a mask for removing stationary reflectors (i.e., main bang, ground clutter, see Fig. 2) from subsequent image analysis steps.

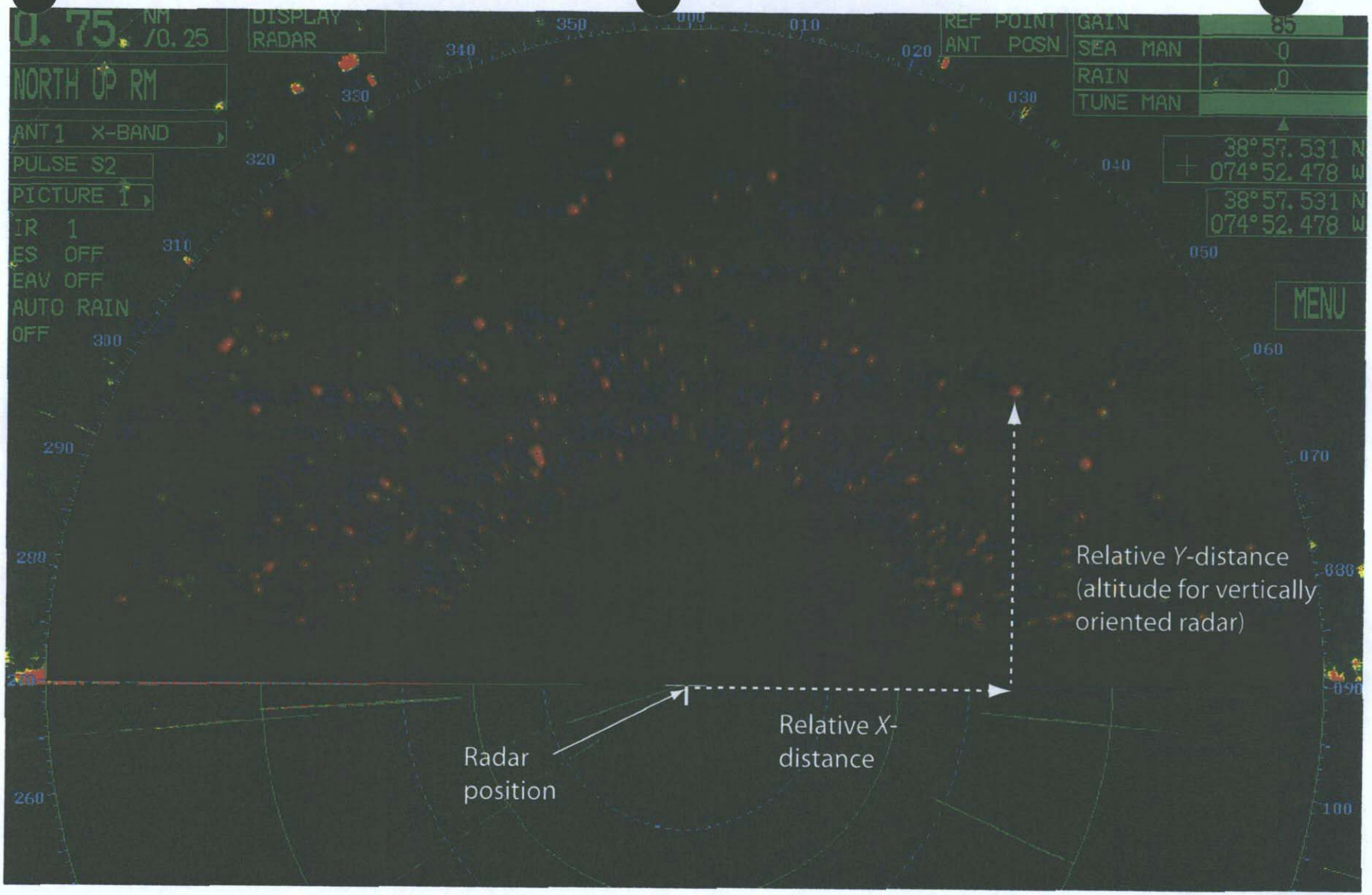


Figure 8. Data image collected on 20 October 2005, at 2357 EDT, with the vertically-oriented radar. NJAS integrated image processing software removes targets with low reflectivity, smooths the data and locates and marks the centroid of each discrete target that remains. In this representation target centroids are marked with white dots. Because coordinates of the scan center (i.e., radar position, GPS) and the image's pixel dimensions are known, we can calculate a target's distance from the radar in the *X*-, *Y*-planes. This allows us to calculate any target's altitude (vertically-oriented radar) or *X*-, *Y*-coordinates (horizontally-oriented radar).

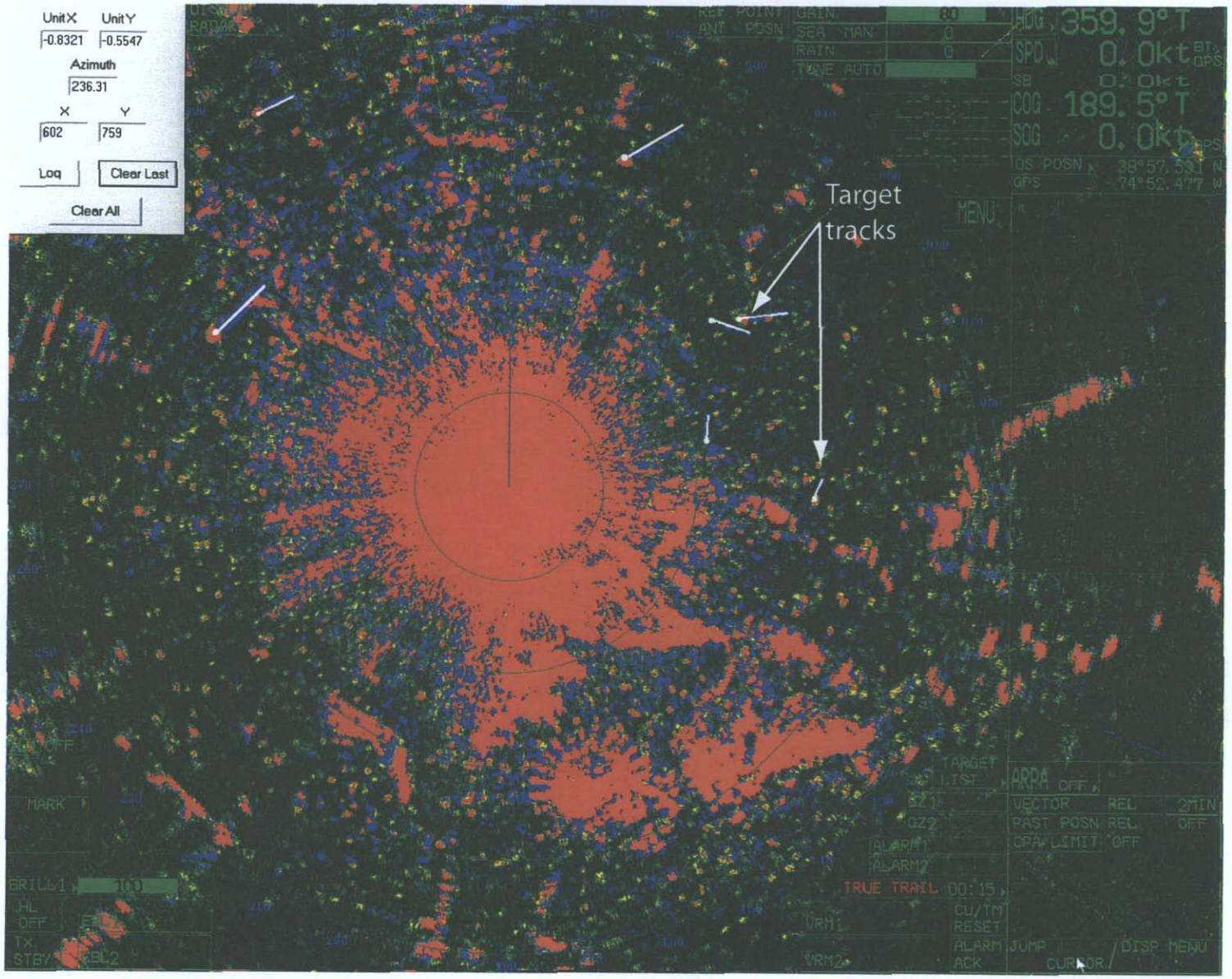


Figure 9. Data image collected on 20 October 2005 at 2357 EDT with the horizontally-oriented radar. Image shows target tracks created using NJAS proprietary software to calculate target directions. The program requires that the end of a target's trail (blue dotted line) and the target (green, yellow or red ellipses) be marked (in that order) manually using the computer's mouse and cursor. The program outputs the position of the trail's tail and the target and from these calculates the target's direction of movement.

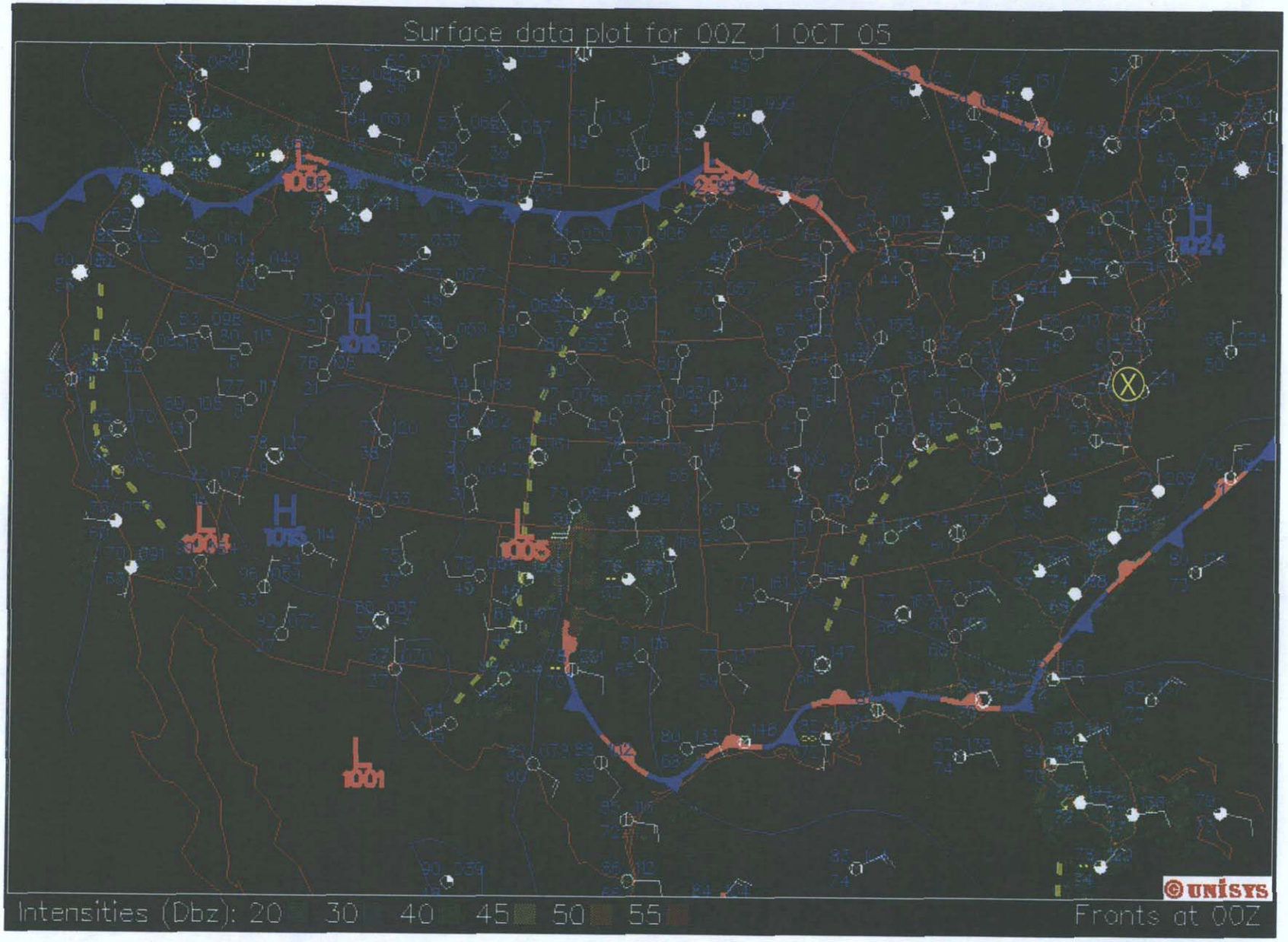


Figure 10. Surface weather map from 1 October 2005, 0000 Greenwich Mean Time (Z, equivalent to 14 September, 2000 EST). Note yellow "X" within yellow circle, indicating general location of the study area. Surface weather maps were used to determine the position of synoptic weather systems (i.e., large scale atmospheric conditions) such as high or low pressure systems or frontal boundaries relative to the study areas.

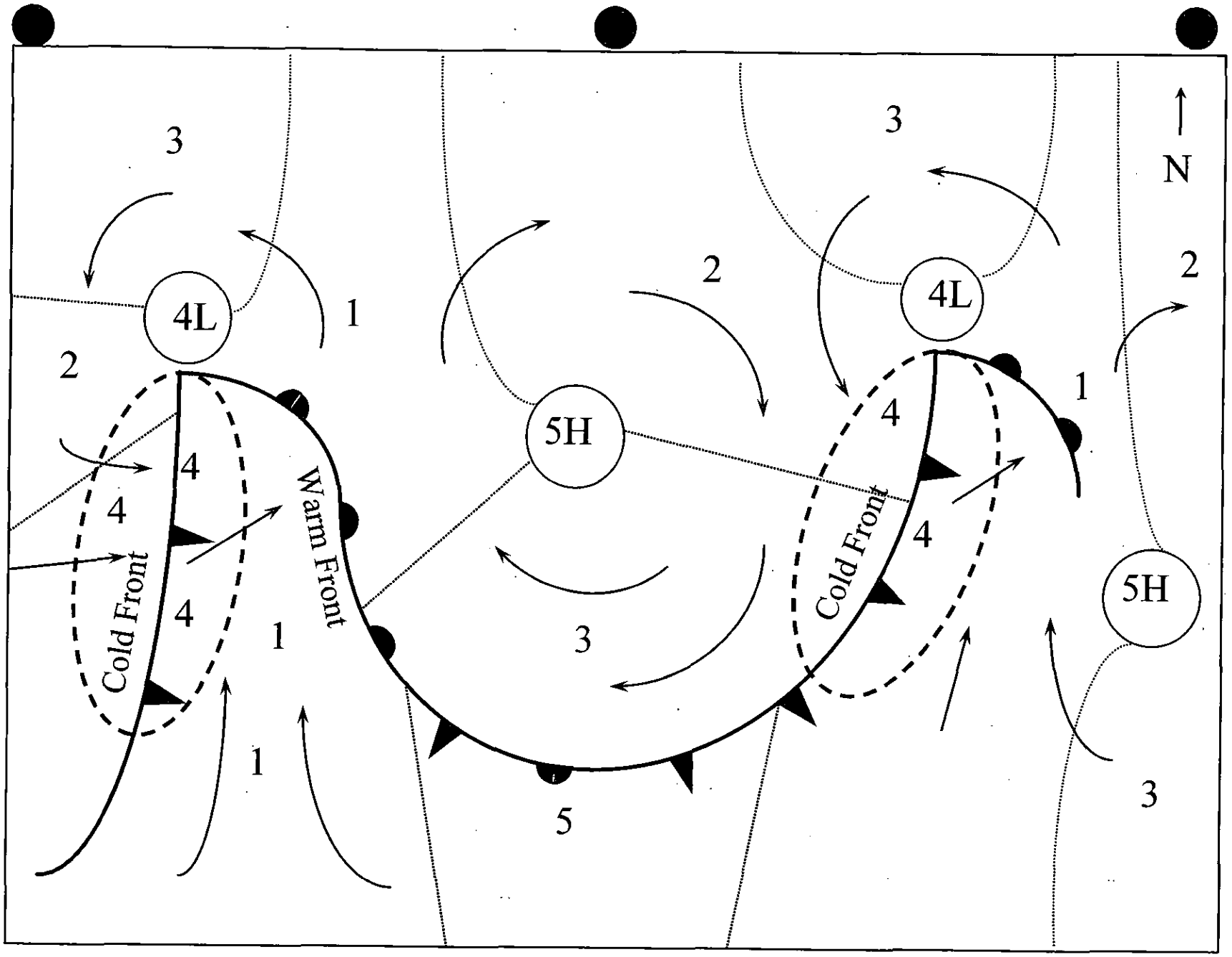


Figure 11 Generalized synoptic weather map with five synoptic regions: (1) southerly winds except after cold fronts, (2) northwesterly winds, (3) northeasterly winds, (4) the center of low pressure systems and (5) calm weather at the center of high pressure systems (after Richardson 1976, Lank 1983).

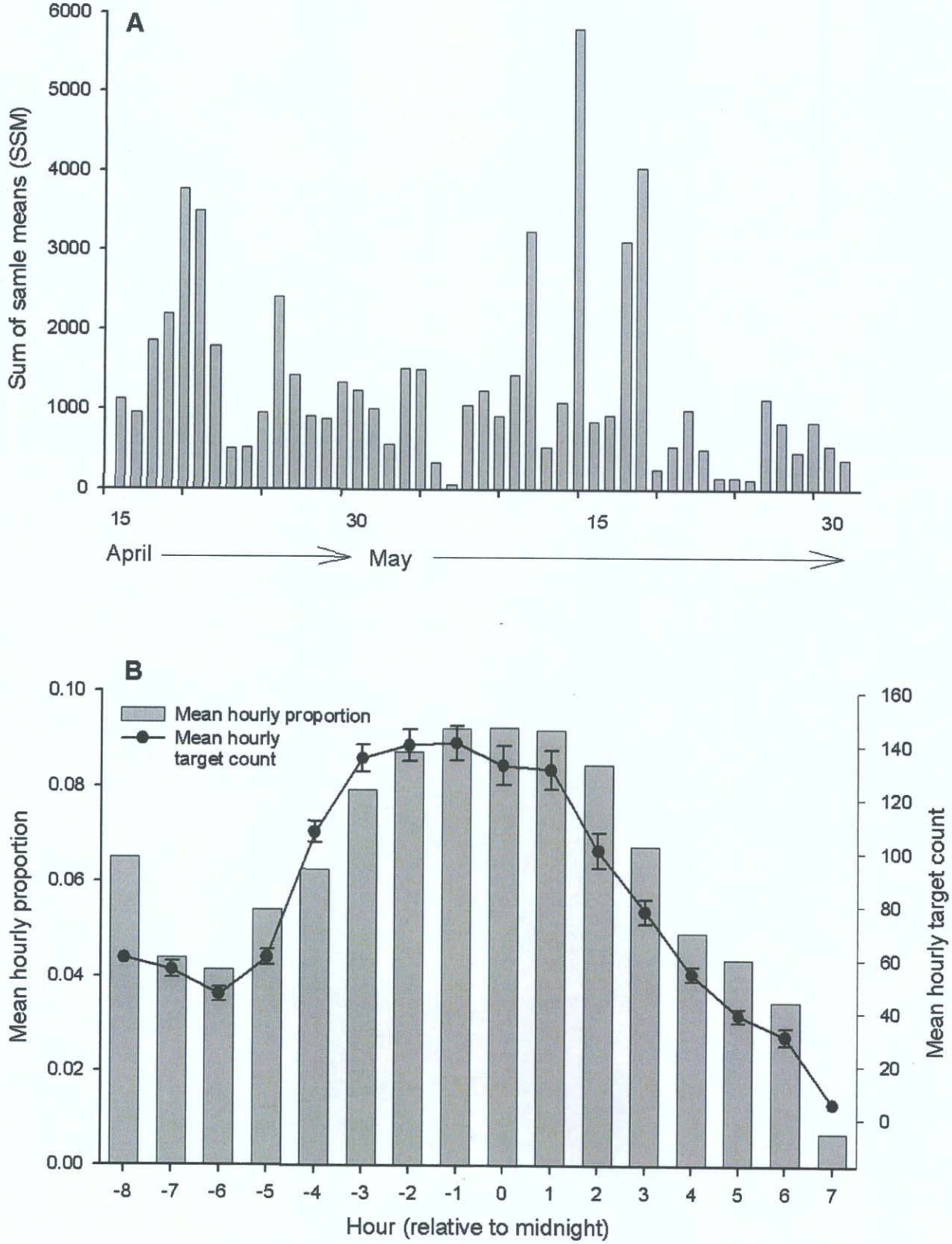


Figure 12. Spring 2005. (A) Seasonal temporal pattern in nightly target counts. (B) Hourly temporal pattern in target counts and proportion of total count averaged over the entire season.

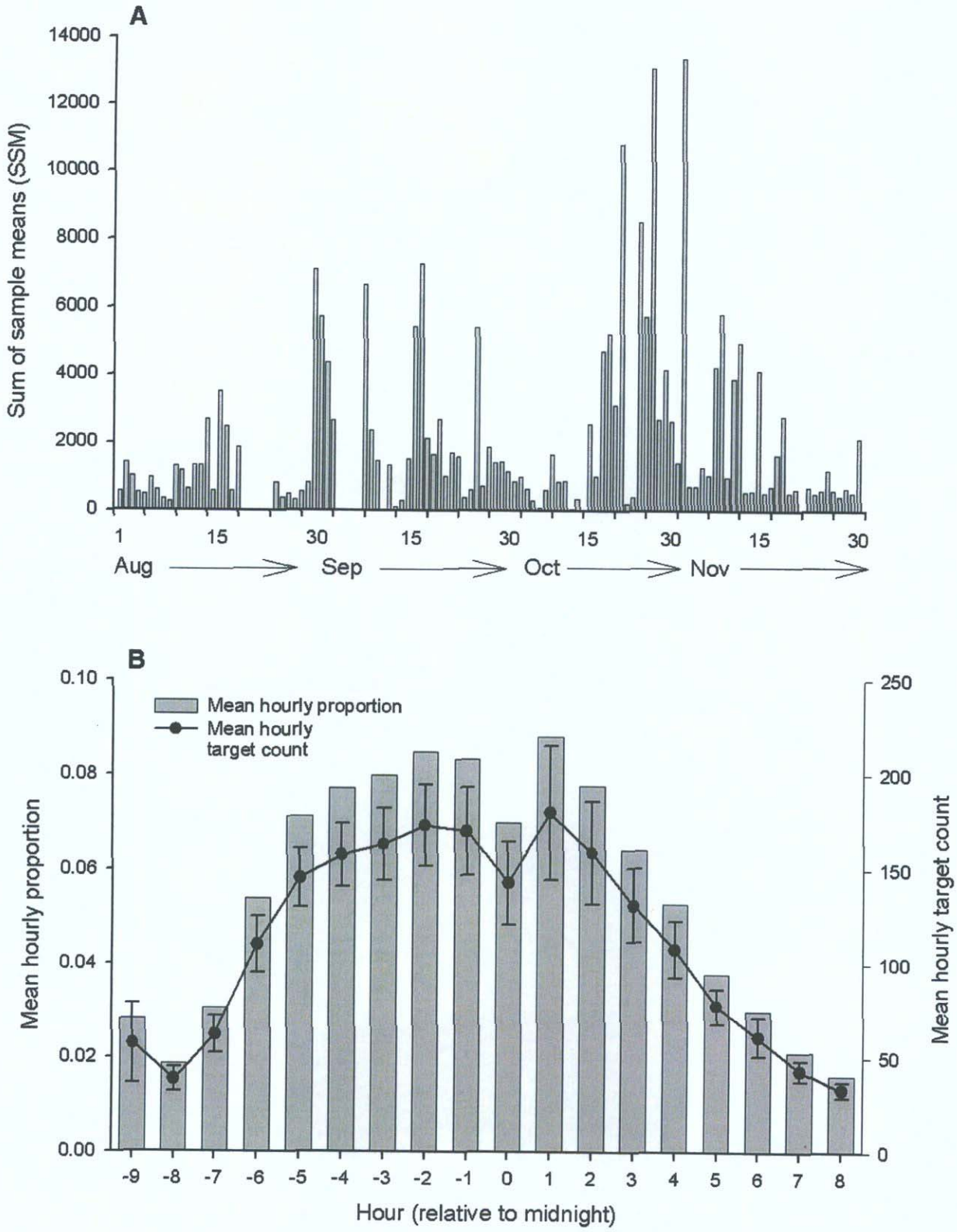


Figure 13 Fall 2005. (A) Seasonal temporal pattern in nightly target counts. (B) Hourly temporal pattern in target counts and proportion of total count averaged over the entire season.

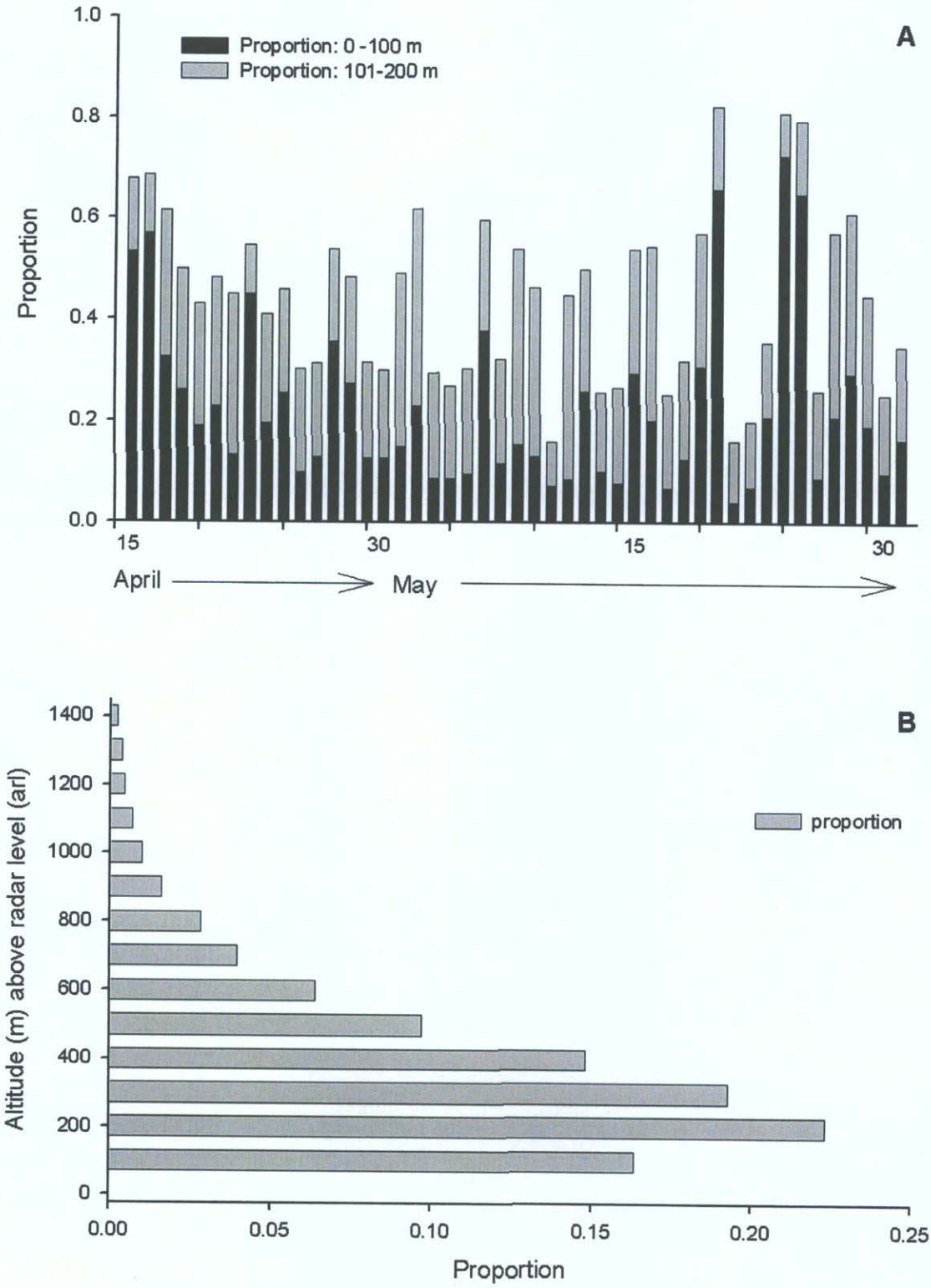


Figure 14. Spring 2005. (A) Seasonal temporal pattern in the proportion of targets detected <= 100 m above radar level (arl) and between 101 and 200 m arl. (B) Altitudinal distribution of detected targets displayed in 100 m strata from 0-1400 m.

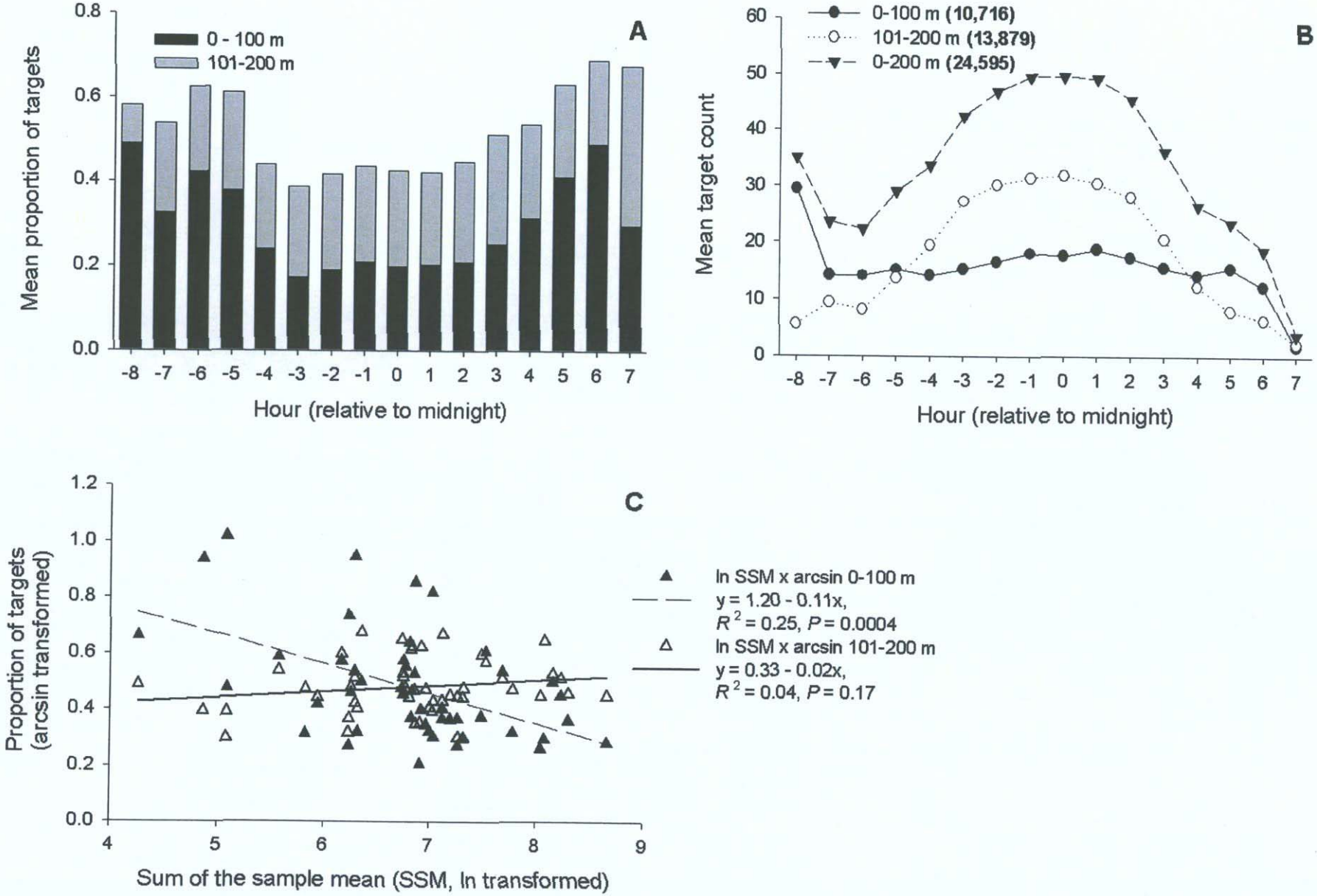


Figure 15. Spring 2005. (A) Mean proportion of targets detected by hour at <=100m and between 101 and 200 m above radar level(arl). (B) Mean number of targets detected by hour at <=100m and between 101 and 200 m arl. (C) Relationship between nightly target counts and proportion of targets <=100 m (dashed line) and between 101 and 200 m arl (solid line).

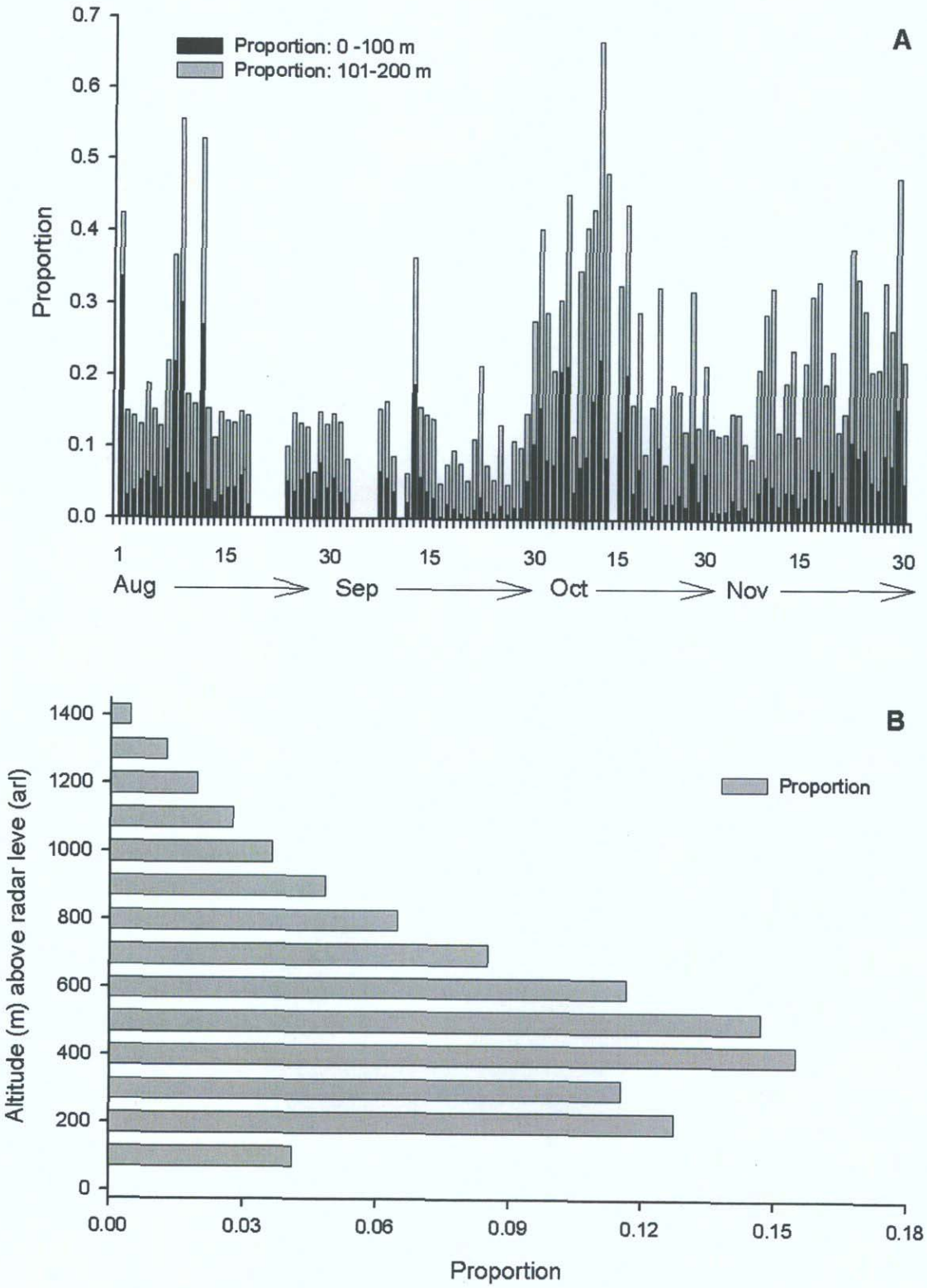


Figure 16. Fall 2005. (A) Seasonal temporal pattern in the proportion of targets detected <= 100 m above radar level (arl) and between 101 and 200 m arl. (B) Altitudinal distribution of detected targets displayed in 100 m strata from 0-1400 m.

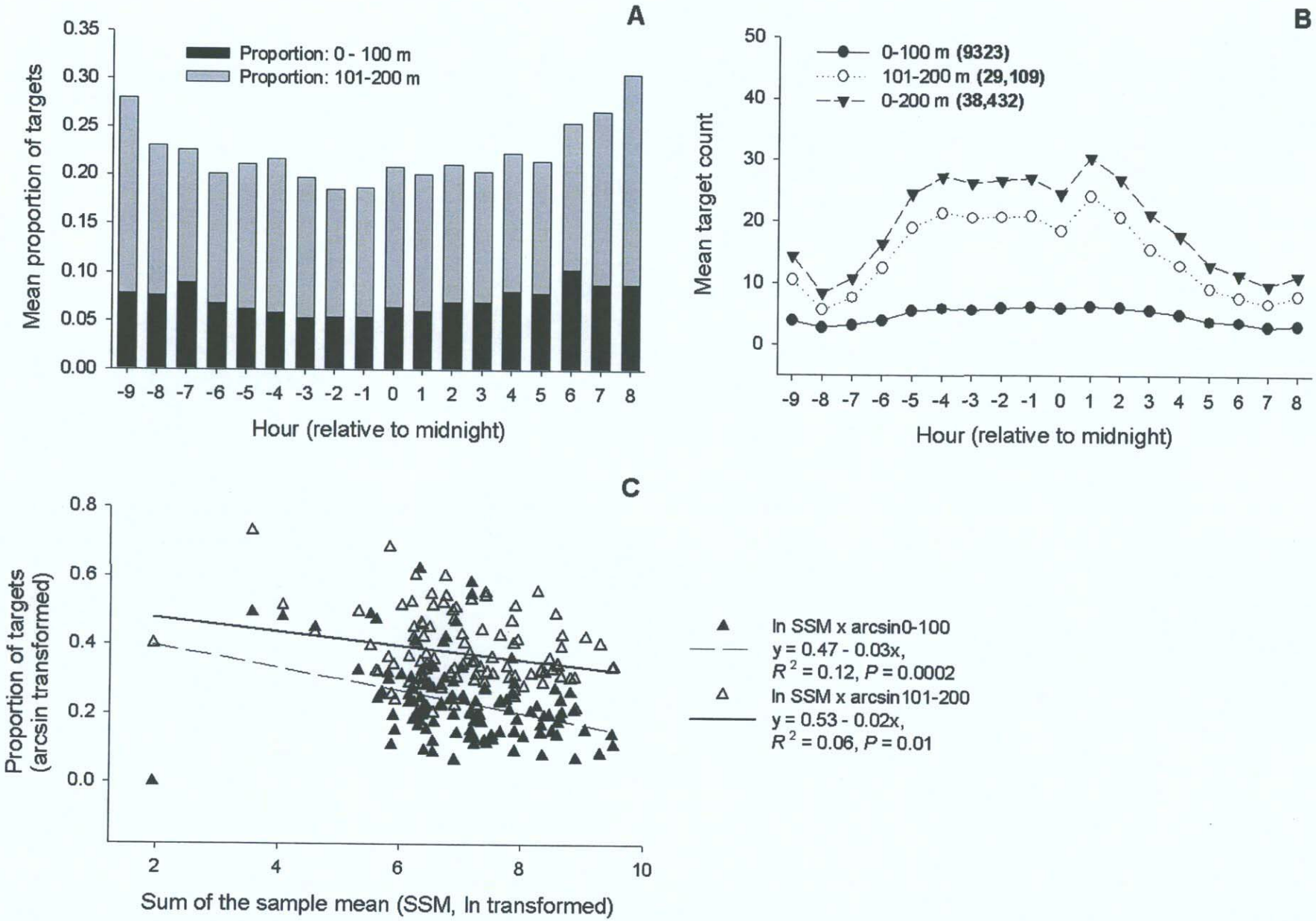
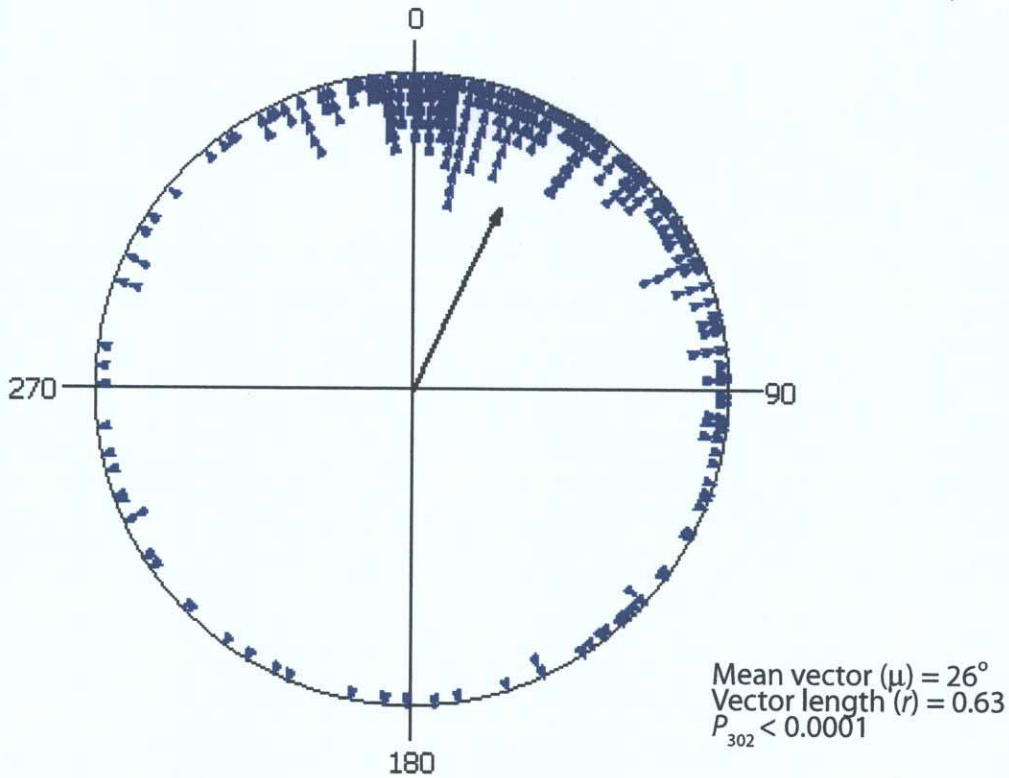


Figure 17. Fall 2005. (A) Mean proportion of targets detected by hour at <=100m and between 101 and 200 m above radar level(arl). (B) Mean number of targets detected by hour at <=100m and between 101 and 200 m arl. (C) Relationship between nightly target counts and proportion of targets <=100 m (dashed line) and between 101 and 200 m arl (solid line).

A



B

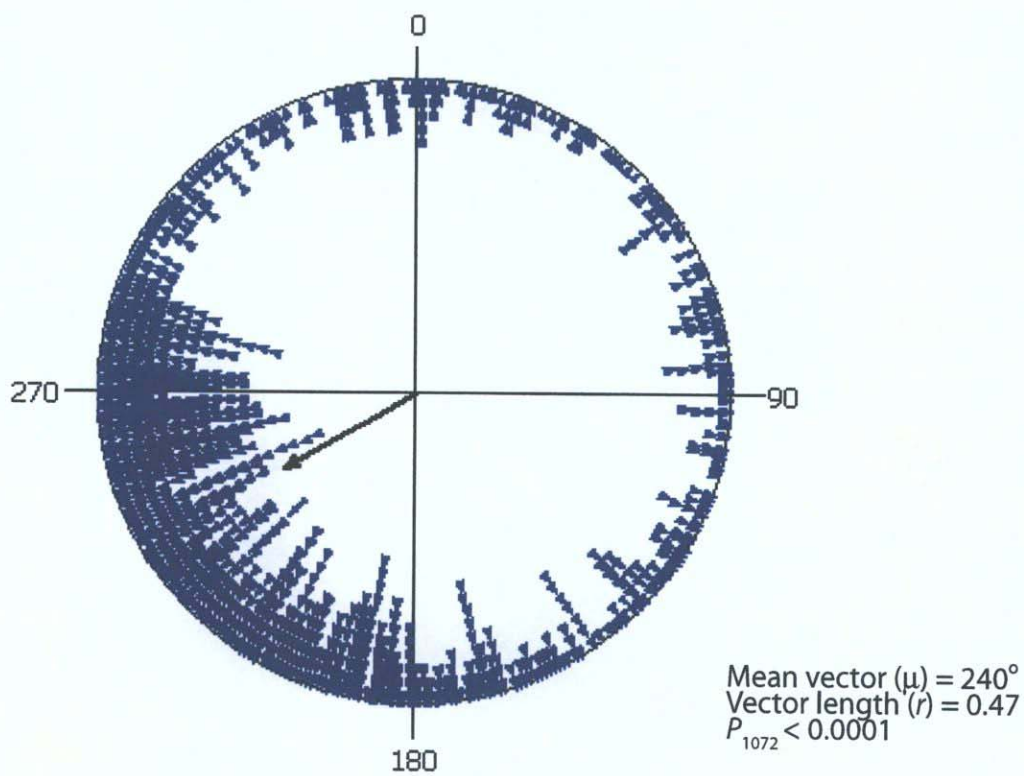
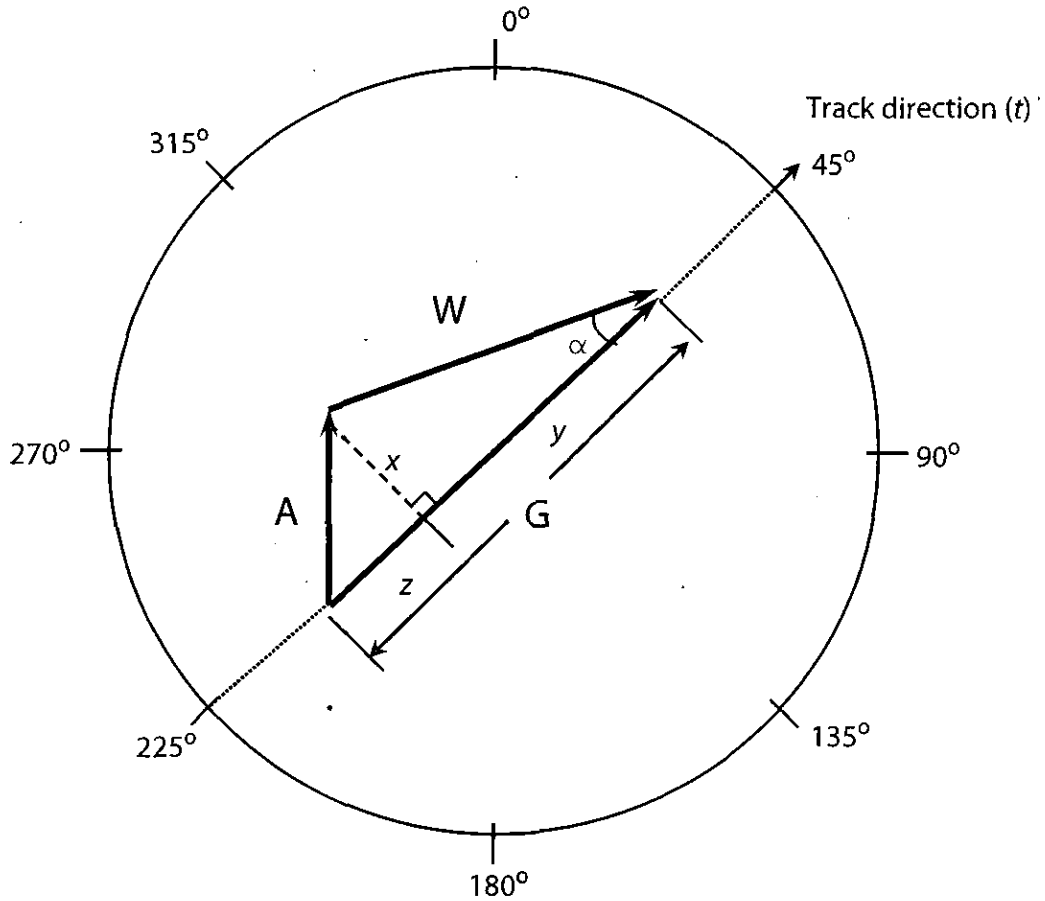


Figure 18. Mean flight direction vectors calculated from data collected with a horizontally-oreiented radar in spring (A) and fall (B) 2005. Arrow in each circular plot points toward the mean vector and its length (i.e., vector length) is a measure of directional tendency that ranges from 0-1. The greater the value, the stronger the directional tendency.

Appendix 1

Wind Vector Schematic



A schematic representation used to calculate head or tailwind vectors (THV) for birds flying in a fixed track direction (*t*) and with a constant air speed (after Piersma and Jukema 1990). If ? is the angular difference between t and the wind direction (*w*), then ? = $w \pm 180^{\circ} - t$. If W is wind velocity, A is the bird's air velocity, and G is its ground velocity, then the 'wind effect,' ?W (THV) = G - A. If birds try to remain on course then the heading of G is always along t. Following the schematic and rules of trigonometry, THV can be calculated as follows: sin? = x/W, therefore x = Wsin?. Also, $z = \sqrt{(A^2 - x^2)}$, and so $z = \sqrt{\{A^2 - (W\sin?)^2\}}$. Additionally, cos? = y/W, and therefore y = Wcos?. Because G = $y + z$, it follows that:

$$G = W\cos? + \sqrt{\{A^2 - (W\sin?)^2\}}.$$

Similarly, because ?W(THV) = G - A, it follows that:

$$?W = W\cos? + \sqrt{\{A^2 - (W\sin?)^2\}} - A.$$

Appendix 2. Results of marine radar image analyses for all altitudinal strata sampled (totals, means for 0-1400 m presented in 100 m bins) on 47 days during spring 2005. Column heading descriptions follow Table 5.

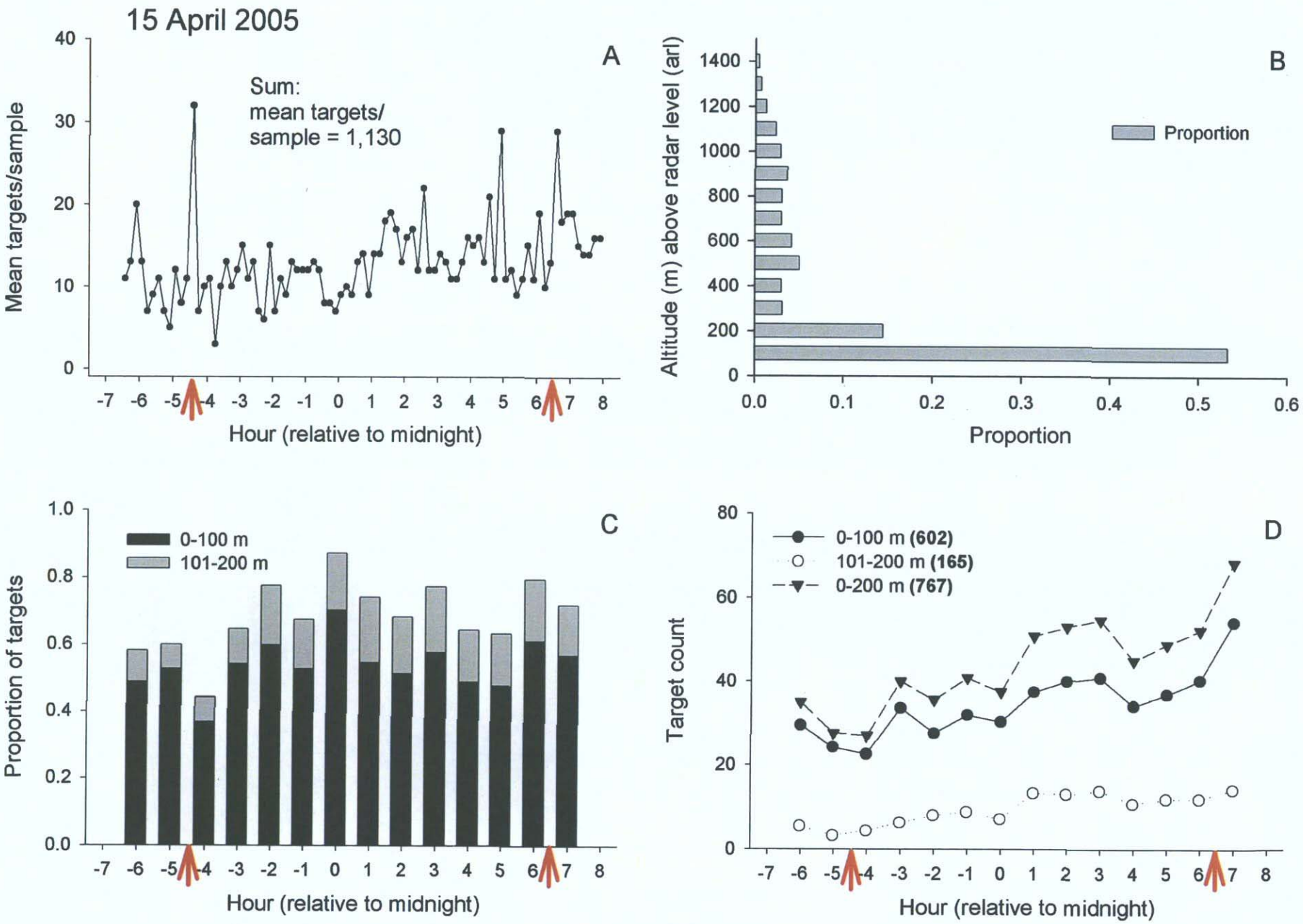
Date	Threshold	Number of images used	Number of images rejected	Total targets detected	Sum of the sample means	Strata (in meters)													
						100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
041505	60	261	0	3393	1130	1808	495	100	104	171	141	102	101	128	98	75	38	22	10
041605	50	249	0	2901	963	1652	338	101	70	190	92	95	90	60	64	57	45	30	17
041705	65	228	0	5587	1863	1817	1626	607	347	217	161	137	224	166	145	53	32	53	2
041805	65	255	0	6564	2189	1707	1563	1254	584	367	223	192	196	160	141	84	52	29	12
041905	125	255	0	11297	3767	2145	2708	2306	1867	1058	505	245	133	106	78	71	36	31	8
042005	125	255	0	10496	3497	2398	2660	2097	1158	816	528	281	254	154	70	37	27	7	9
042105	75	255	0	5396	1794	724	1697	1013	564	433	369	190	127	98	76	53	31	13	8
042205	25	106	149	1334	508	599	130	61	127	65	40	52	92	63	38	34	18	12	3
042305	50	141	0	1558	520	307	330	122	292	88	54	57	90	61	59	27	40	26	5
042405	100	216	36	2884	955	735	587	254	459	232	106	111	92	92	31	70	27	45	43
042505	85	255	0	7207	2404	712	1474	1446	1227	618	402	334	290	229	191	138	45	29	72
042605	60	183	72	4283	1428	555	789	1195	494	371	283	207	152	128	52	28	10	11	8
042705	85	240	0	2711	906	967	494	274	423	158	51	15	18	3	10	54	129	108	7
042805	60	231	0	2626	874	722	548	645	279	157	88	21	22	17	17	26	67	15	2
042905	70	113	115	3957	1338	507	745	821	641	427	251	209	174	77	53	25	10	11	6
043005	85	93	159	3720	1242	478	645	753	559	359	293	213	165	112	82	39	15	6	1
050105	50	252	0	3053	1015	459	1039	537	369	354	156	48	43	26	8	5	2	2	5
050205	50	195	54	1726	574	396	674	265	190	94	59	19	14	9	6	0	0	0	0
050305	50	249	0	4564	1517	399	953	1250	706	415	244	208	176	61	56	31	35	3	27
050405	60	249	0	4507	1501	386	821	766	643	709	526	390	174	71	10	3	4	2	2
050505	30	249	0	1024	340	98	213	201	137	64	21	4	15	3	30	30	10	107	91
050605	25	66	186	215	71	81	47	28	35	5	18	0	1	0	0	0	0	0	0
050705	50	243	0	3190	1063	368	657	681	711	389	206	100	42	23	7	1	2	3	0
050805	50	252	0	3718	1239	575	1429	741	409	265	151	78	49	18	3	0	0	0	0
050905	50	415	0	4597	923	607	1521	667	546	315	269	197	176	123	92	68	16	0	0
051005	60	415	0	7197	1437	517	631	1292	1530	917	603	525	484	302	100	102	57	54	83
051105	100	410	0	16189	3237	1382	5866	3810	1947	1442	840	469	210	97	57	35	27	7	0
051205	35	410	0	2686	539	698	643	539	576	102	20	18	56	4	8	15	2	1	4
051305	50	410	0	5472	1099	549	854	1032	1019	554	461	512	310	126	26	7	11	6	5
051405	400	410	0	29049	5807	2293	5475	5823	4867	3413	2576	1580	1326	670	333	256	212	163	62
051505	100	175	230	4289	855	1267	1045	466	465	309	295	192	122	81	28	11	8	0	0
051605	50	410	0	4647	930	942	1586	778	391	254	219	130	83	92	41	70	40	12	9
051705	125	410	0	15624	3123	1060	2907	3492	2864	2151	1481	888	430	176	89	43	30	13	0
051805	125	415	0	20224	4045	2544	3928	4216	3731	2565	1600	831	402	186	150	49	20	1	1
051905	20	172	238	1185	264	366	312	166	88	56	26	20	74	7	17	7	8	21	17
052005	45	315	80	2707	541	1782	453	278	72	65	26	9	8	9	4	1	0	0	0
052105	55	395	15	5046	1006	215	599	1023	1257	952	733	212	50	3	0	2	0	0	0
052205	65	315	95	2564	510	183	329	663	572	362	222	94	47	27	28	28	8	1	0
052305	25	395	15	825	162	173	120	186	148	89	57	30	9	1	12	0	0	0	0

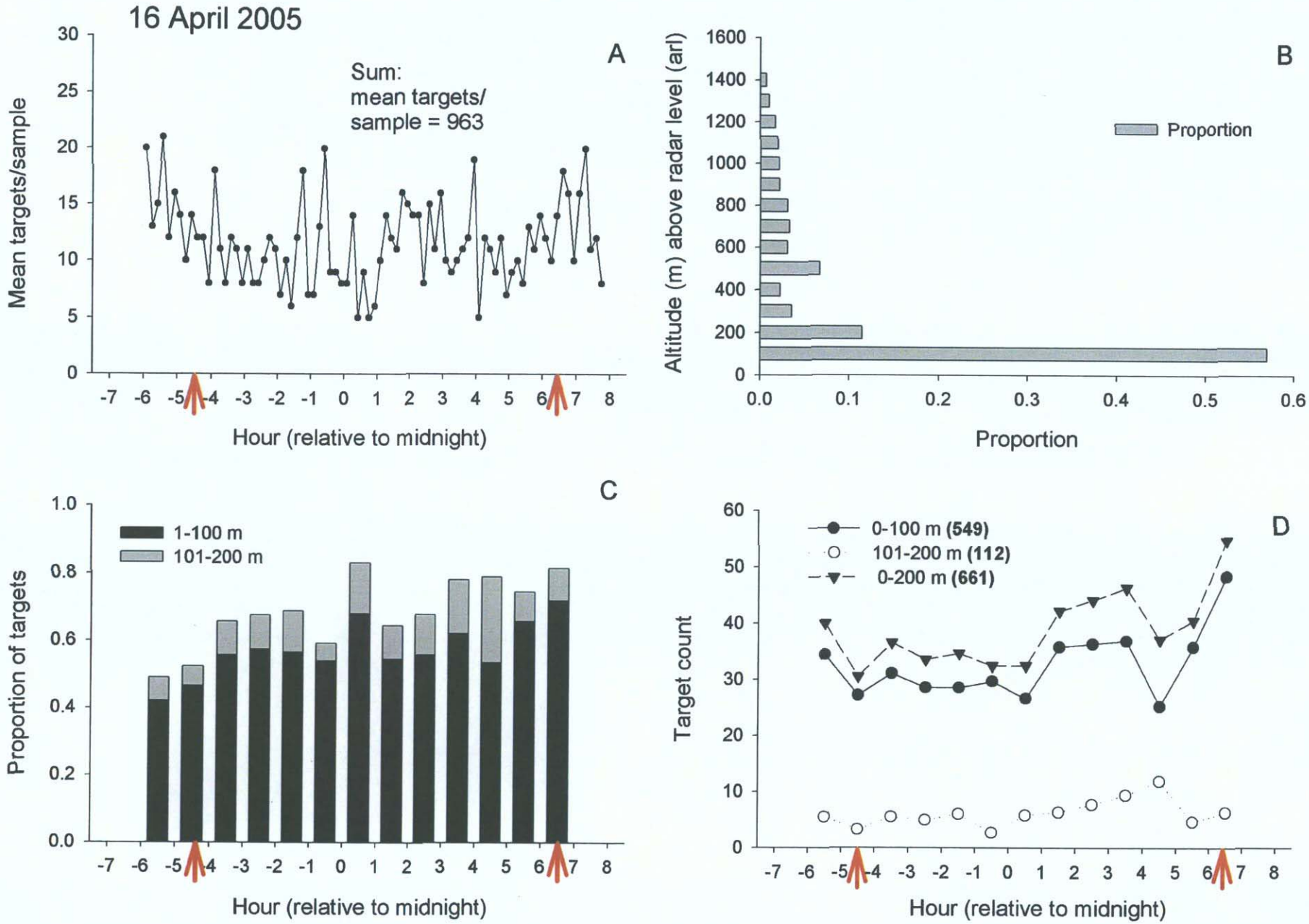
Appendix 2. Continued

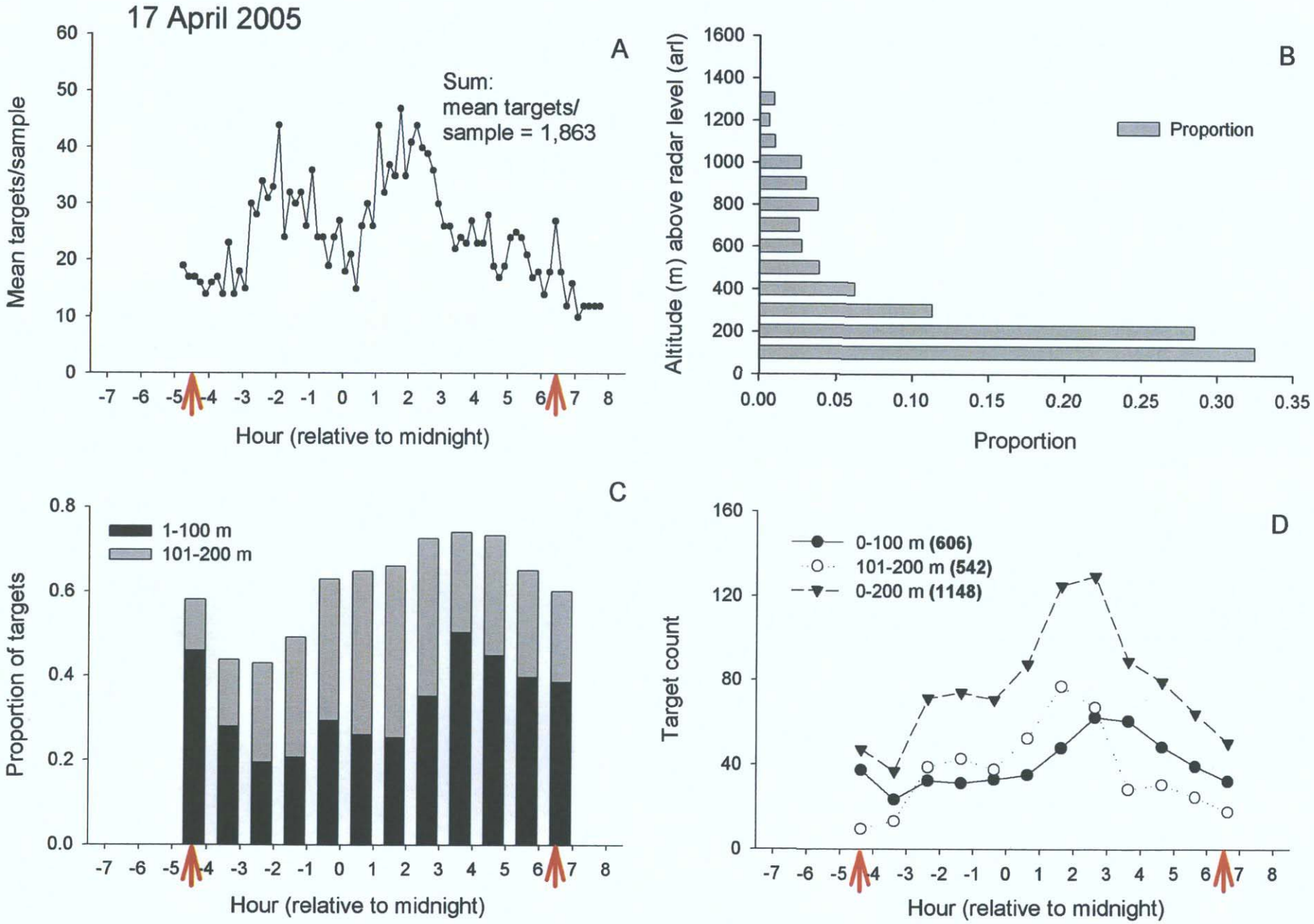
052405	20	356	54	778	161	564	67	47	24	17	3	0	0	2	3	17	16	14	4
052505	25	155	255	670	130	435	98	83	22	26	6	0	0	0	0	0	0	0	0
052605	75	410	0	5711	1144	507	986	1202	902	766	506	417	225	114	57	22	7	0	0
052705	50	410	0	4214	843	886	1534	668	497	276	129	79	65	28	21	21	7	3	0
052805	50	410	0	2382	476	702	755	373	303	155	55	16	15	4	0	0	2	2	0
052905	50	410	0	4266	853	823	1084	1270	665	217	102	34	40	2	13	10	6	0	0
053005	50	345	50	2786	555	277	431	725	661	407	216	51	7	1	5	2	1	1	1
053105	50	410	0	1908	381	316	350	521	394	171	100	10	18	8	14	6	0	0	0
Totals				242927	61719	39683	54236	46838	35936	23603	15513	9622	6891	3928	2423	1713	1153	864	524
Means				5168.66	1313.17	844.32	1153.96	996.55	764.60	502.19	330.06	204.72	146.62	83.57	51.55	36.45	24.53	18.38	11.15

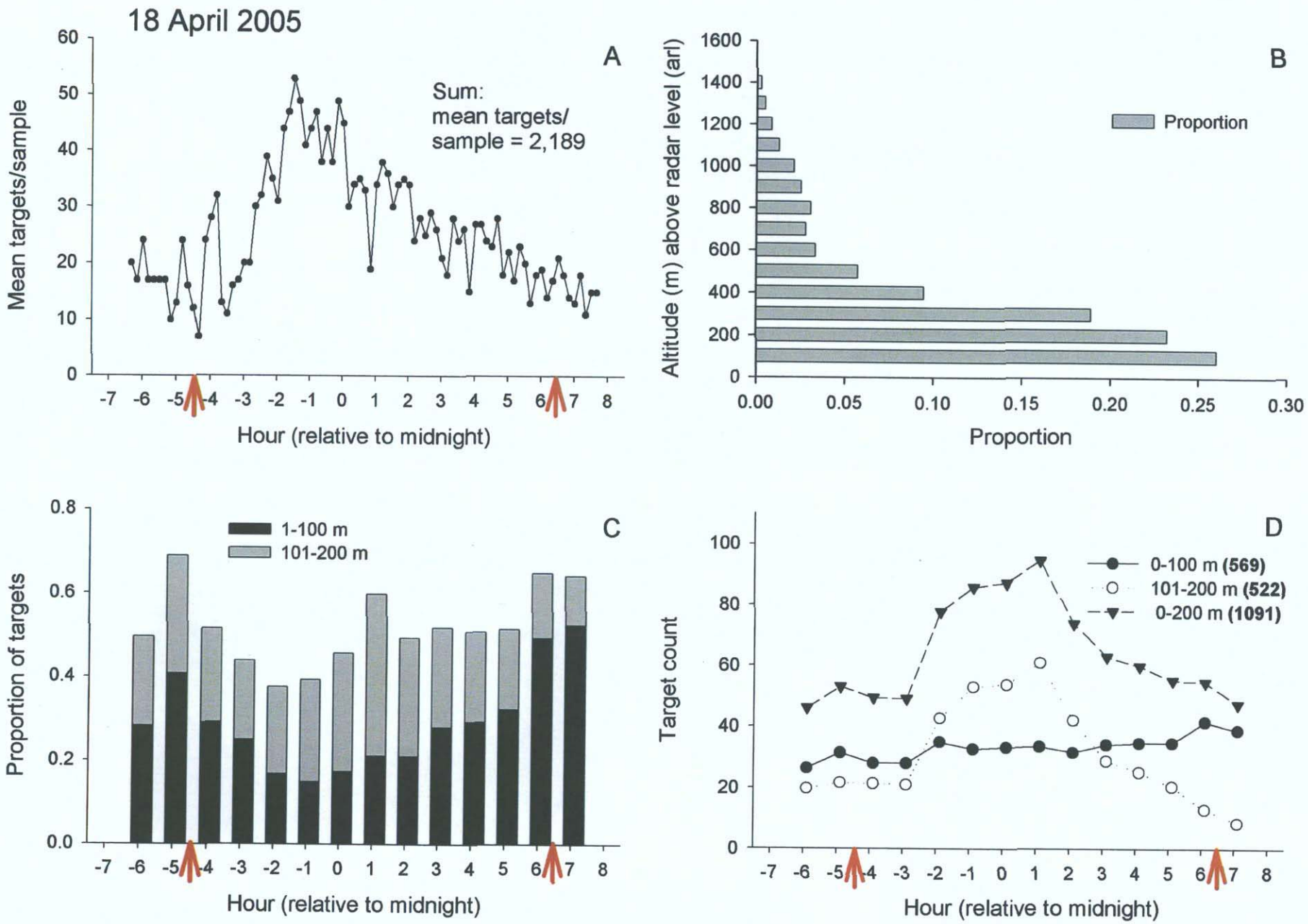
Appendix 3

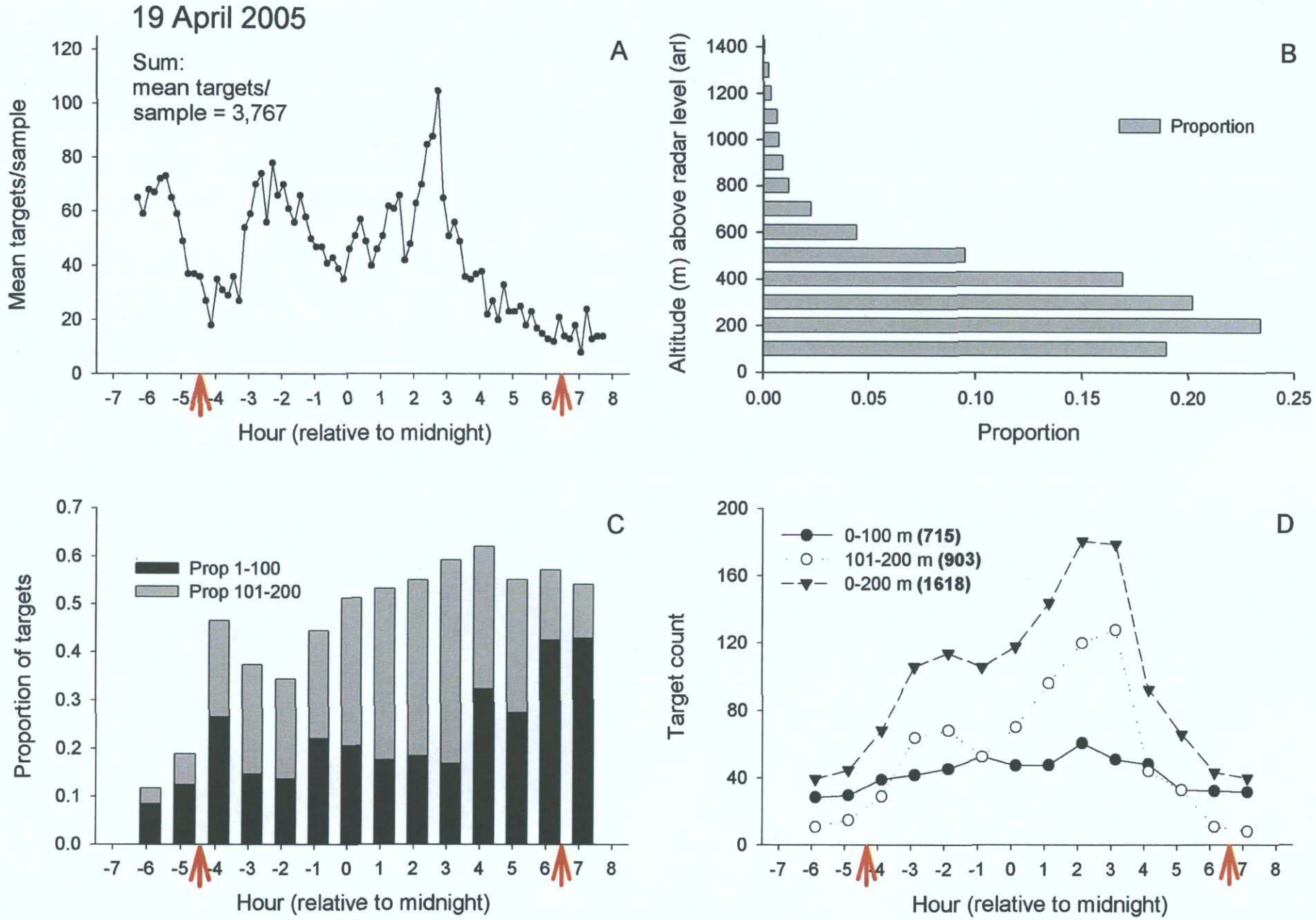
Four-panel graphs: one for each night of data collection in spring 2005. Graphs represent data collected with the vertically-oriented radar. Descriptions of graphs for each night are as follows: (A) Nightly temporal pattern in mean targets/sample (i.e., five succesive images every 10 min). (B) Altitudinal distribution of targets in 100 m strata from 0 - 1400 m arl. (C) Nightly temporal pattern in the proportion of targets <=100 m and between 101 m and 200 m. (D) Nightly temporal pattern in the number of targets <=100 m and between 101 m and 200 m.

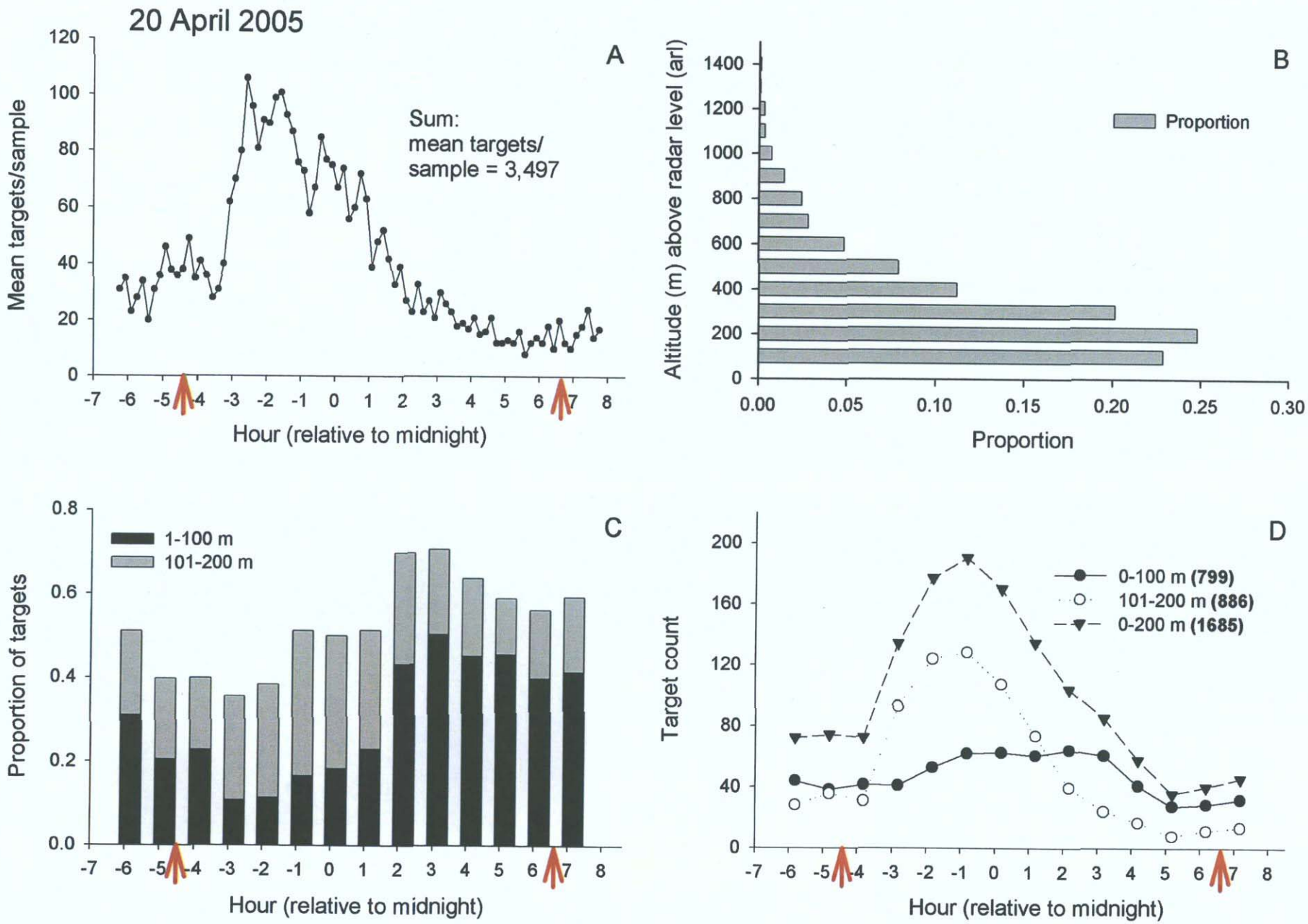

15 April 2005
A
Sum:
mean targets/
sample = 1,130
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (602)
101-200 m (165)
0-200 m (767)
Target count
Hour (relative to midnight)

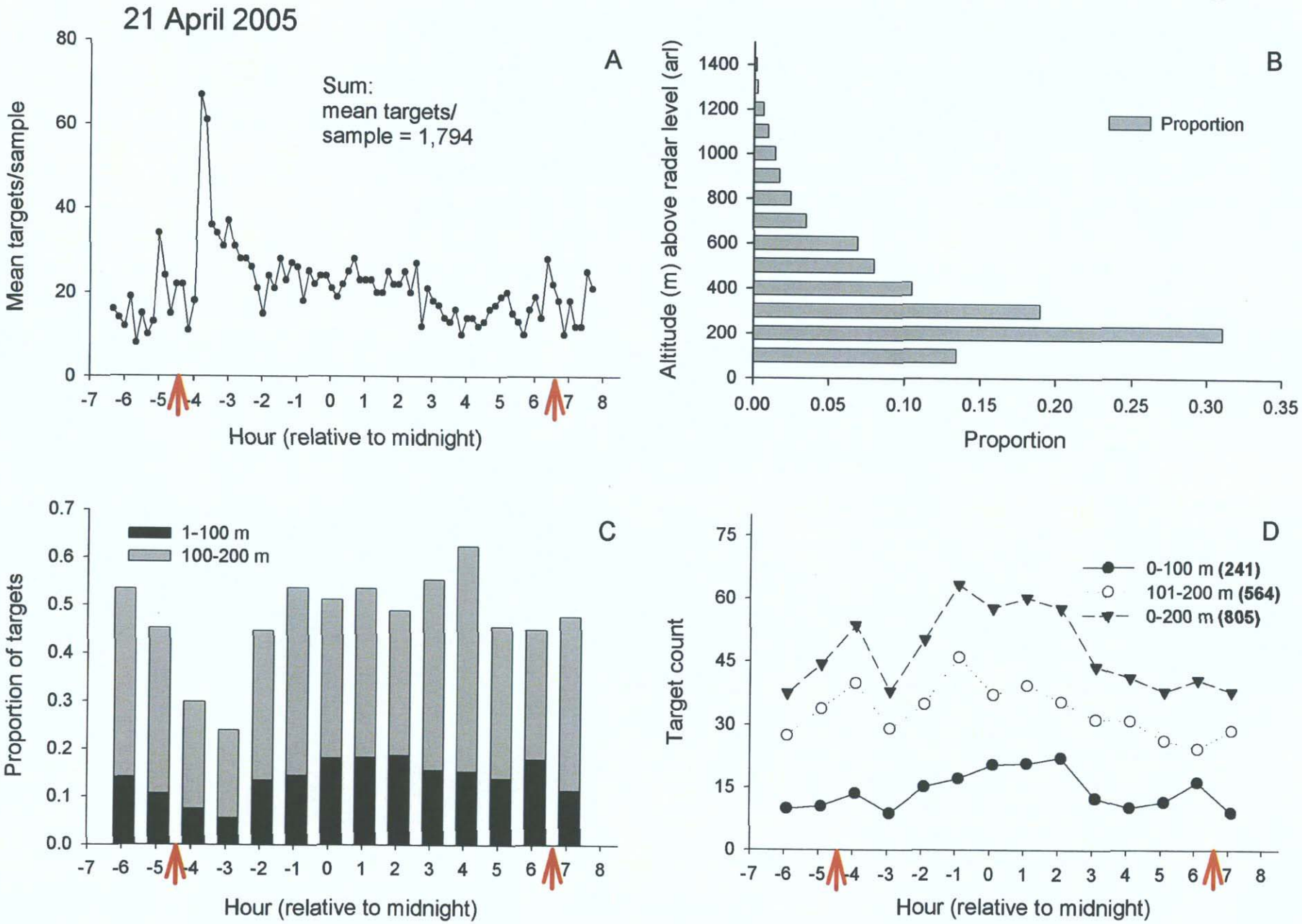

16 April 2005
A
Sum:
mean targets/
sample = 963
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (549)
101-200 m (112)
0-200 m (661)
Target count
Hour (relative to midnight)

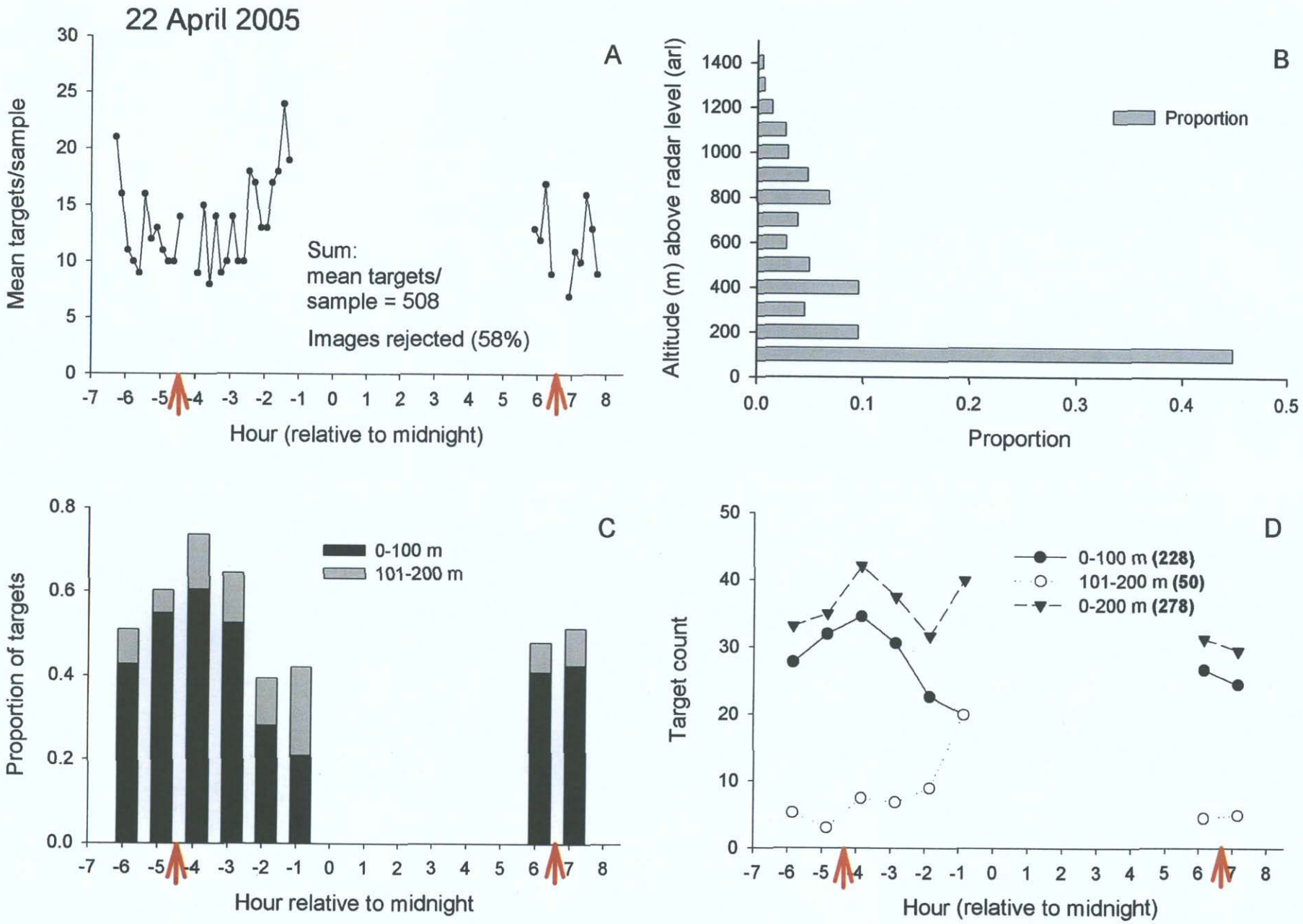

17 April 2005
A
Sum:
mean targets/
sample = 1,863
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (606)
101-200 m (542)
0-200 m (1148)
Target count
Hour (relative to midnight)

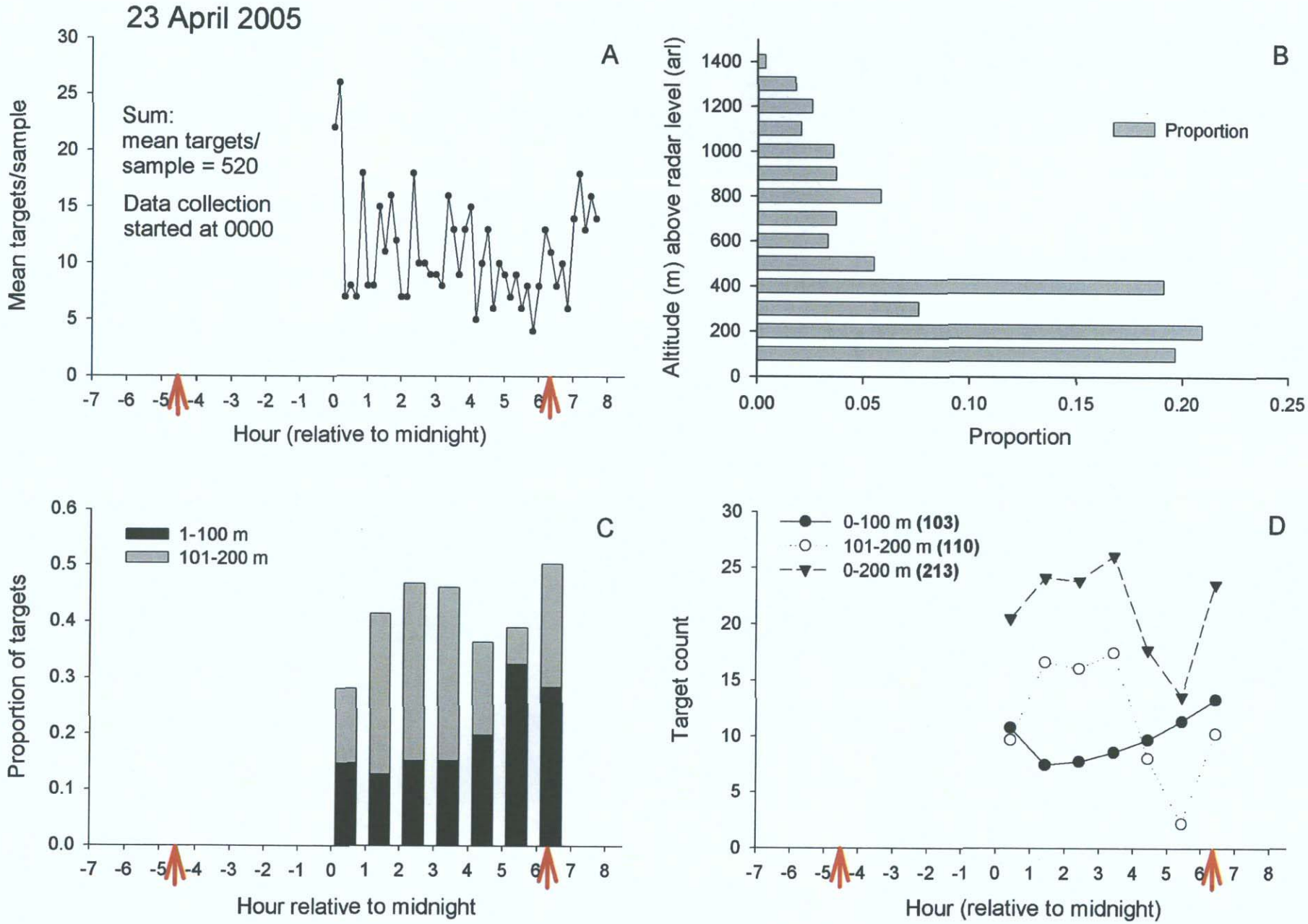

18 April 2005
A
Sum:
mean targets/
sample = 2,189
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (569)
101-200 m (522)
0-200 m (1091)
Target count
Hour (relative to midnight)

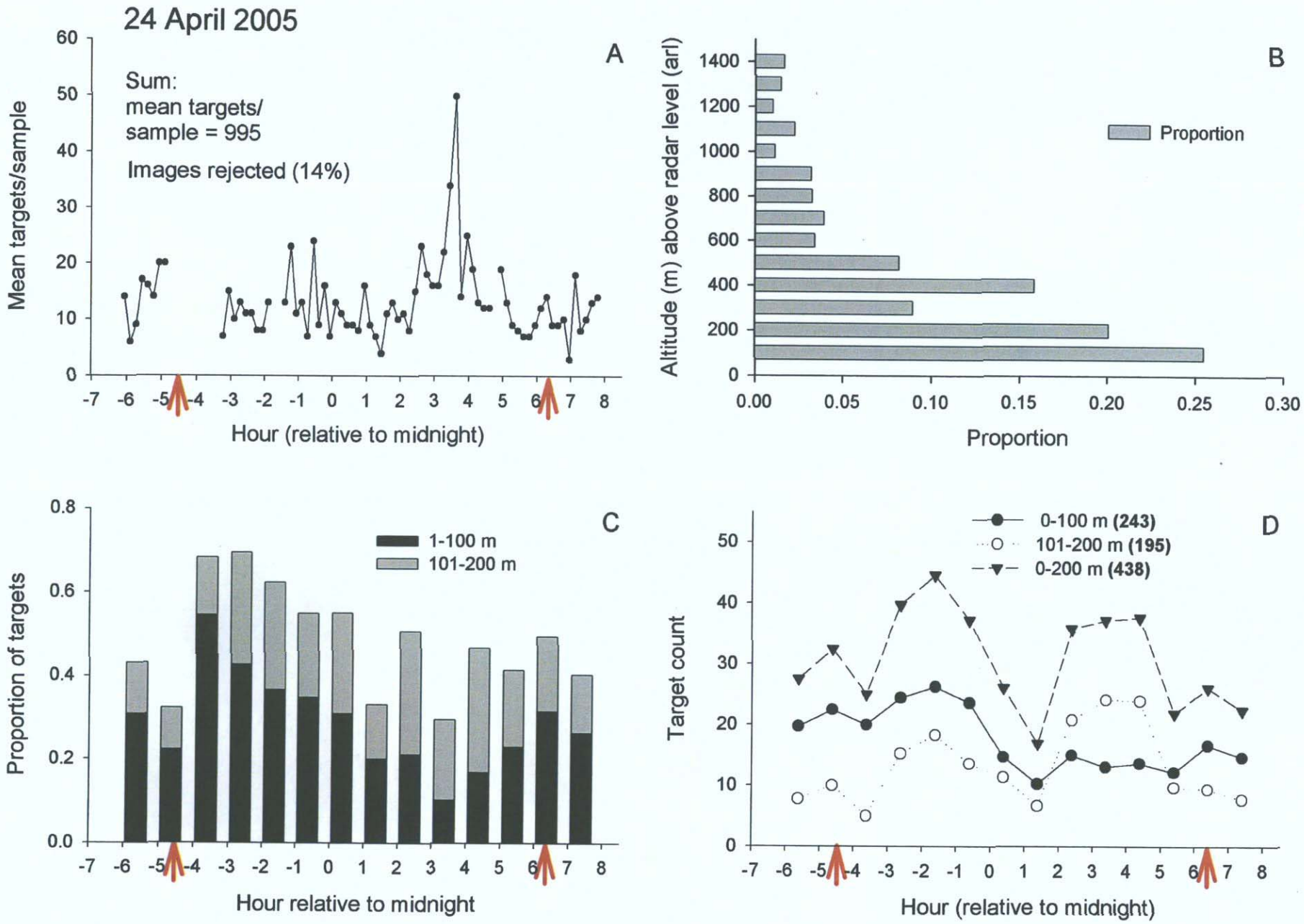

19 April 2005
A
Sum:
mean targets/
sample = 3,767
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Prop 1-100
Prop 101-200
Proportion of targets
Hour (relative to midnight)
D
0-100 m (715)
101-200 m (903)
0-200 m (1618)
Target count
Hour (relative to midnight)

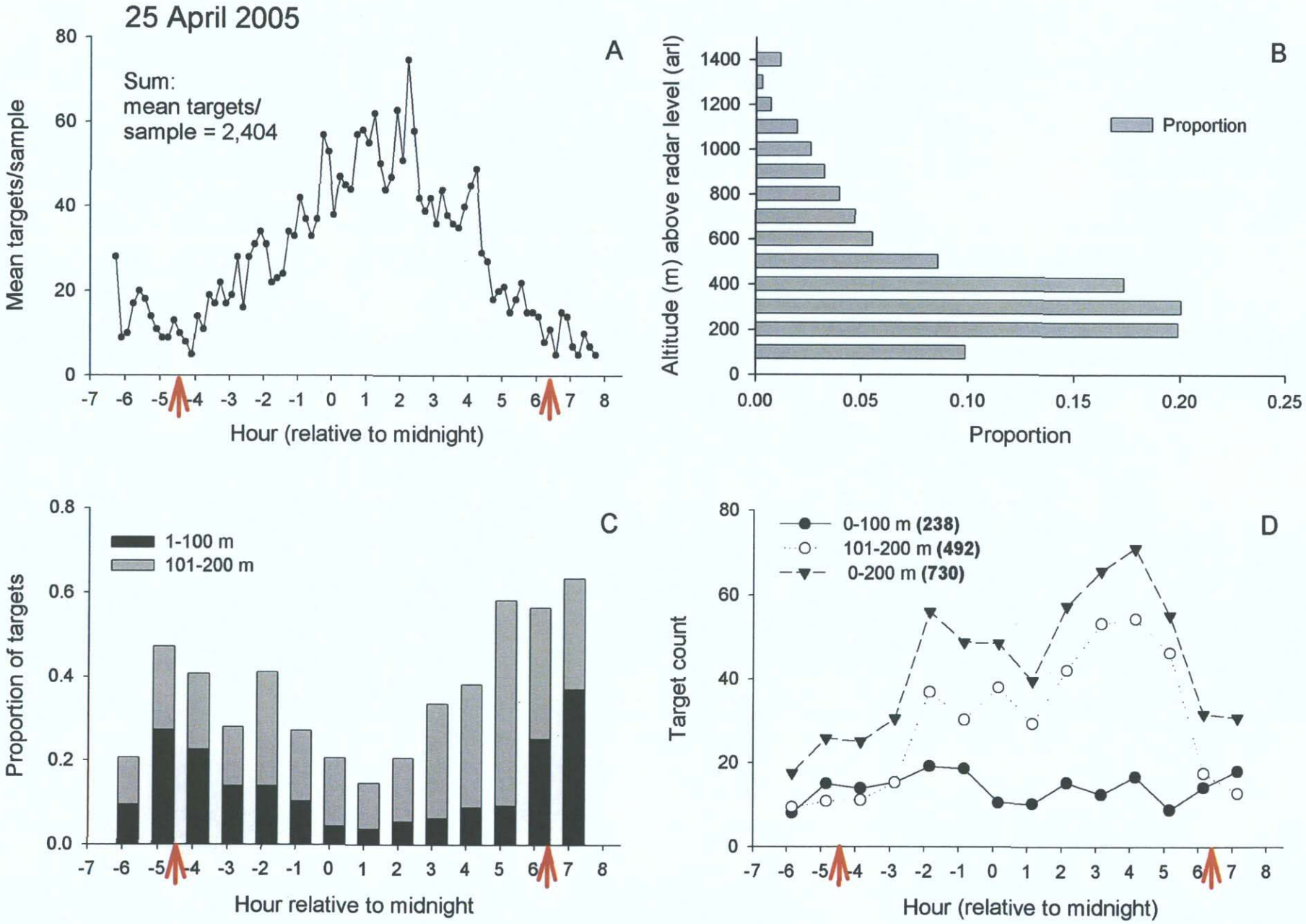

20 April 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 3,497
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
1-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (799)
101-200 m (886)
0-200 m (1685)
Hour (relative to midnight)

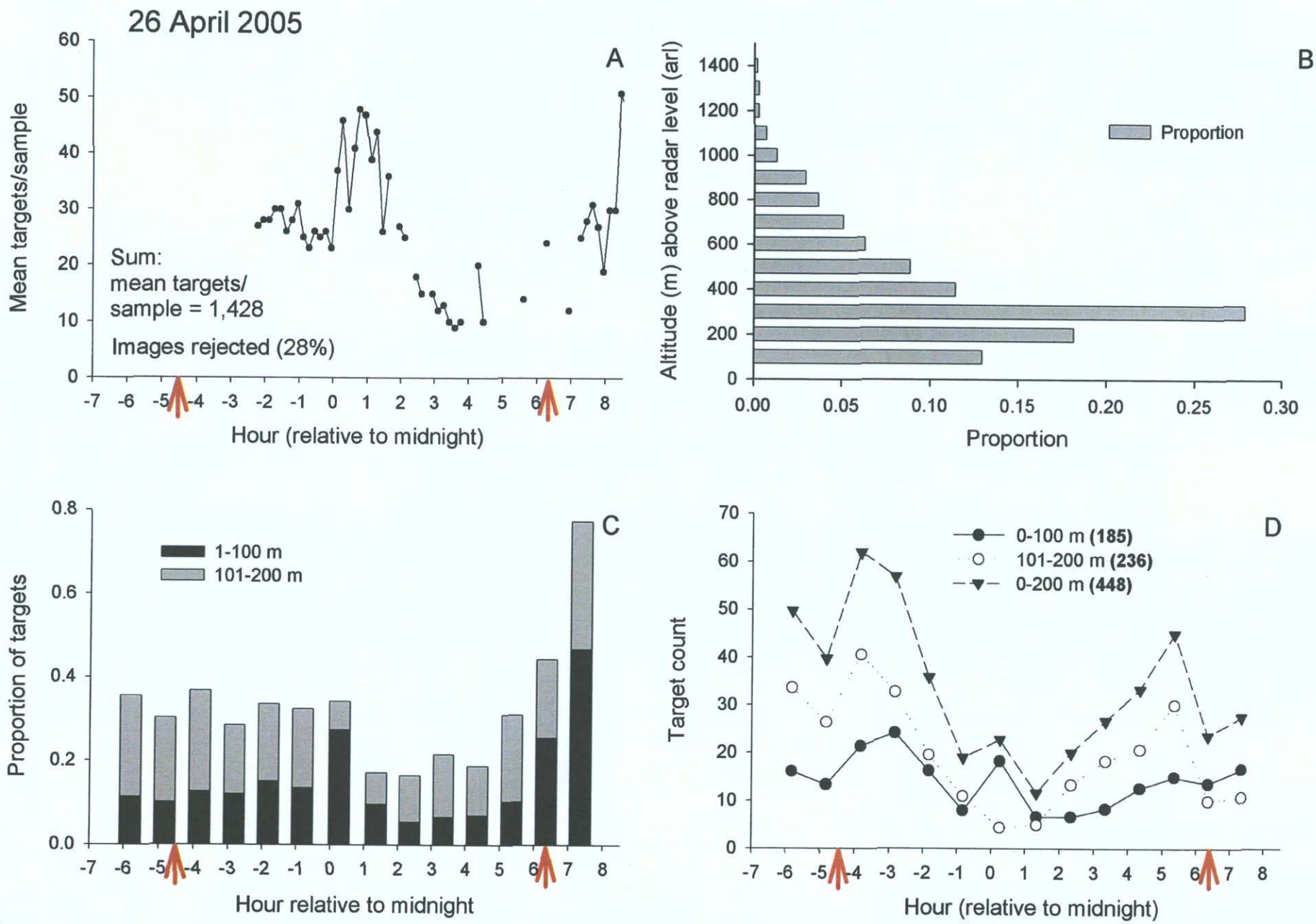

21 April 2005
A
Sum:
mean targets/
sample = 1,794
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
100-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (241)
101-200 m (564)
0-200 m (805)
Target count
Hour (relative to midnight)

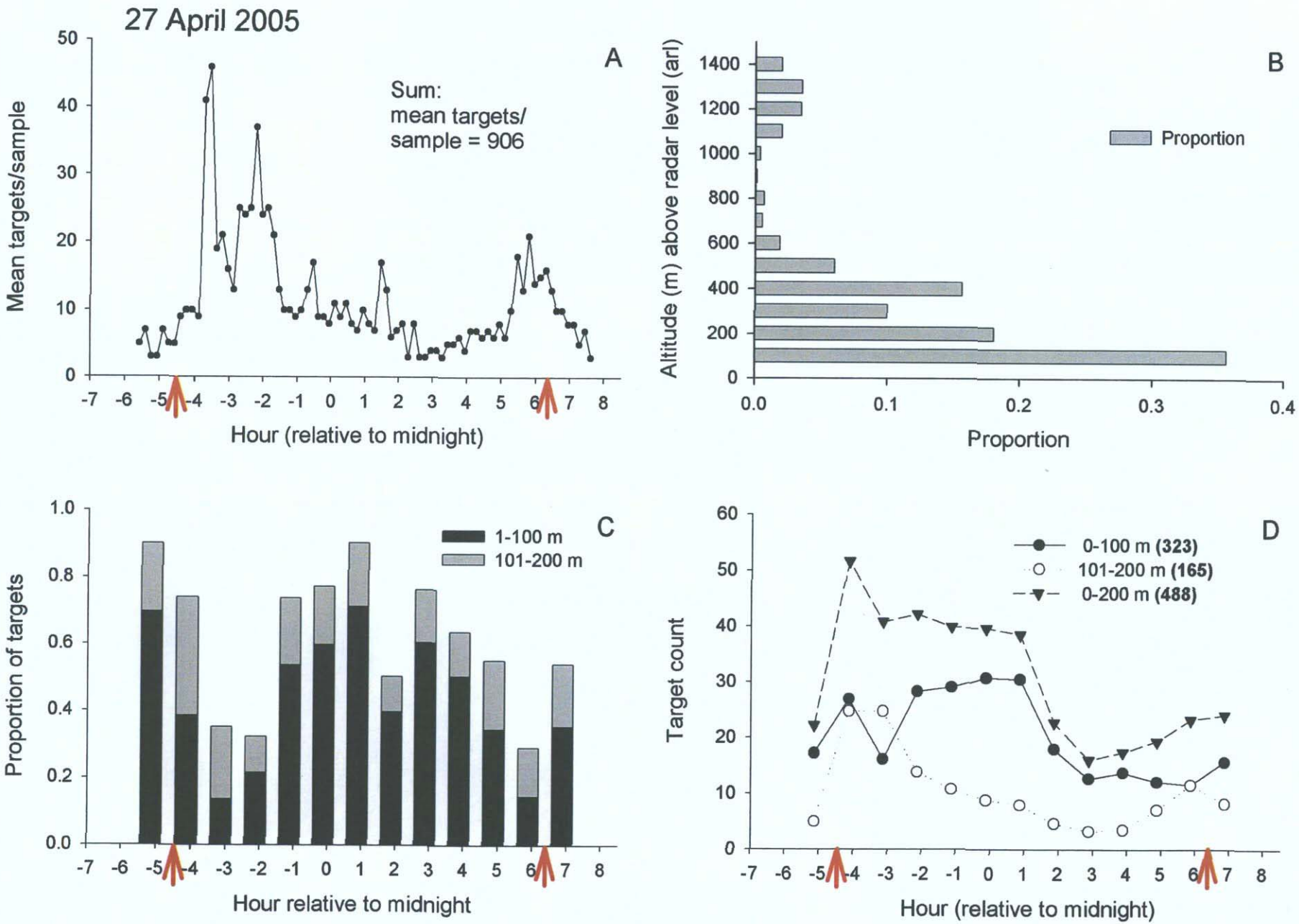

22 April 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 508
Images rejected (58%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour relative to midnight
D
Target count
0-100 m (228)
101-200 m (50)
0-200 m (278)
Hour (relative to midnight)

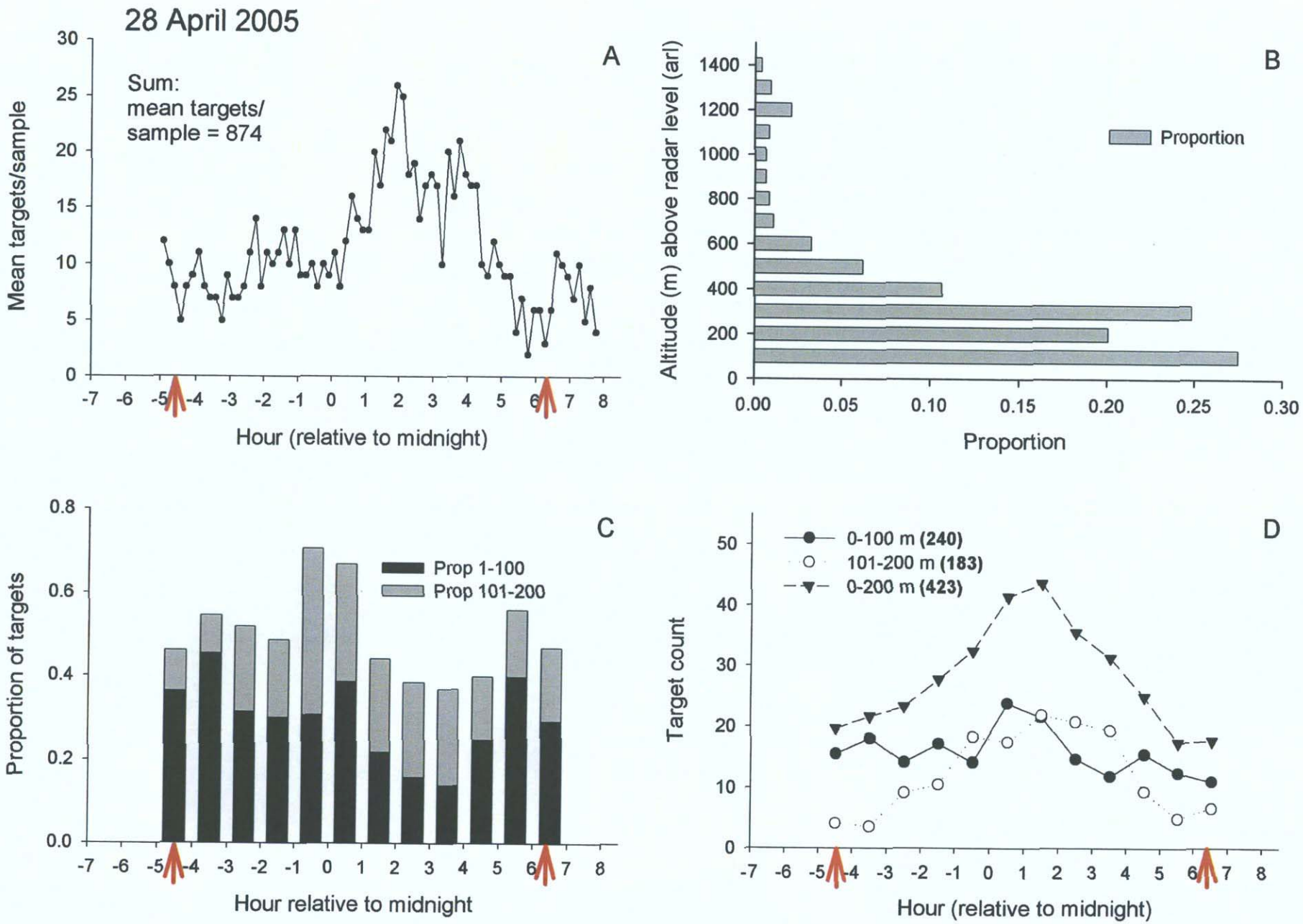

23 April 2005
A
Sum:
mean targets/
sample = 520
Data collection
started at 0000
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (103)
101-200 m (110)
0-200 m (213)
Target count
Hour (relative to midnight)

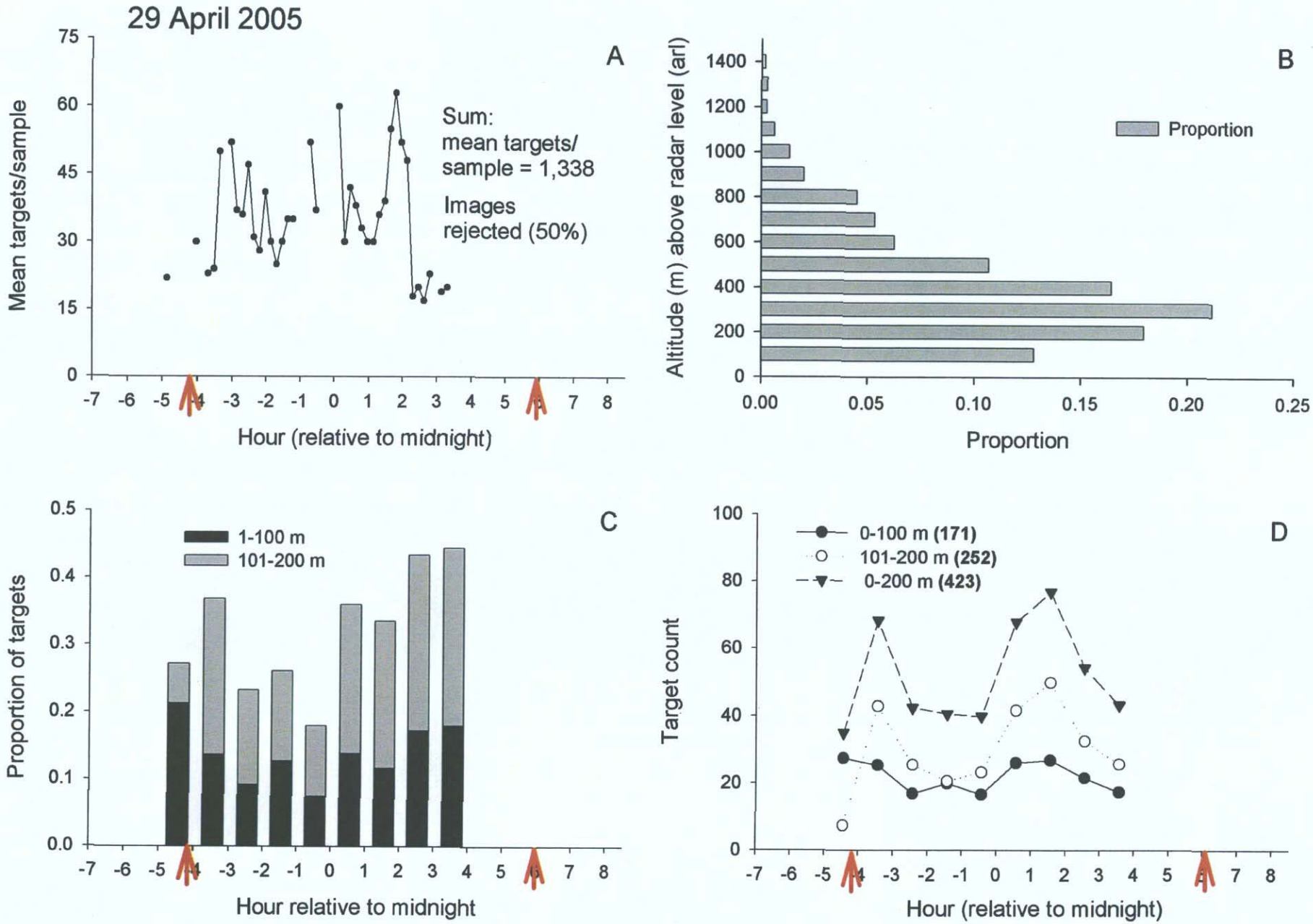

24 April 2005
A
Sum:
mean targets/
sample = 995
Images rejected (14%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (243)
101-200 m (195)
0-200 m (438)
Target count
Hour (relative to midnight)

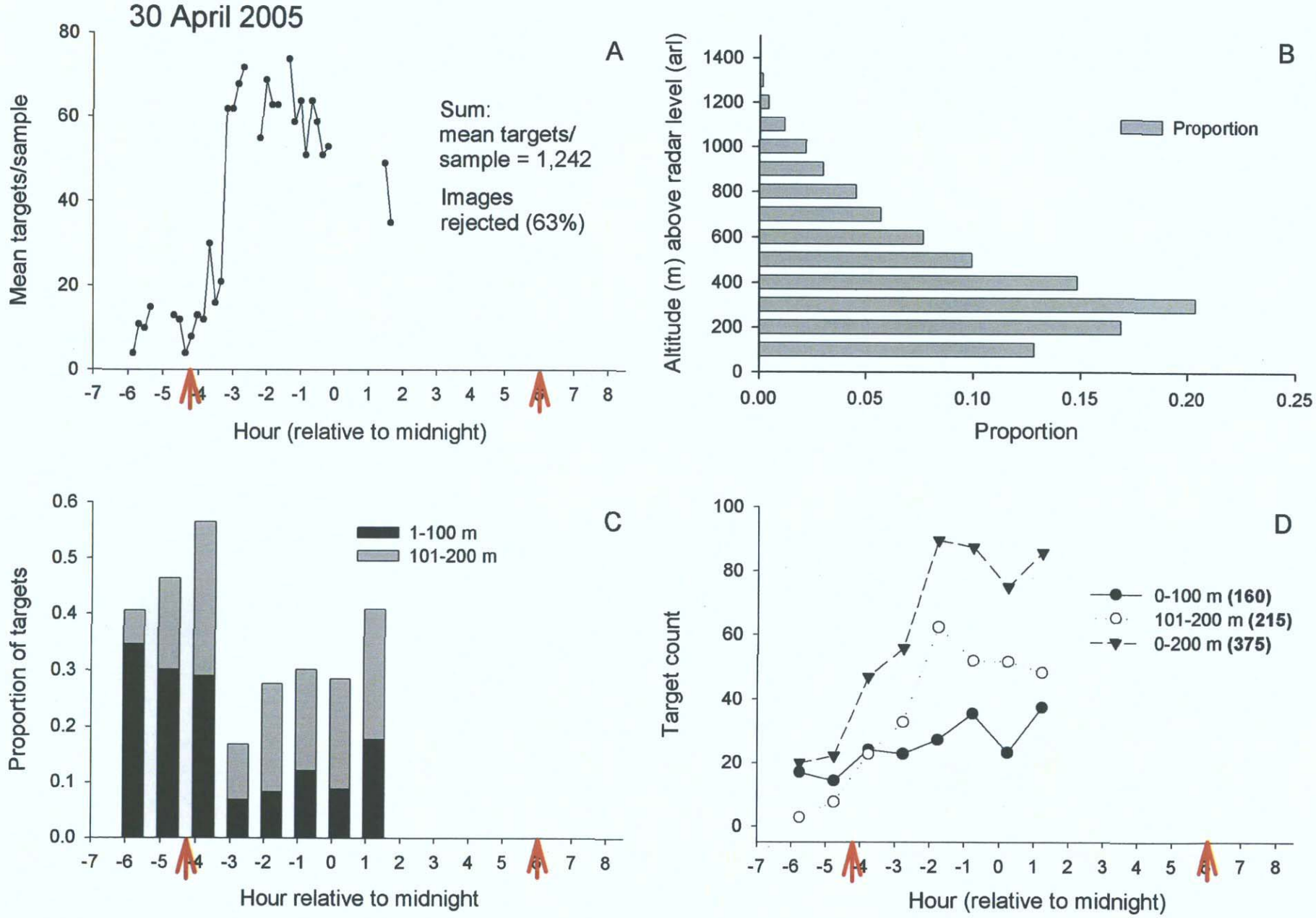

25 April 2005
A
Sum:
mean targets/
sample = 2,404
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (238)
101-200 m (492)
0-200 m (730)
Target count
Hour (relative to midnight)

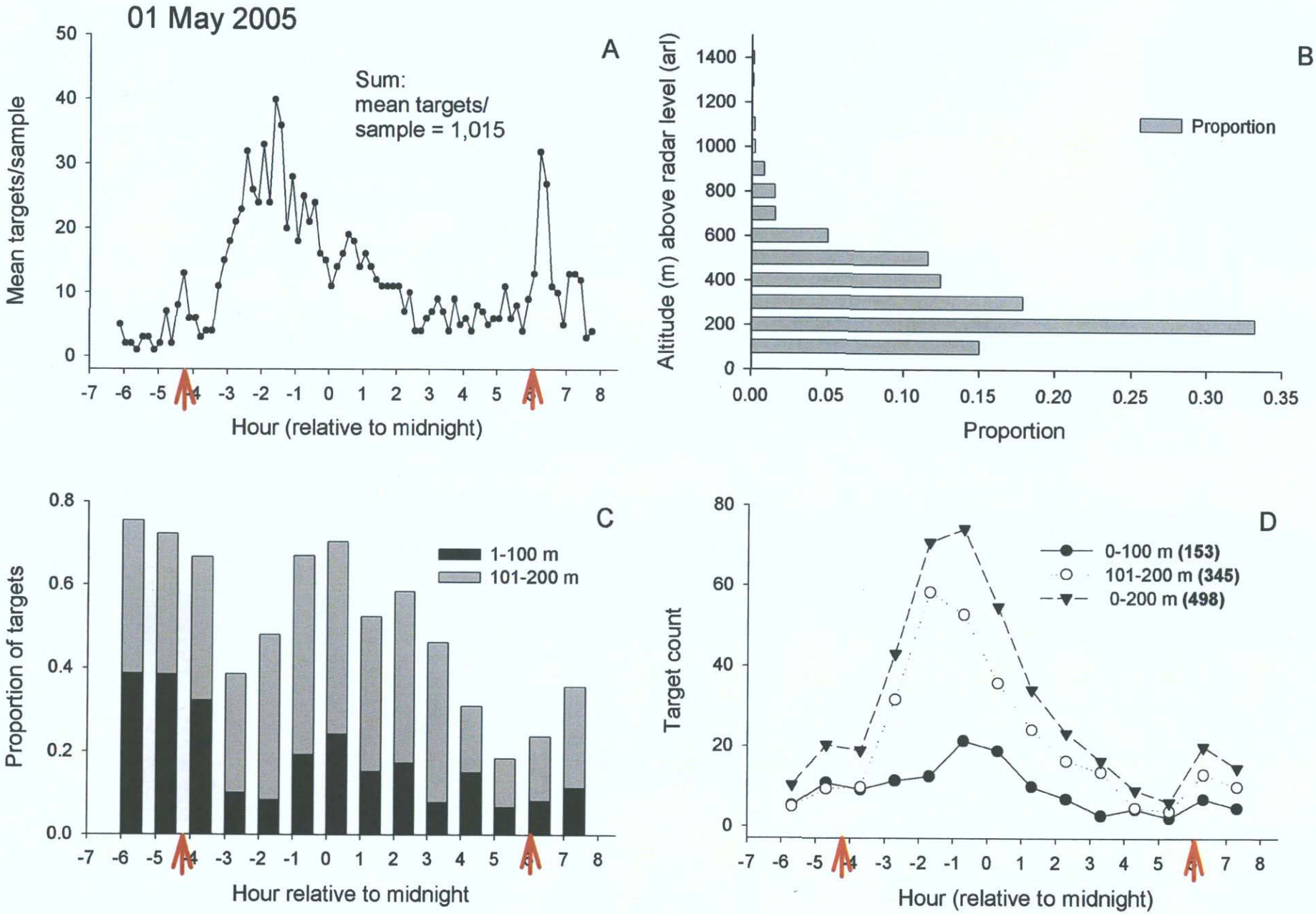

26 April 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 1,428
Images rejected (28%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
1-100 m
101-200 m
Hour relative to midnight
D
Target count
0-100 m (185)
101-200 m (236)
0-200 m (448)
Hour (relative to midnight)

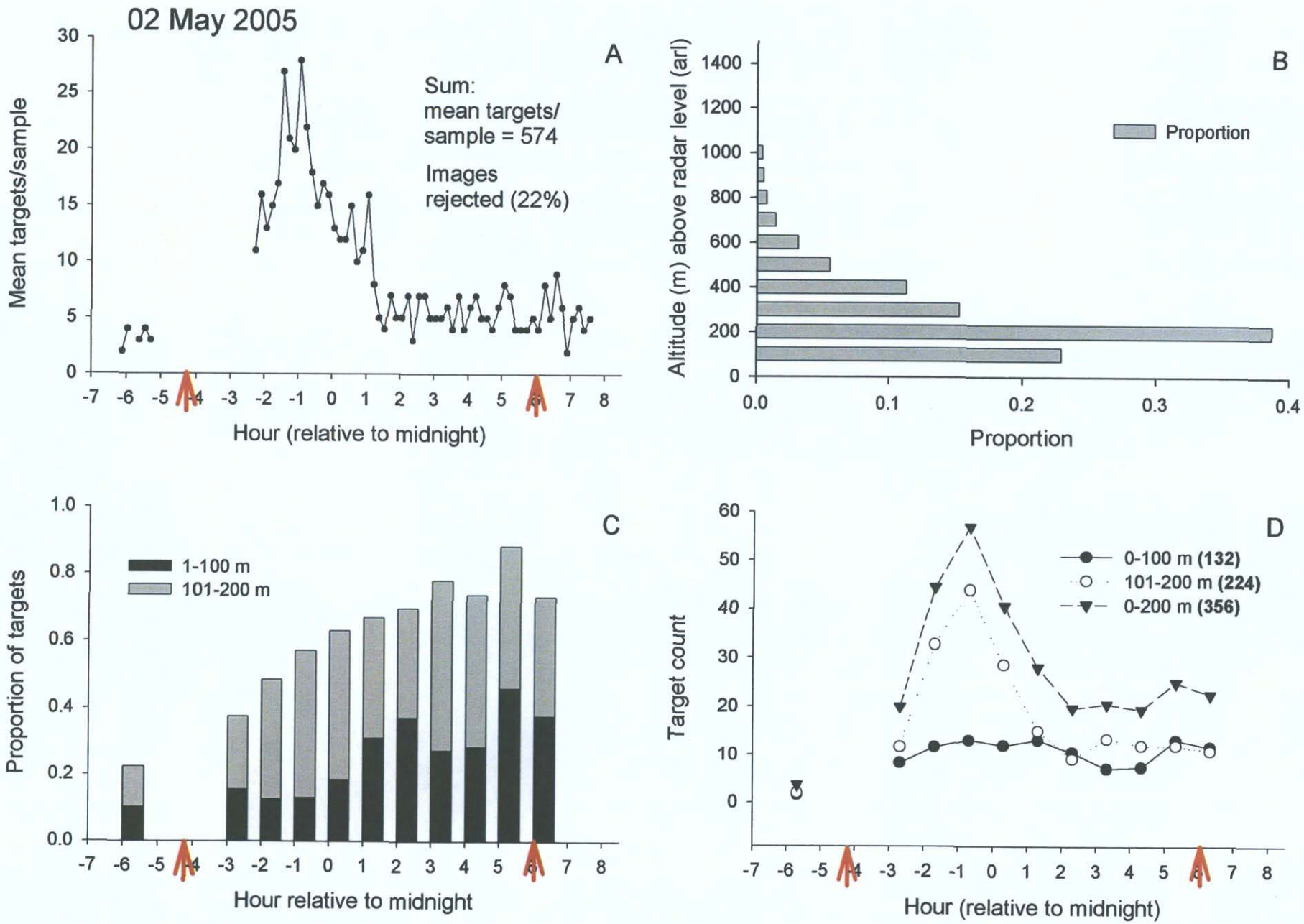

27 April 2005
A
Sum:
mean targets/
sample = 906
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (323)
101-200 m (165)
0-200 m (488)
Target count
Hour (relative to midnight)

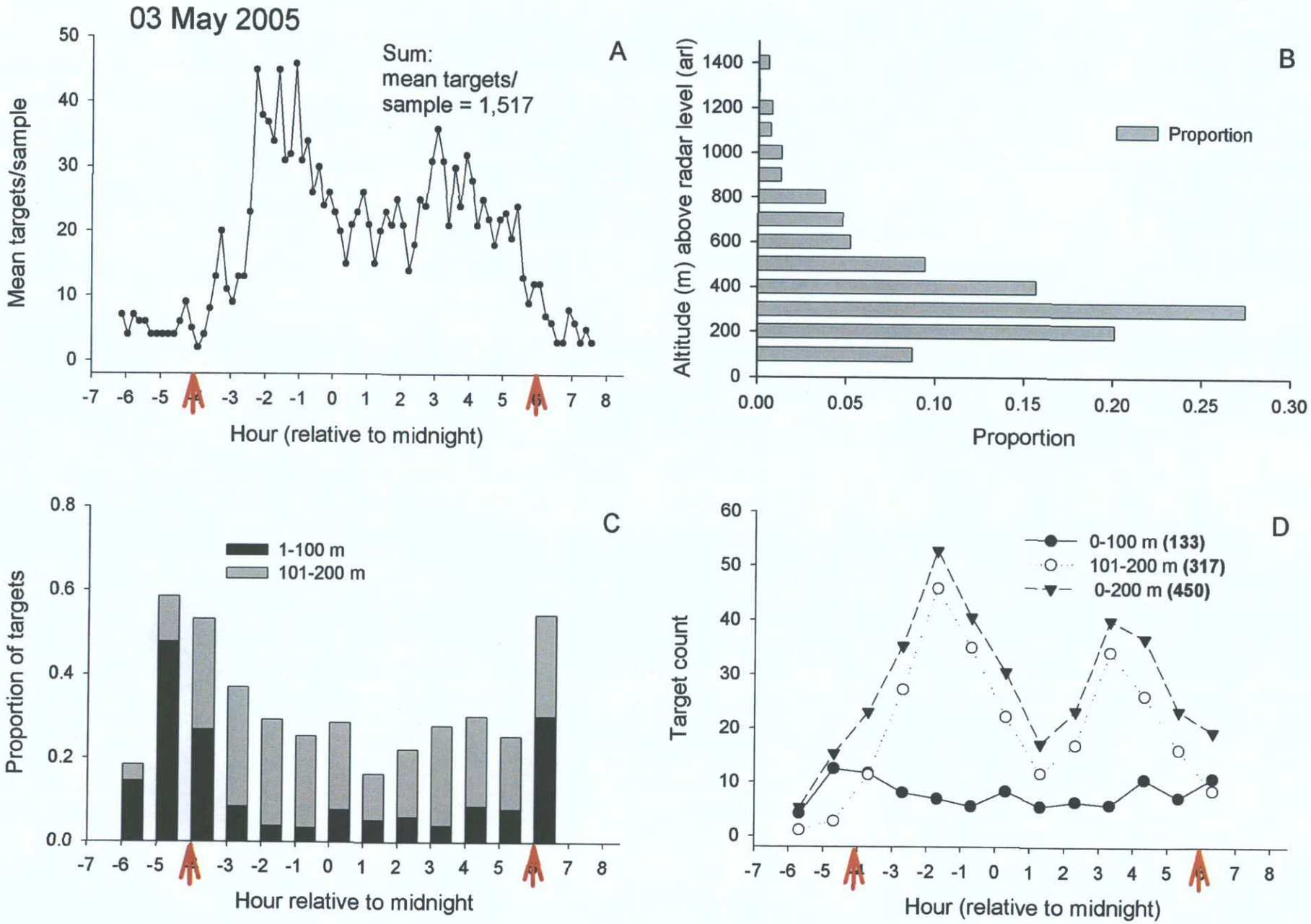

28 April 2005
A
Sum:
mean targets/
sample = 874
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Prop 1-100
Prop 101-200
Proportion of targets
Hour relative to midnight
D
0-100 m (240)
101-200 m (183)
0-200 m (423)
Target count
Hour (relative to midnight)

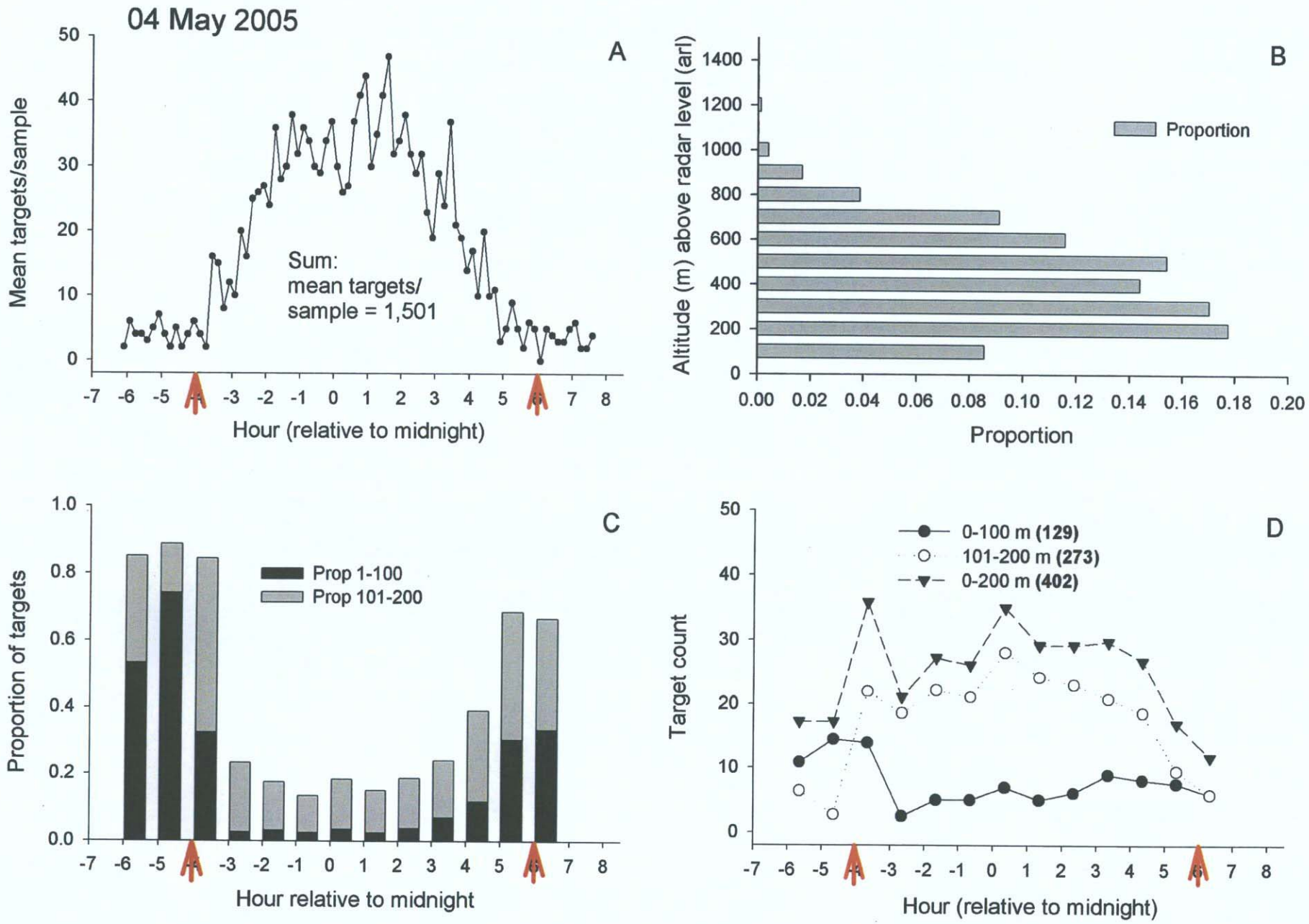

29 April 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 1,338
Images
rejected (50%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
1-100 m
101-200 m
Hour relative to midnight
D
Target count
0-100 m (171)
101-200 m (252)
0-200 m (423)
Hour (relative to midnight)

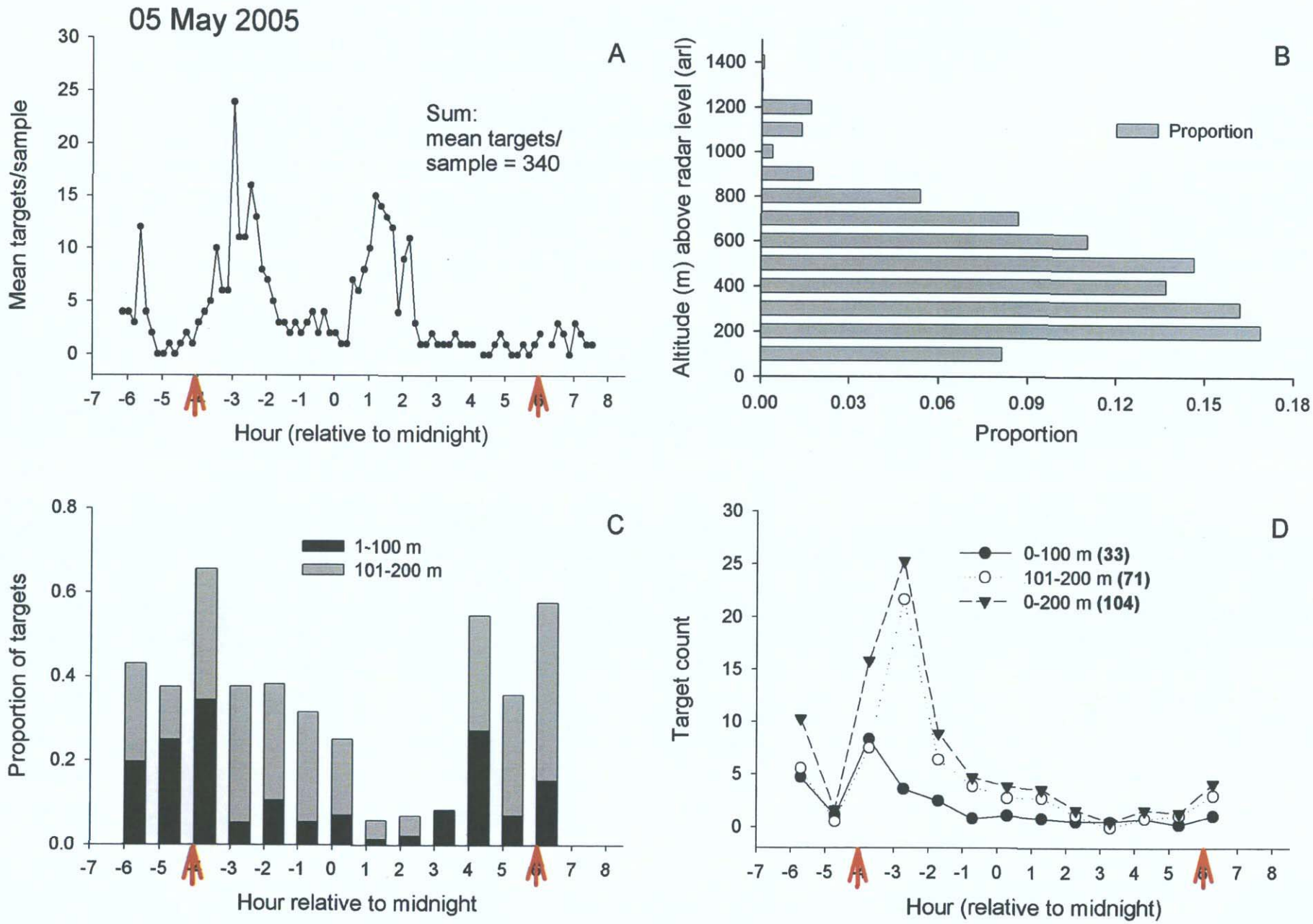

30 April 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 1,242
Images
rejected (63%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
1-100 m
101-200 m
Hour relative to midnight
D
Target count
0-100 m (160)
101-200 m (215)
0-200 m (375)
Hour (relative to midnight)

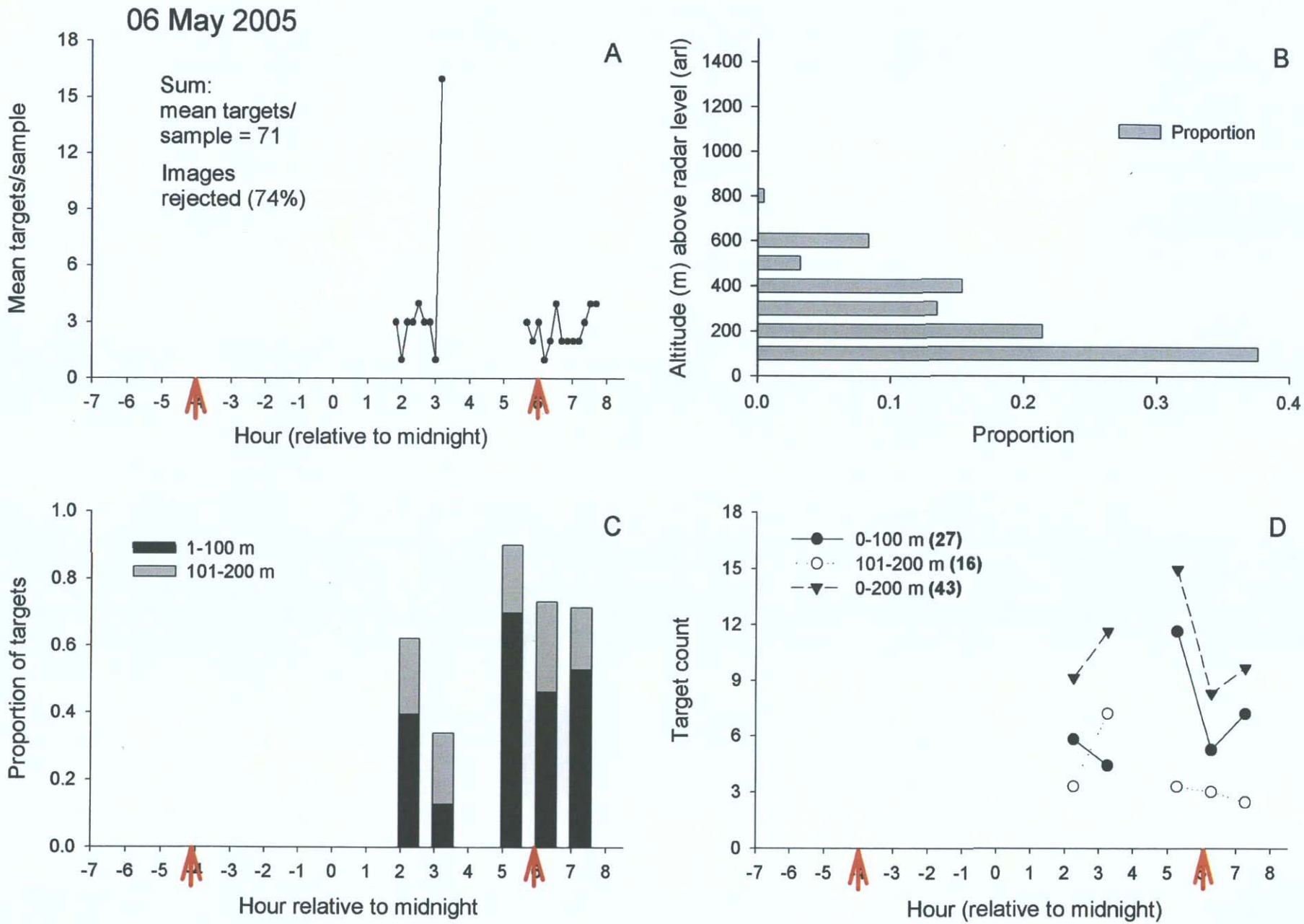

01 May 2005
A
Sum:
mean targets/
sample = 1,015
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (153)
101-200 m (345)
0-200 m (498)
Target count
Hour (relative to midnight)

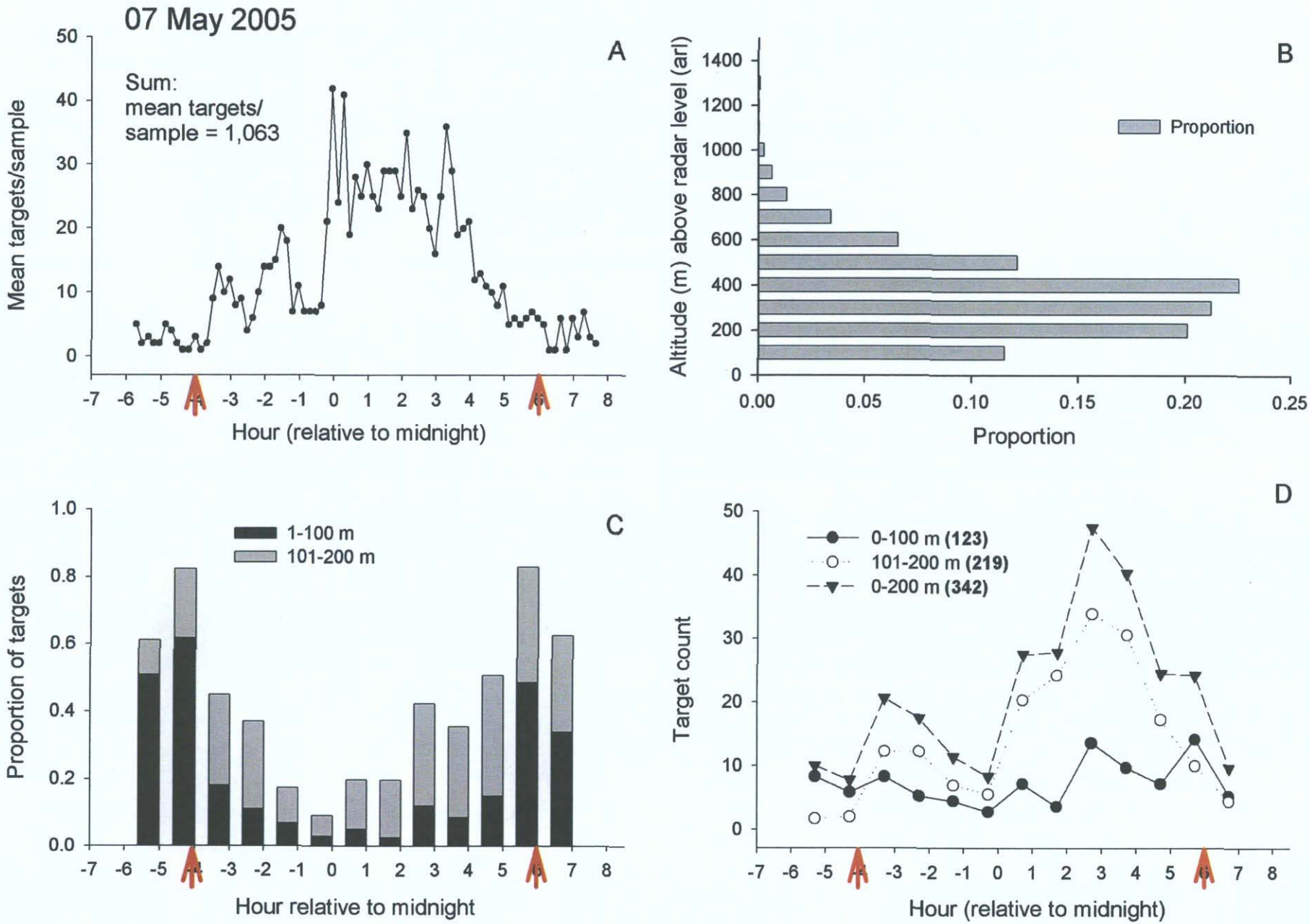

02 May 2005
A
Sum:
mean targets/
sample = 574
Images
rejected (22%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (132)
101-200 m (224)
0-200 m (356)
Target count
Hour (relative to midnight)

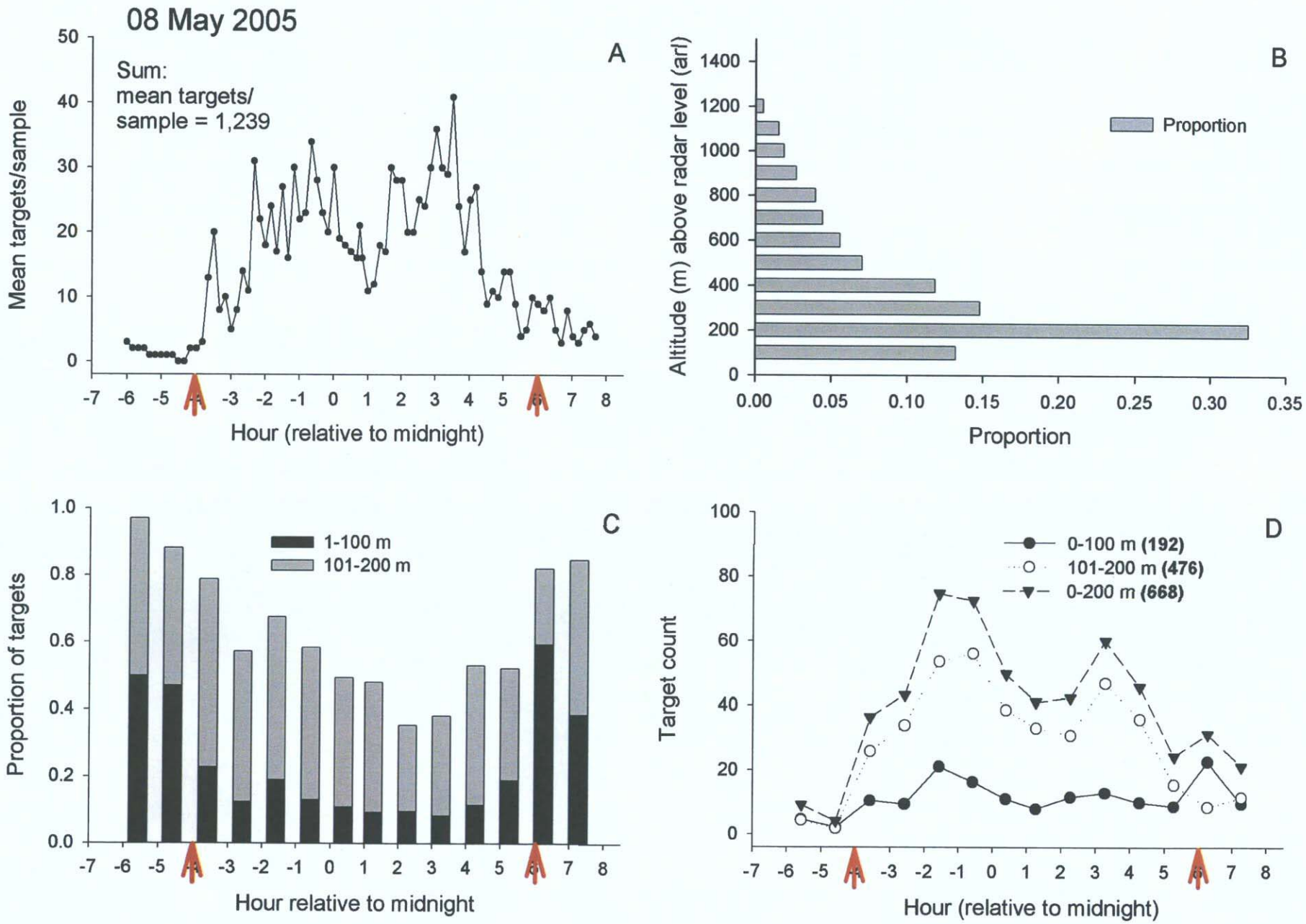

03 May 2005
A
Sum:
mean targets/
sample = 1,517
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (133)
101-200 m (317)
0-200 m (450)
Target count
Hour (relative to midnight)

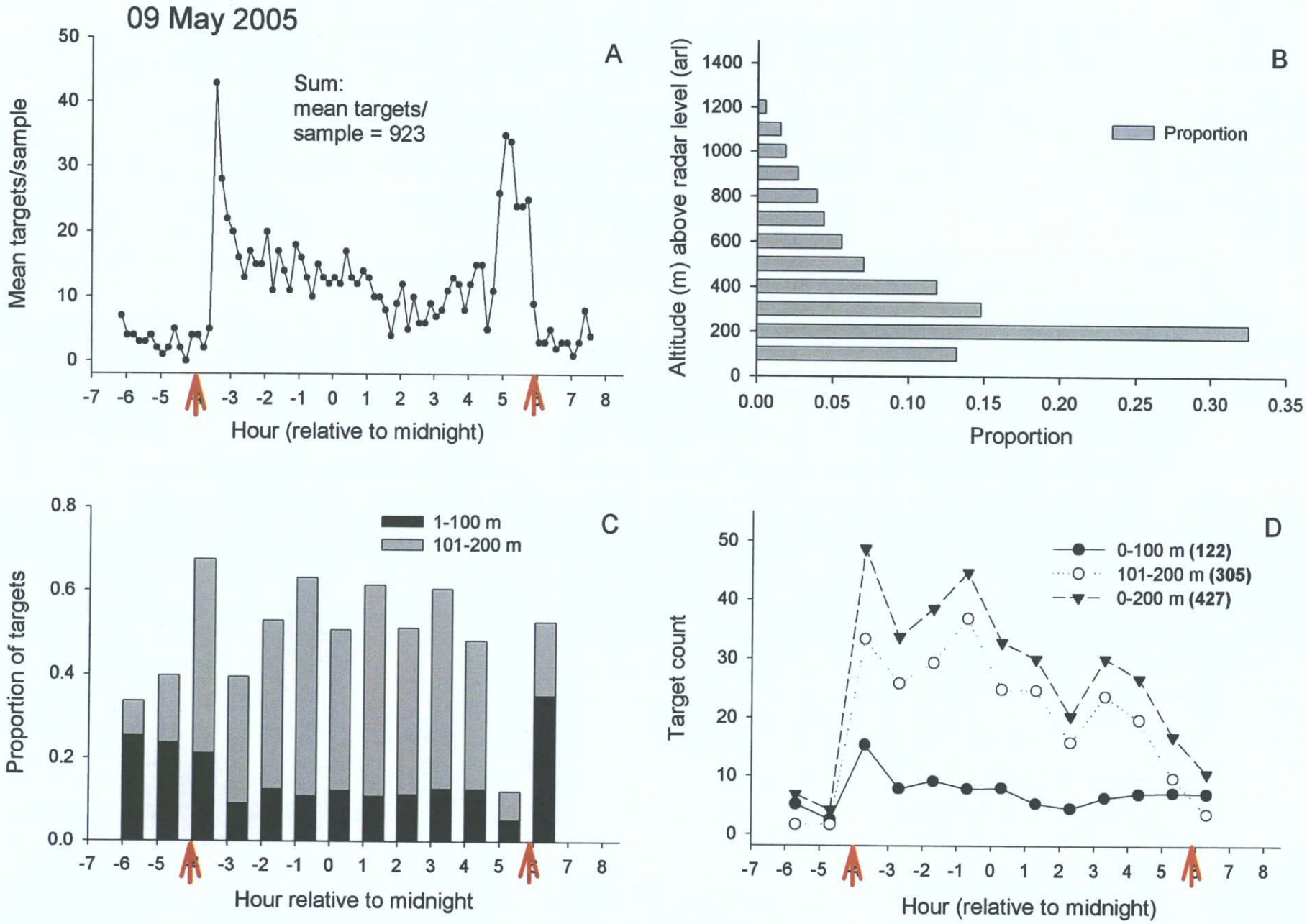

04 May 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 1,501
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
Prop 1-100
Prop 101-200
Hour relative to midnight
D
Target count
0-100 m (129)
101-200 m (273)
0-200 m (402)
Hour (relative to midnight)

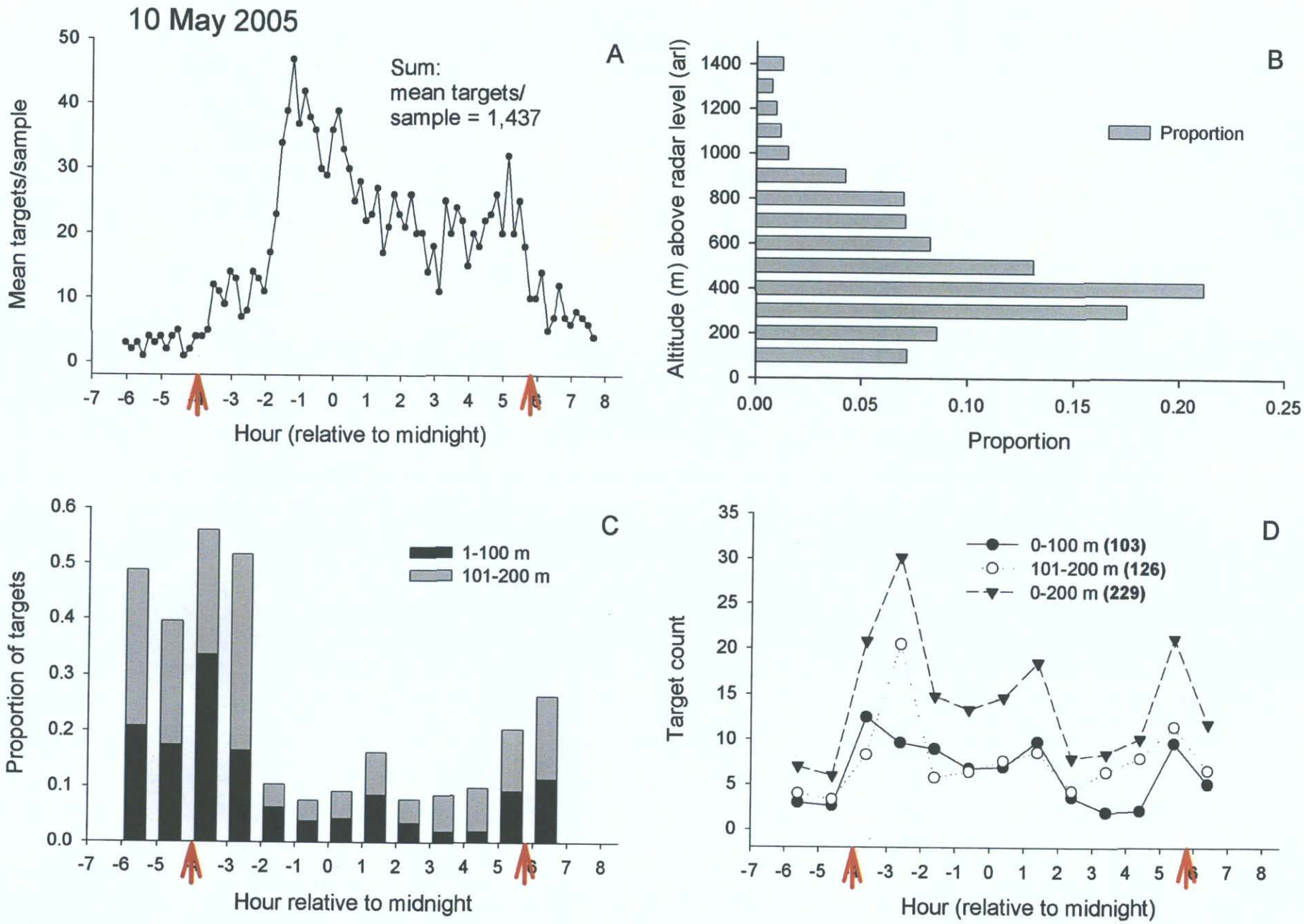

05 May 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 340
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
1-100 m
101-200 m
Hour relative to midnight
D
Target count
0-100 m (33)
101-200 m (71)
0-200 m (104)
Hour (relative to midnight)

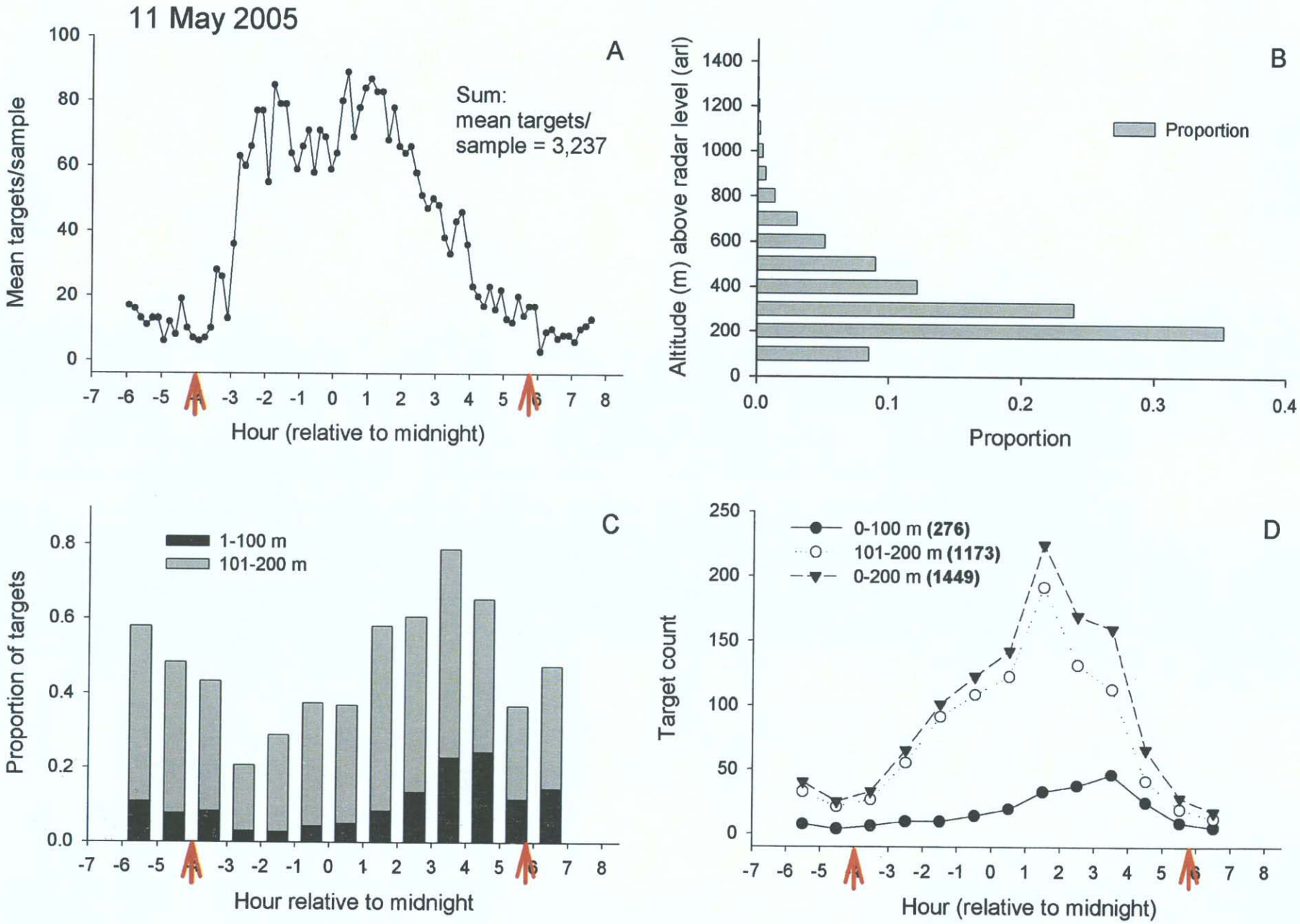

06 May 2005
A
Sum:
mean targets/
sample = 71
Images
rejected (74%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (27)
101-200 m (16)
0-200 m (43)
Target count
Hour (relative to midnight)

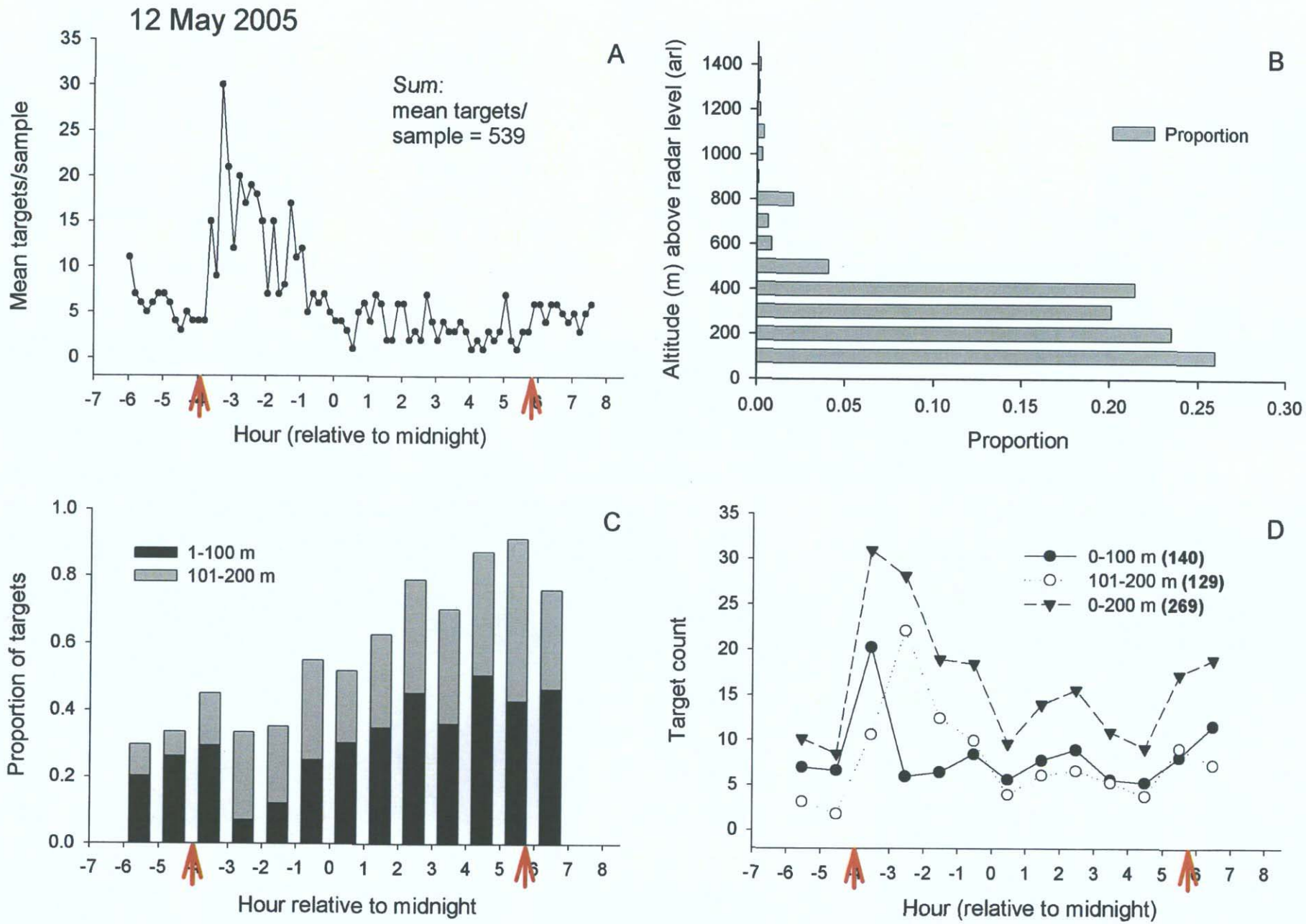

07 May 2005
A
Sum:
mean targets/
sample = 1,063
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (123)
101-200 m (219)
0-200 m (342)
Target count
Hour (relative to midnight)

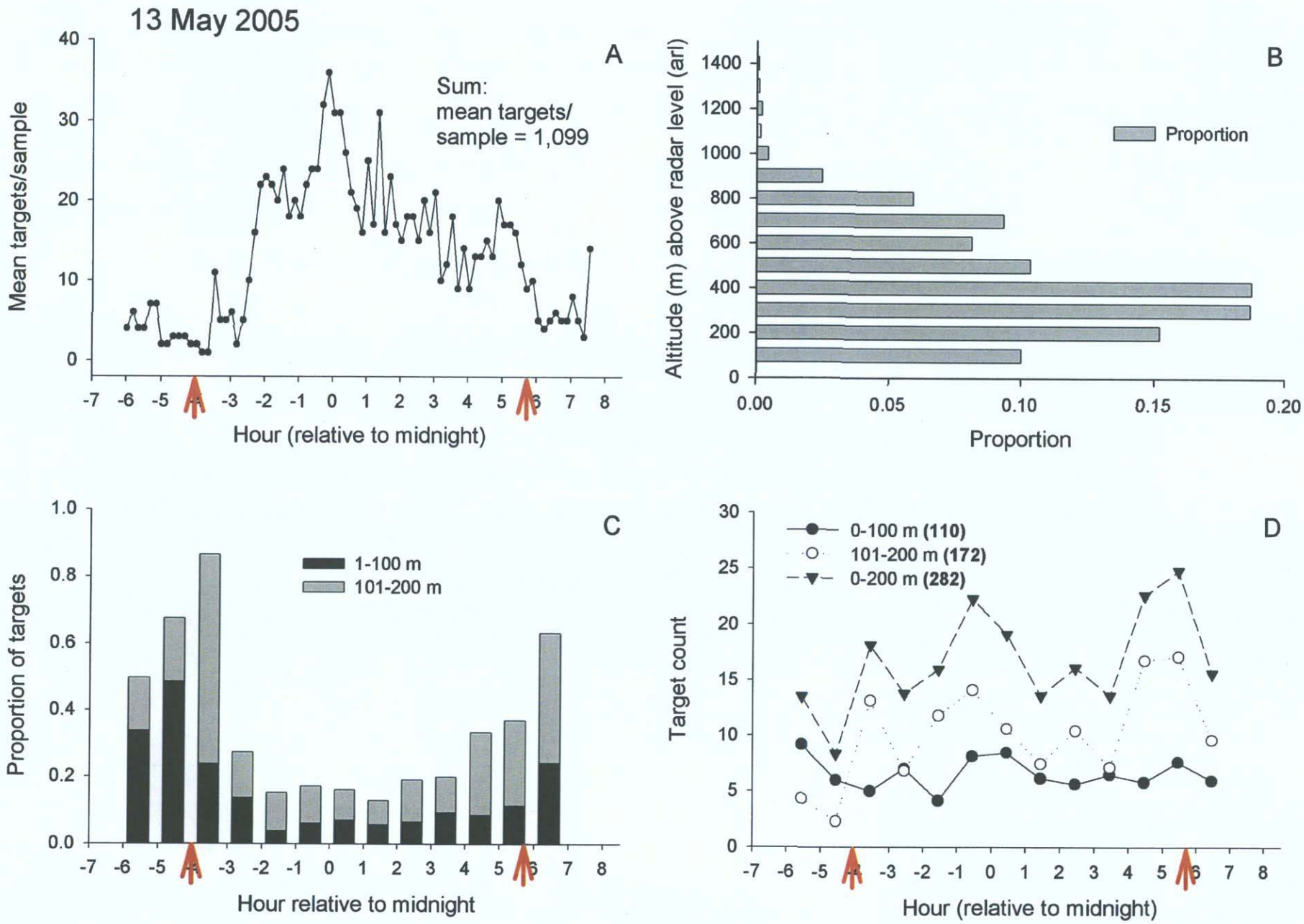

08 May 2005
A
Sum:
mean targets/
sample = 1,239
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (192)
101-200 m (476)
0-200 m (668)
Target count
Hour (relative to midnight)

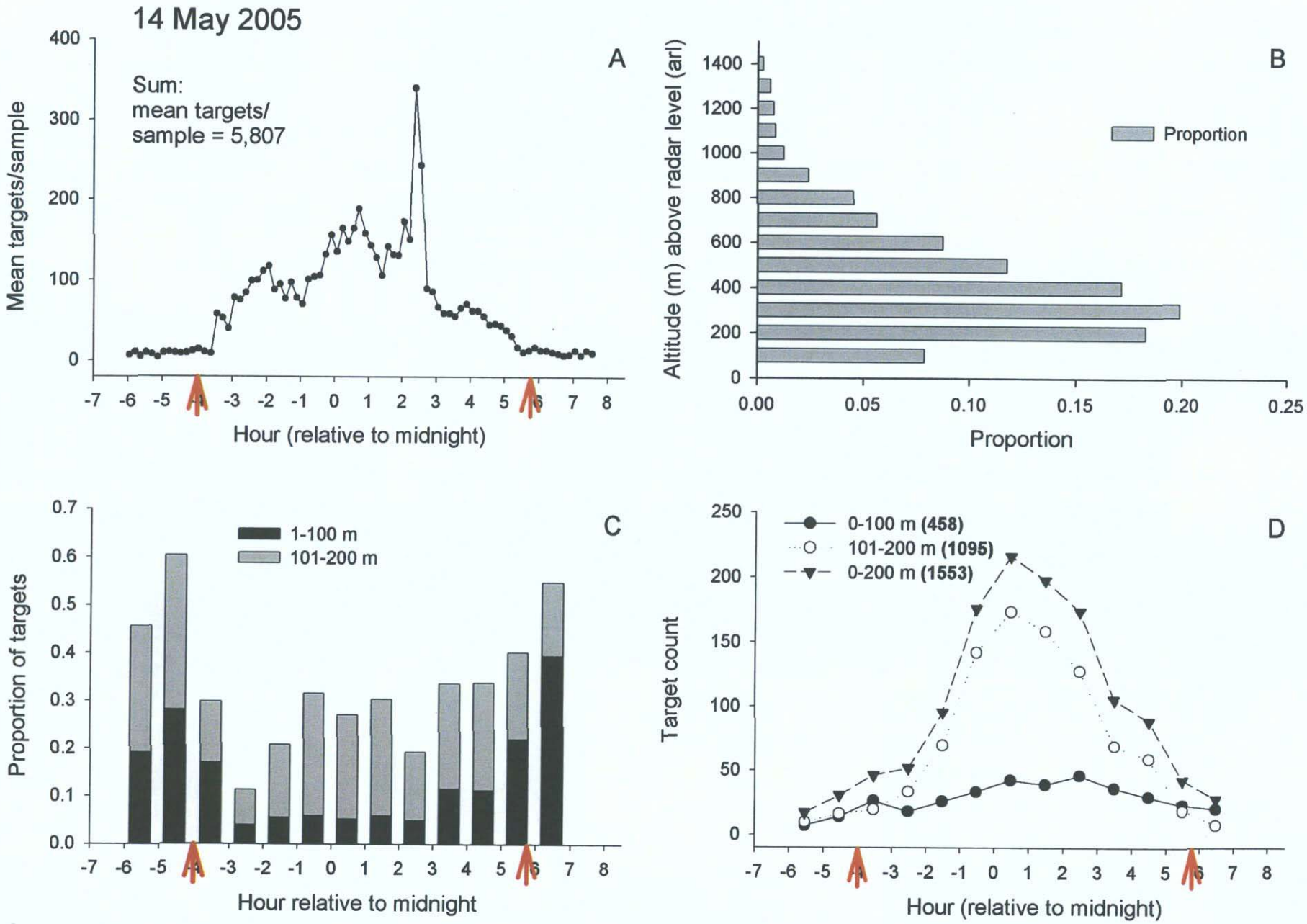

09 May 2005
A
Sum:
mean targets/
sample = 923
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (122)
101-200 m (305)
0-200 m (427)
Target count
Hour (relative to midnight)

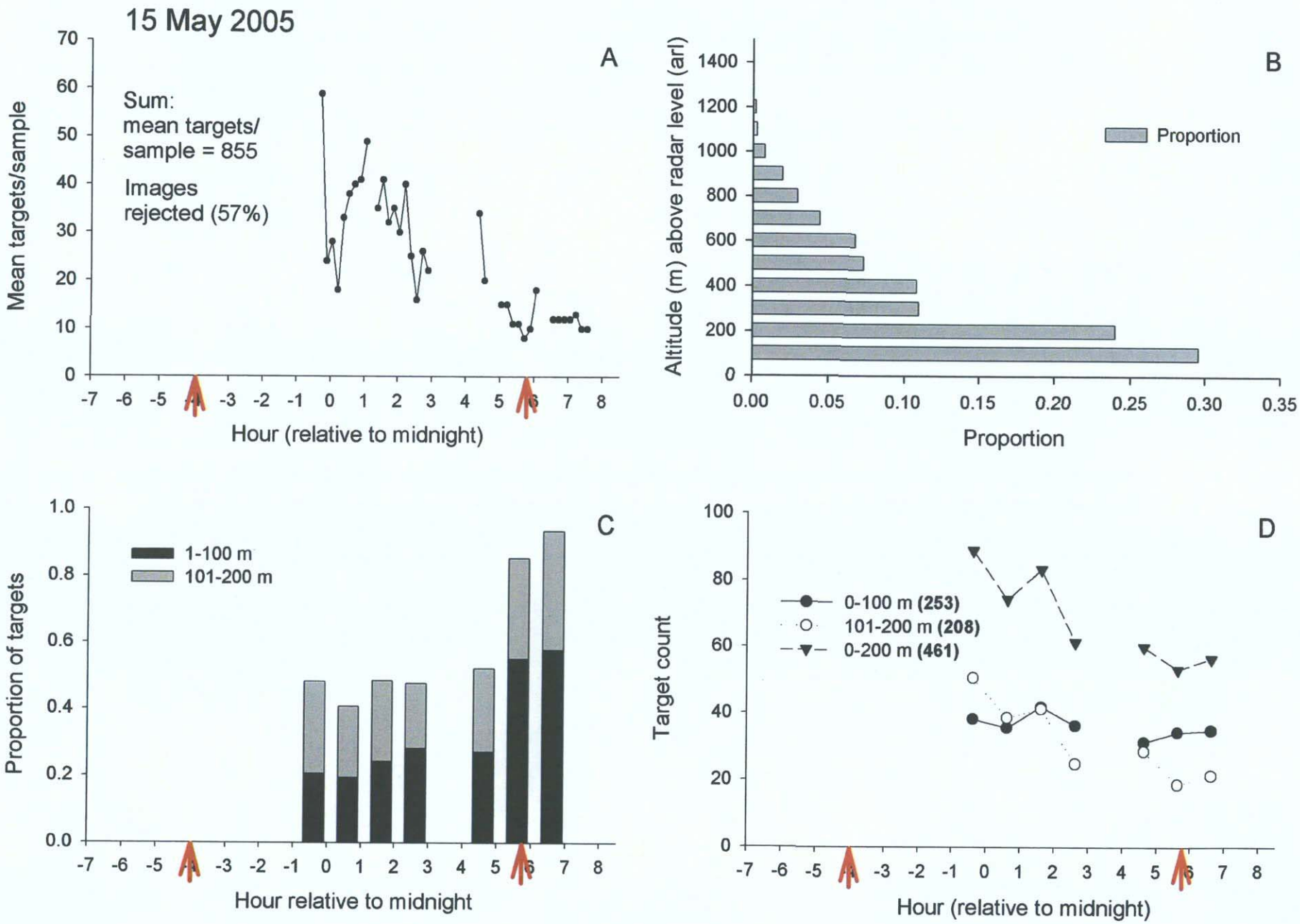

10 May 2005
A
Sum:
mean targets/
sample = 1,437
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (103)
101-200 m (126)
0-200 m (229)
Target count
Hour (relative to midnight)

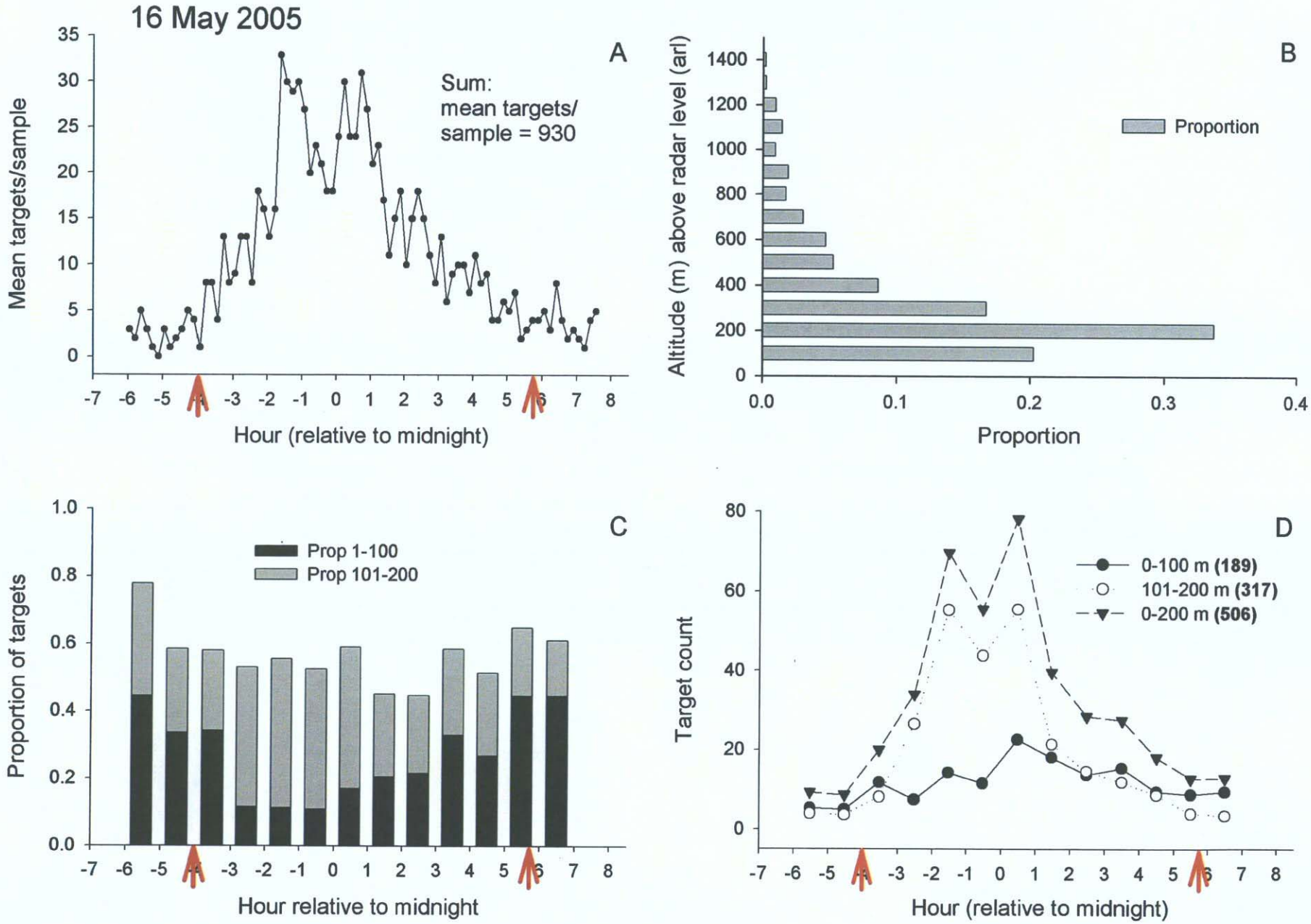

11 May 2005
A
Sum:
mean targets/
sample = 3,237
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (276)
101-200 m (1173)
0-200 m (1449)
Target count
Hour (relative to midnight)

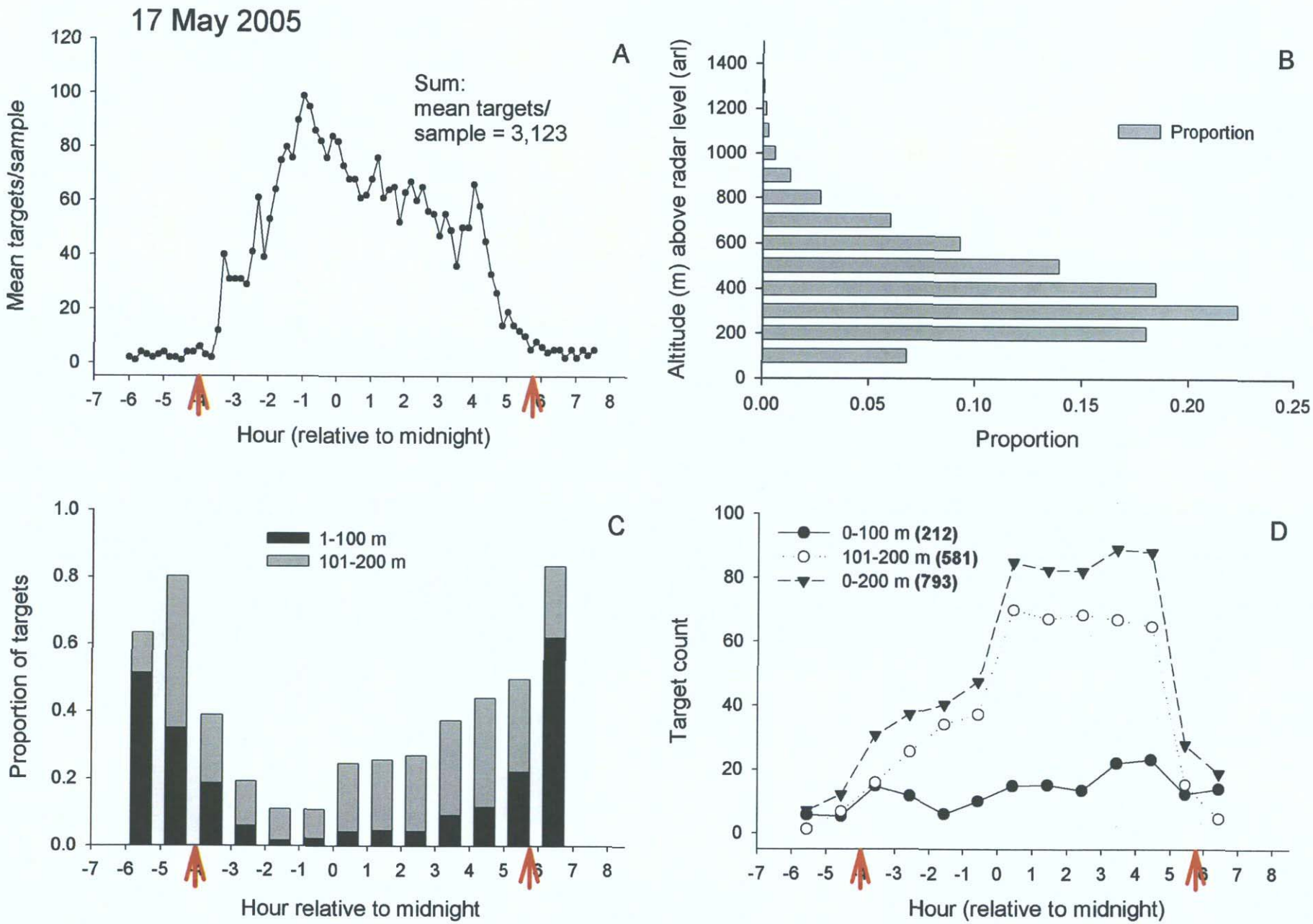

12 May 2005
A
Sum:
mean targets/
sample = 539
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (140)
101-200 m (129)
0-200 m (269)
Target count
Hour (relative to midnight)

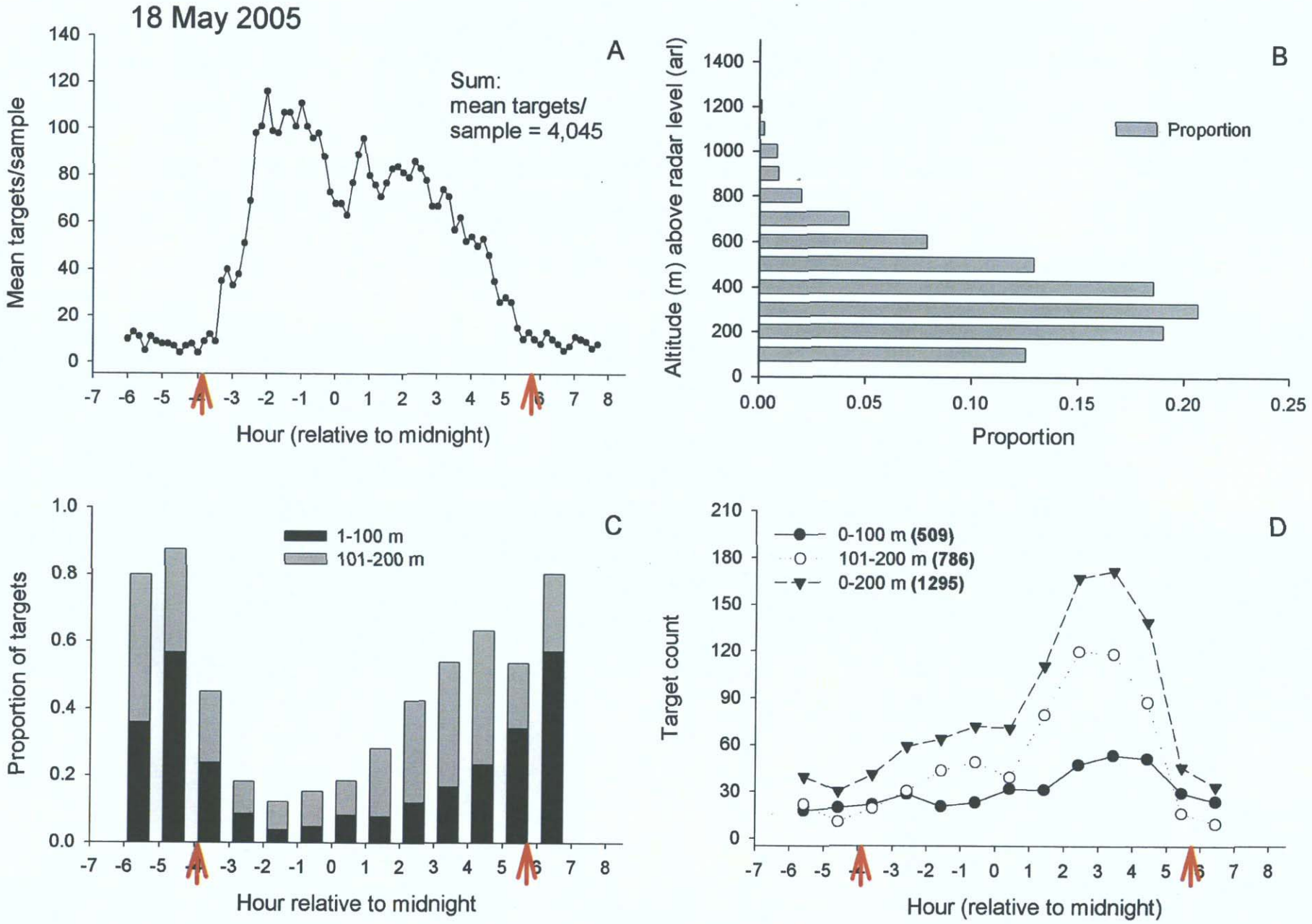

13 May 2005
A
Sum:
mean targets/
sample = 1,099
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (110)
101-200 m (172)
0-200 m (282)
Target count
Hour (relative to midnight)

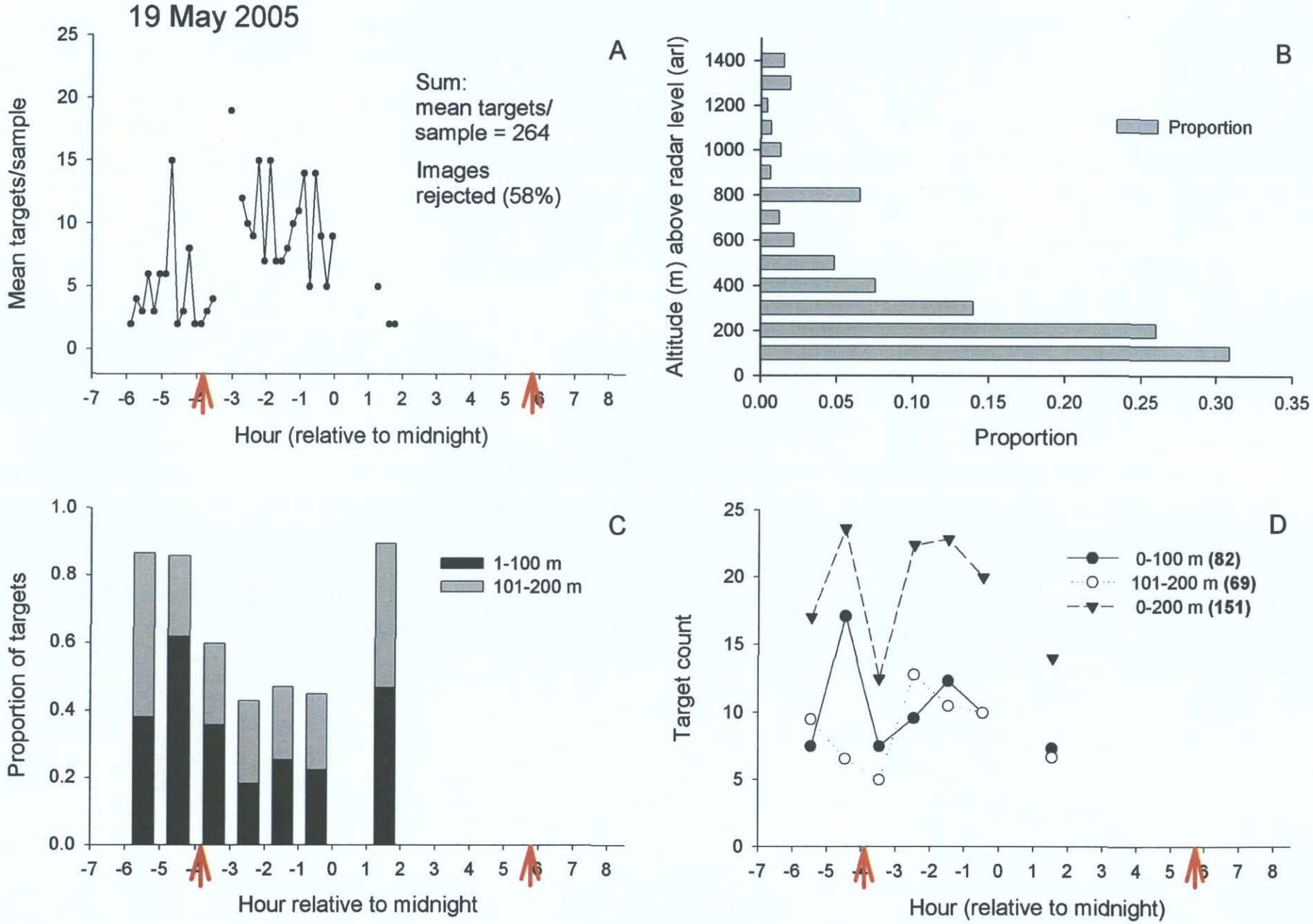

14 May 2005
A
Sum:
mean targets/
sample = 5,807
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (458)
101-200 m (1095)
0-200 m (1553)
Target count
Hour (relative to midnight)

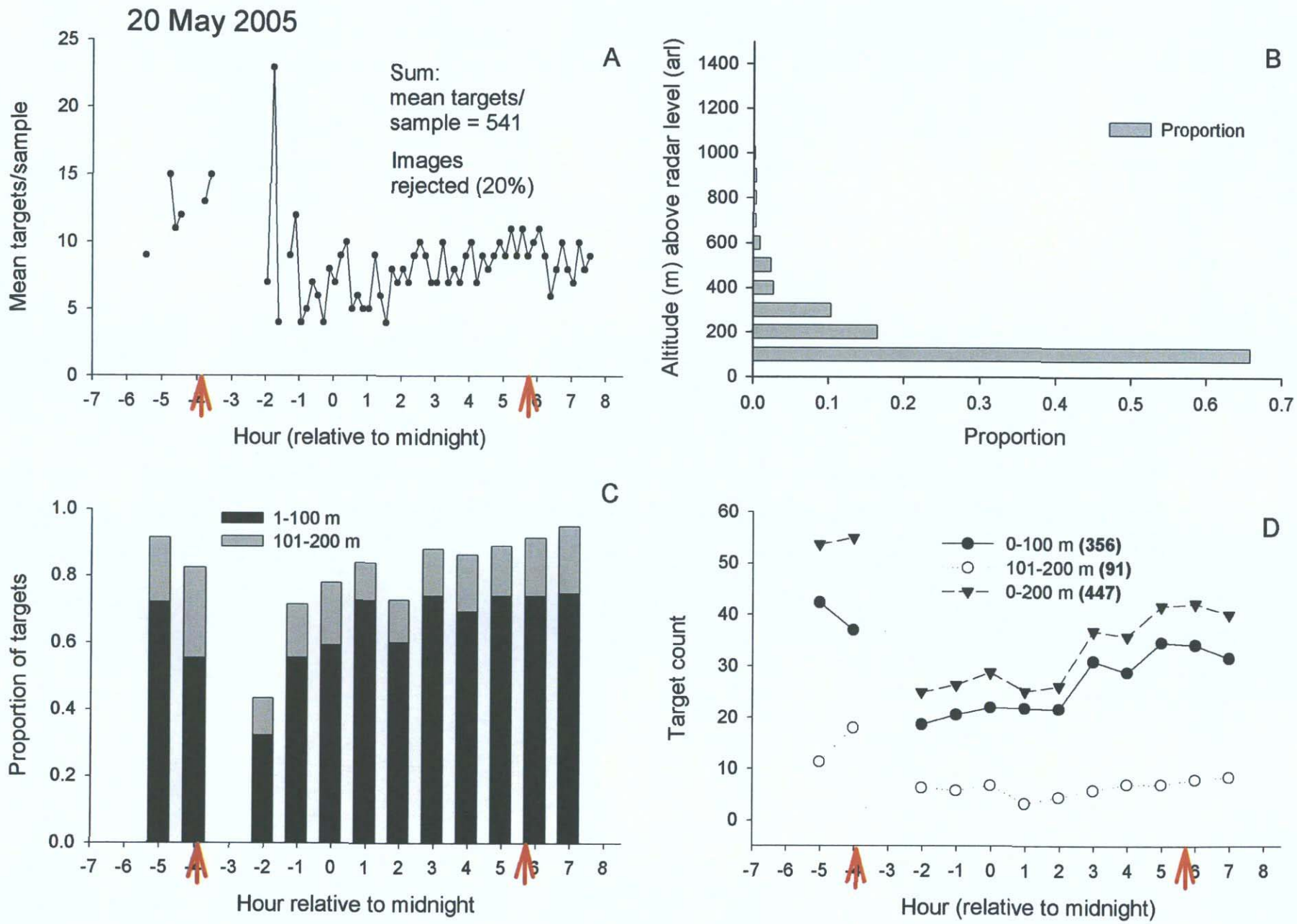

15 May 2005
A
Sum:
mean targets/
sample = 855
Images
rejected (57%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (253)
101-200 m (208)
0-200 m (461)
Target count
Hour (relative to midnight)

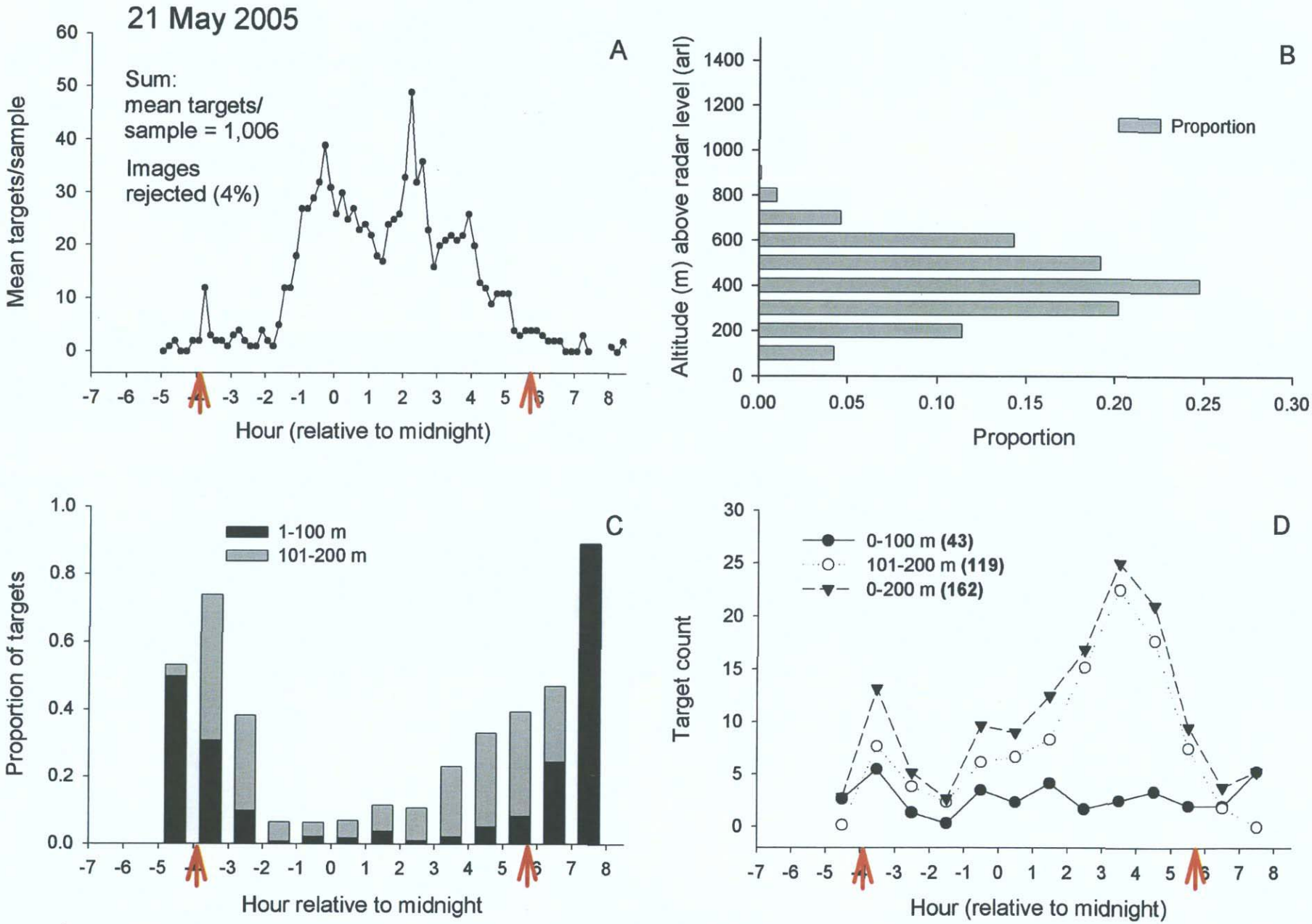

16 May 2005
A
Sum:
mean targets/
sample = 930
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Prop 1-100
Prop 101-200
Proportion of targets
Hour relative to midnight
D
0-100 m (189)
101-200 m (317)
0-200 m (506)
Target count
Hour (relative to midnight)

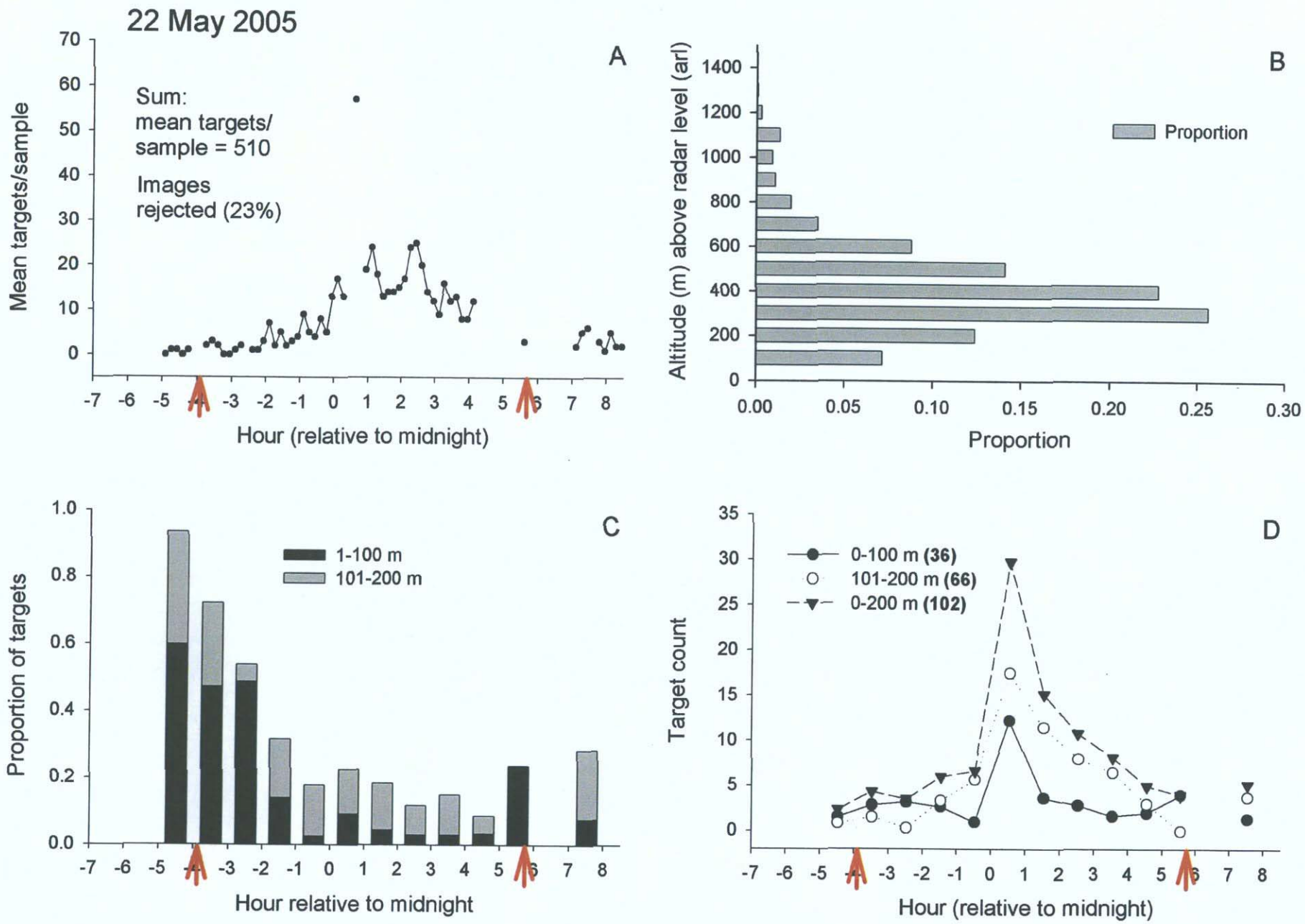

17 May 2005
A
Sum:
mean targets/
sample = 3,123
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (212)
101-200 m (581)
0-200 m (793)
Target count
Hour (relative to midnight)

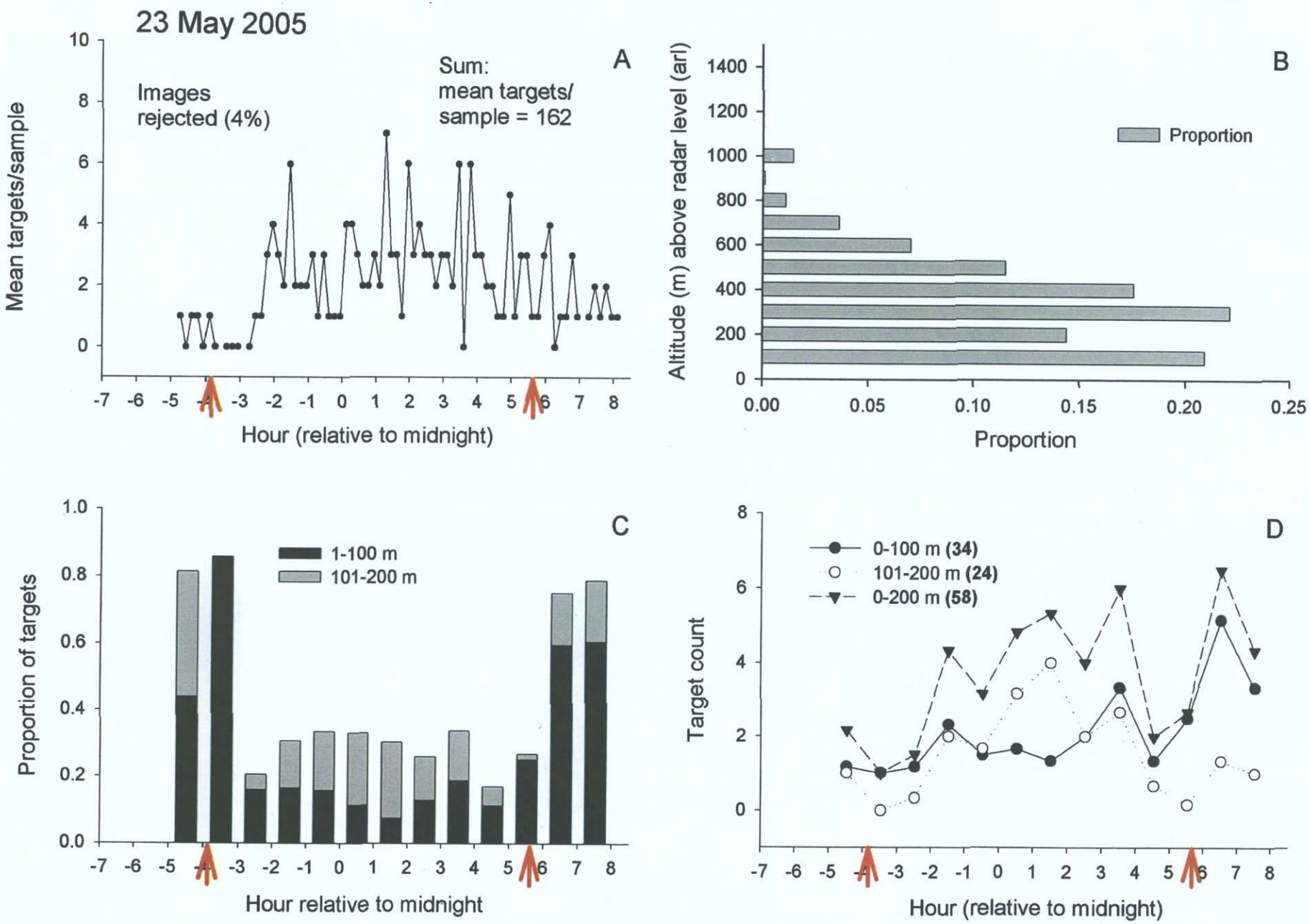

18 May 2005
A
Sum:
mean targets/
sample = 4,045
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (509)
101-200 m (786)
0-200 m (1295)
Target count
Hour (relative to midnight)

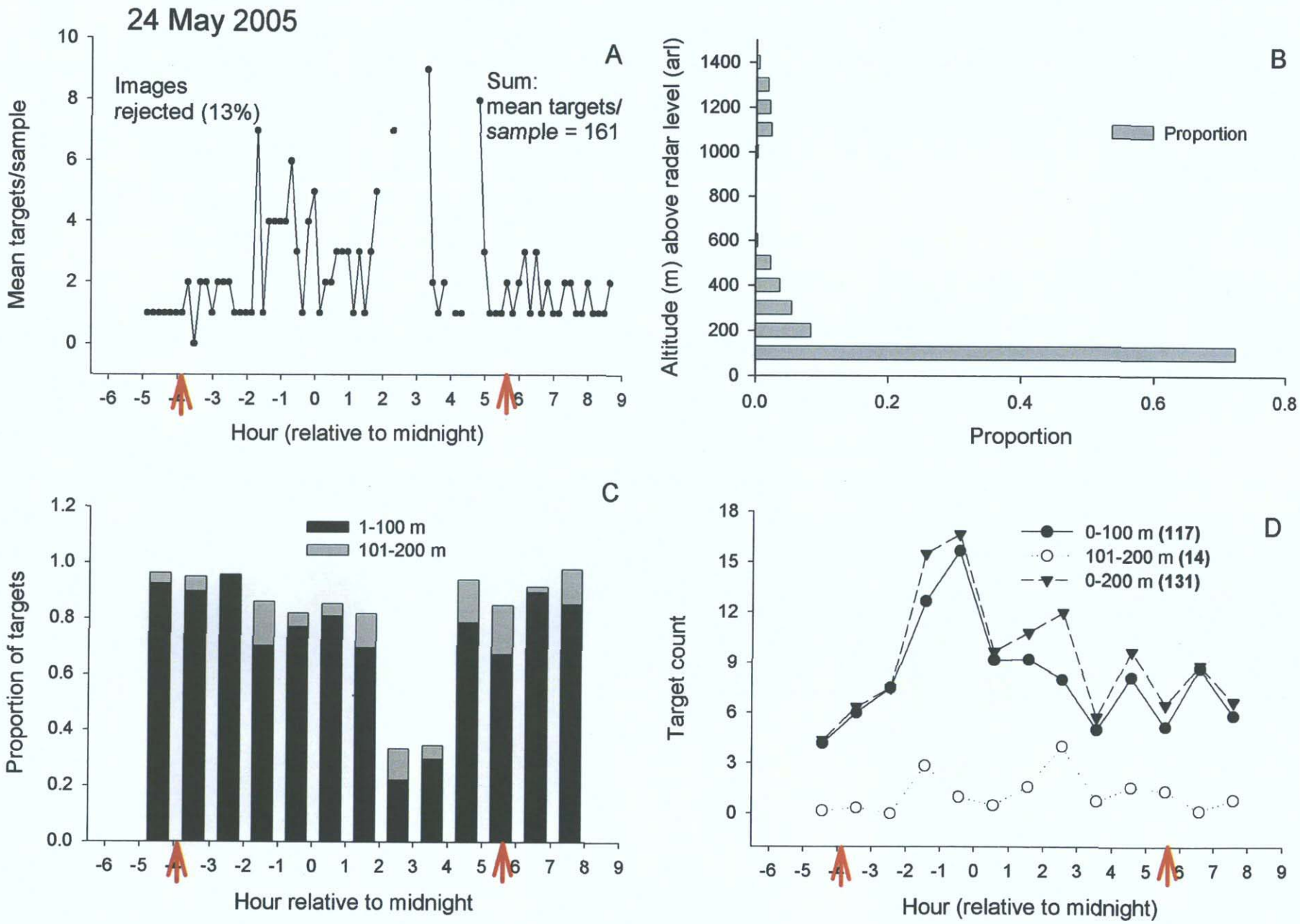

19 May 2005
A
Sum:
mean targets/
sample = 264
Images
rejected (58%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (82)
101-200 m (69)
0-200 m (151)
Target count
Hour (relative to midnight)

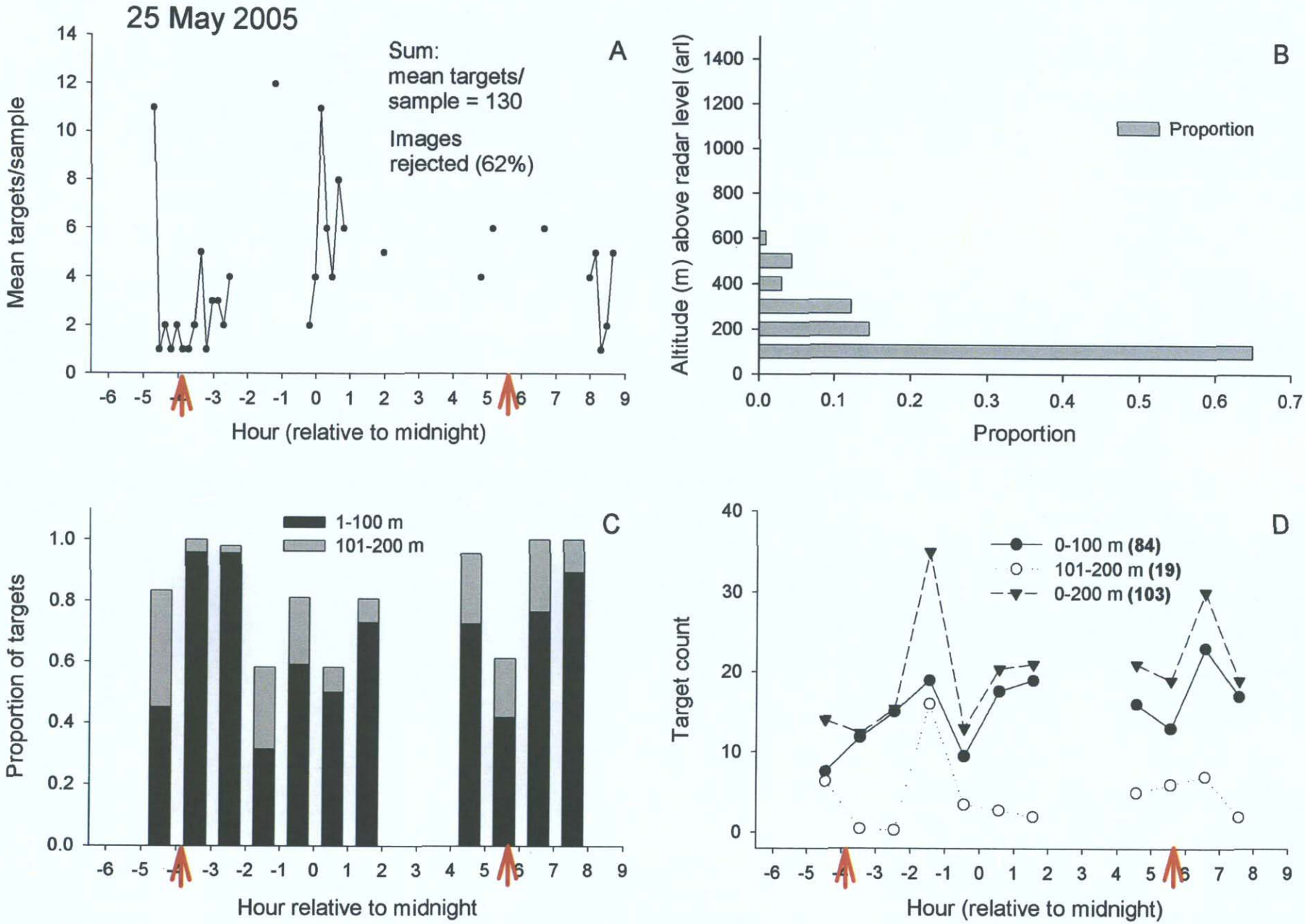

20 May 2005
A
Sum:
mean targets/
sample = 541
Images
rejected (20%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (356)
101-200 m (91)
0-200 m (447)
Target count
Hour (relative to midnight)

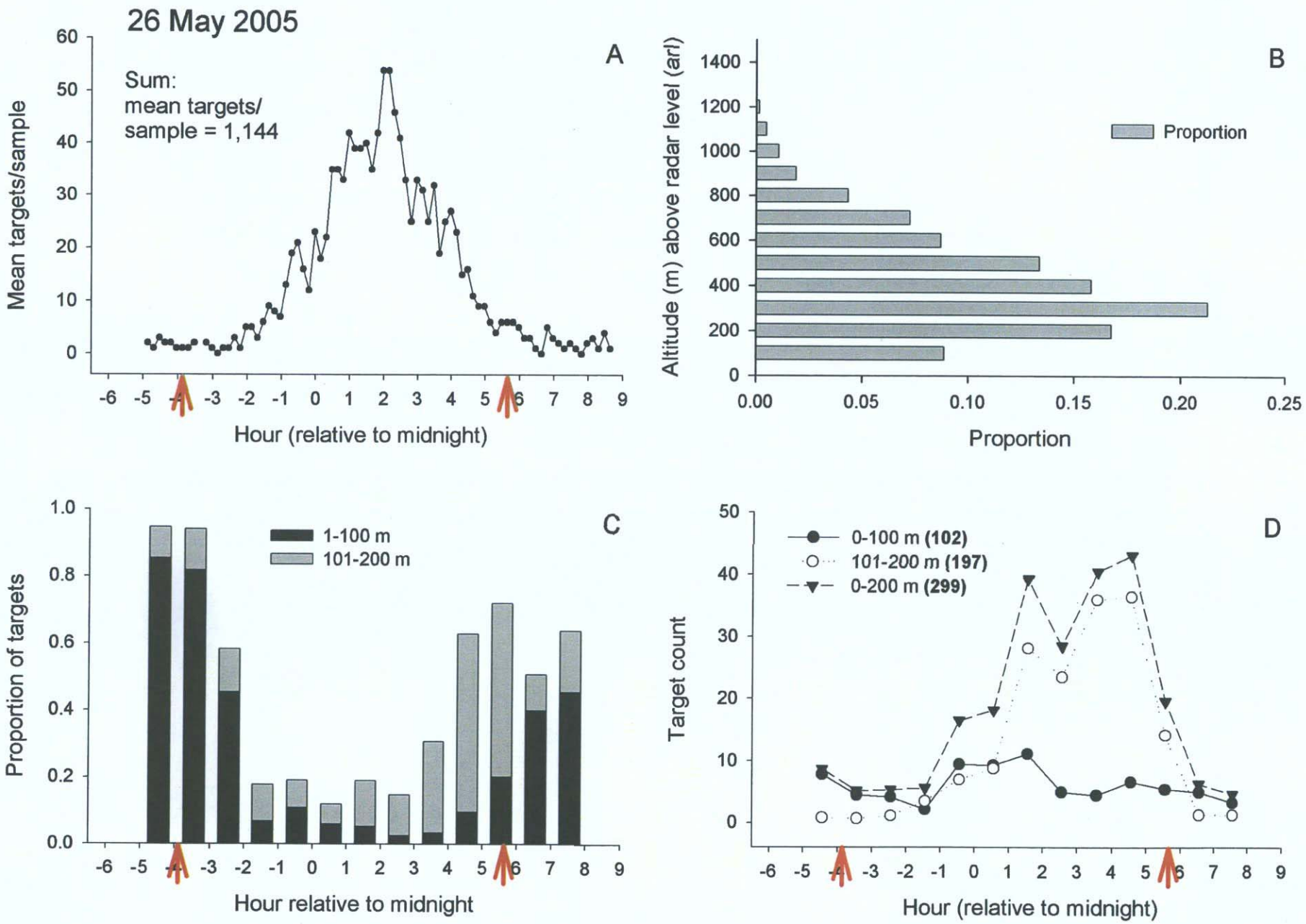

21 May 2005
A
Sum:
mean targets/
sample = 1,006
Images
rejected (4%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (43)
101-200 m (119)
0-200 m (162)
Target count
Hour (relative to midnight)

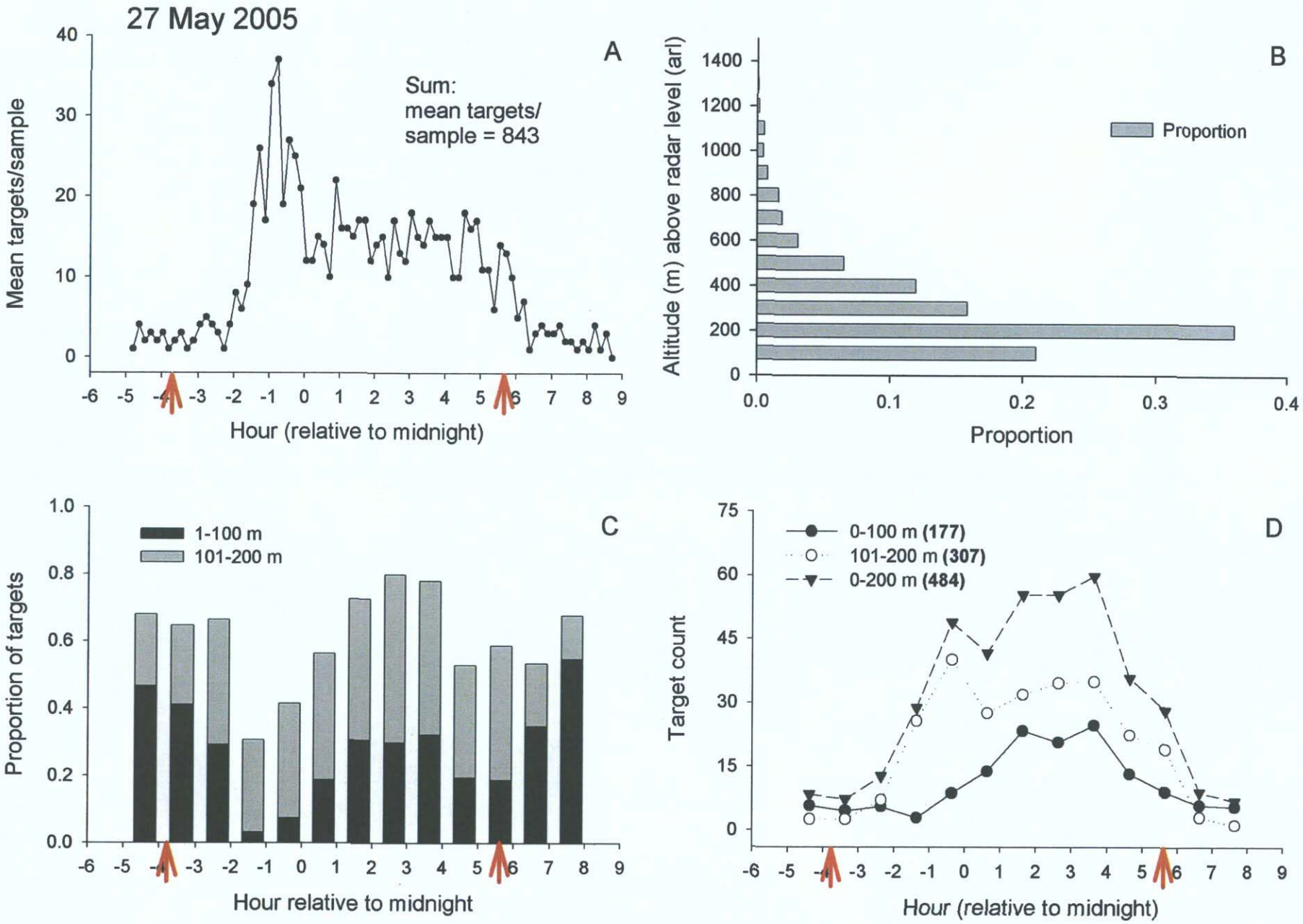

22 May 2005
A
Sum:
mean targets/
sample = 510
Images
rejected (23%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (36)
101-200 m (66)
0-200 m (102)
Target count
Hour (relative to midnight)

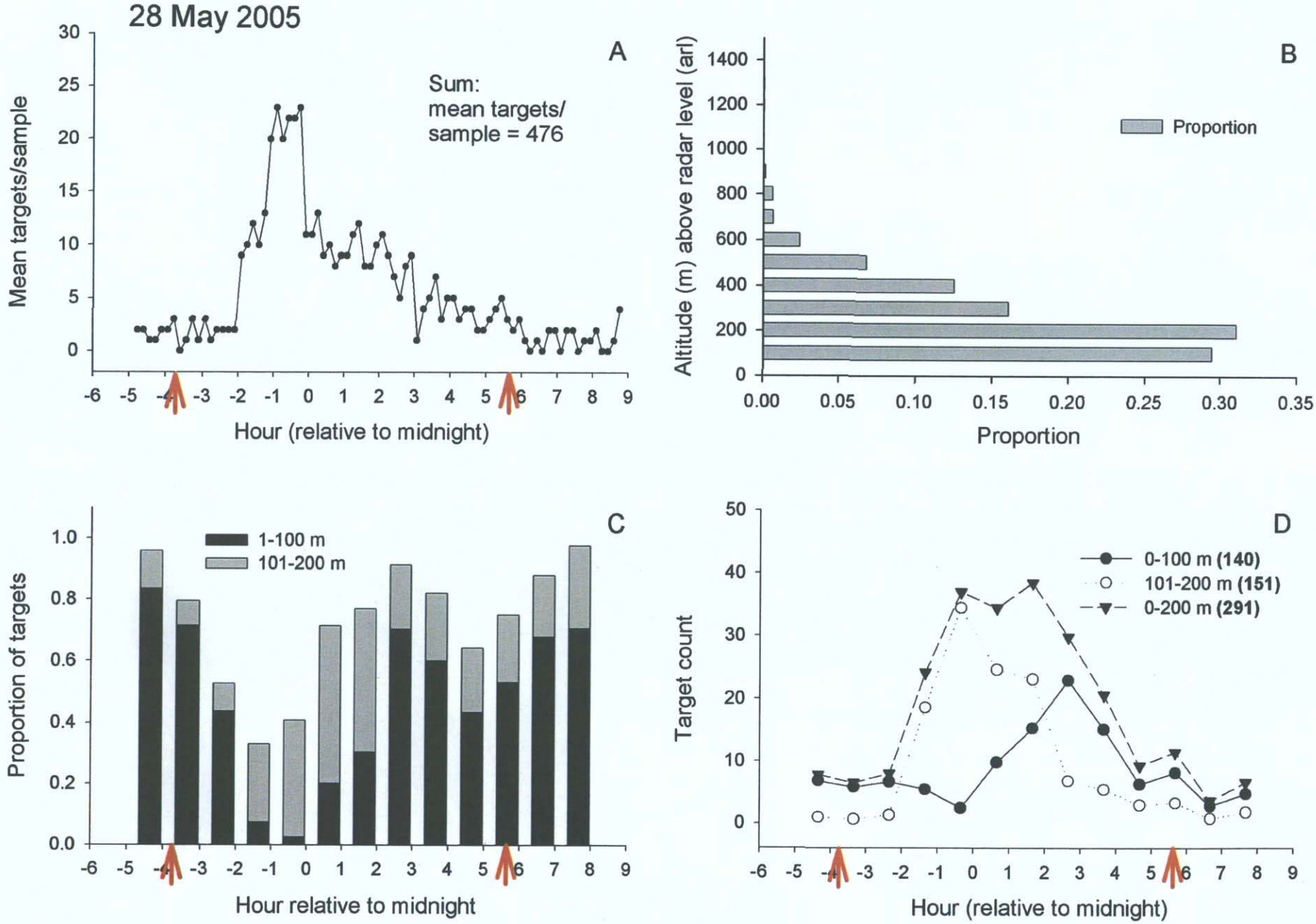

23 May 2005
A
Images rejected (4%)
Sum: mean targets/ sample = 162
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (34)
101-200 m (24)
0-200 m (58)
Target count
Hour (relative to midnight)

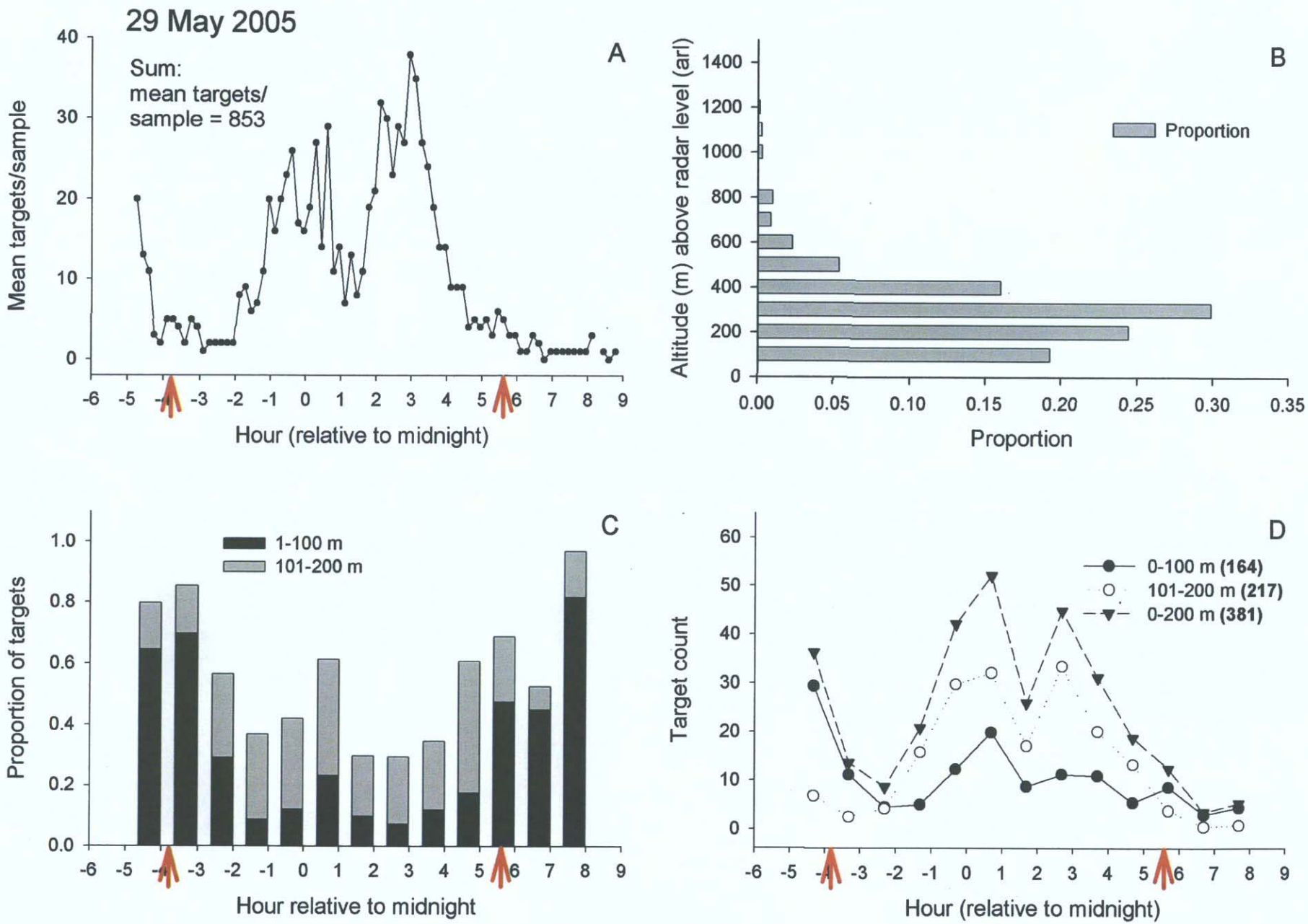

24 May 2005
A
Images rejected (13%)
Sum: mean targets/ sample = 161
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (117)
101-200 m (14)
0-200 m (131)
Target count
Hour (relative to midnight)

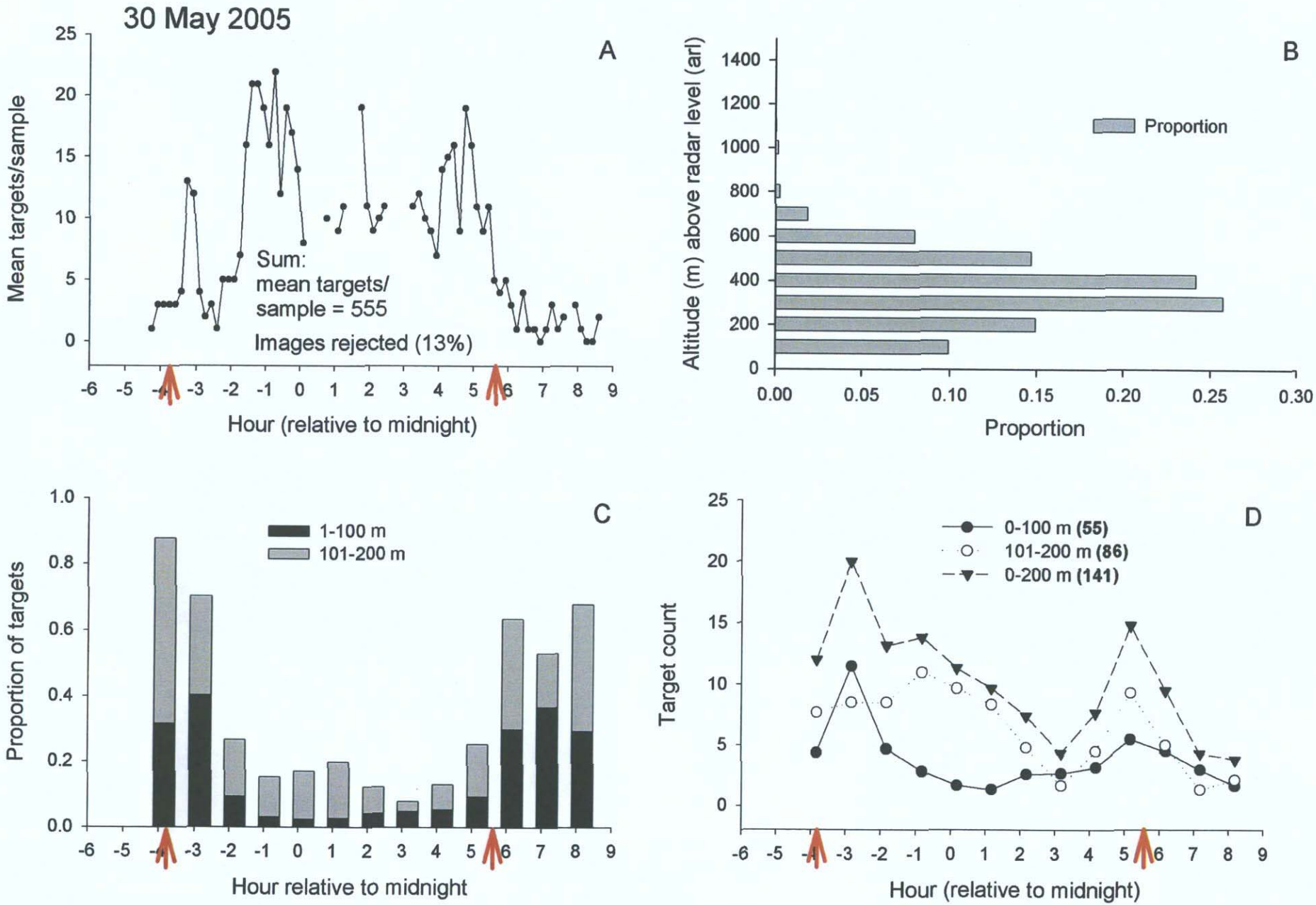

25 May 2005
A
Sum:
mean targets/
sample = 130
Images
rejected (62%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (84)
101-200 m (19)
0-200 m (103)
Target count
Hour (relative to midnight)

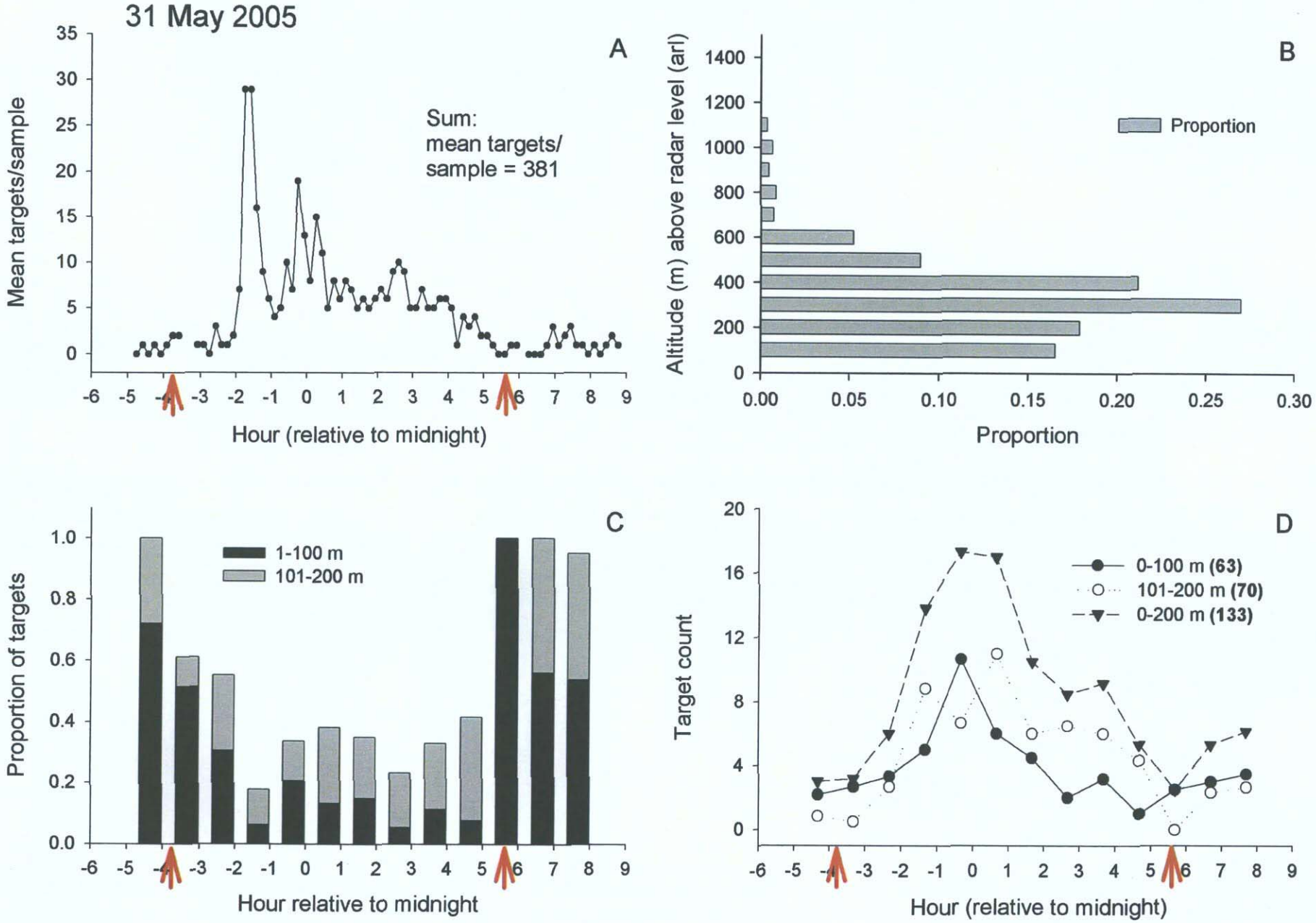

26 May 2005
A
Sum:
mean targets/
sample = 1,144
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (102)
101-200 m (197)
0-200 m (299)
Target count
Hour (relative to midnight)


27 May 2005
A
Sum:
mean targets/
sample = 843
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (177)
101-200 m (307)
0-200 m (484)
Target count
Hour (relative to midnight)


28 May 2005
A
Sum:
mean targets/
sample = 476
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (140)
101-200 m (151)
0-200 m (291)
Target count
Hour (relative to midnight)


29 May 2005
Sum:
mean targets/
sample = 853
A
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
1-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (164)
101-200 m (217)
0-200 m (381)
Target count
Hour (relative to midnight)


30 May 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 555
Images rejected (13%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
1-100 m
101-200 m
Hour relative to midnight
D
Target count
0-100 m (55)
101-200 m (86)
0-200 m (141)
Hour (relative to midnight)


31 May 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 381
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
1-100 m
101-200 m
Hour relative to midnight
D
Target count
0-100 m (63)
101-200 m (70)
0-200 m (133)
Hour (relative to midnight)

Appendix 4. Results of marine radar image analyses for all altitudinal strata sampled (totals, means for 0-1400 m presented in 100 m bins) on 109 days during fall 2005. Column heading descriptions follow Table 6.

Date	Threshold	Number of images used	Number of images rejected	Total targets detected	Sum of the sample means	Strata (in meters)													
						100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400
080105	150	395	0	2793	556	945	239	234	301	274	218	128	146	106	80	50	45	21	6
080205	150	420	0	6966	1387	216	825	915	1196	1081	944	493	452	313	247	144	89	43	8
080305	150	410	0	4959	989	190	518	742	1098	718	400	319	358	206	172	117	70	39	12
080405	150	420	0	2569	513	135	203	343	552	427	286	181	137	78	69	57	61	34	6
080505	25	365	60	2242	467	141	281	290	501	342	234	148	98	70	37	35	21	32	12
080605	150	425	0	4680	935	264	452	508	966	898	492	400	284	143	114	66	45	34	14
080705	175	430	0	2977	599	125	263	371	742	553	410	193	92	81	58	38	30	16	5
080805	100	365	65	1658	333	159	207	247	309	209	196	99	67	50	41	36	26	5	7
080905	22	295	135	1231	247	270	182	122	152	103	93	52	91	46	21	43	30	17	9
081005	150	435	0	6511	1302	1963	1660	438	709	582	430	261	184	96	82	38	26	27	15
081105	150	435	0	5697	1145	353	636	727	1123	1175	694	419	206	135	104	63	42	20	0
081205	150	435	0	3186	637	155	355	562	747	536	307	162	136	81	45	37	28	25	10
081305	150	425	0	6564	1313	1777	1688	570	844	618	455	225	143	92	62	42	30	13	5
081405	50	414	21	6581	1326	254	762	915	1328	890	631	544	553	290	186	120	67	36	5
081505	100	405	30	13394	2680	284	1226	1888	3642	3194	1788	696	308	152	96	45	28	33	14
081605	50	143	207	2774	572	87	324	401	573	426	416	279	113	58	25	32	24	8	8
081705	330	435	0	17470	3493	729	1657	1600	3236	3360	3023	1907	990	428	228	175	75	51	11
081805	80	327	83	12110	2458	530	1088	752	2547	2398	1733	1521	832	329	117	157	65	32	9
081905	25	327	118	2731	574	160	249	179	659	562	340	200	109	64	53	39	66	34	17
082005	175	405	0	9198	1841	173	1150	1028	2741	1803	972	647	304	170	80	39	40	35	16
082605	150	450	0	4057	811	208	197	322	1028	832	496	372	197	160	116	62	30	27	10
082705	25	418	37	1686	362	63	187	180	313	218	162	90	109	119	113	76	34	17	5
082805	150	425	0	2350	470	125	188	219	451	415	298	207	149	110	84	59	21	16	8
082905	150	440	0	1500	300	94	99	151	286	204	169	120	87	75	70	60	49	28	8
083005	100	445	10	2744	548	74	102	184	668	737	413	197	96	93	74	43	33	19	11
083105	25	246	214	2737	806	213	196	264	484	381	444	231	157	110	106	57	59	32	3
090105	450	450	0	35514	7105	1544	3140	3973	6448	5049	4400	3479	2631	1728	1227	889	554	373	79
090205	350	455	0	28587	5719	1598	2599	3526	6157	5715	3495	2084	1262	847	537	332	240	150	45
090305	100	411	49	20063	4367	742	1970	2505	4225	3377	2841	1648	1035	582	438	320	223	106	51
090405	150	455	5	13300	2663	291	807	1149	3353	3013	2173	1283	700	202	147	101	53	20	8
090905	300	470	0	33249	6648	2201	2931	2897	5053	5669	5662	4250	2214	865	516	483	314	153	41
091005	250	460	0	11786	2355	671	1269	1105	2267	2037	1448	881	617	341	379	379	185	154	53
091105	150	445	0	7269	1451	277	354	381	1429	1422	1393	1007	450	261	142	78	50	24	1
091305	225	470	0	6573	1313	148	266	493	1563	1569	1708	508	211	54	23	17	2	8	3
091405	100	475	0	516	99	97	91	52	116	78	33	24	9	4	0	11	1	0	0
091505	100	460	0	1397	280	81	137	109	150	136	132	137	120	140	93	68	51	31	12
091605	70	364	86	7554	1520	283	815	912	1452	1403	887	595	254	223	217	174	164	107	68
091705	200	415	55	27129	5425	819	2985	3448	6450	5363	3476	2022	1121	638	334	220	134	99	20
091805	450	475	0	36302	7257	177	1625	2266	4897	8599	6050	4327	3055	2084	1417	933	540	246	86
091905	100	455	15	10598	2122	229	575	1071	3142	2330	1397	845	437	185	147	128	56	46	10
092005	50	330	130	7717	1627	114	630	419	1324	1899	1347	734	499	334	209	104	58	38	8

Appendix 4. Continued

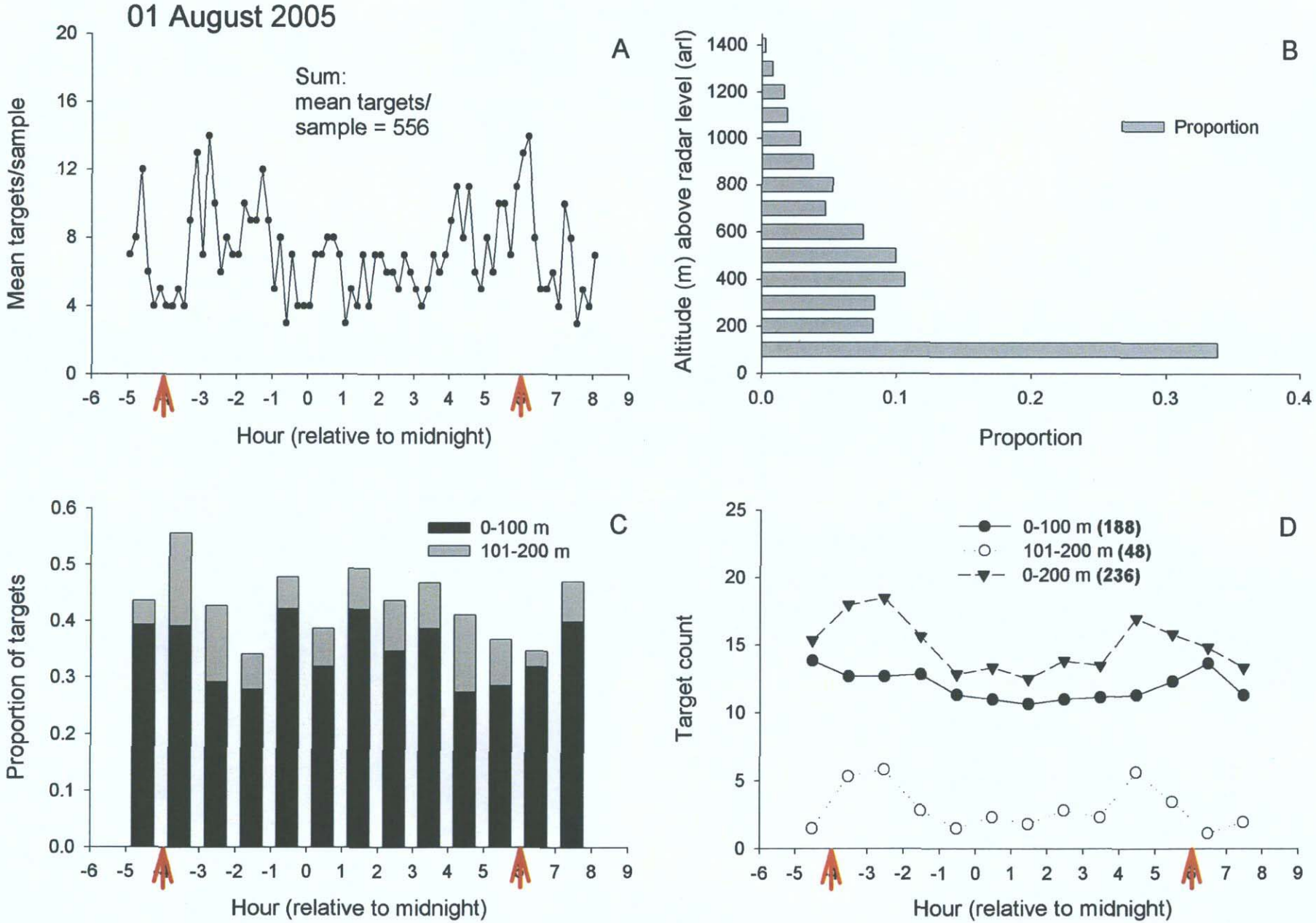
092105	325	425	0	13407	2678	115	936	891	1516	2456	2320	1692	1203	839	528	377	284	182	68
092205	150	485	0	4999	1000	22	243	542	1069	1179	817	431	228	180	114	72	46	45	11
092305	70	276	214	7614	1704	99	753	758	1091	1607	1222	844	449	339	188	143	83	29	9
092405	100	475	10	7803	1562	240	1433	948	1078	1425	830	477	434	301	286	132	117	75	27
092505	150	485	0	1783	353	21	113	141	204	385	262	157	129	110	117	74	43	22	5
092605	28	363	117	2946	610	26	138	143	435	637	500	359	301	156	99	75	51	25	1
092705	375	485	0	26915	5385	511	3050	2534	4569	5460	3819	2580	2002	1094	548	346	224	139	39
092805	150	495	0	3521	706	27	142	221	538	1004	643	331	214	130	96	84	33	46	12
092905	175	490	0	9339	1864	148	883	834	1427	1807	1428	1003	674	512	315	151	101	37	19
093005	225	470	0	6917	1385	116	582	390	501	996	1061	1205	856	510	331	203	122	29	15
100105	150	490	0	7084	1416	384	665	472	988	1091	1031	1046	613	297	211	148	101	27	10
100205	150	490	0	5651	1122	595	971	770	904	594	567	390	273	245	169	70	47	42	14
100305	30	317	163	3860	826	606	956	447	255	235	325	256	236	186	130	98	74	39	17
100405	150	465	0	4913	980	406	1019	759	718	558	413	309	251	190	99	91	67	22	11
100505	150	490	10	3132	627	241	410	309	372	334	322	316	247	198	130	103	78	51	21
100605	17	436	24	1324	271	275	132	62	81	98	59	90	128	162	89	57	40	27	24
100705	25	39	461	272	58	58	65	77	27	2	6	7	8	8	7	2	1	0	4
100805	25	280	200	2585	597	99	202	395	526	637	264	125	93	94	71	41	20	14	4
100905	125	470	10	8237	1645	606	2263	1867	1221	511	380	329	346	253	173	127	85	62	14
101005	25	276	199	3779	851	335	1203	618	551	316	242	128	108	114	60	49	37	12	6
101105	35	325	150	4040	866	677	1071	892	537	194	146	102	95	94	73	73	44	26	16
101205	25	15	455	178	35	40	79	22	4	12	5	4	2	6	2	1	0	1	0
101305	20	204	276	1527	335	132	606	131	170	75	91	80	84	70	47	24	11	2	4
101505	150	480	0	12686	2535	1571	2591	1725	1727	1307	1066	766	636	536	323	184	159	76	19
101605	150	505	0	5074	1012	1031	1196	627	526	363	294	217	183	189	175	125	85	56	7
101705	200	344	0	23543	4709	901	2900	2242	3464	3728	2908	2438	1881	1219	863	401	326	218	54
101805	250	490	0	26007	5203	1865	5711	5473	5614	3385	1546	839	568	425	272	138	84	66	21
101905	125	495	0	15532	3105	278	1160	1750	4354	3274	2346	1098	509	303	220	128	70	28	14
102005	600	415	100	53927	10788	385	8204	7487	5831	6002	5800	5020	4233	3782	2506	2219	1386	793	279
102105	25	84	411	769	202	78	173	87	149	71	63	42	29	25	15	10	6	13	8
102405	25	5	235	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
102505	17	173	351	1731	373	39	96	57	79	42	1385	21	6	0	0	5	1	0	0
102605	275	485	0	42398	8481	979	7061	4546	4352	4365	4051	3473	3087	3083	2854	1924	1339	976	308
102705	350	500	0	28635	5728	989	4186	3699	4139	4101	3478	2862	2054	1363	712	460	312	199	81
102805	375	515	0	65377	13077	1277	6891	7505	7790	7971	7190	6104	5217	4128	3193	3010	2576	1921	604
102905	150	490	0	13370	2677	1079	3198	1484	1586	1024	883	809	641	598	538	429	443	493	165
103005	300	530	0	20701	4143	568	2114	1725	2125	1556	1383	1444	1778	1999	2174	1796	1127	678	234
103105	225	530	0	13117	2624	843	2003	1617	2264	1832	1309	1137	924	525	292	192	99	65	15
110105	60	515	15	6960	1389	87	807	565	723	1134	998	745	689	491	327	181	132	69	12
110205	375	494	0	66837	13368	794	7162	9126	10056	11057	8382	5930	4695	3309	2147	1580	1207	867	525
110305	150	515	0	3483	704	49	373	394	383	545	397	344	259	200	202	158	76	80	23
110405	150	505	0	3571	714	107	435	327	336	452	506	351	317	234	204	119	83	67	33
110505	60	510	30	6402	1279	108	846	708	635	954	700	617	545	456	271	239	153	133	37
110605	150	540	0	5172	1034	105	458	632	578	820	624	546	434	338	231	161	131	85	29
110705	175	500	0	21181	4234	135	1708	2083	2083	2026	1827	1916	2139	1841	1636	1514	1125	860	288
110805	300	480	60	28952	5789	1187	4951	3835	4301	3265	2662	2035	1561	1458	1476	1017	724	337	143
110905	25	393	142	4538	962	280	1037	821	562	446	421	285	206	90	91	125	96	49	29
111005	200	540	0	19346	3869	929	5361	3034	2453	1866	1465	1059	908	677	512	481	337	207	57
111105	175	525	0	24778	4956	552	2536	2413	2302	2288	2510	2484	2580	2418	1970	1322	831	458	114

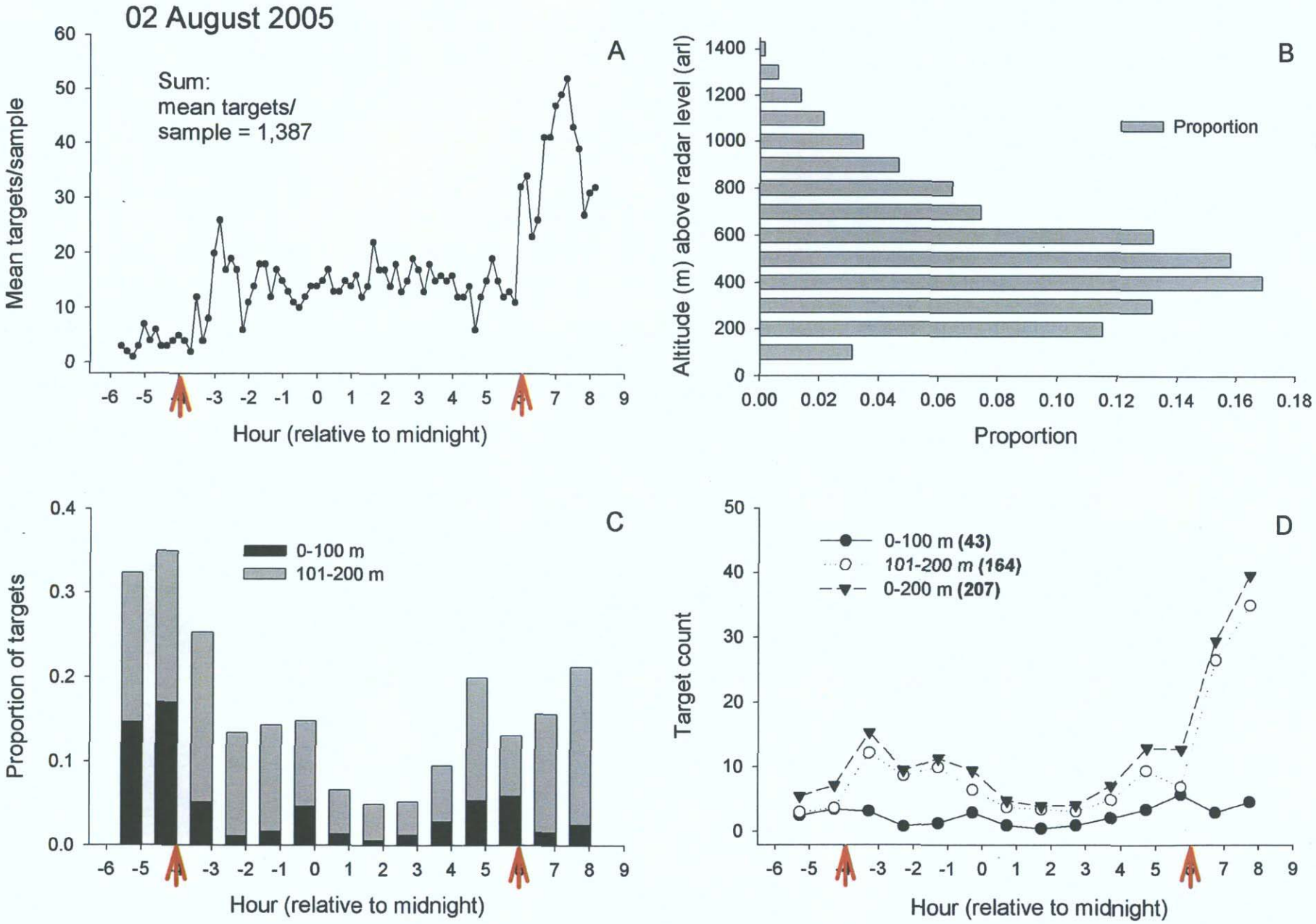
Appendix 4. Continued

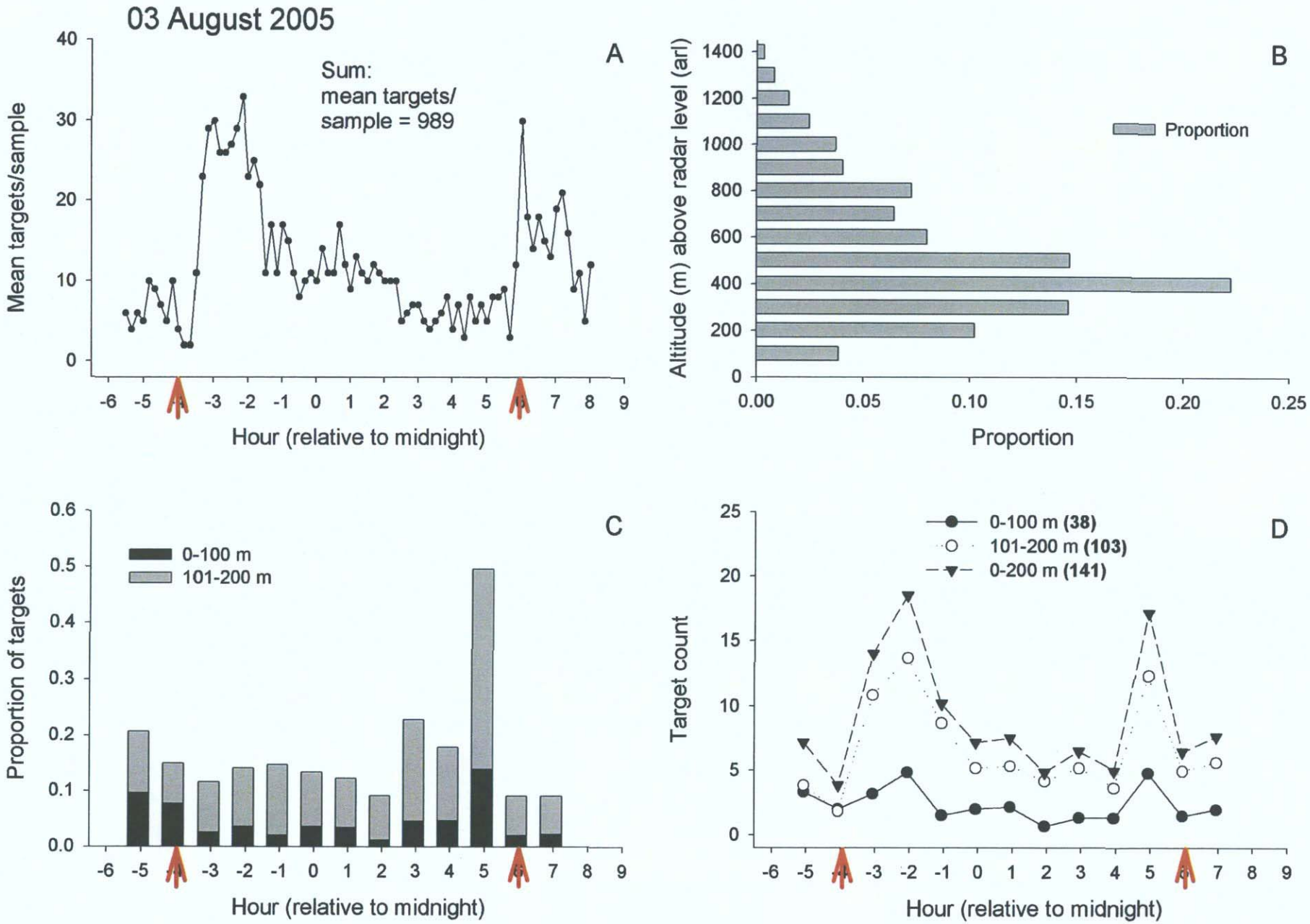
111205	150	545	0	2704	540	108	416	213	323	239	218	194	203	238	203	125	131	68	25
111305	150	540	0	2894	577	113	578	420	465	232	175	223	176	179	96	121	62	37	17
111405	300	530	0	20623	4120	426	2037	2020	2602	2619	2187	1730	1882	2022	1636	765	456	202	39
111505	150	540	5	2516	508	84	473	282	353	179	203	203	194	171	108	103	78	62	23
111605	50	328	217	3397	698	250	819	527	532	333	267	176	148	115	101	60	36	24	9
111705	50	541	4	8158	1637	577	2159	1151	663	498	320	302	421	396	390	316	418	380	167
111805	150	545	0	13924	2790	457	2229	1580	1391	1305	970	936	899	853	766	986	826	543	183
111905	150	550	0	2545	505	179	425	249	248	198	206	188	189	181	127	142	92	87	34
112005	150	550	0	3178	633	75	325	262	276	253	291	291	335	320	236	223	170	95	26
112105	25	15	530	33	7	0	5	7	7	3	2	1	5	2	0	0	1	0	0
112205	35	519	26	3373	677	376	908	512	372	234	178	163	118	142	130	108	72	36	24
112305	15	435	120	2273	489	204	567	360	270	141	114	114	97	97	81	67	62	41	58
112405	25	528	22	2784	587	284	540	518	367	143	129	167	158	142	99	100	87	34	16
112505	50	555	0	5873	1176	330	906	671	533	490	425	379	341	398	475	398	312	180	35
112605	50	555	0	3017	599	137	506	536	621	136	169	189	193	163	139	86	80	51	11
112705	25	496	59	1957	414	184	471	325	151	135	127	124	113	116	75	59	39	27	11
112805	50	555	0	3284	657	261	619	1062	416	146	139	131	117	117	109	82	57	24	4
112905	50	235	320	2592	519	414	827	547	158	101	99	95	75	75	85	49	30	30	7
113005	75	555	0	10531	2107	560	1807	1308	1294	1222	1053	741	697	582	345	376	259	223	64
Totals				1120488	225686	45973	142818	129193	173458	164689	130705	95105	72427	54227	40594	30592	21644	14141	4922
Means				10279.706	2070.51	421.77	1310.26	1185.26	1591.36	1510.91	1199.13	872.52	664.47	497.50	372.42	280.66	198.57	129.73	45.16

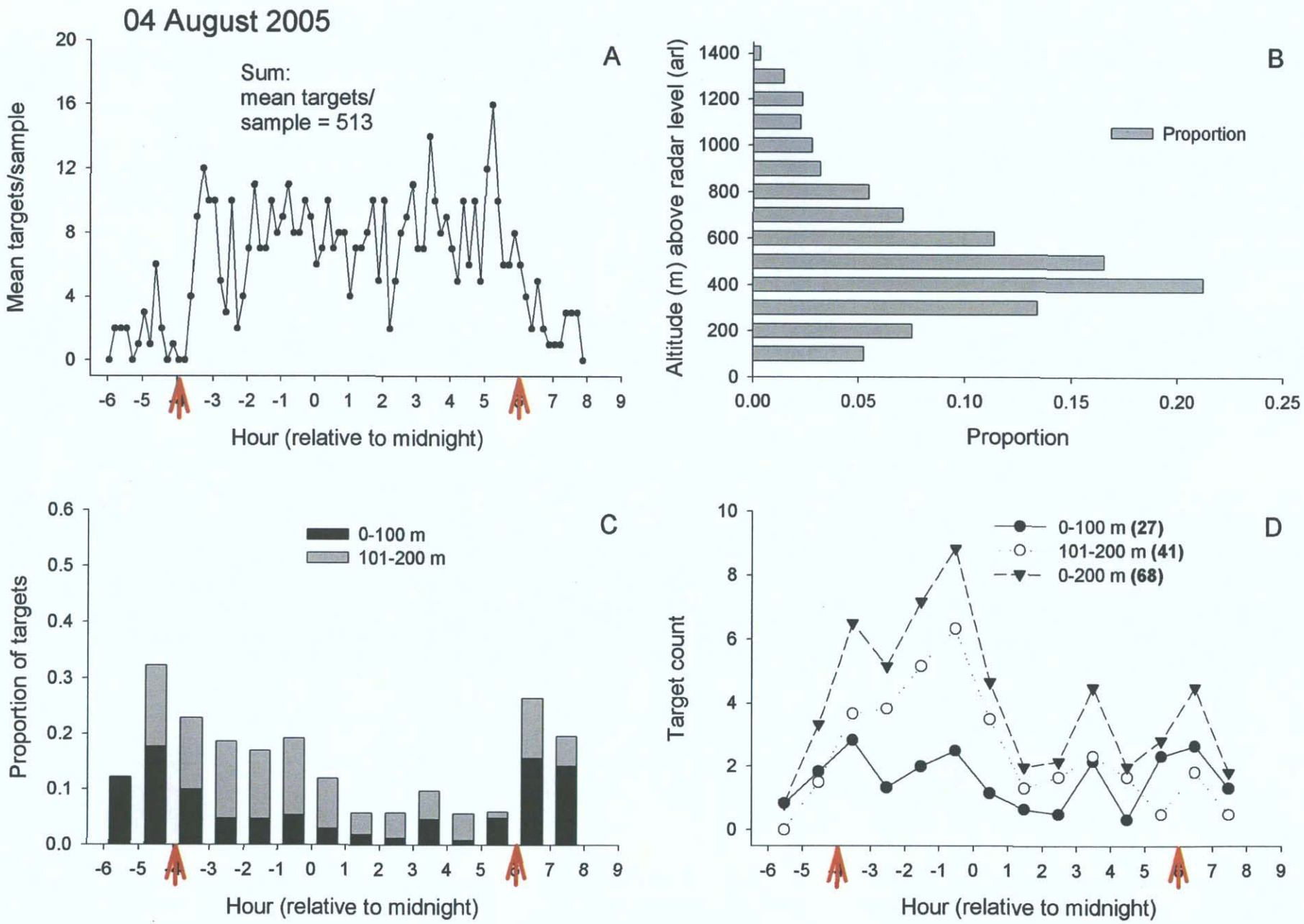
Appendix 5

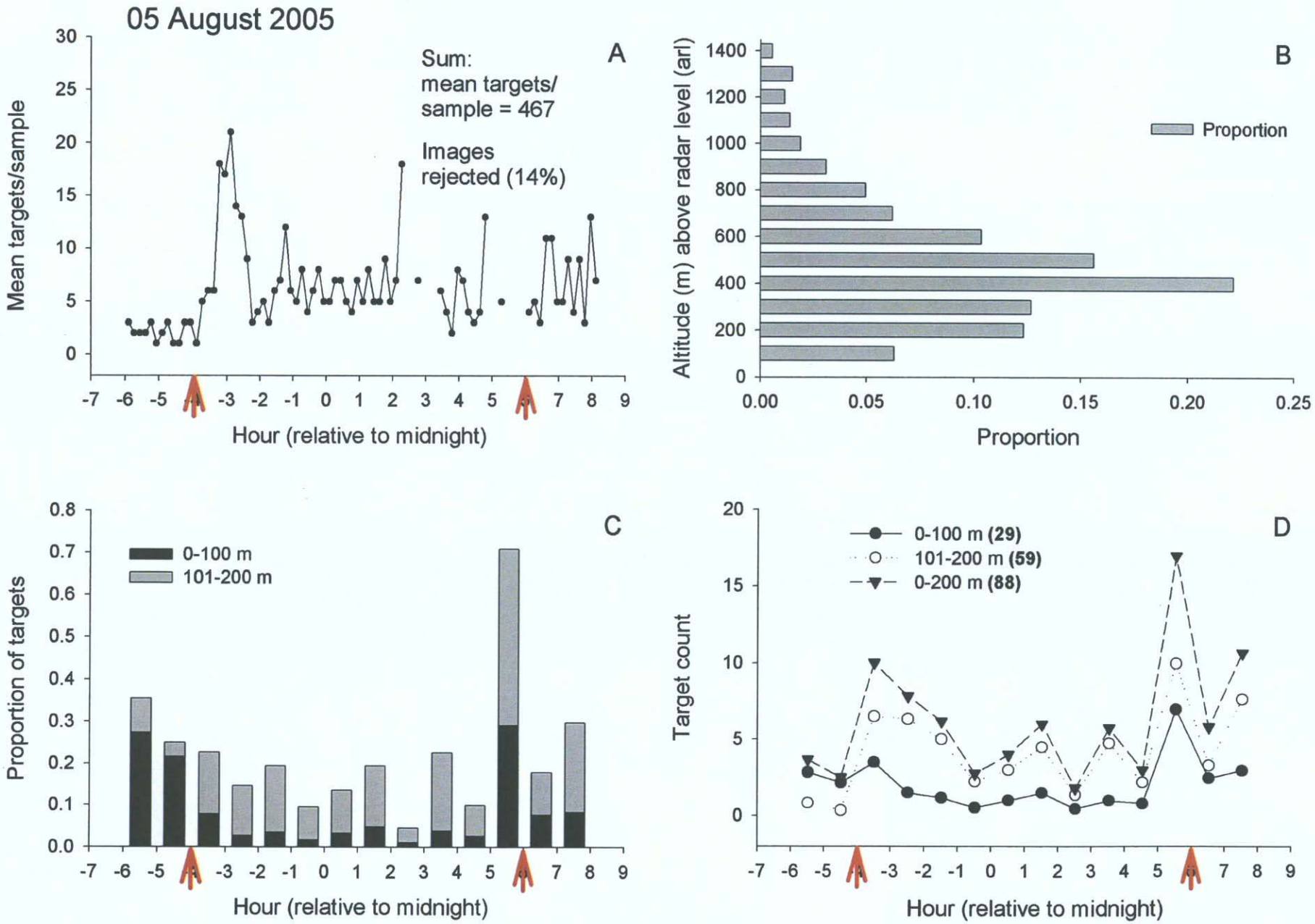
Four-panel graphs: one for each night of data collection in fall 2005. Graphs represent data collected with the vertically-oriented radar. Descriptions of graphs for each night are as follows: (A) Nightly temporal pattern in mean targets/sample (i.e., five succesive images every 10 min). (B) Altitudinal distribution of targets in 100 m strata from 0 - 1400 m arl. (C) Nightly temporal pattern in the proportion of targets <=100 m and between 101 m and 200 m. (D) Nightly temporal pattern in the number of targets <=100 m and between 101 m and 200 m.

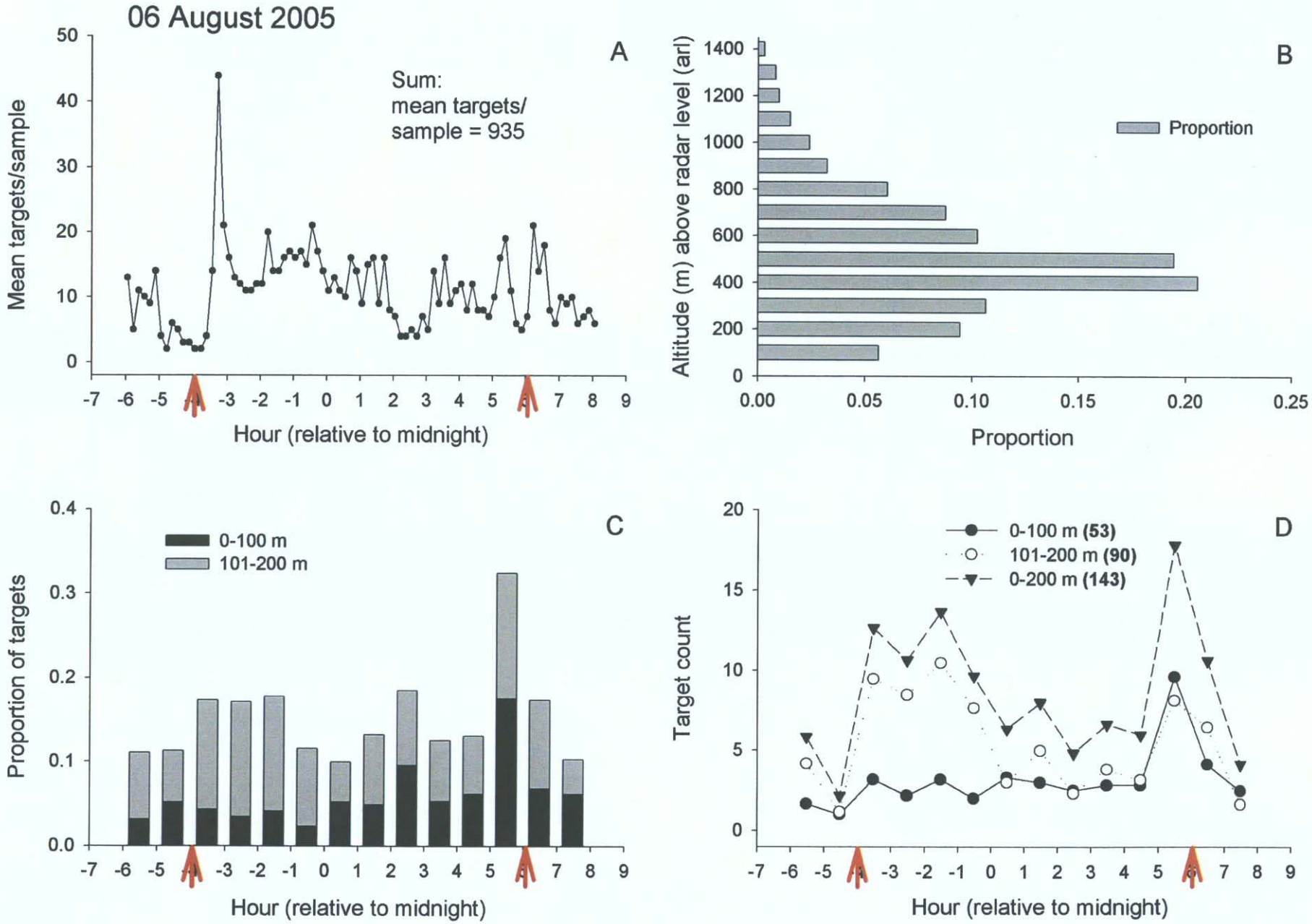

01 August 2005
A
Sum:
mean targets/
sample = 556
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (188)
101-200 m (48)
0-200 m (236)
Target count
Hour (relative to midnight)

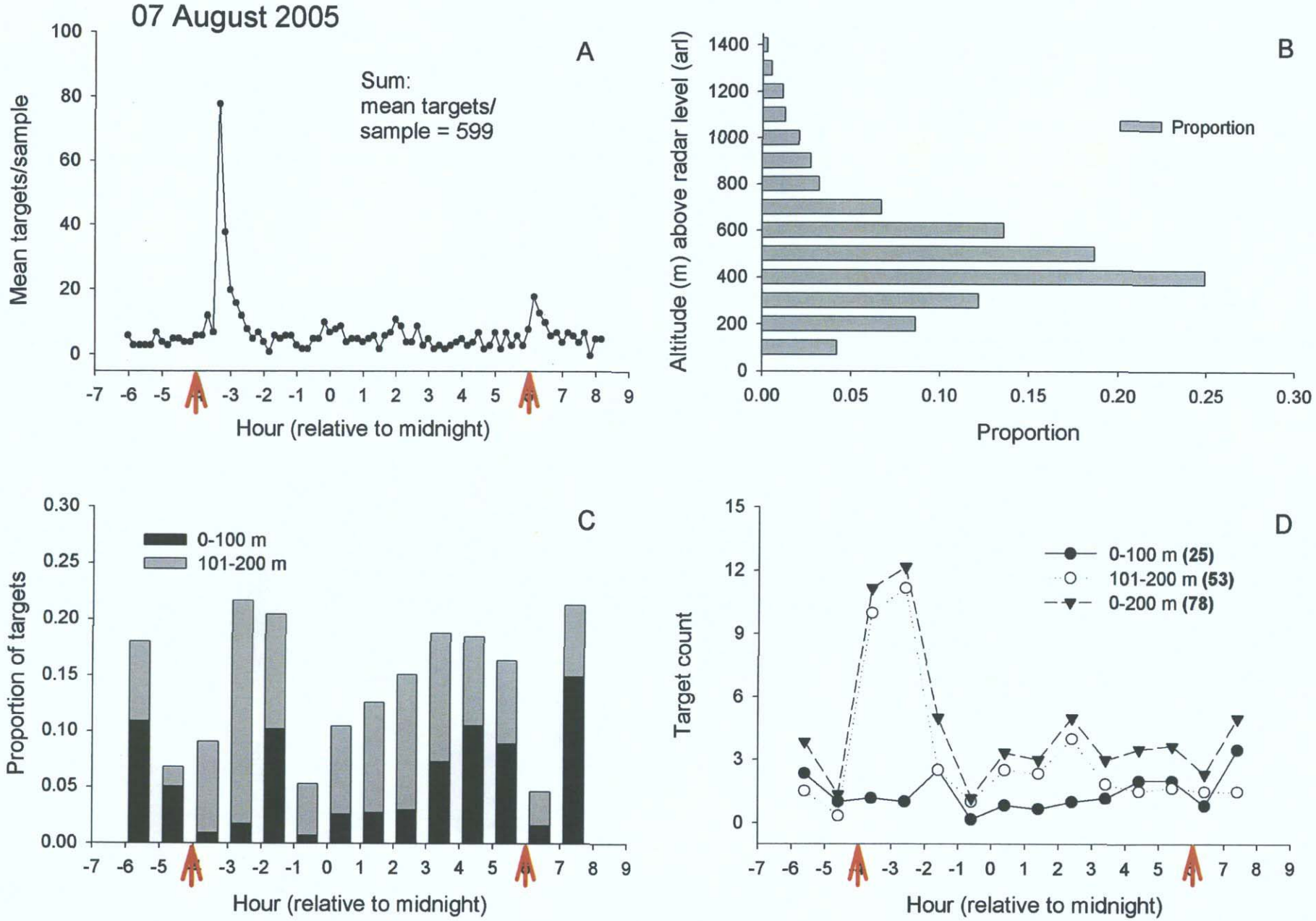

02 August 2005
A
Sum:
mean targets/
sample = 1,387
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (43)
101-200 m (164)
0-200 m (207)
Target count
Hour (relative to midnight)

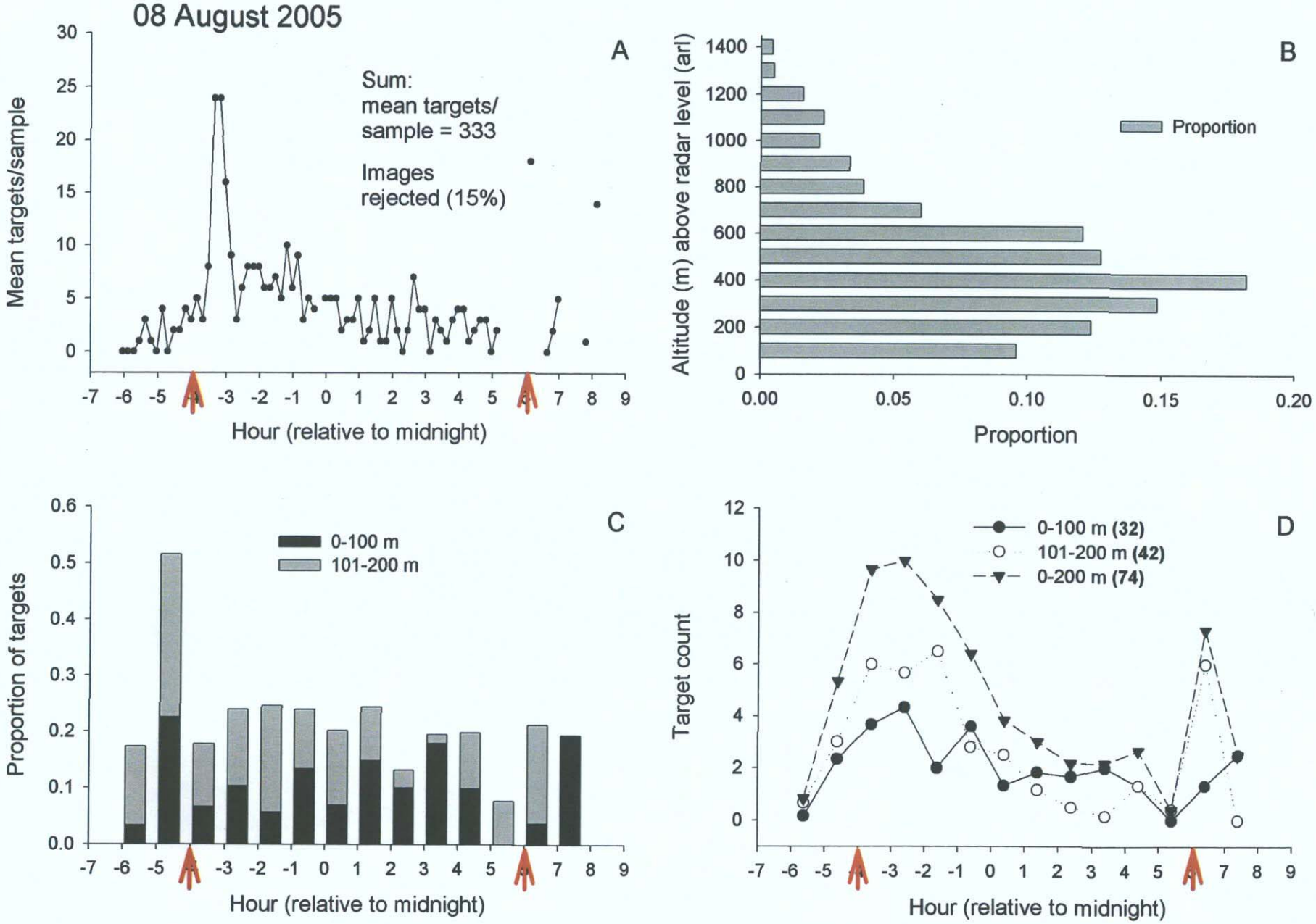

03 August 2005
A
Sum:
mean targets/
sample = 989
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (38)
101-200 m (103)
0-200 m (141)
Target count
Hour (relative to midnight)

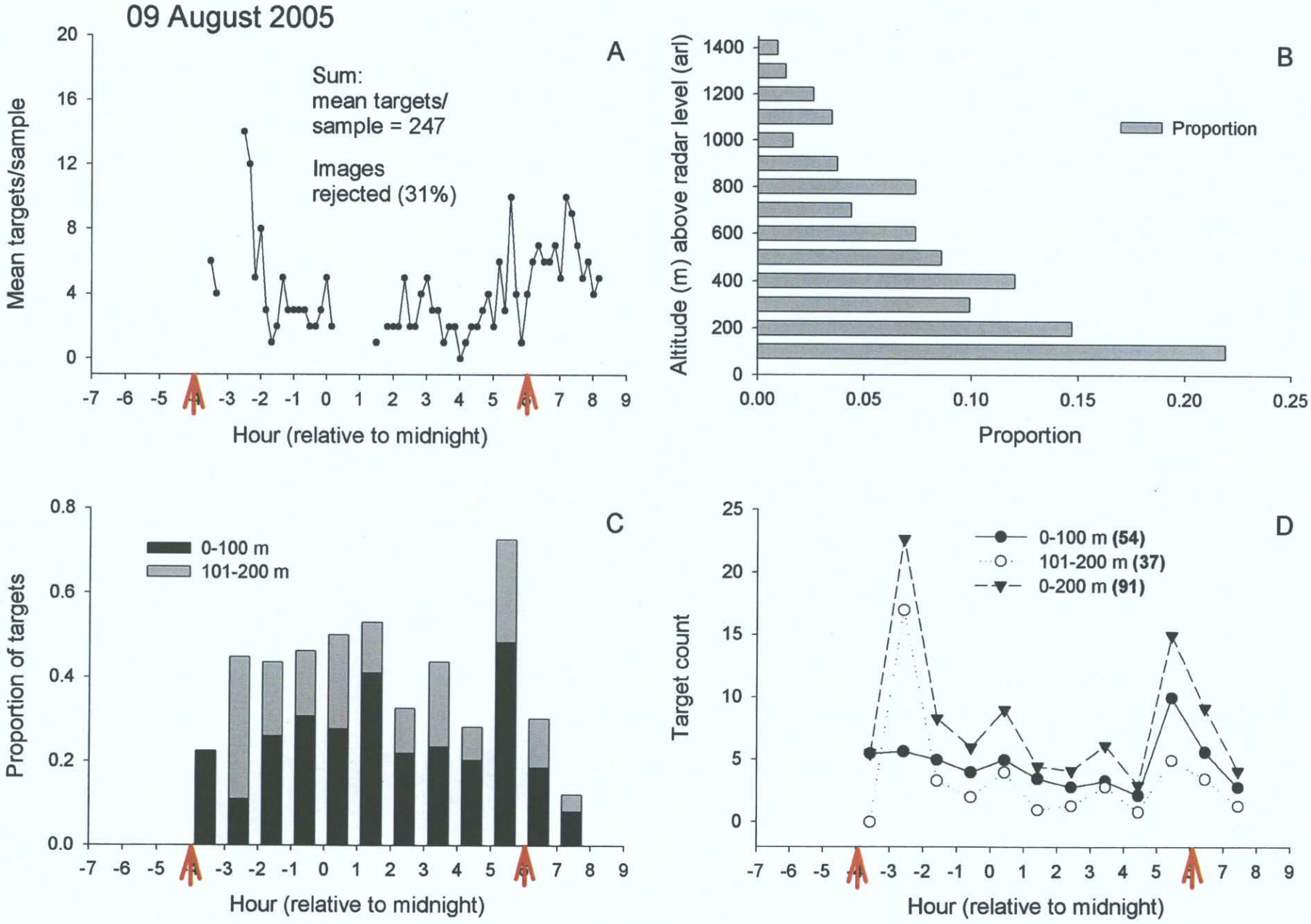

04 August 2005
A
Sum:
mean targets/
sample = 513
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (27)
101-200 m (41)
0-200 m (68)
Target count
Hour (relative to midnight)

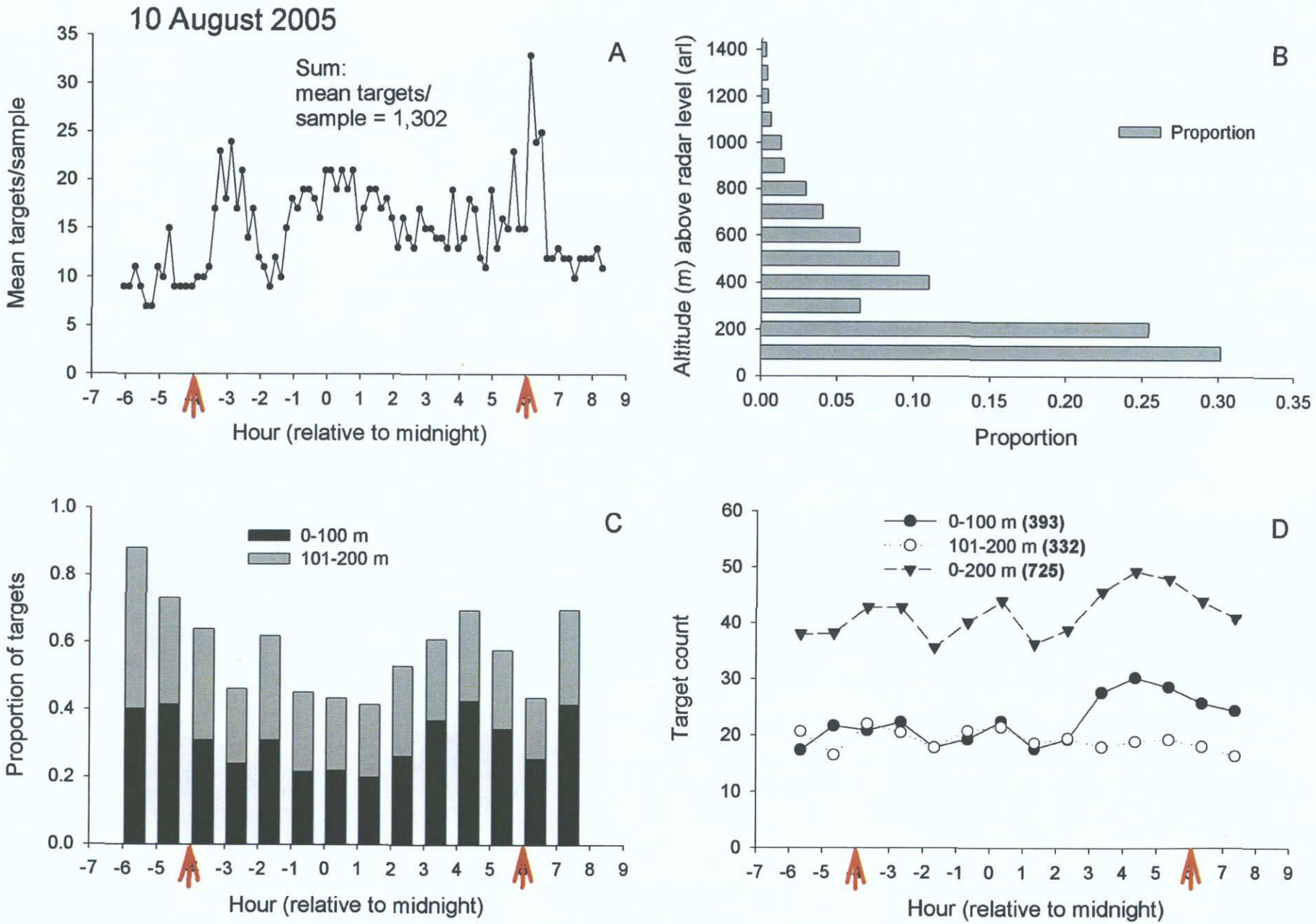

05 August 2005
A
Sum:
mean targets/
sample = 467
Images
rejected (14%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (29)
101-200 m (59)
0-200 m (88)
Target count
Hour (relative to midnight)

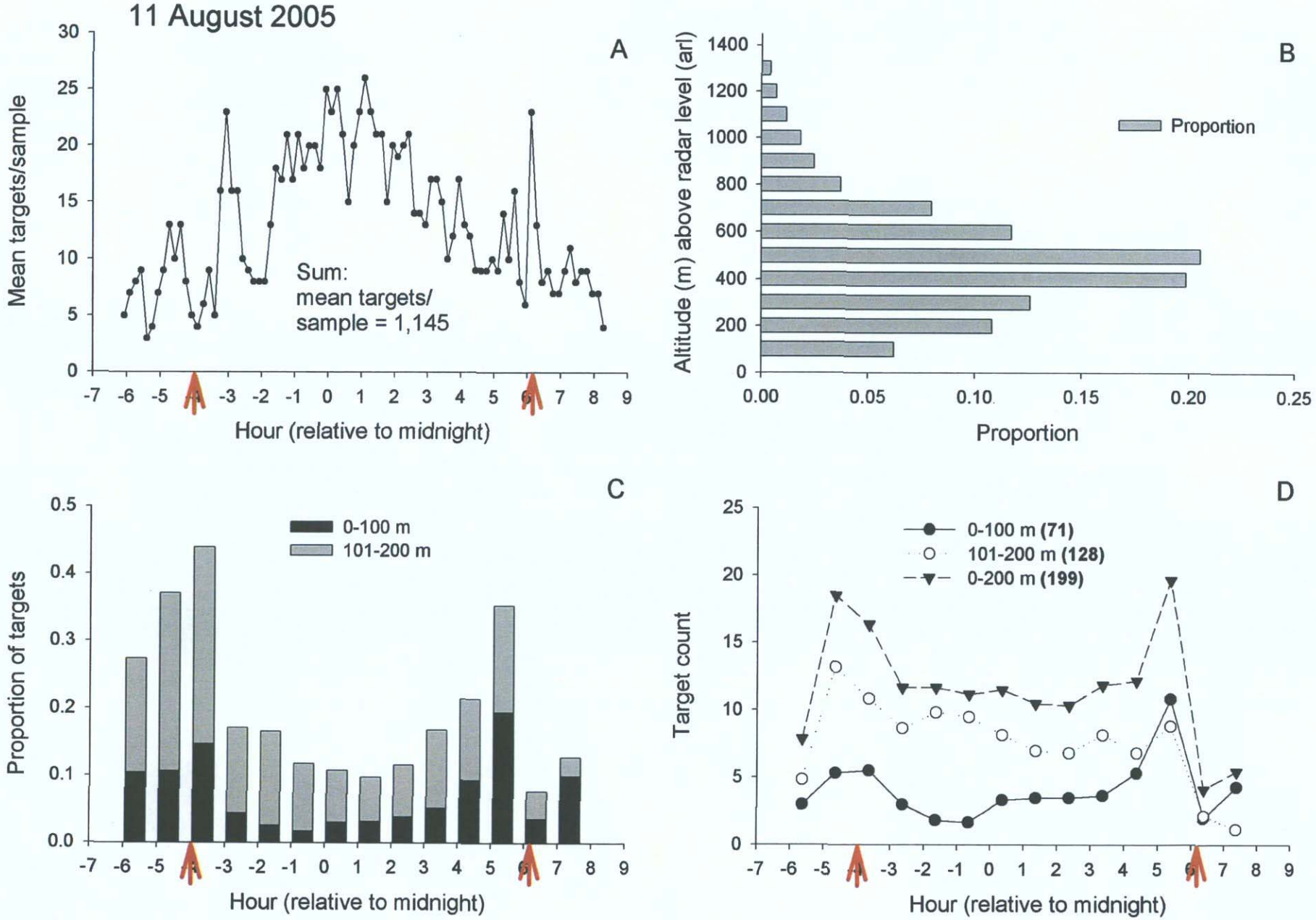

06 August 2005
A
Sum:
mean targets/
sample = 935
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (53)
101-200 m (90)
0-200 m (143)
Target count
Hour (relative to midnight)

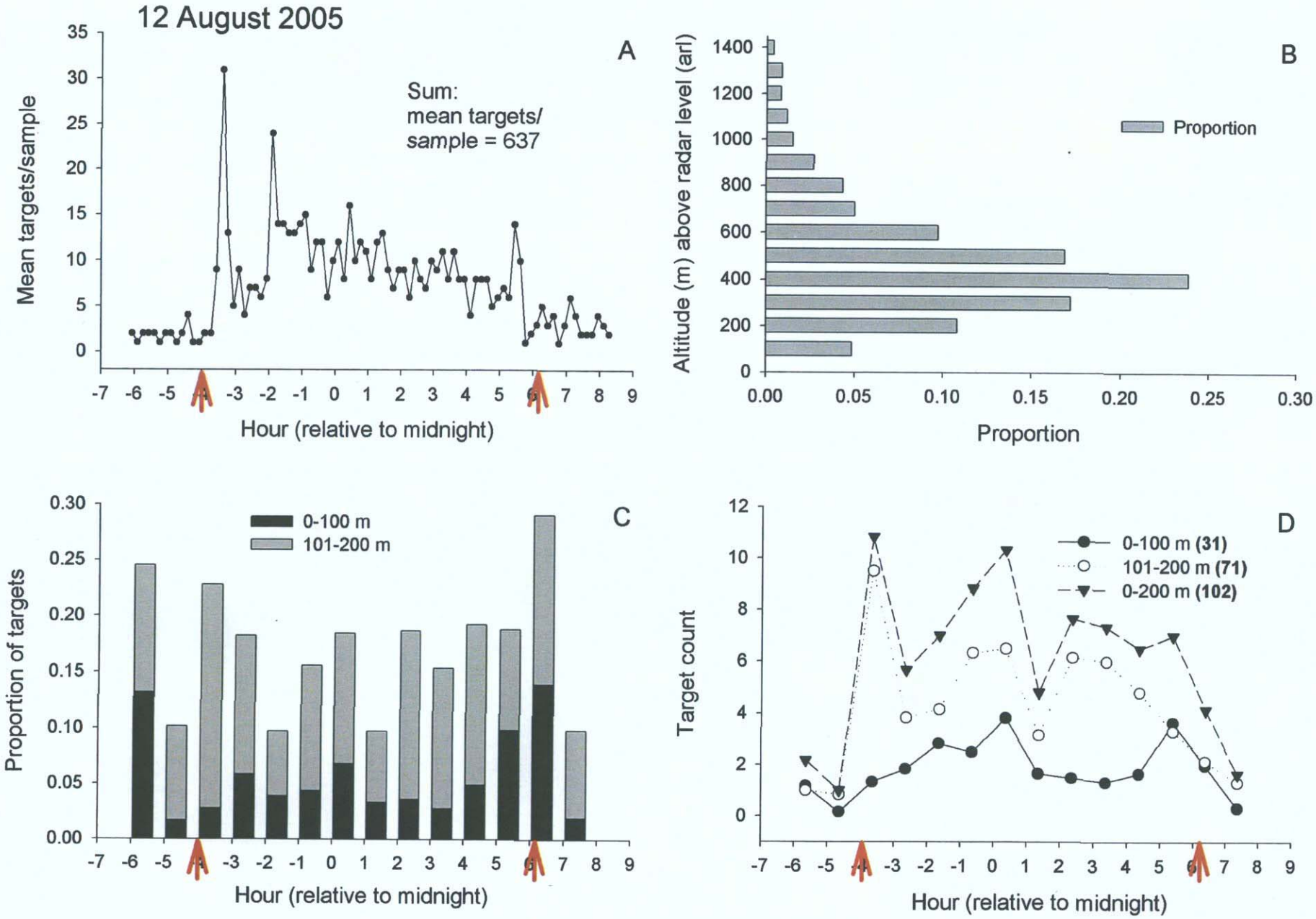

07 August 2005
A
Sum:
mean targets/
sample = 599
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (25)
101-200 m (53)
0-200 m (78)
Target count
Hour (relative to midnight)

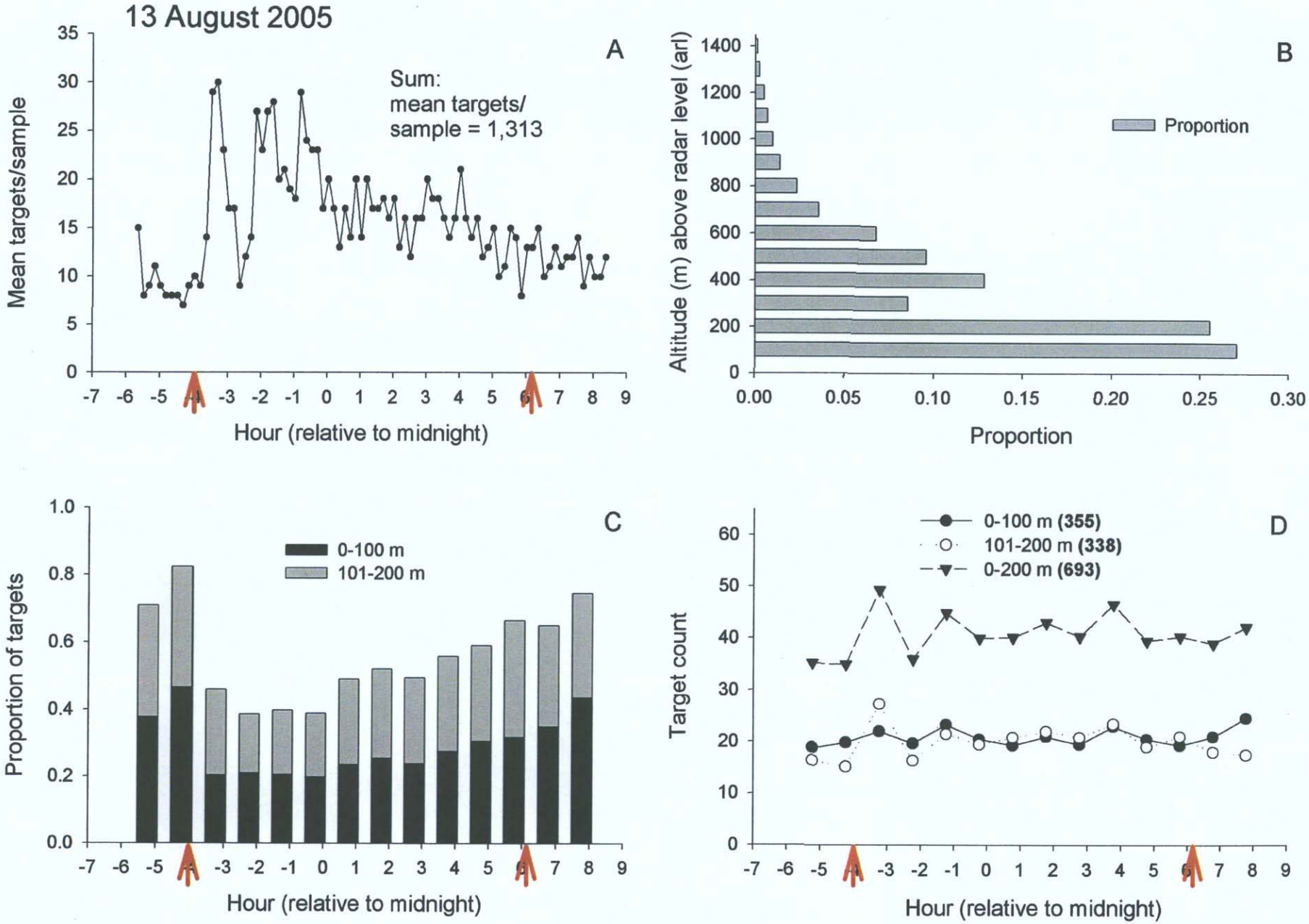

08 August 2005
A
Sum:
mean targets/
sample = 333
Images
rejected (15%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (32)
101-200 m (42)
0-200 m (74)
Target count
Hour (relative to midnight)

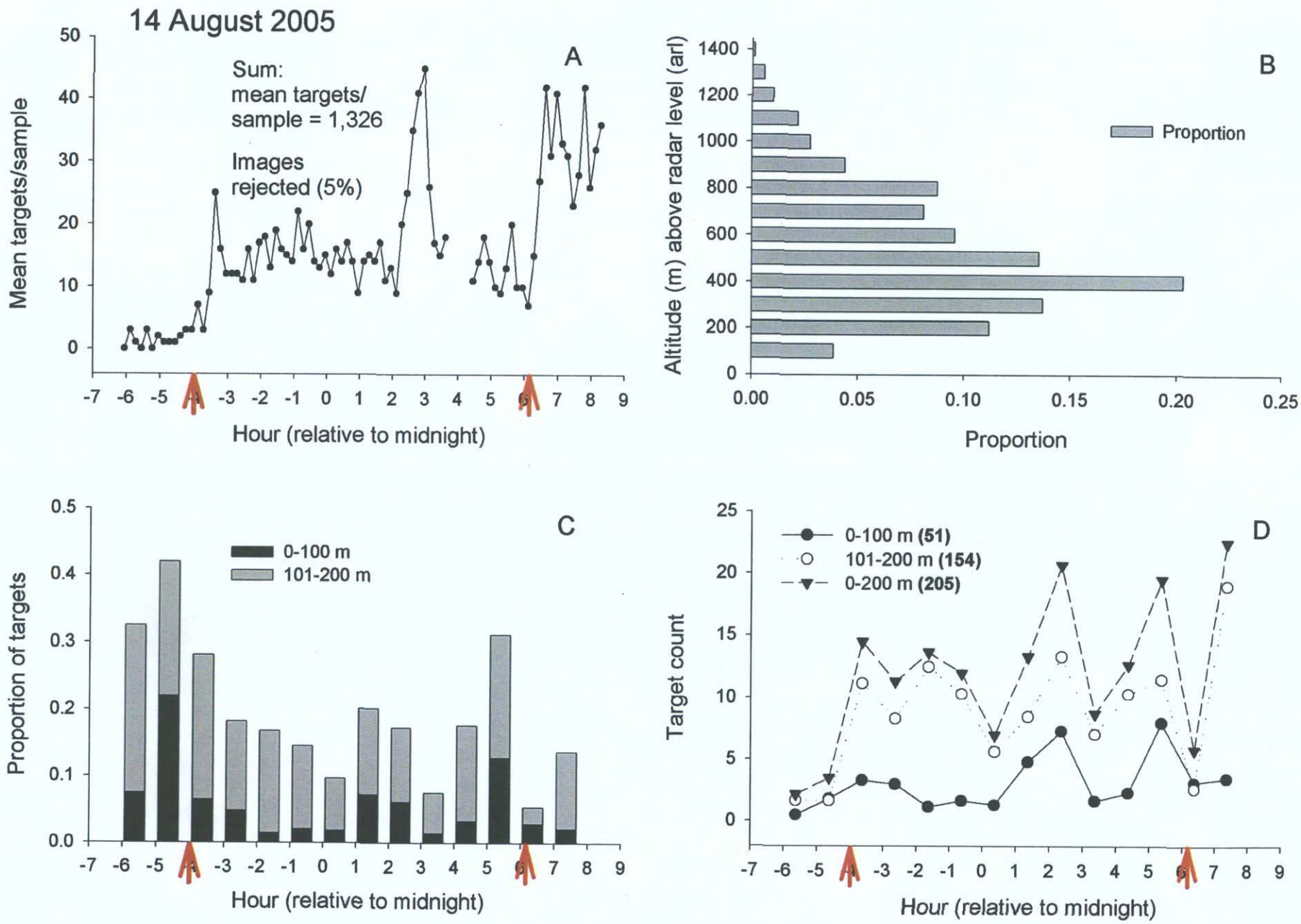

09 August 2005
A
Sum:
mean targets/
sample = 247
Images
rejected (31%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (54)
101-200 m (37)
0-200 m (91)
Target count
Hour (relative to midnight)

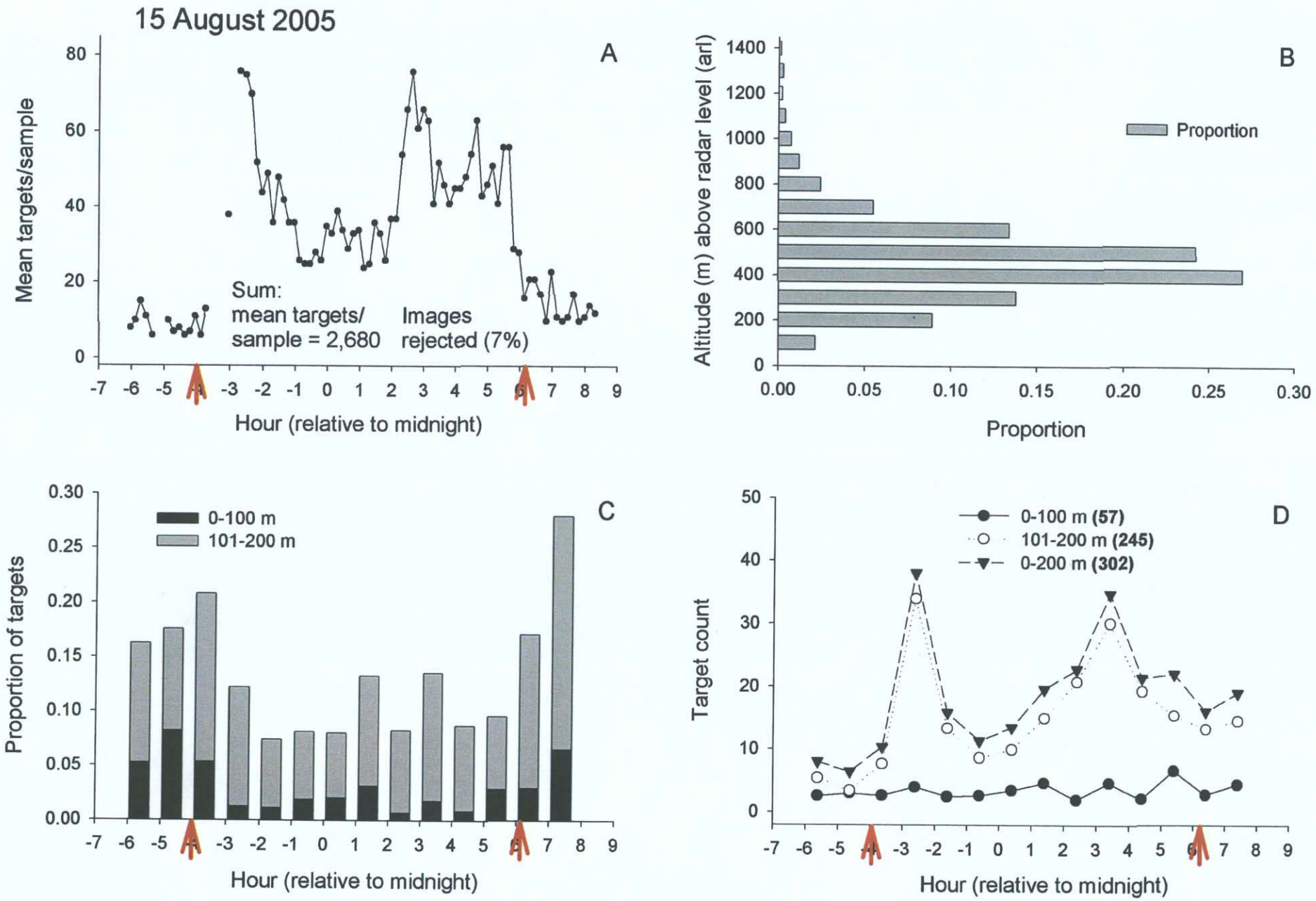

10 August 2005
A
Sum:
mean targets/
sample = 1,302
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (393)
101-200 m (332)
0-200 m (725)
Target count
Hour (relative to midnight)

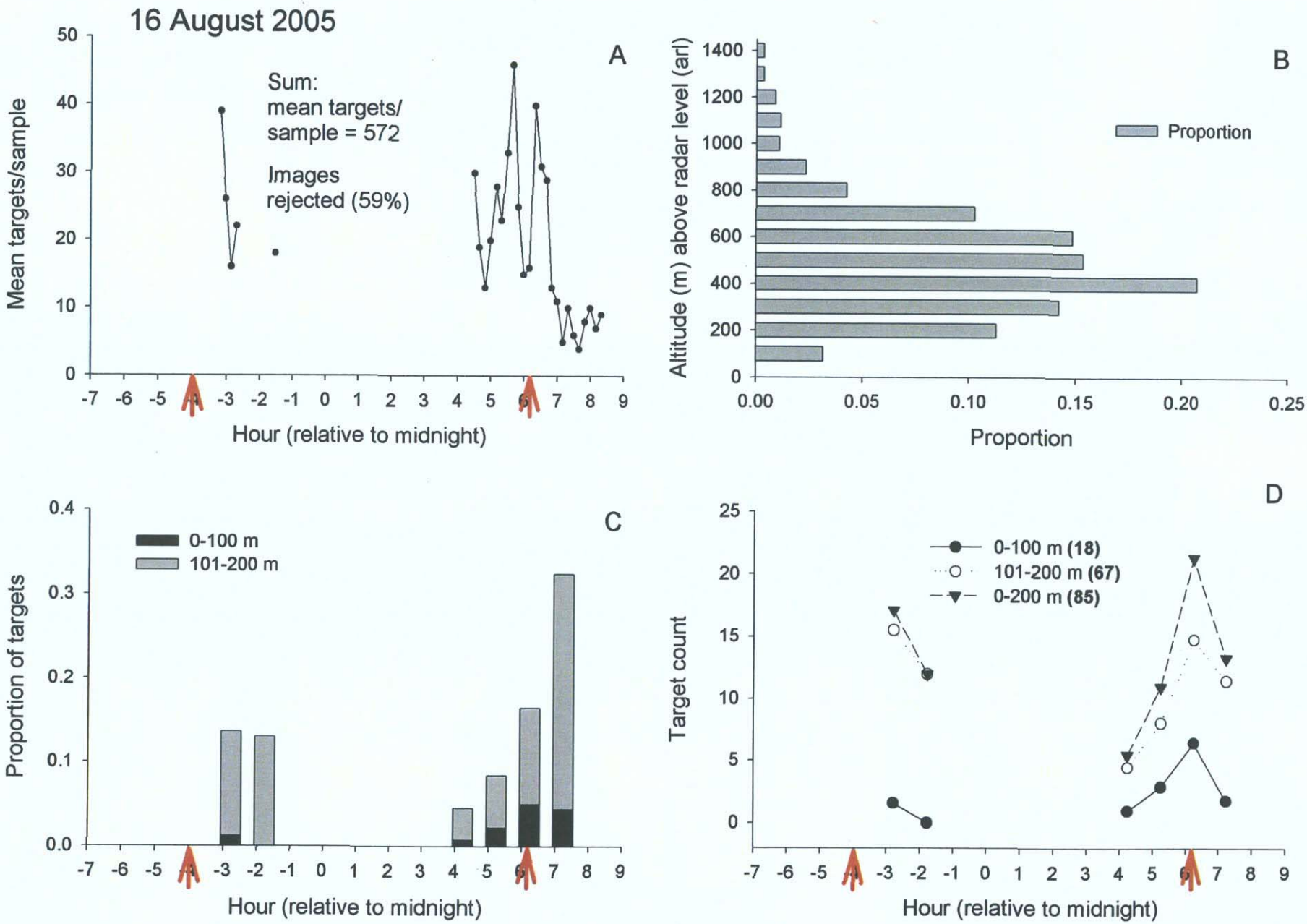

11 August 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 1,145
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (71)
101-200 m (128)
0-200 m (199)
Hour (relative to midnight)

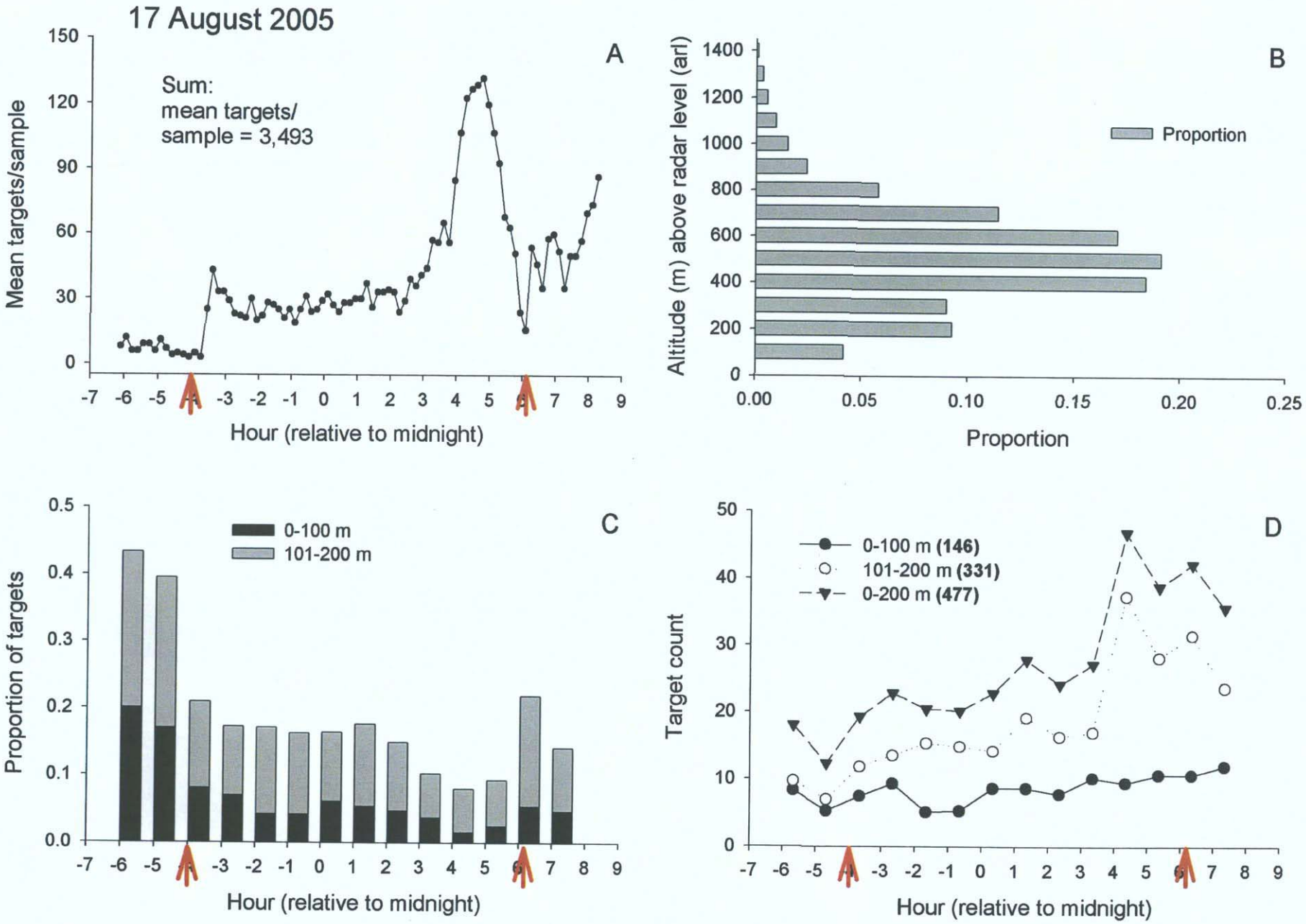

12 August 2005
A
Sum:
mean targets/
sample = 637
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (31)
101-200 m (71)
0-200 m (102)
Target count
Hour (relative to midnight)

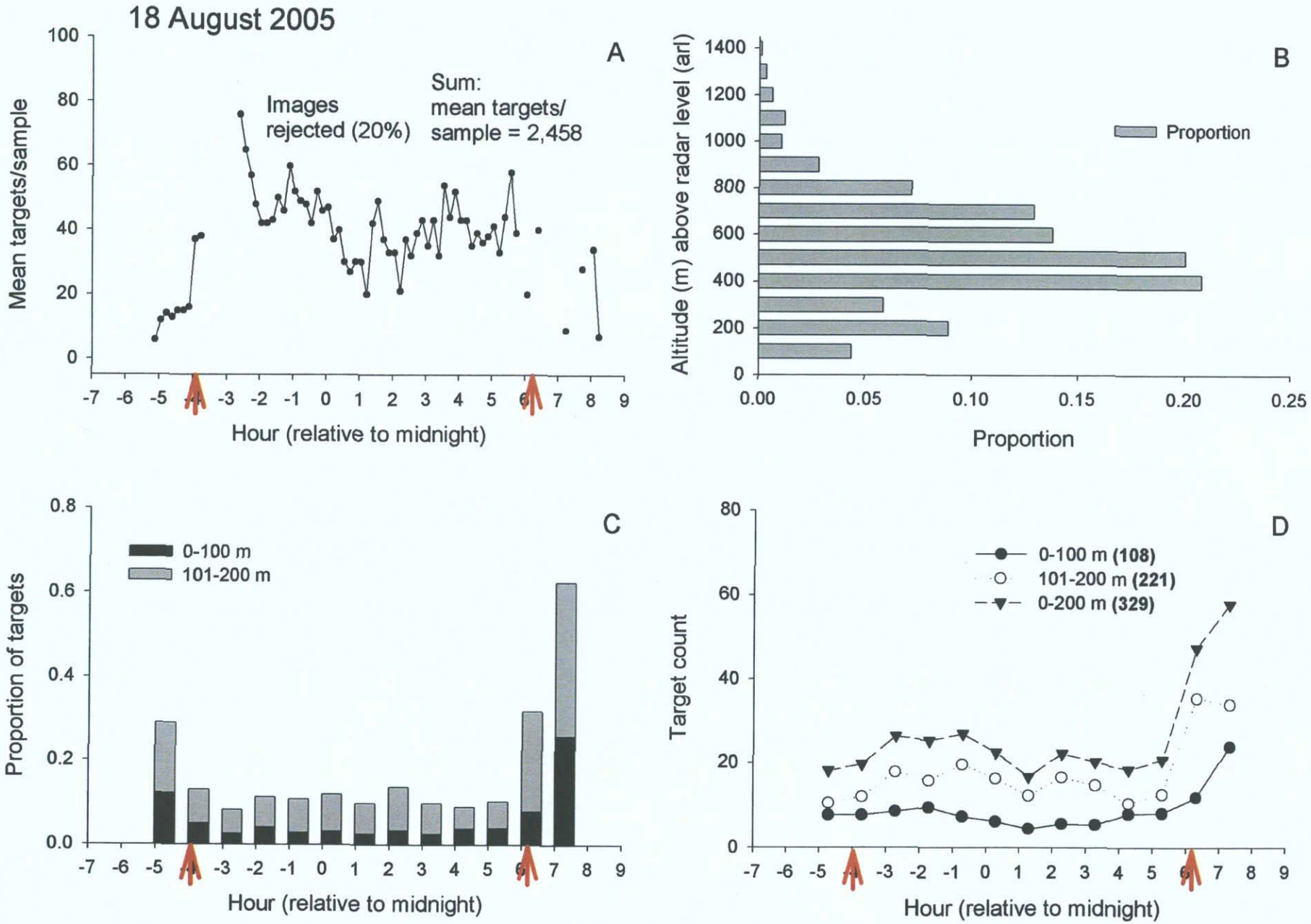

13 August 2005
A
Sum:
mean targets/
sample = 1,313
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (355)
101-200 m (338)
0-200 m (693)
Target count
Hour (relative to midnight)

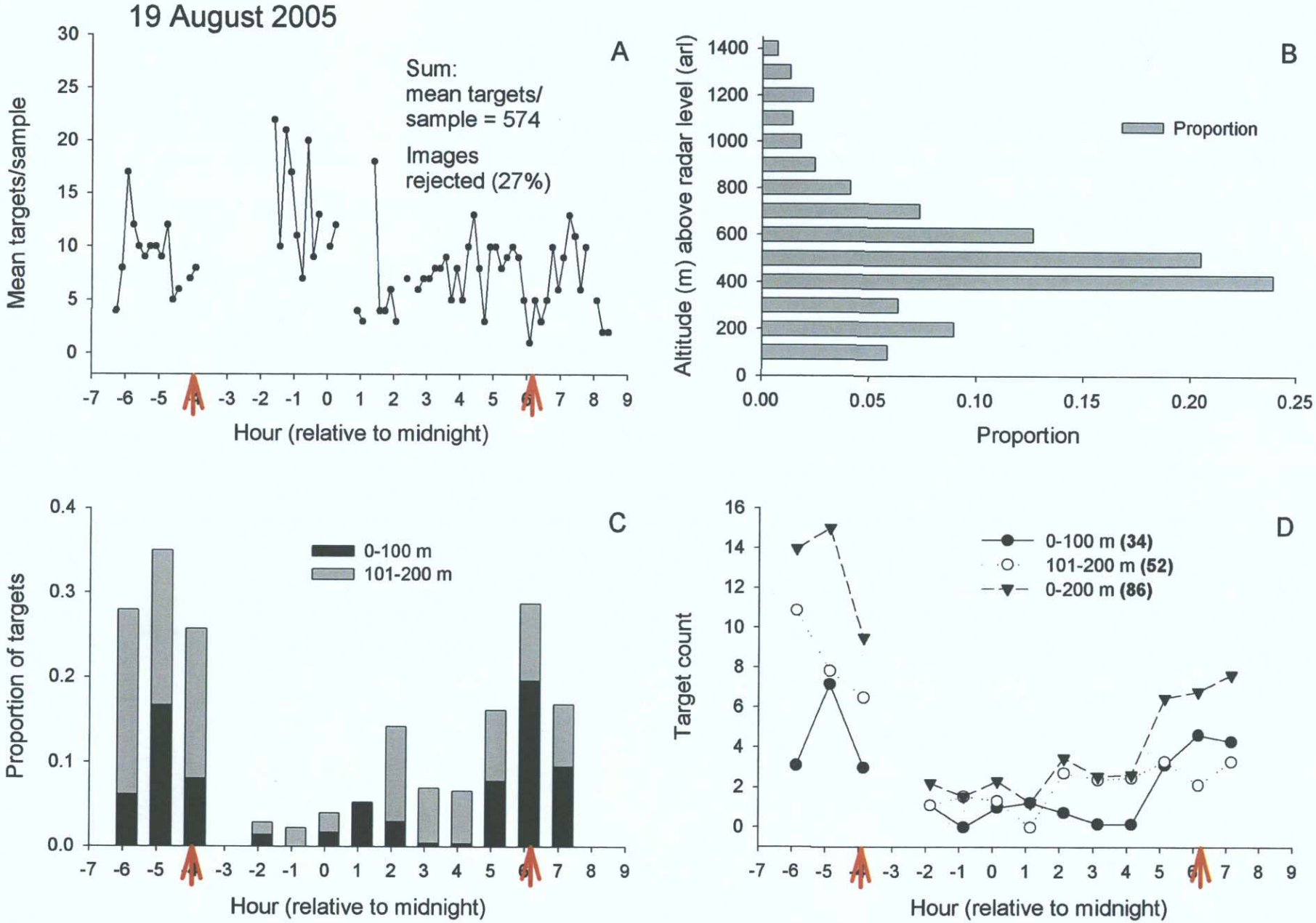

14 August 2005
A
Sum:
mean targets/
sample = 1,326
Images
rejected (5%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (51)
101-200 m (154)
0-200 m (205)
Target count
Hour (relative to midnight)

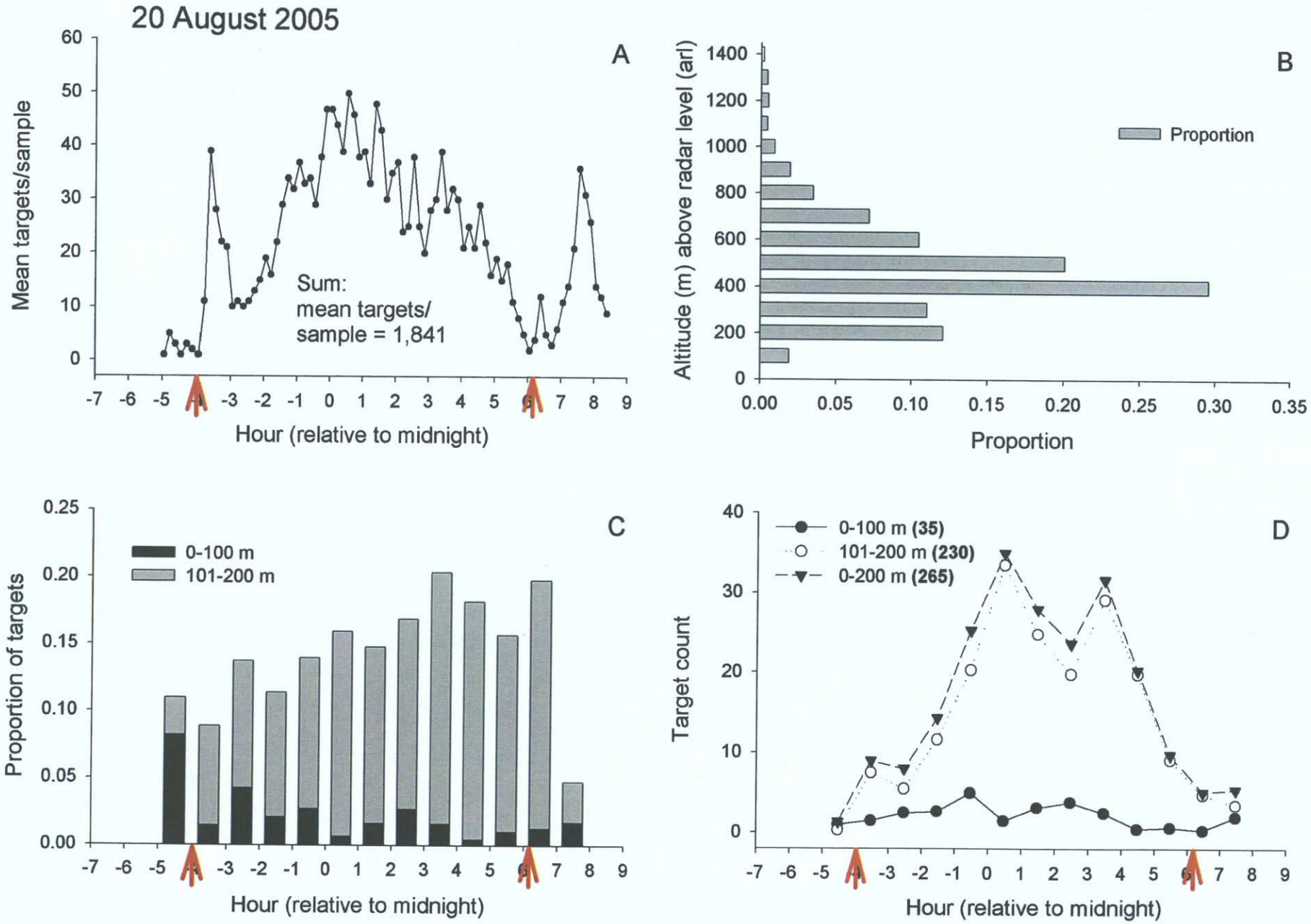

15 August 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 2,680
Images
rejected (7%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (57)
101-200 m (245)
0-200 m (302)
Target count
Hour (relative to midnight)

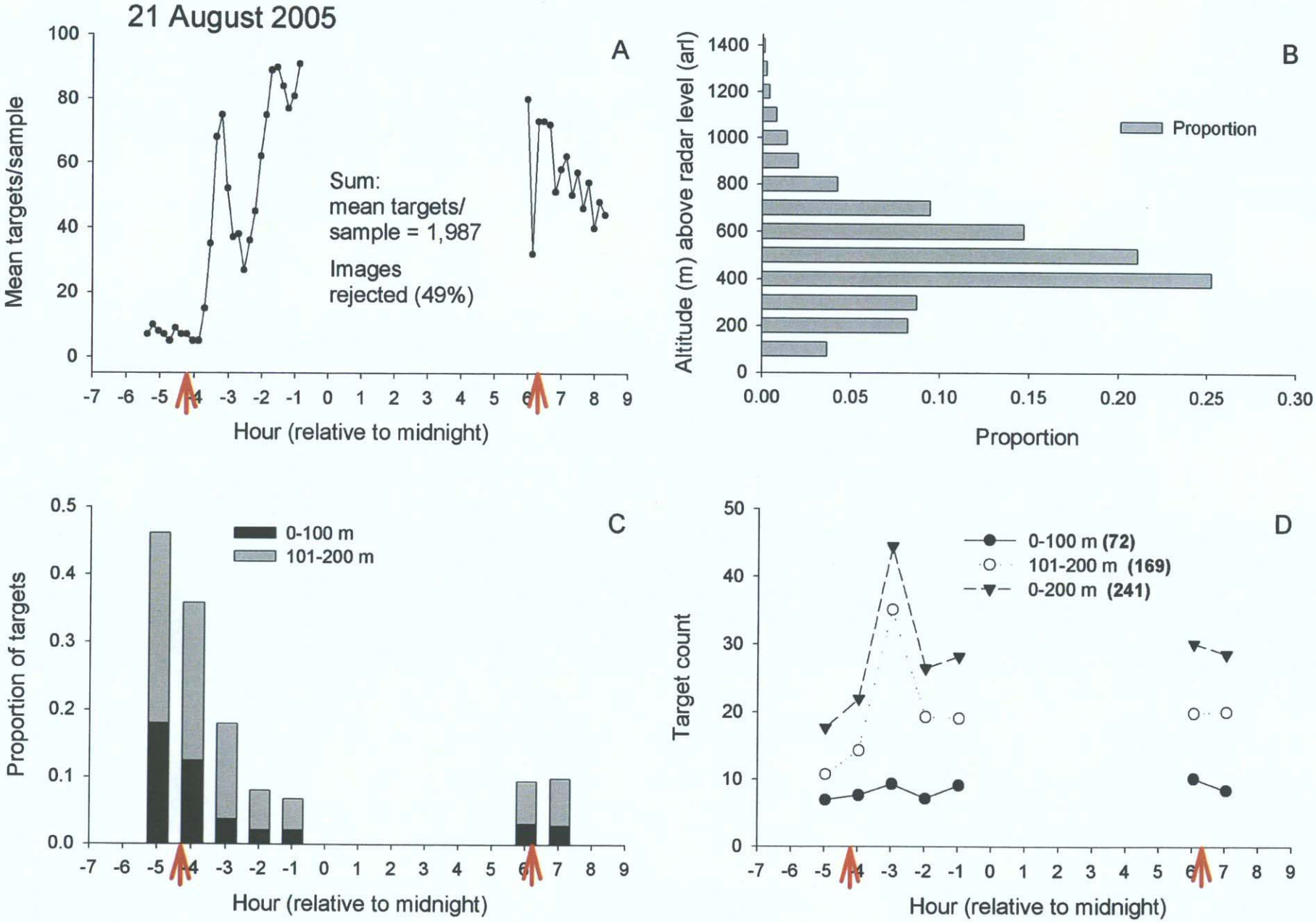

16 August 2005
A
Sum:
mean targets/
sample = 572
Images
rejected (59%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (18)
101-200 m (67)
0-200 m (85)
Target count
Hour (relative to midnight)

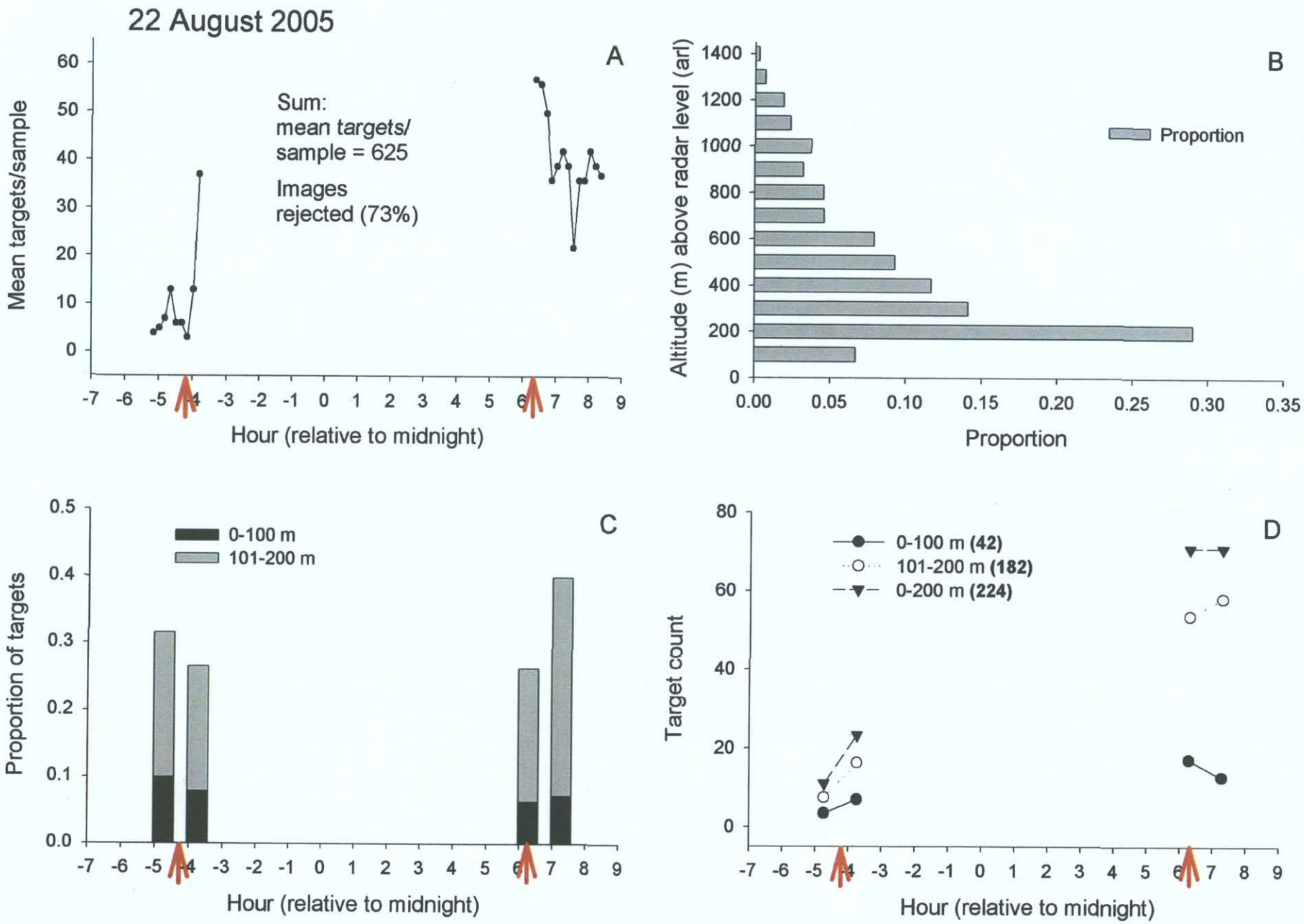

17 August 2005
A
Sum:
mean targets/
sample = 3,493
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (146)
101-200 m (331)
0-200 m (477)
Target count
Hour (relative to midnight)

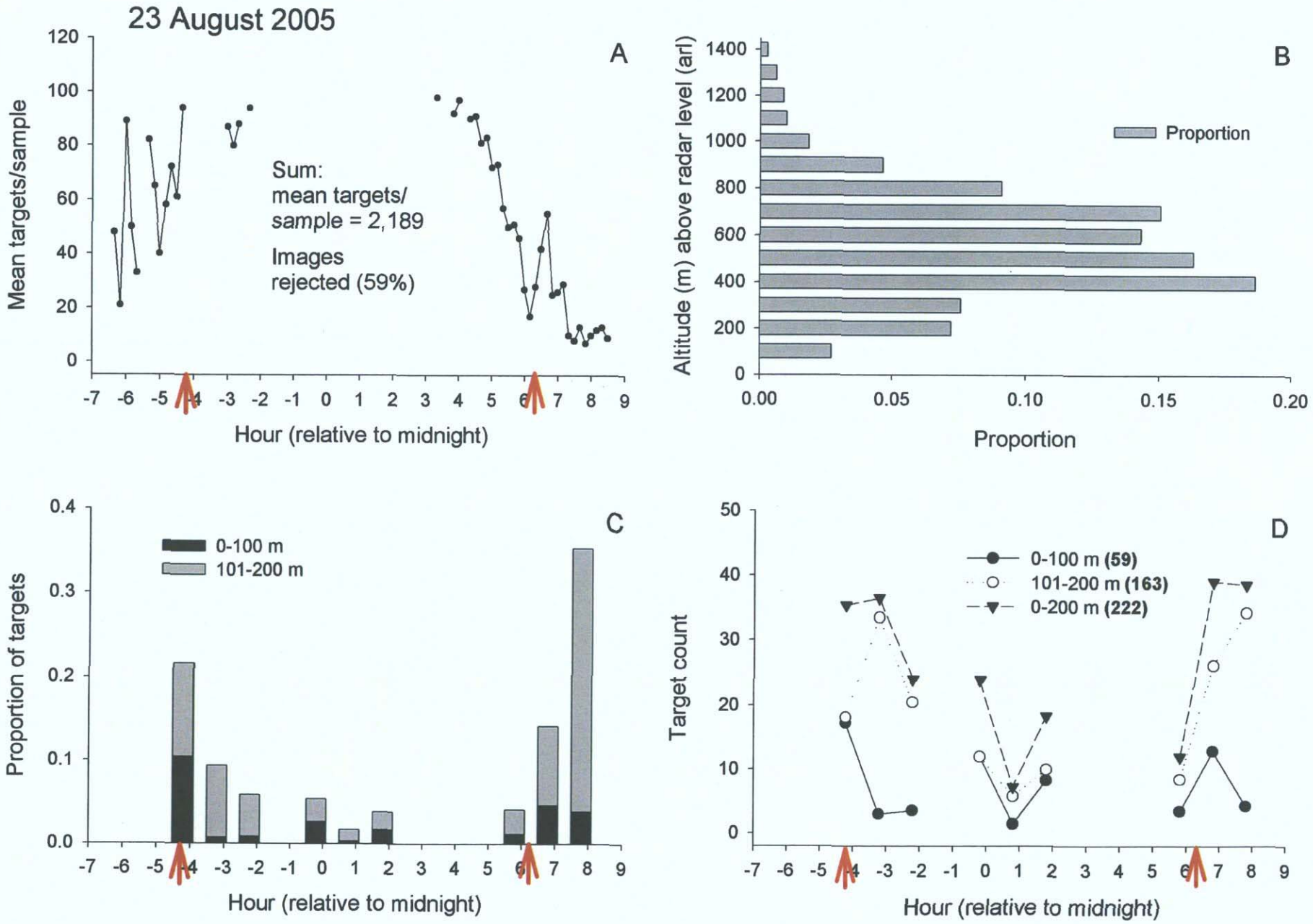

18 August 2005
A
Mean targets/sample
Images rejected (20%)
Sum: mean targets/ sample = 2,458
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (108)
101-200 m (221)
0-200 m (329)
Hour (relative to midnight)

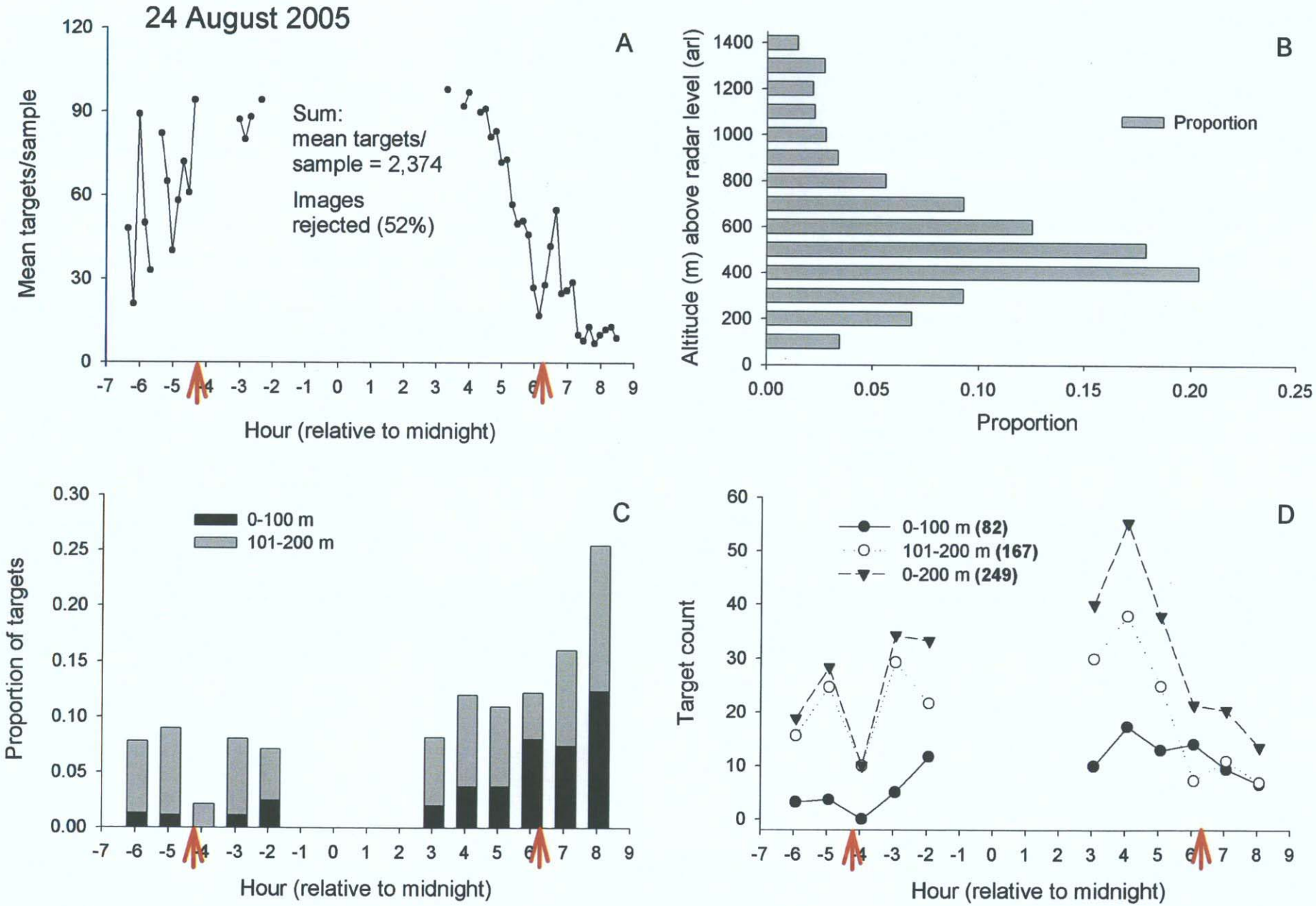

19 August 2005
A
Sum:
mean targets/
sample = 574
Images
rejected (27%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (34)
101-200 m (52)
0-200 m (86)
Target count
Hour (relative to midnight)

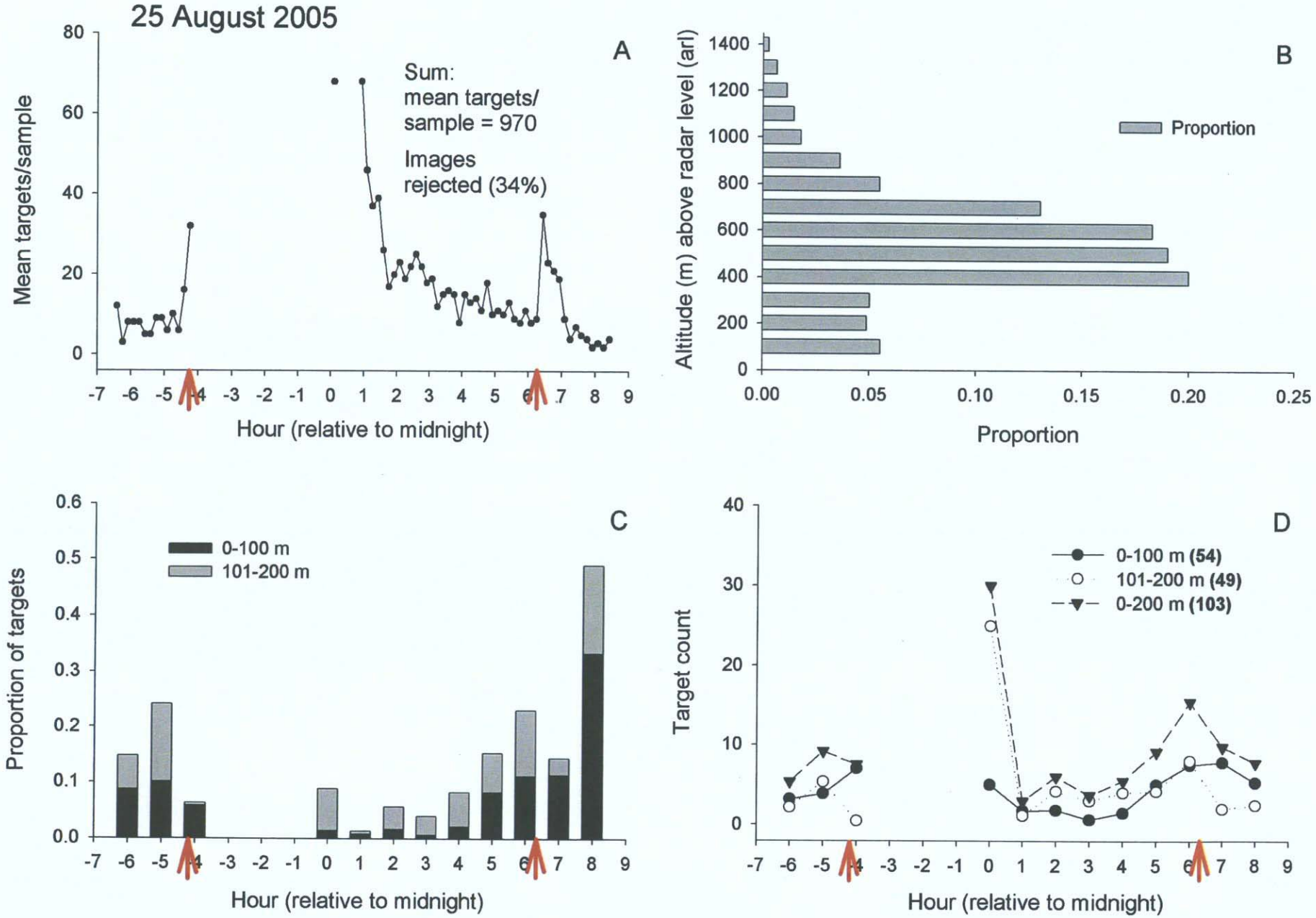

20 August 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 1,841
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (35)
101-200 m (230)
0-200 m (265)
Hour (relative to midnight)

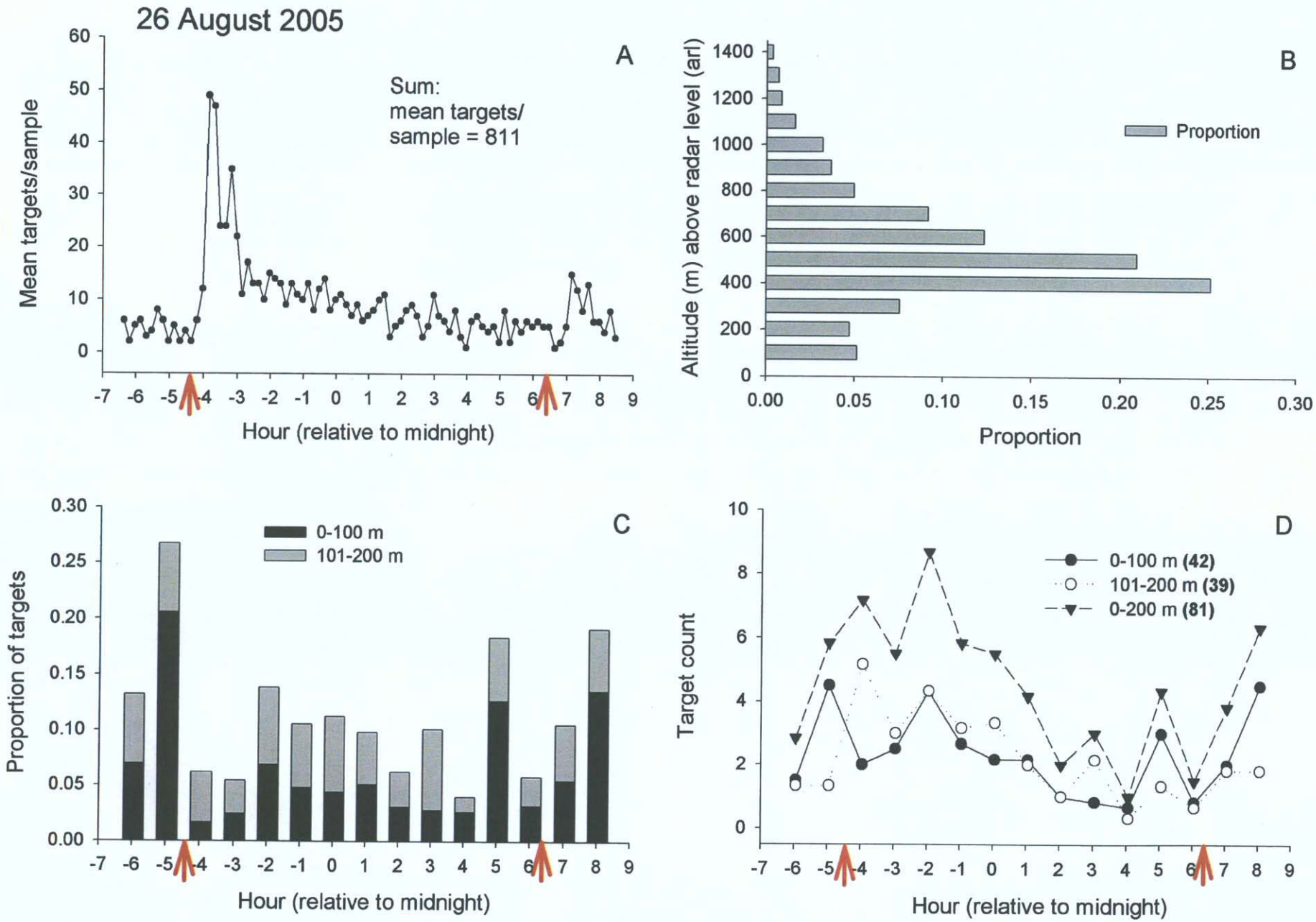

21 August 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 1,987
Images
rejected (49%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (72)
101-200 m (169)
0-200 m (241)
Hour (relative to midnight)

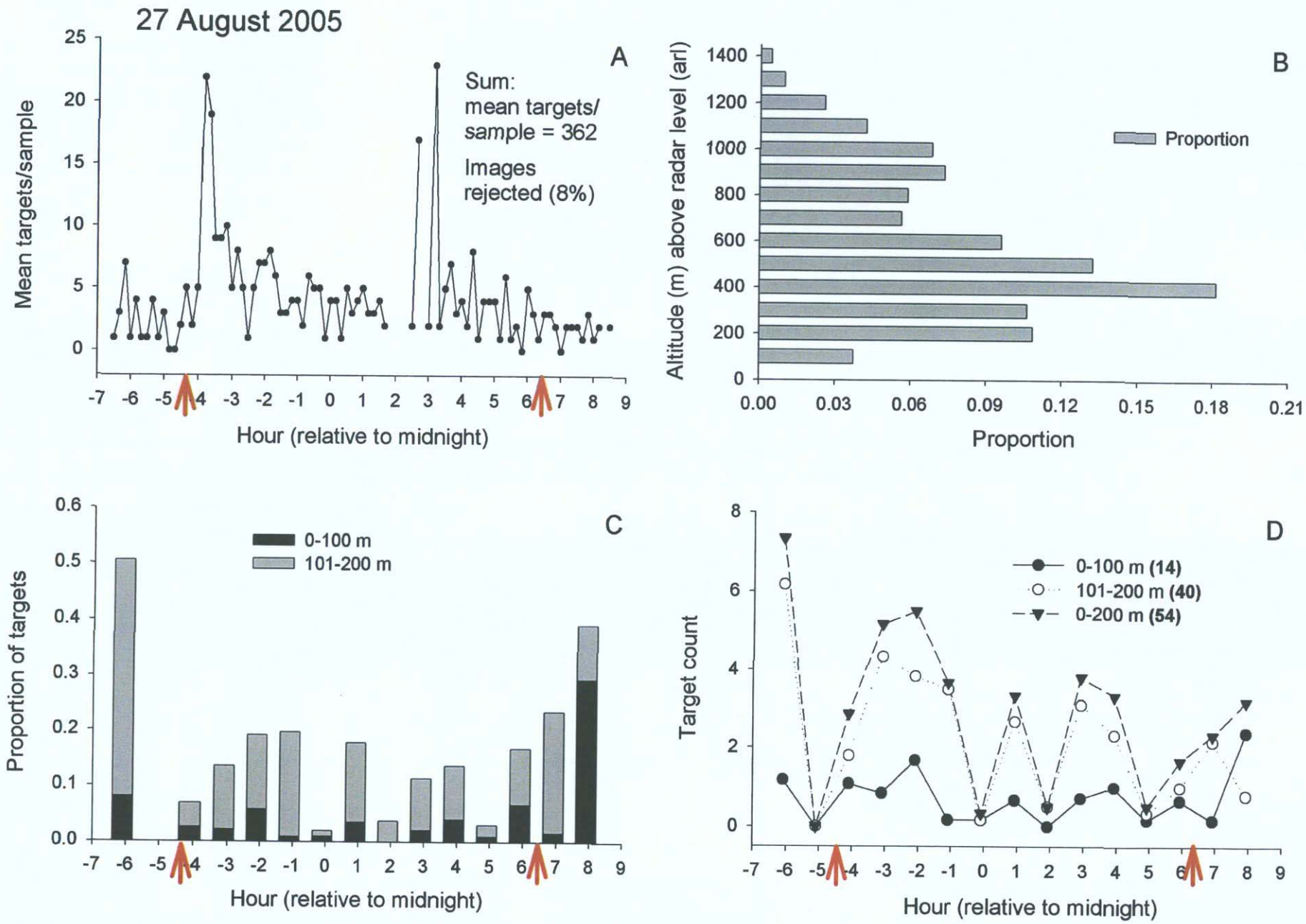

22 August 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 625
Images
rejected (73%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (42)
101-200 m (182)
0-200 m (224)
Hour (relative to midnight)

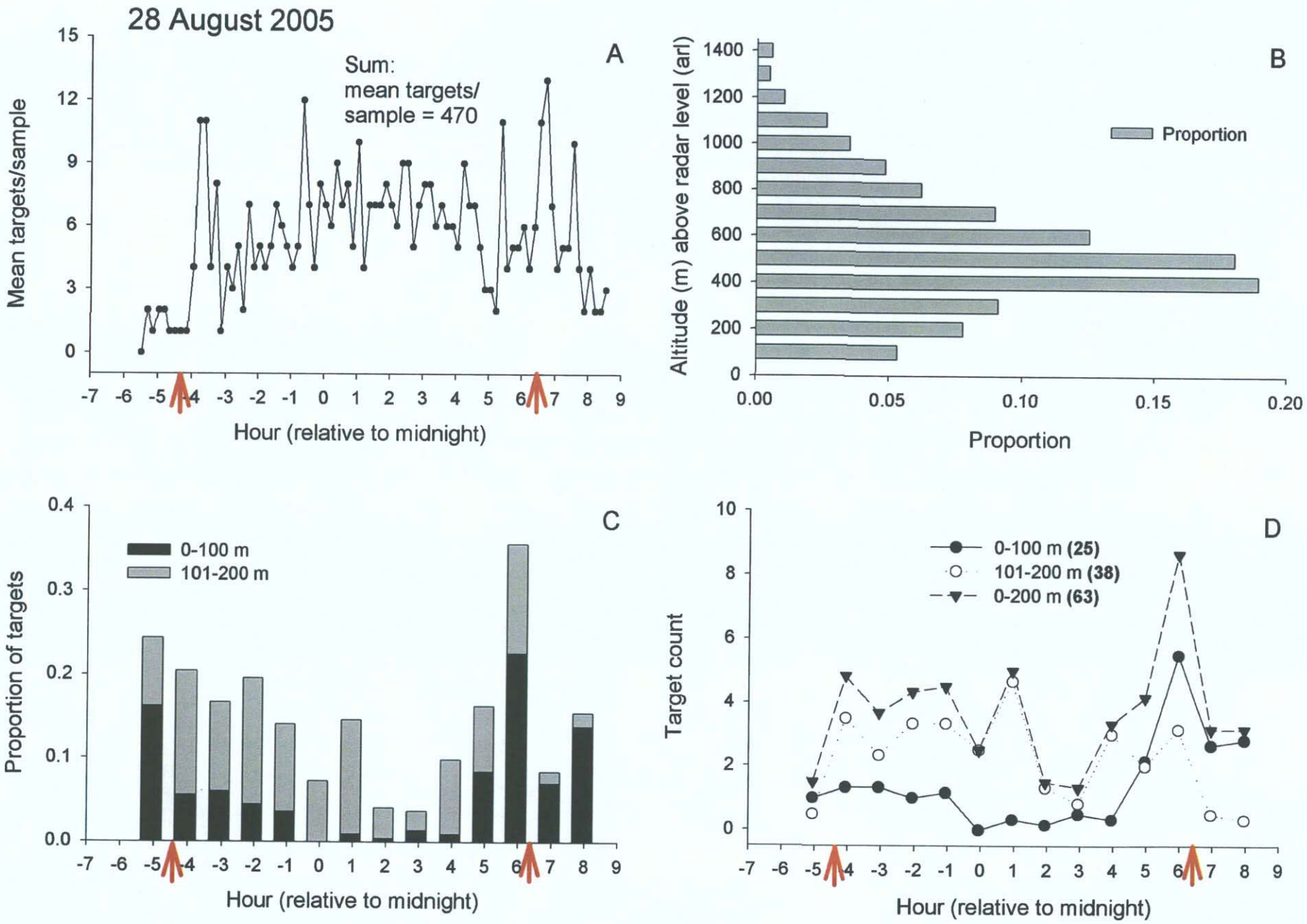

23 August 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 2,189
Images
rejected (59%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (59)
101-200 m (163)
0-200 m (222)
Hour (relative to midnight)

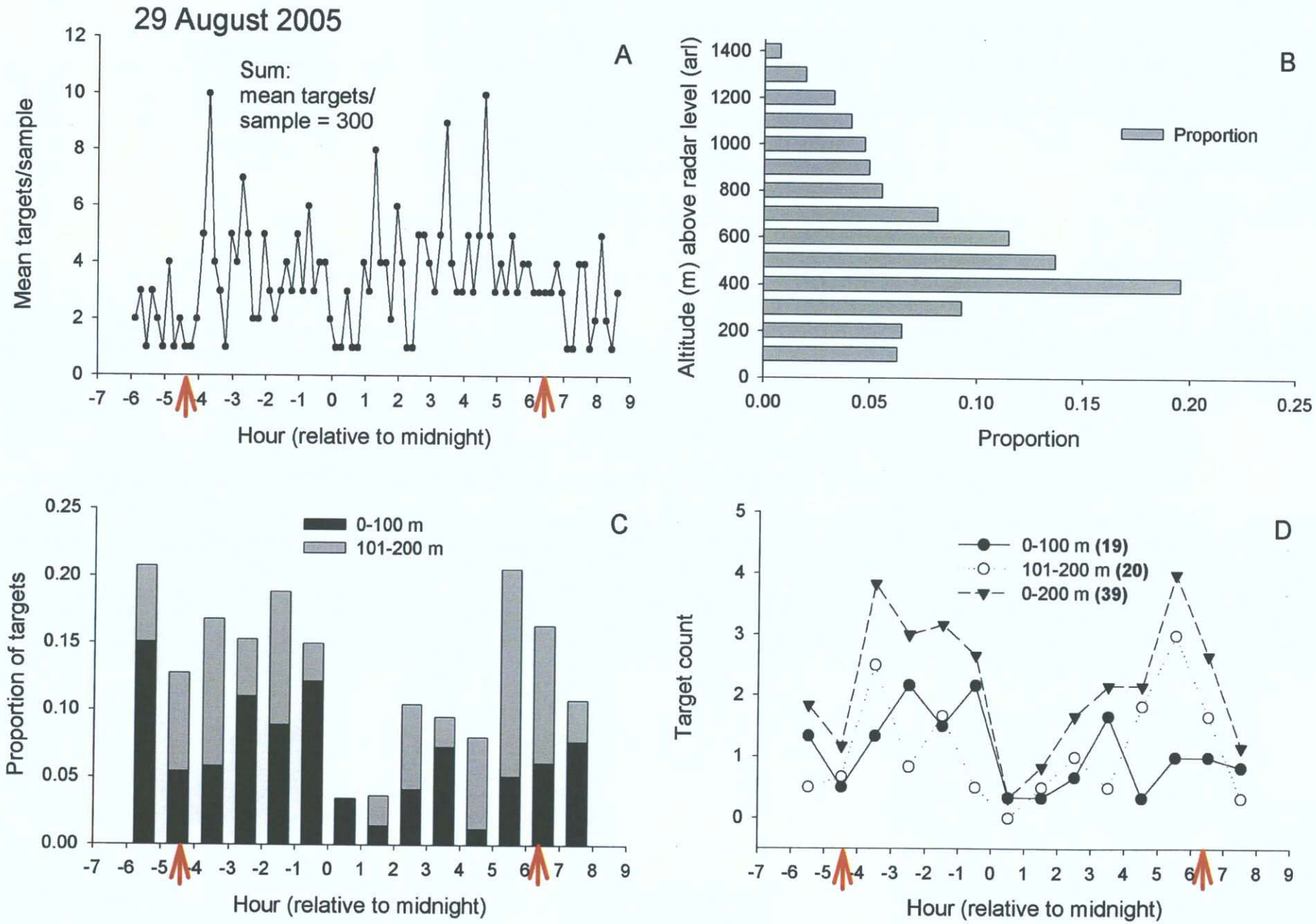

24 August 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 2,374
Images
rejected (52%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (82)
101-200 m (167)
0-200 m (249)
Hour (relative to midnight)

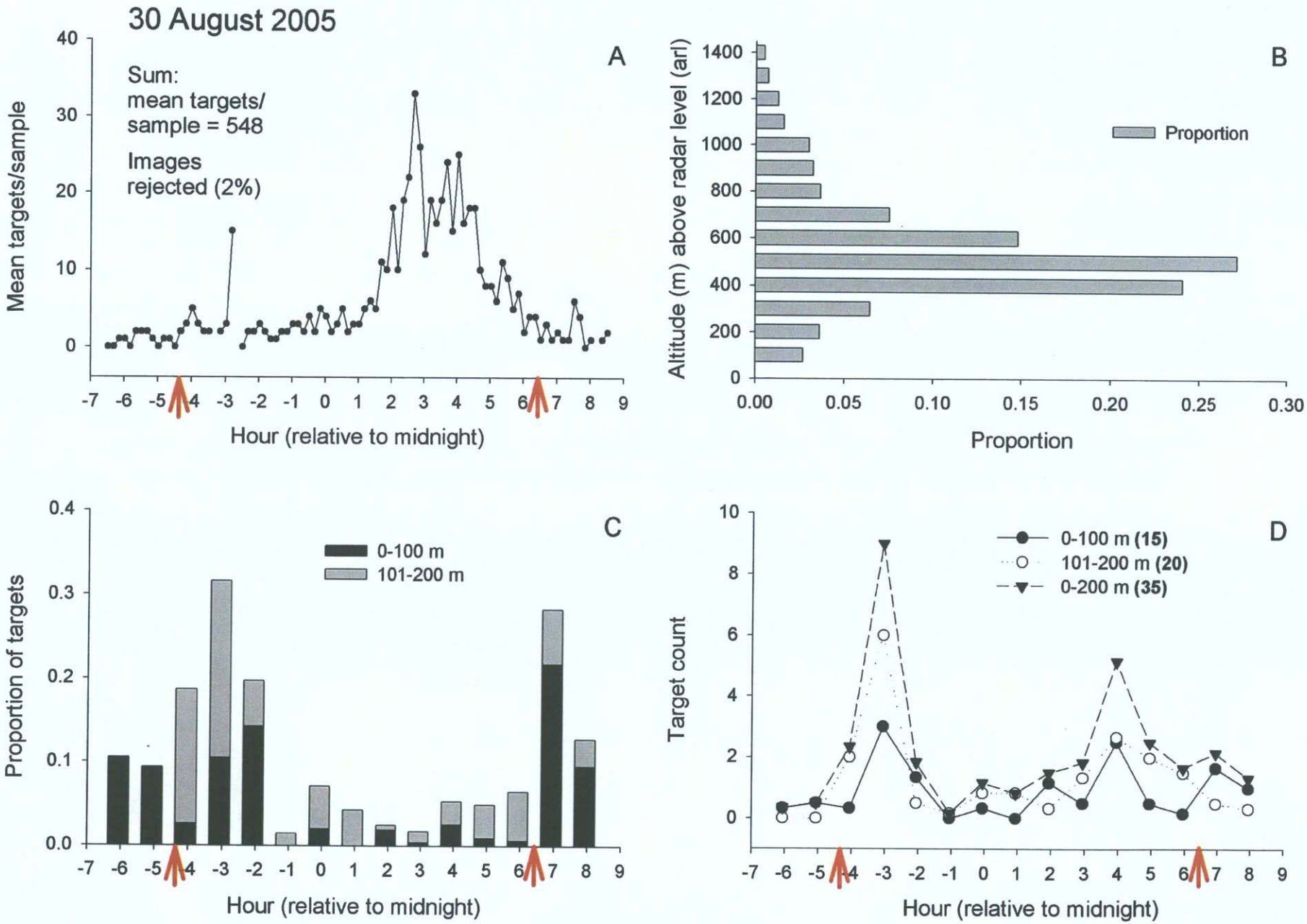

25 August 2005
A
Sum:
mean targets/
sample = 970
Images
rejected (34%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (54)
101-200 m (49)
0-200 m (103)
Target count
Hour (relative to midnight)

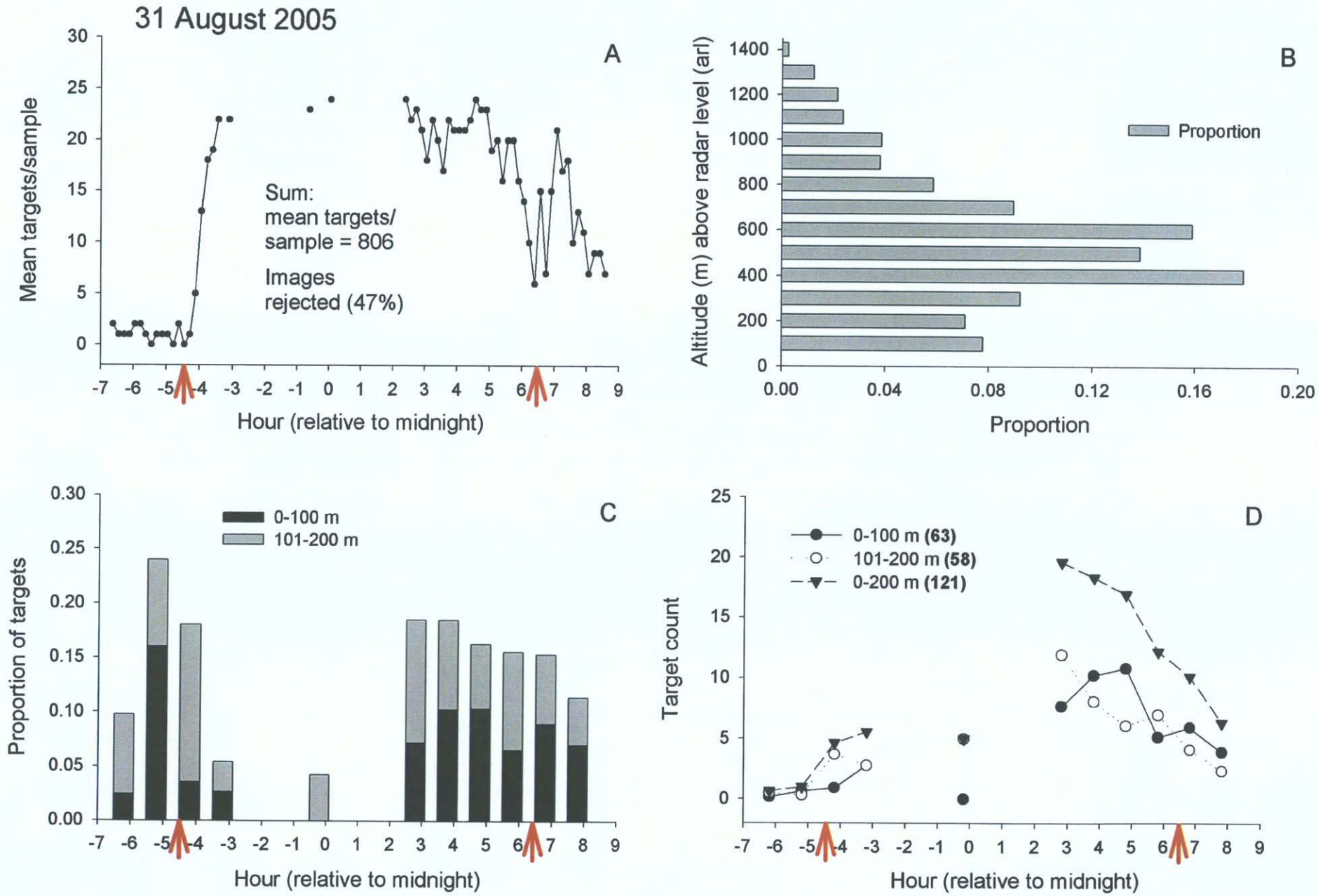

26 August 2005
A
Sum:
mean targets/
sample = 811
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (42)
101-200 m (39)
0-200 m (81)
Target count
Hour (relative to midnight)

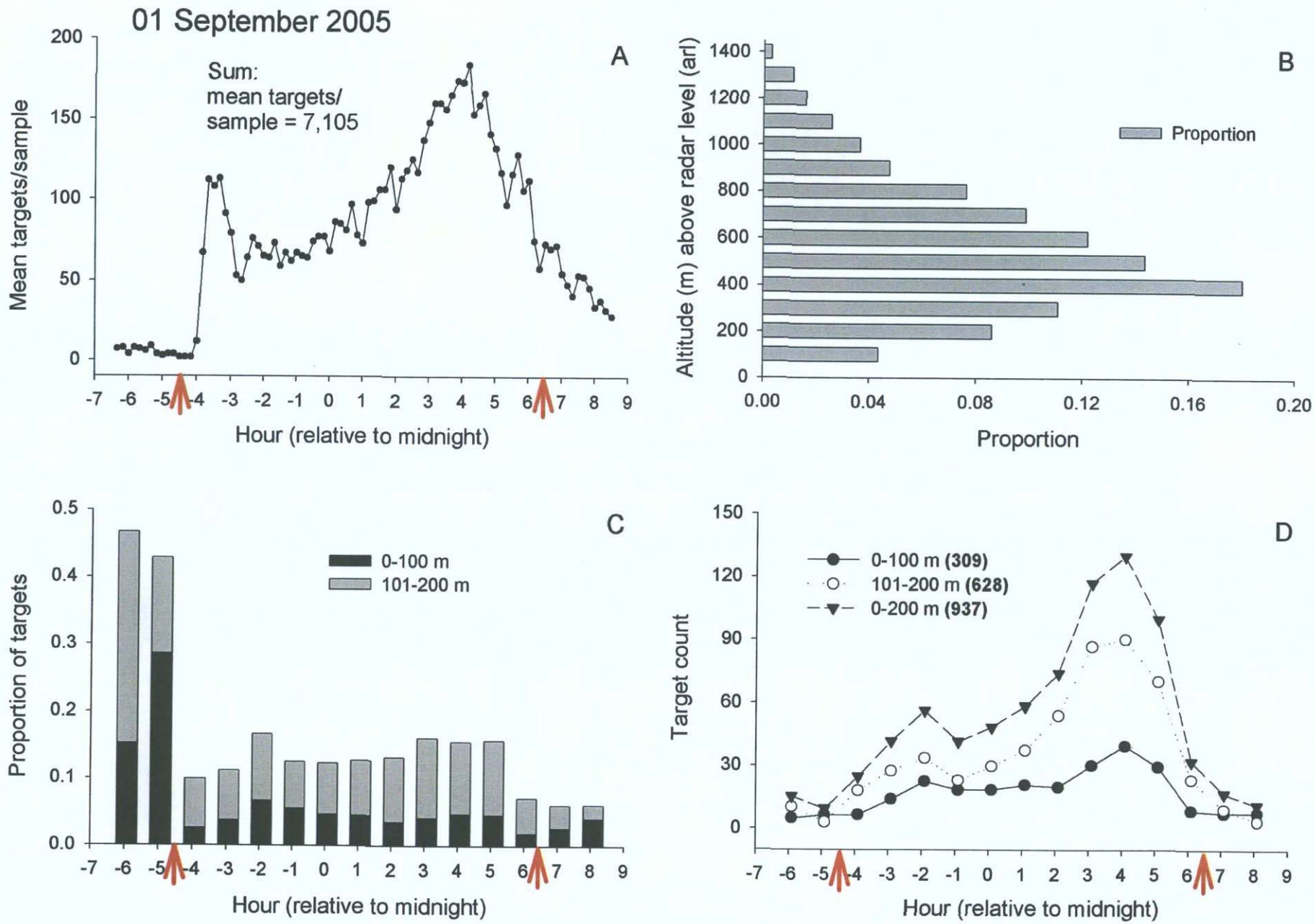

27 August 2005
A
Sum:
mean targets/
sample = 362
Images
rejected (8%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (14)
101-200 m (40)
0-200 m (54)
Target count
Hour (relative to midnight)

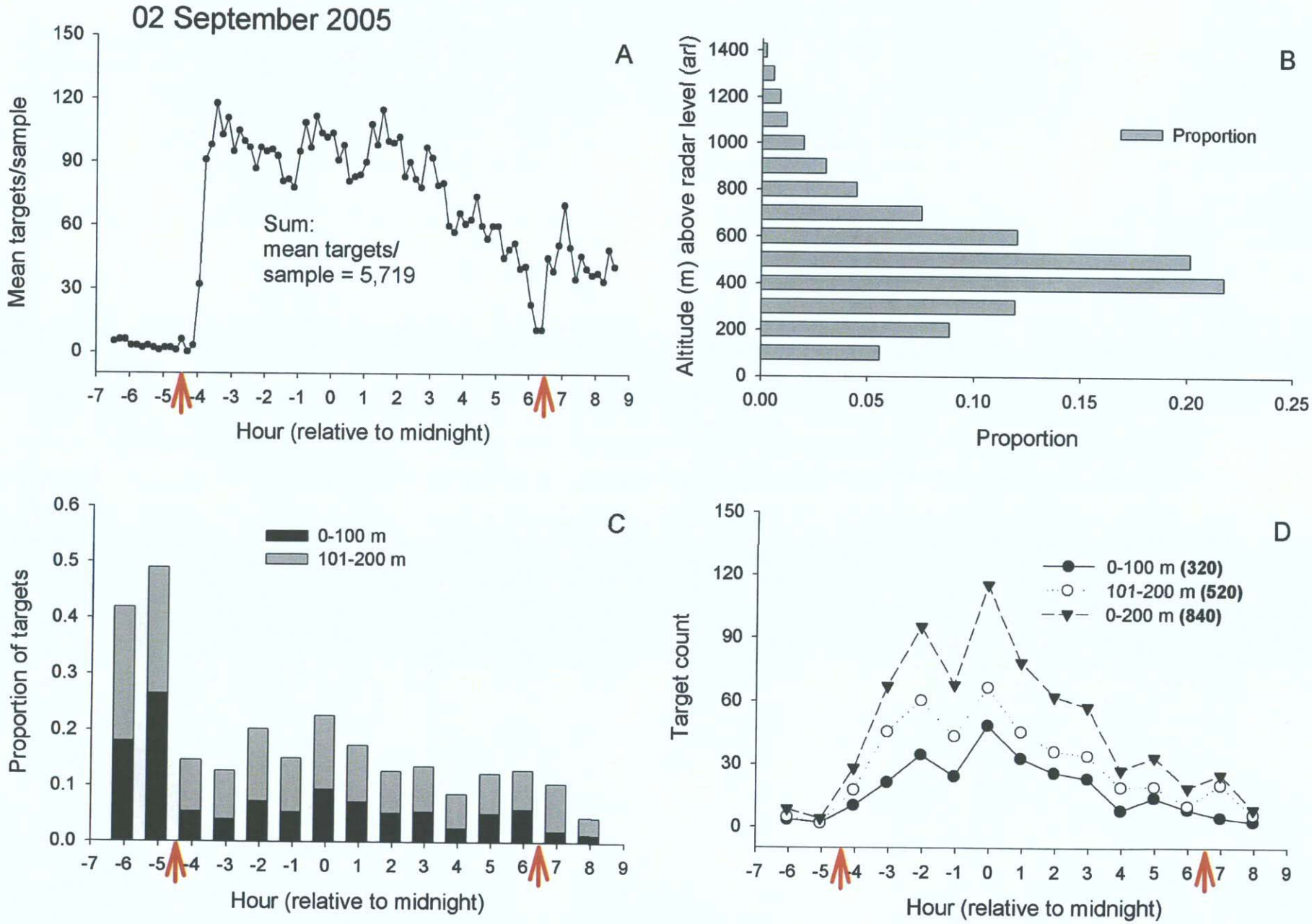

28 August 2005
A
Sum:
mean targets/
sample = 470
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (25)
101-200 m (38)
0-200 m (63)
Target count
Hour (relative to midnight)

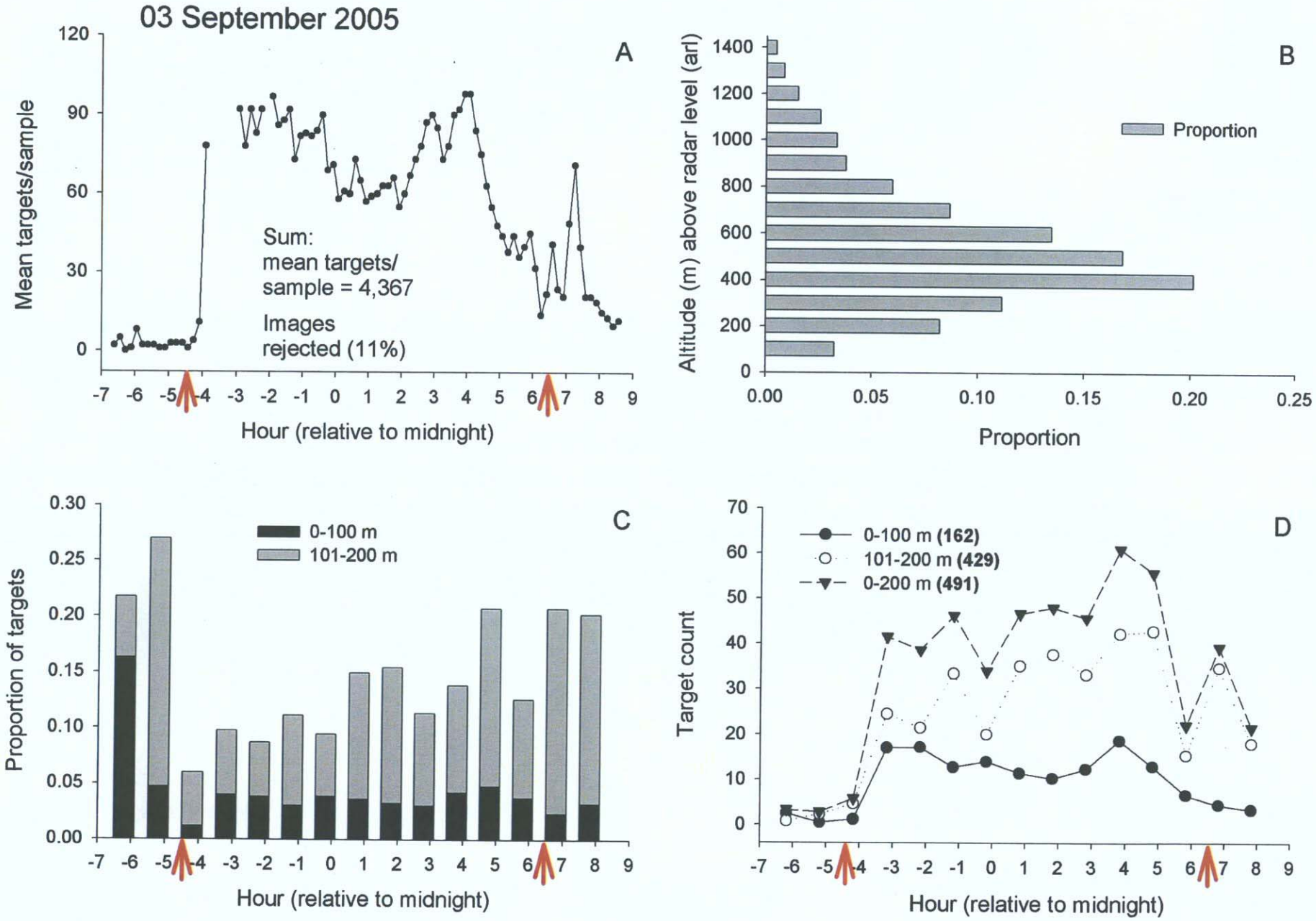

29 August 2005
A
Sum:
mean targets/
sample = 300
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (19)
101-200 m (20)
0-200 m (39)
Target count
Hour (relative to midnight)

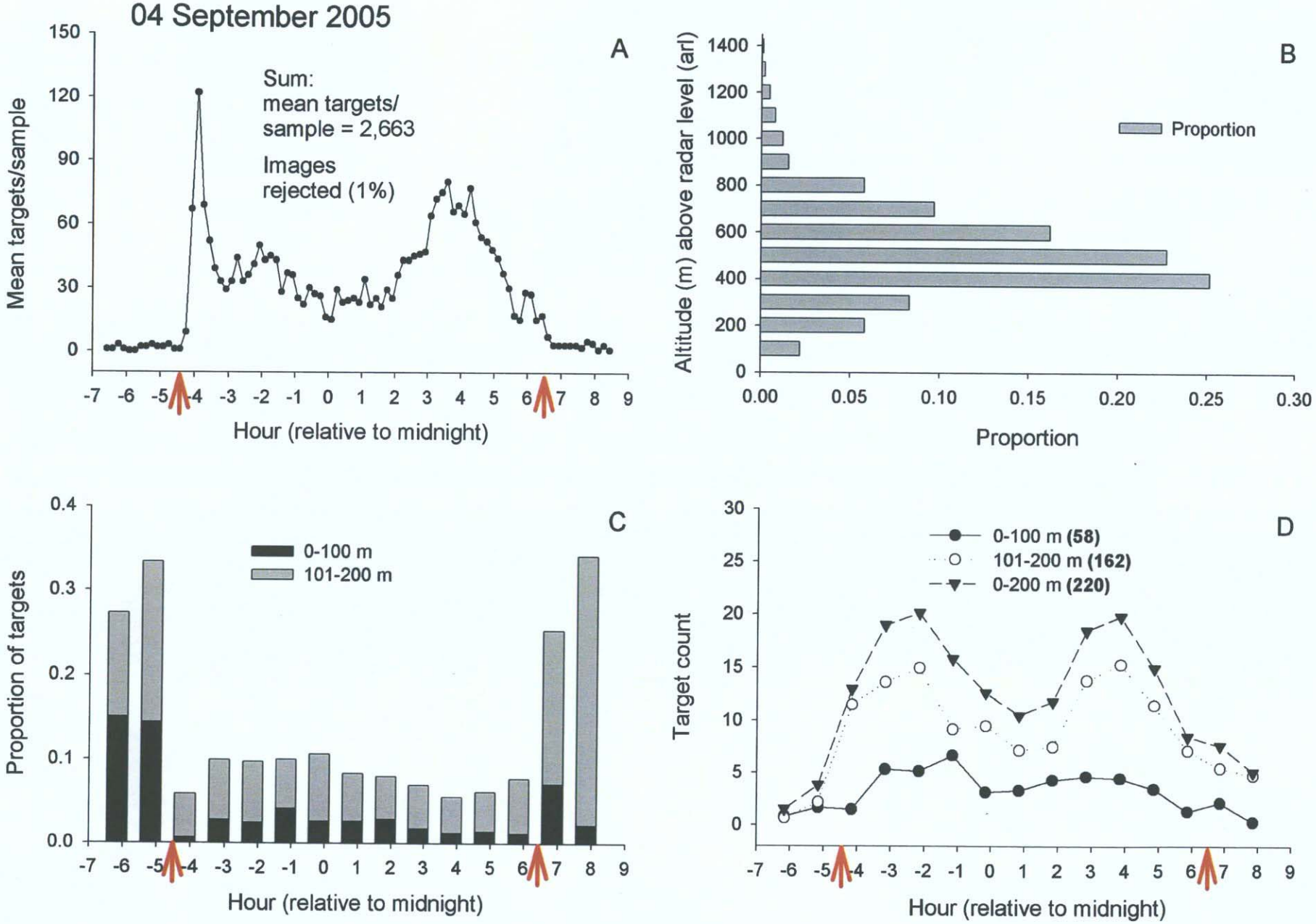

30 August 2005
A
Sum:
mean targets/
sample = 548
Images
rejected (2%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (15)
101-200 m (20)
0-200 m (35)
Target count
Hour (relative to midnight)

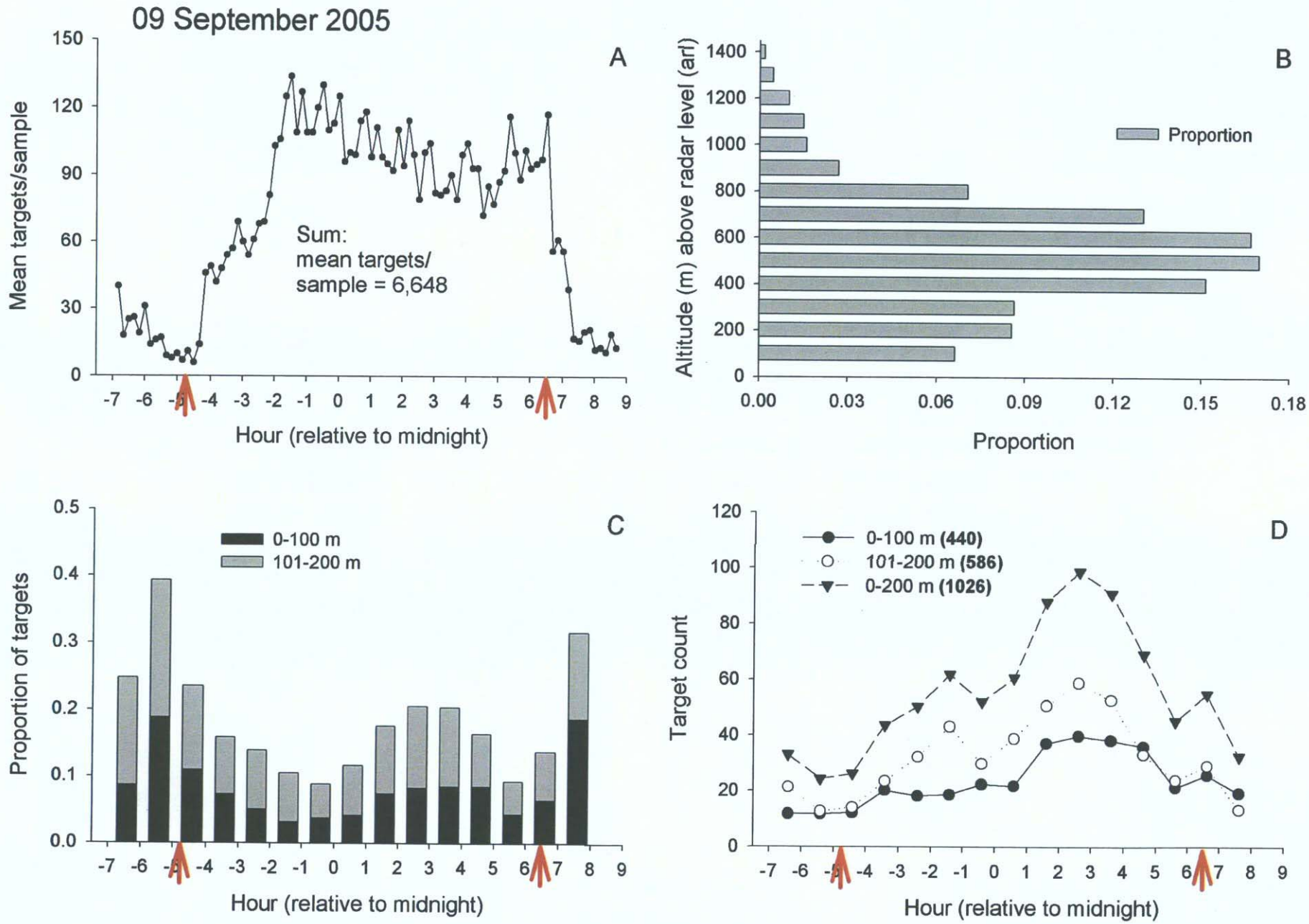

31 August 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 806
Images
rejected (47%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (63)
101-200 m (58)
0-200 m (121)
Hour (relative to midnight)

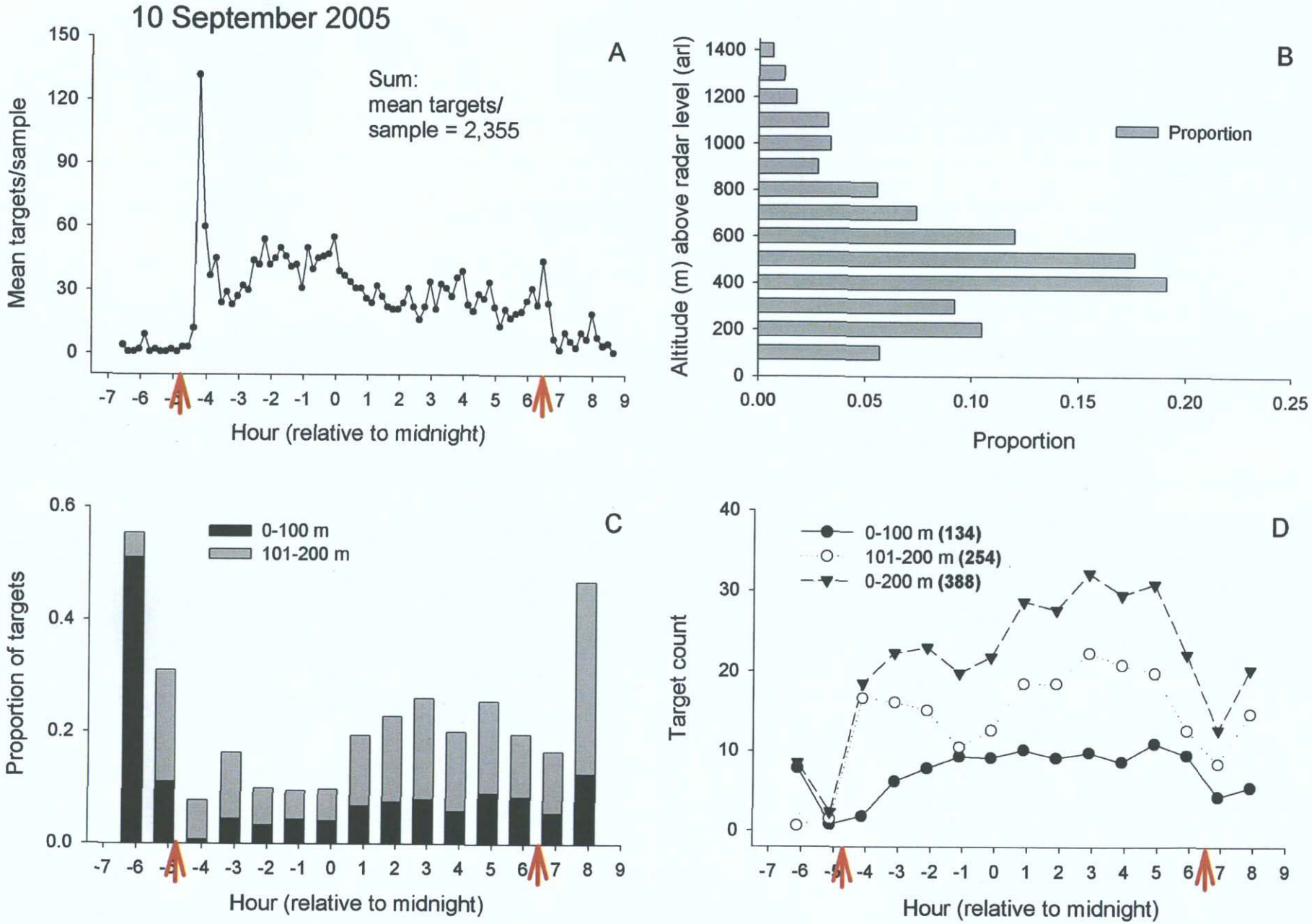

01 September 2005
A
Sum:
mean targets/
sample = 7,105
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (309)
101-200 m (628)
0-200 m (937)
Target count
Hour (relative to midnight)

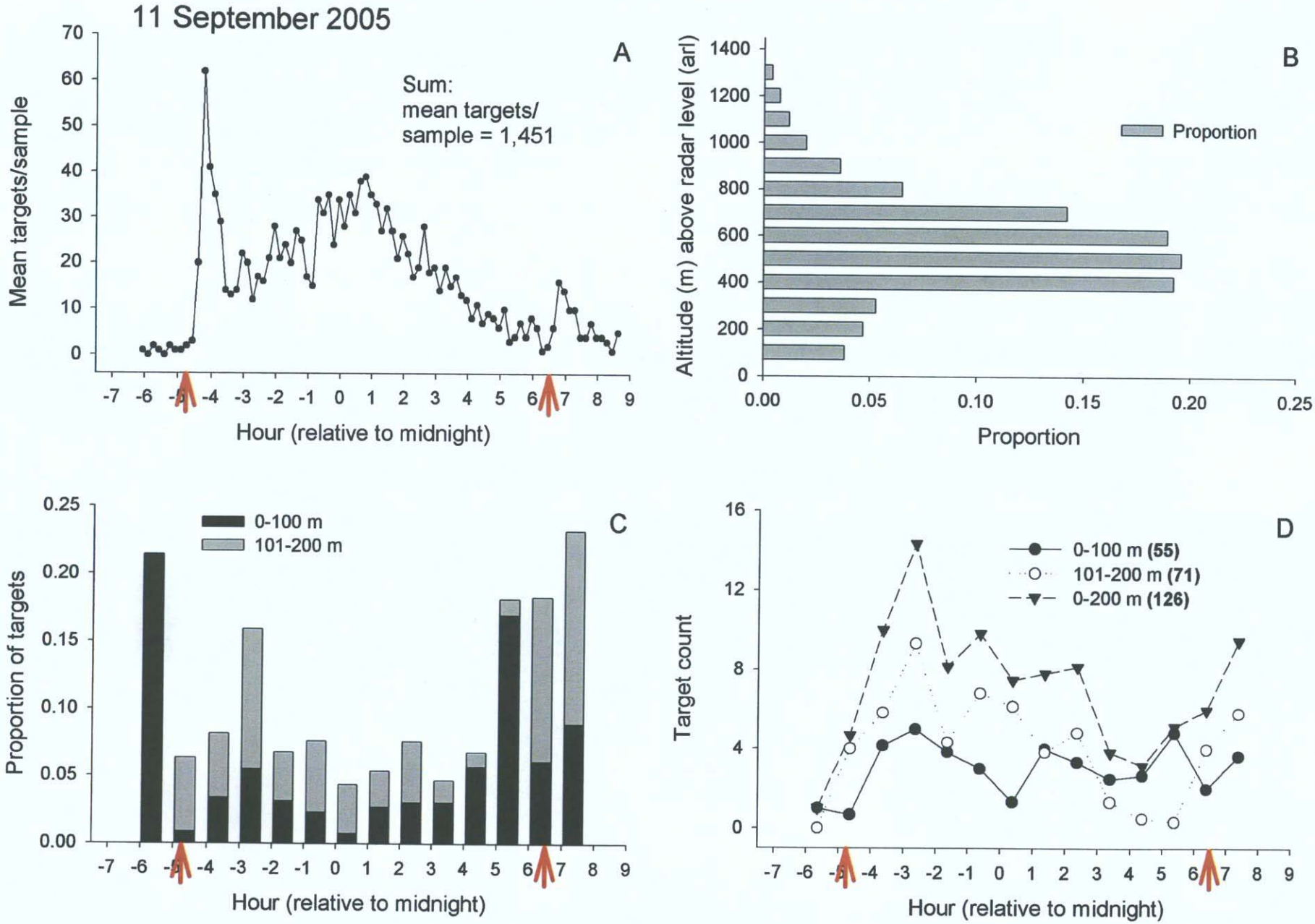

02 September 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 5,719
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (320)
101-200 m (520)
0-200 m (840)
Hour (relative to midnight)

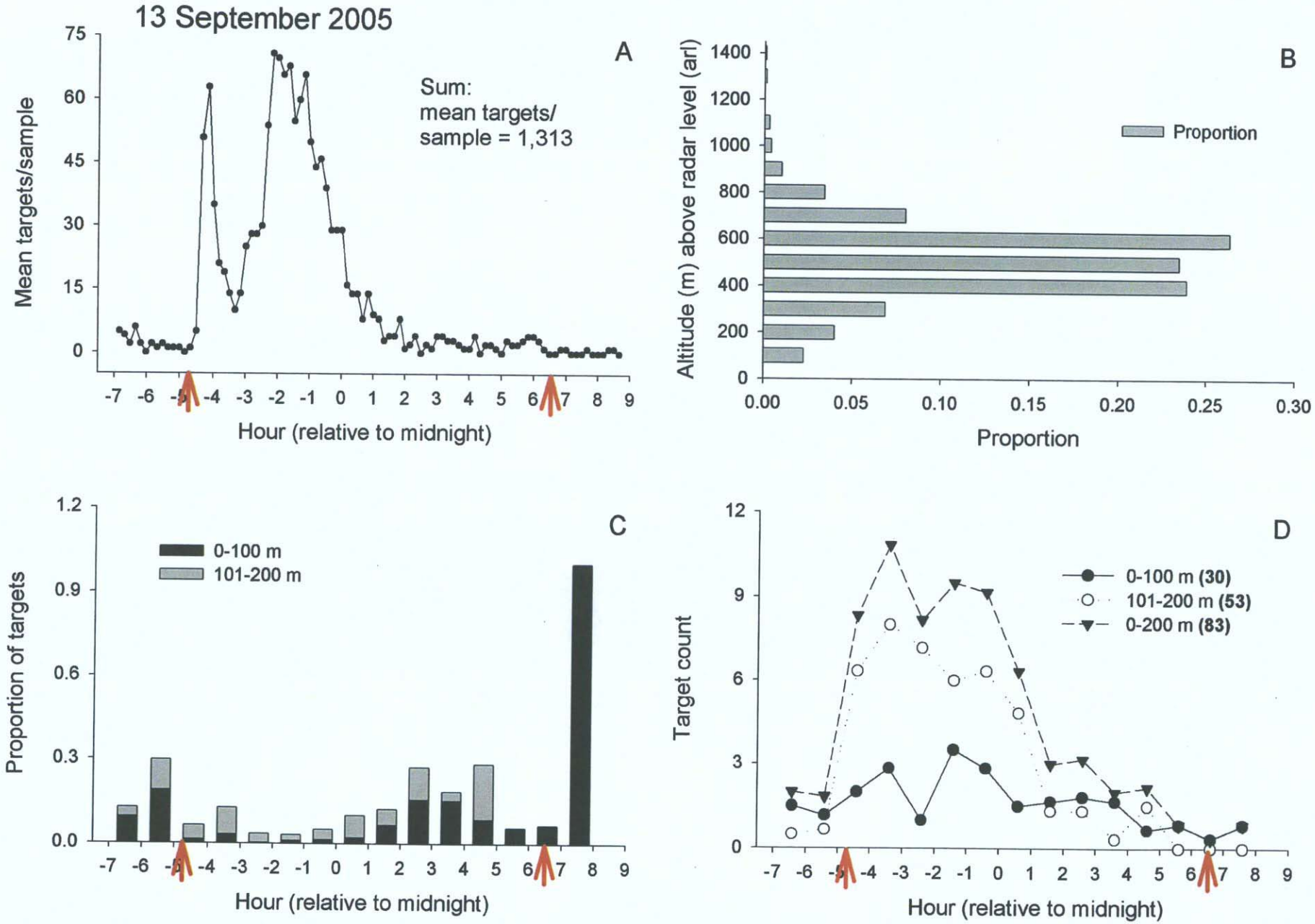

03 September 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 4,367
Images
rejected (11%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (162)
101-200 m (429)
0-200 m (491)
Hour (relative to midnight)

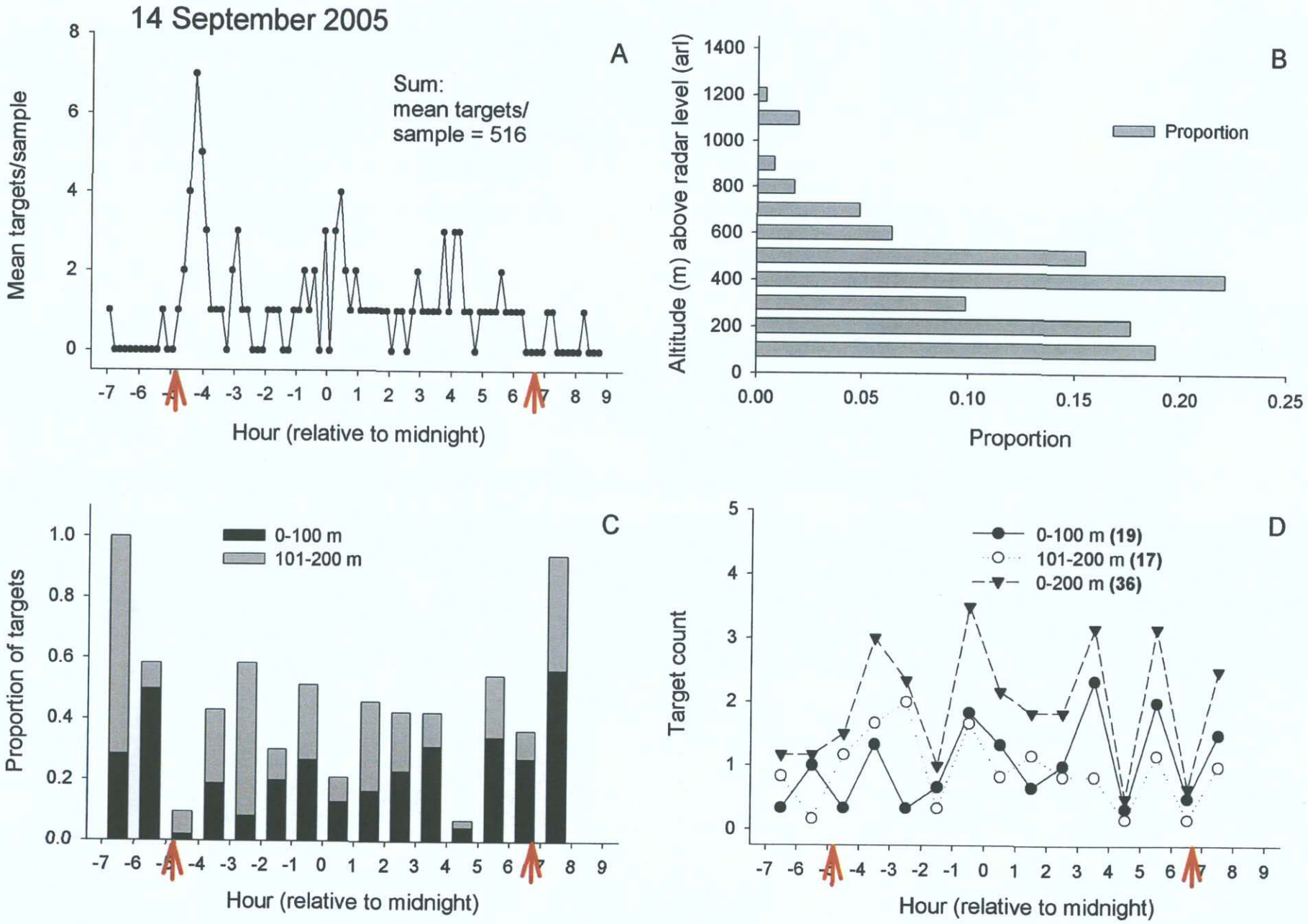

04 September 2005
A
Sum:
mean targets/
sample = 2,663
Images
rejected (1%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (58)
101-200 m (162)
0-200 m (220)
Target count
Hour (relative to midnight)

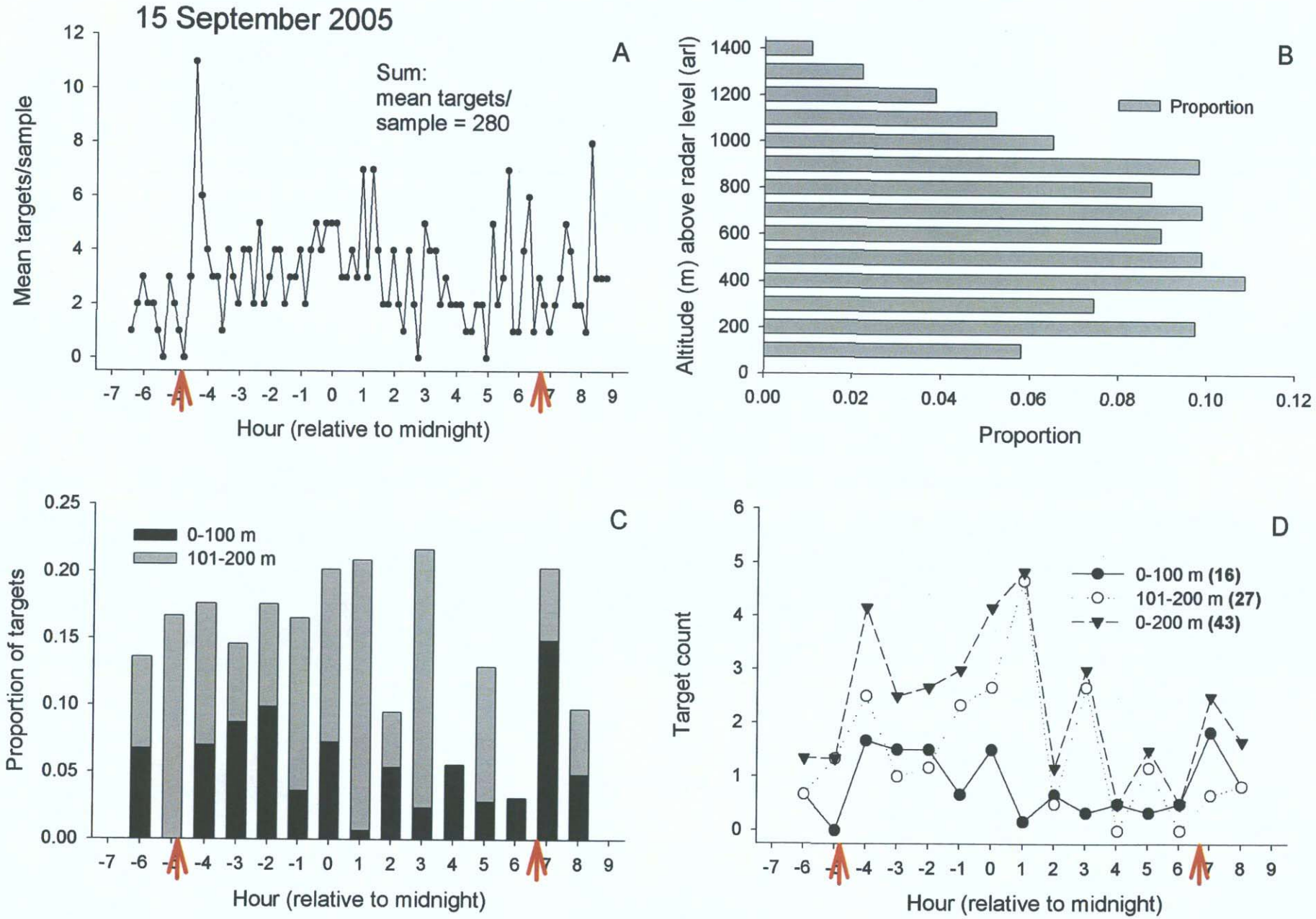

09 September 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 6,648
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (440)
101-200 m (586)
0-200 m (1026)
Hour (relative to midnight)

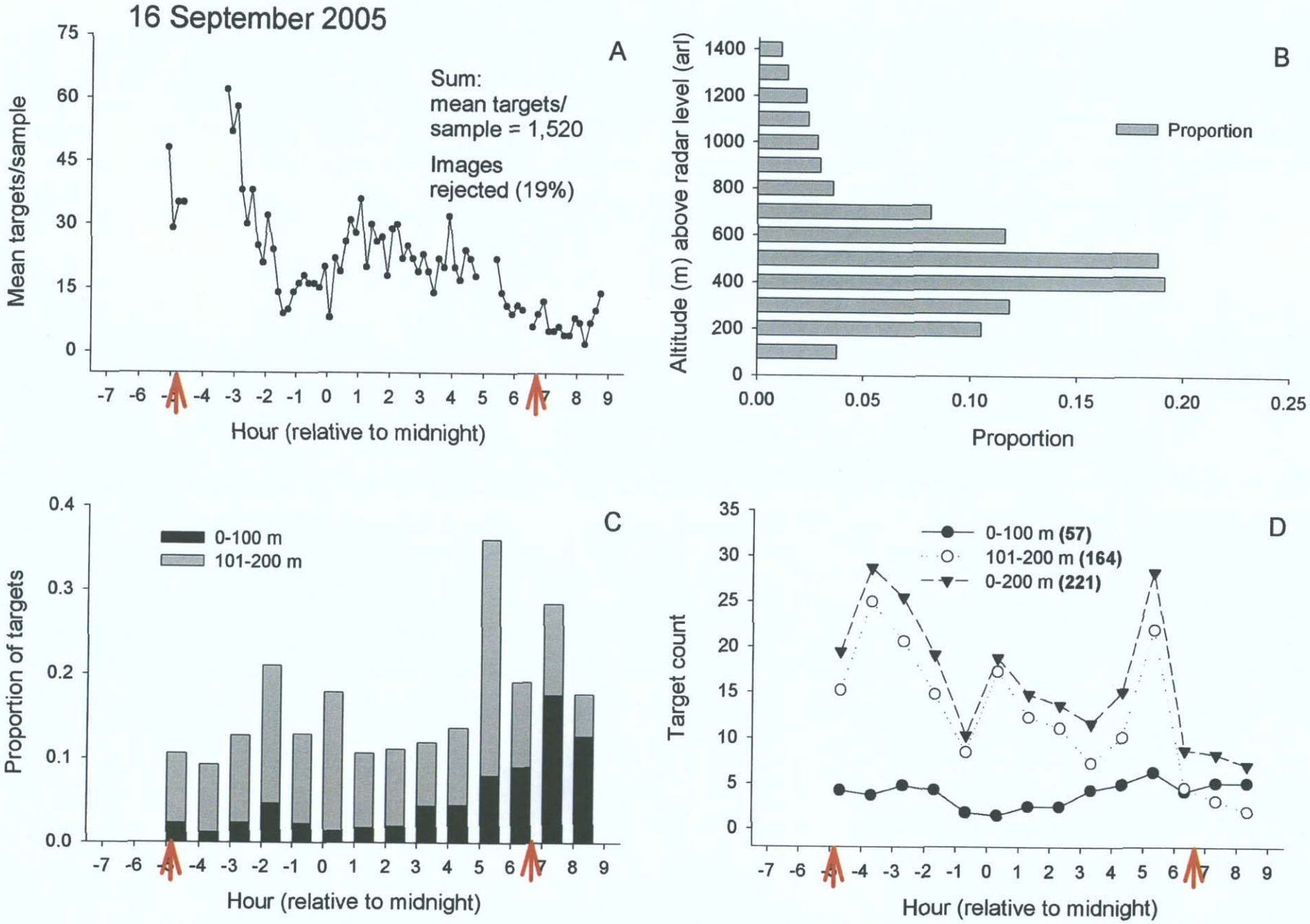

10 September 2005
A
Sum:
mean targets/
sample = 2,355
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (134)
101-200 m (254)
0-200 m (388)
Target count
Hour (relative to midnight)

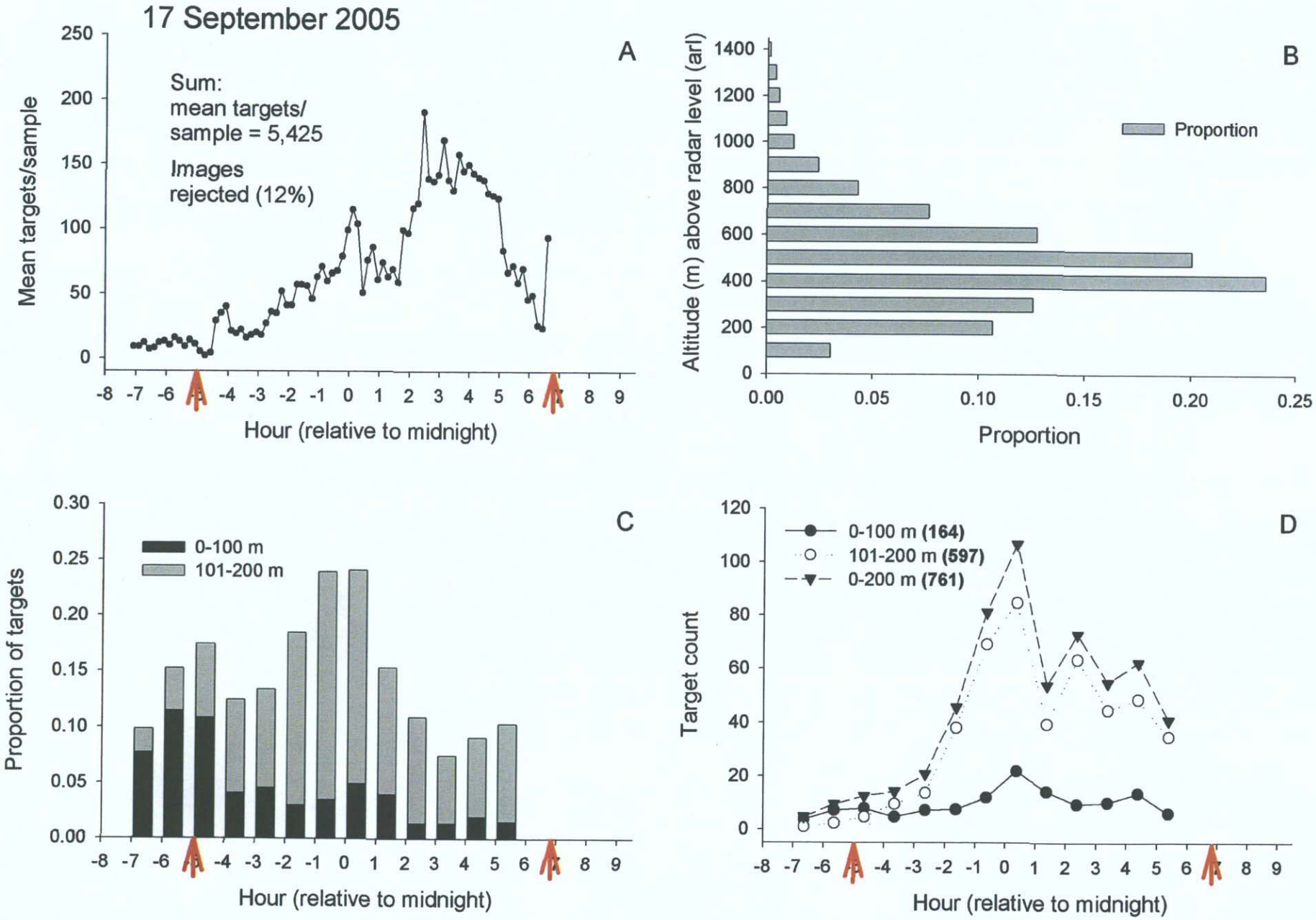

11 September 2005
A
Sum:
mean targets/
sample = 1,451
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (55)
101-200 m (71)
0-200 m (126)
Target count
Hour (relative to midnight)

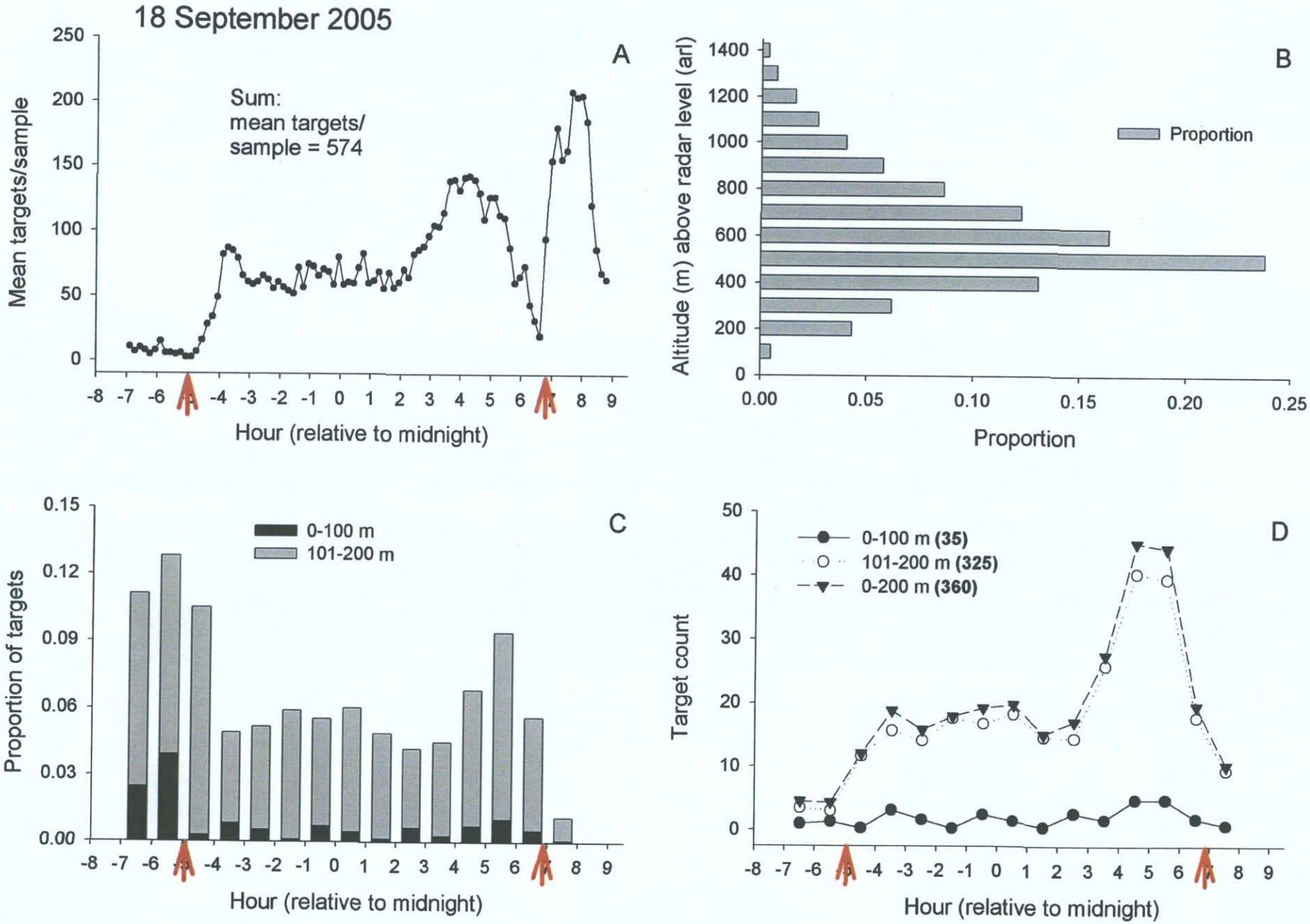

13 September 2005
A
Sum:
mean targets/
sample = 1,313
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (30)
101-200 m (53)
0-200 m (83)
Target count
Hour (relative to midnight)

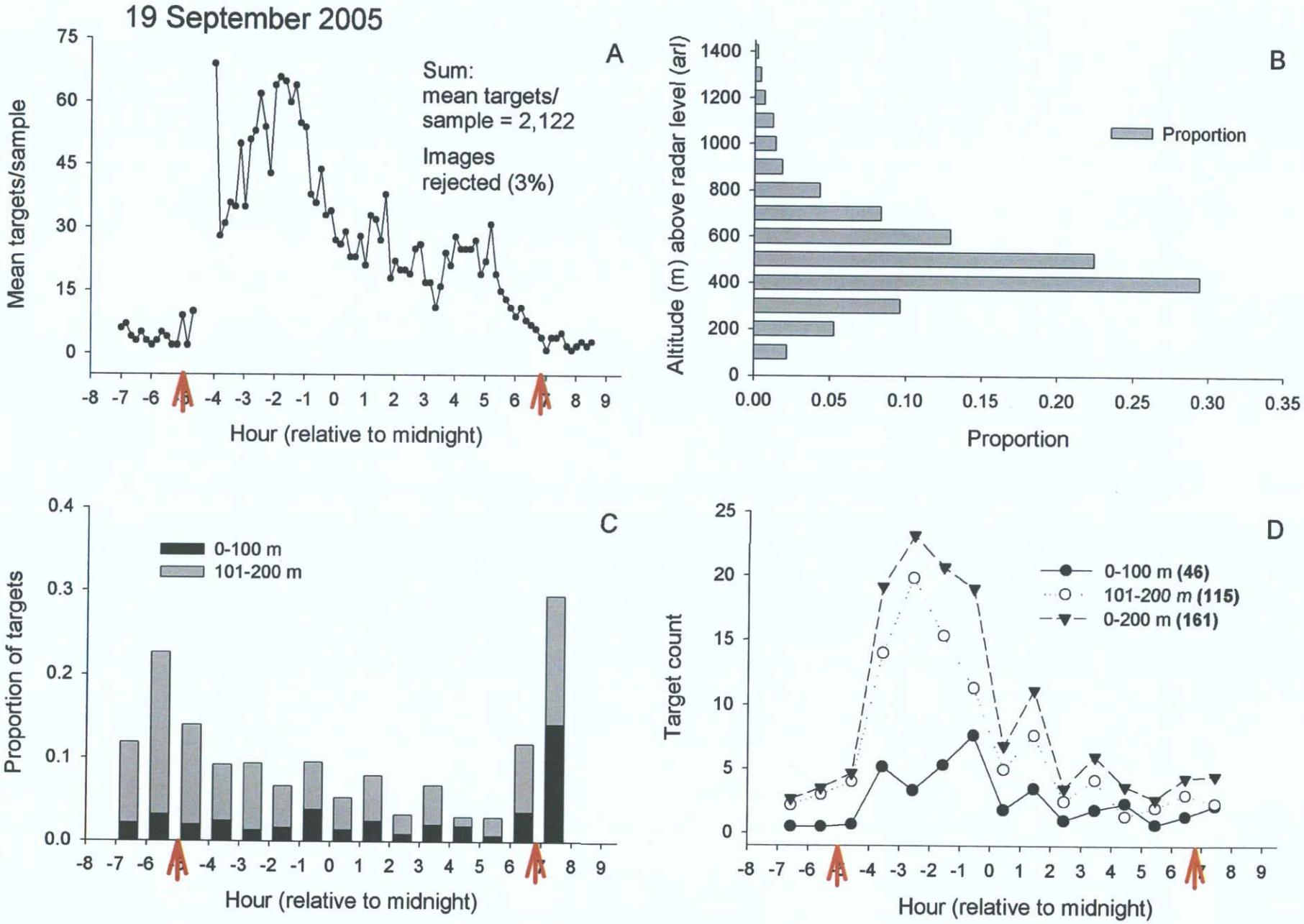

14 September 2005
A
Sum:
mean targets/
sample = 516
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (19)
101-200 m (17)
0-200 m (36)
Target count
Hour (relative to midnight)

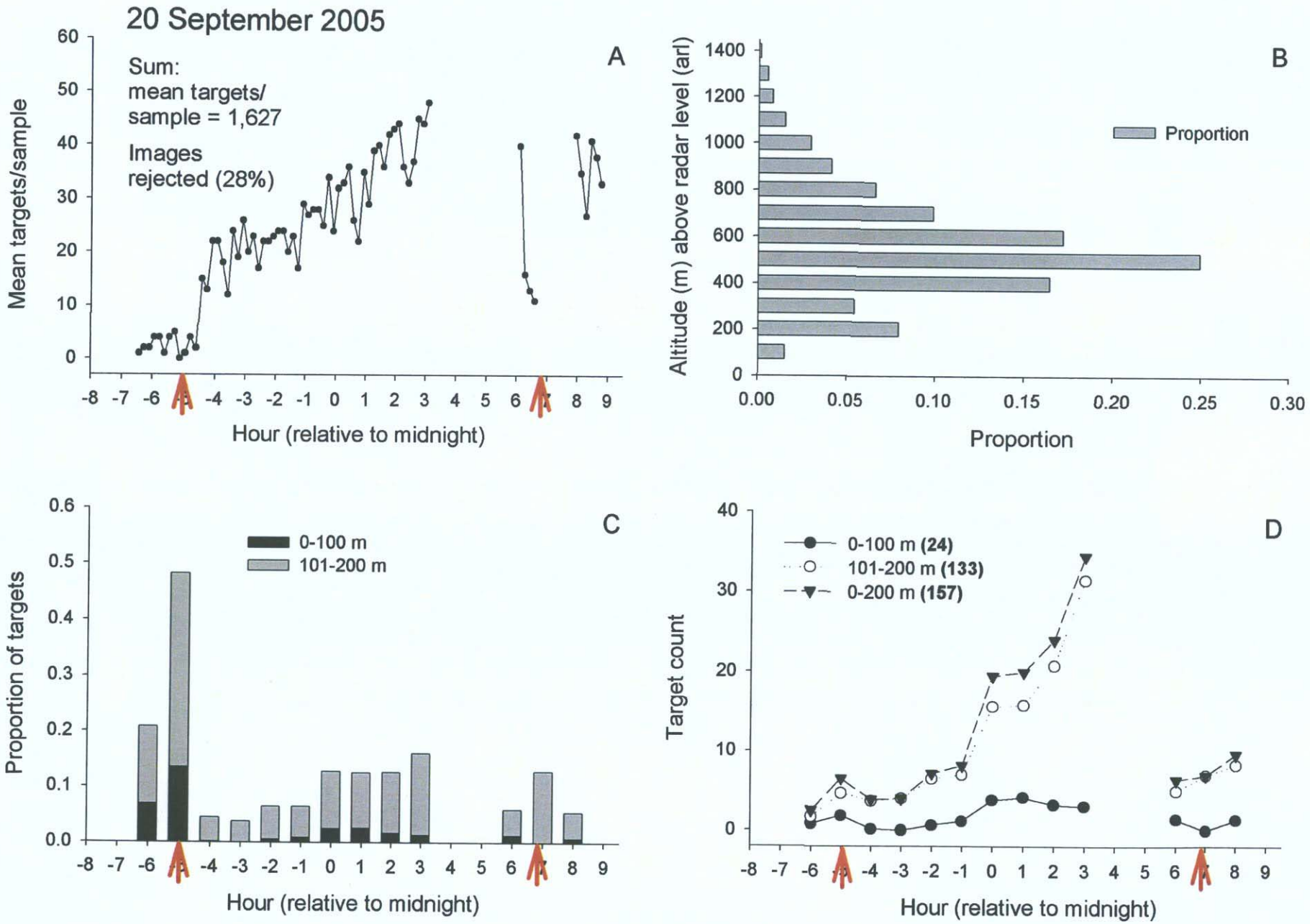

15 September 2005
A
Sum:
mean targets/
sample = 280
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (16)
101-200 m (27)
0-200 m (43)
Target count
Hour (relative to midnight)

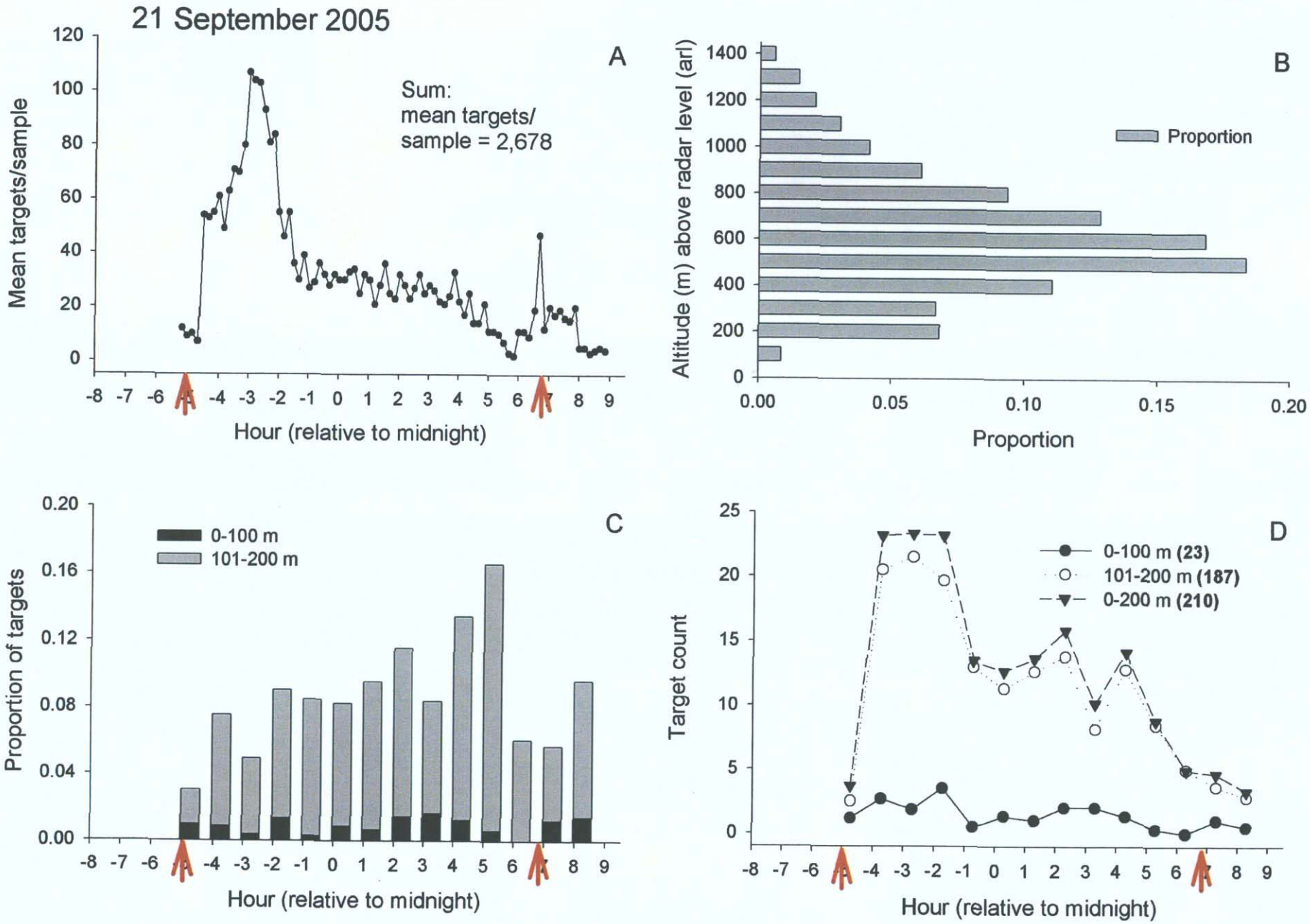

16 September 2005
A
Sum:
mean targets/
sample = 1,520
Images
rejected (19%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (57)
101-200 m (164)
0-200 m (221)
Target count
Hour (relative to midnight)

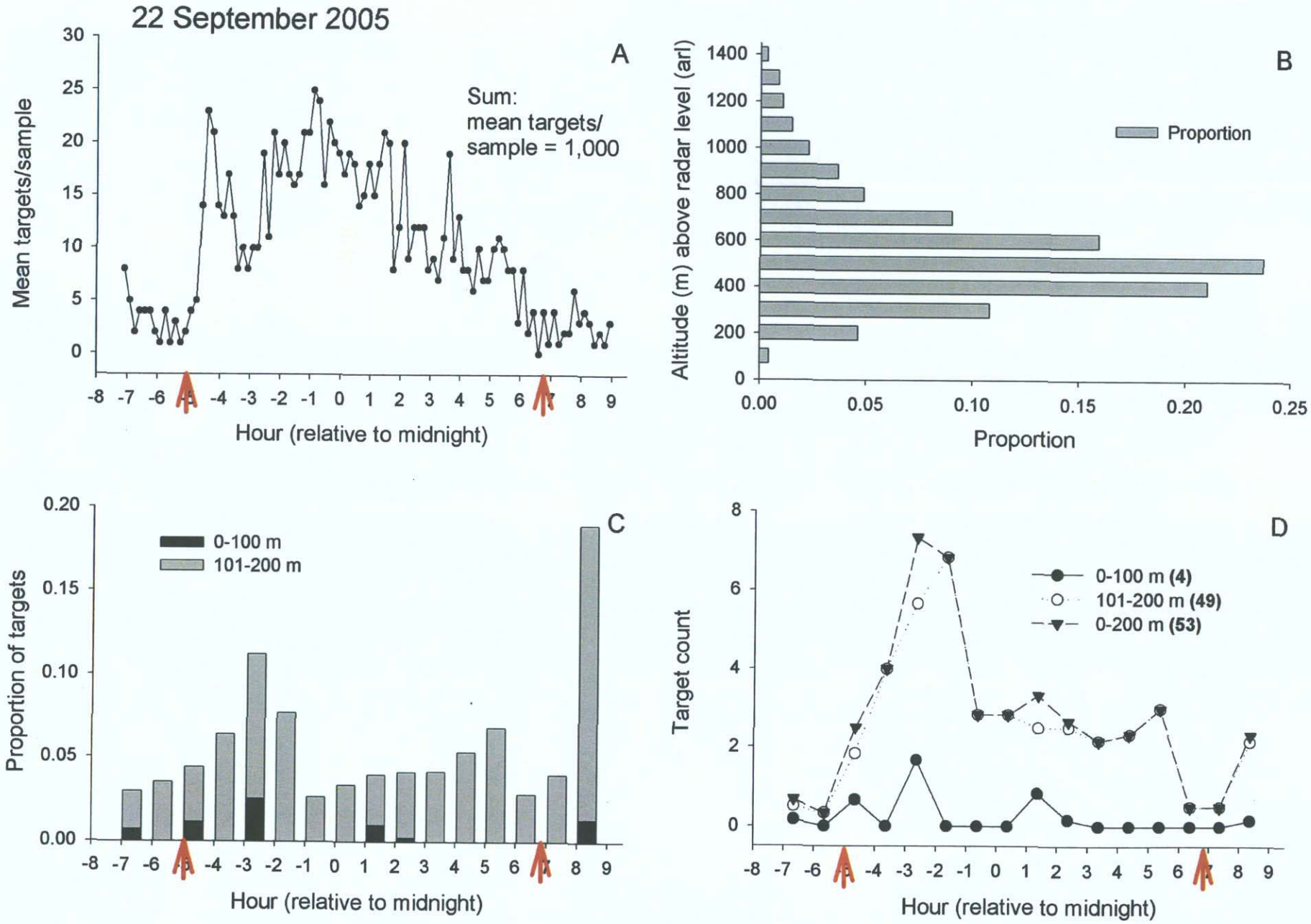

17 September 2005
A
Sum:
mean targets/
sample = 5,425
Images
rejected (12%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (164)
101-200 m (597)
0-200 m (761)
Target count
Hour (relative to midnight)

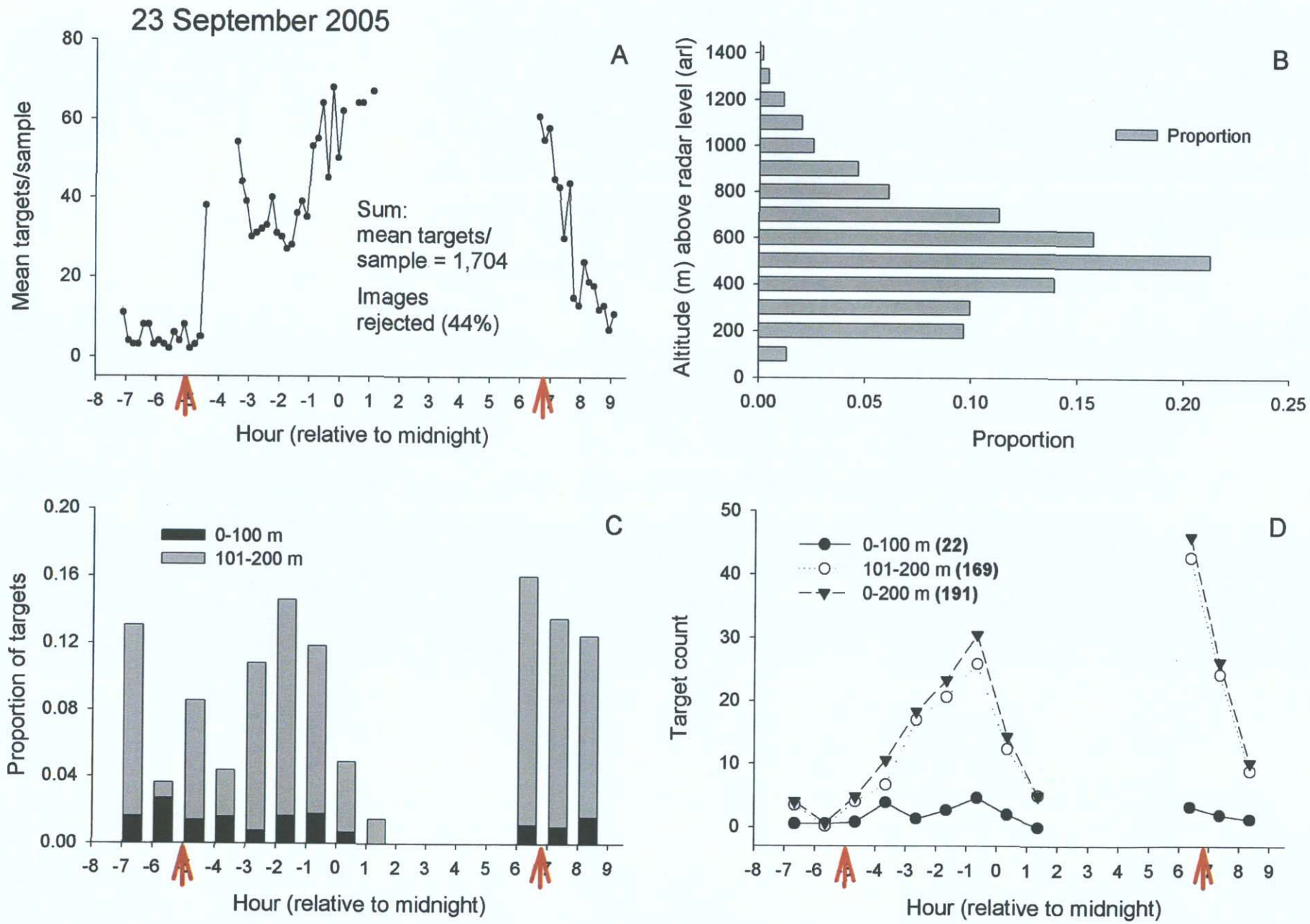

18 September 2005
A
Sum:
mean targets/
sample = 574
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (35)
101-200 m (325)
0-200 m (360)
Target count
Hour (relative to midnight)

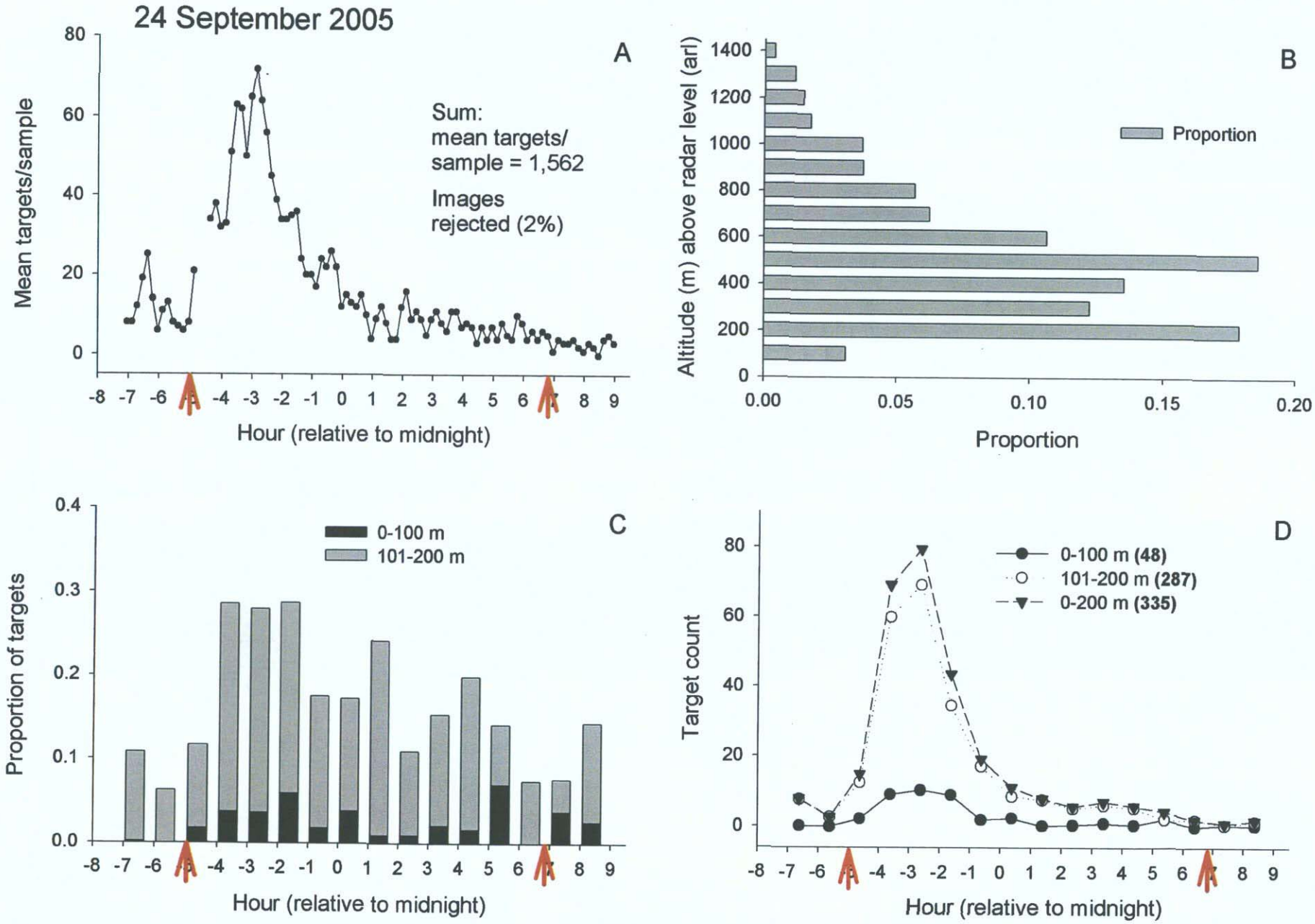

19 September 2005
A
Sum:
mean targets/
sample = 2,122
Images
rejected (3%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (46)
101-200 m (115)
0-200 m (161)
Target count
Hour (relative to midnight)

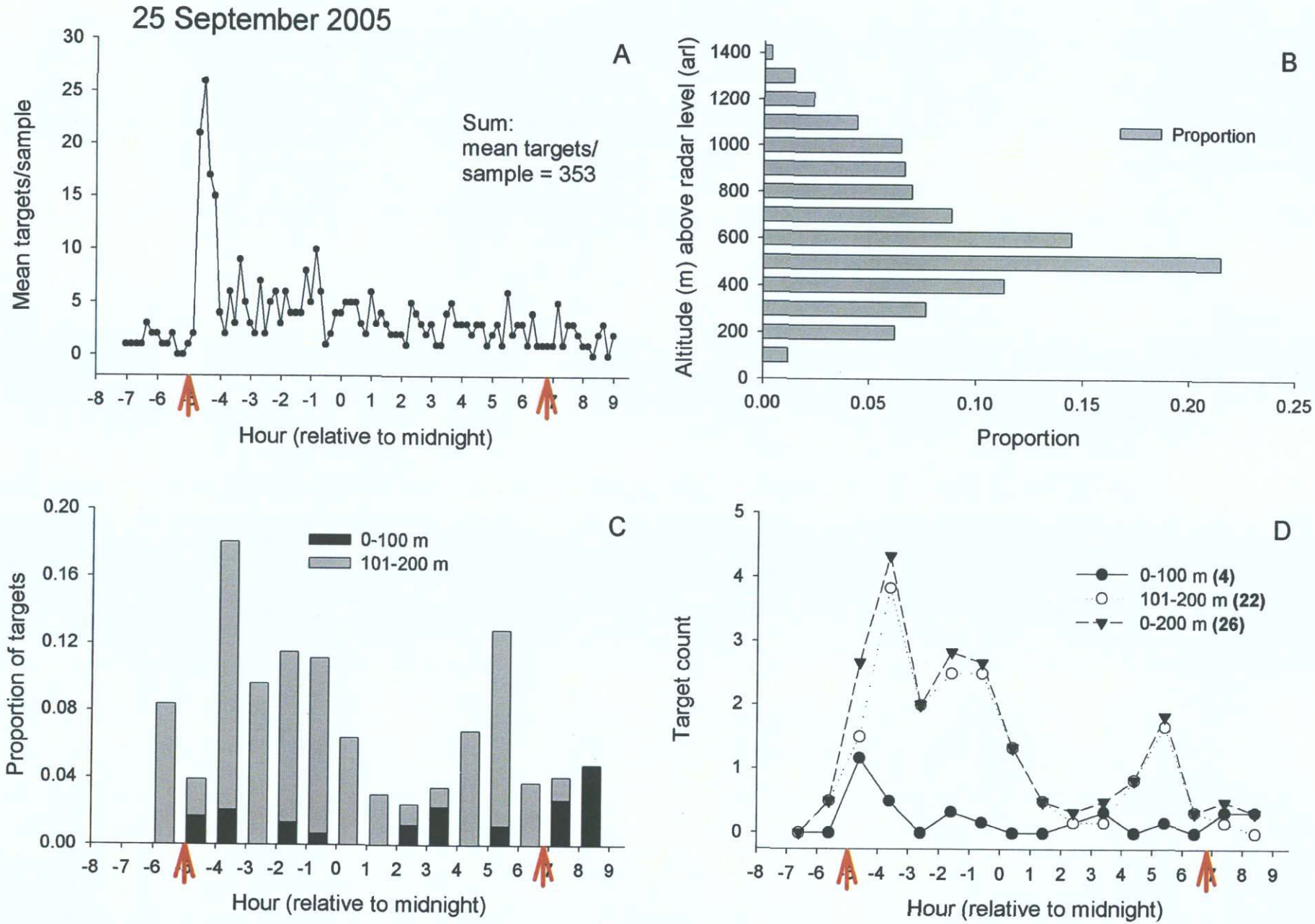

20 September 2005
A
Sum:
mean targets/
sample = 1,627
Images
rejected (28%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (24)
101-200 m (133)
0-200 m (157)
Target count
Hour (relative to midnight)

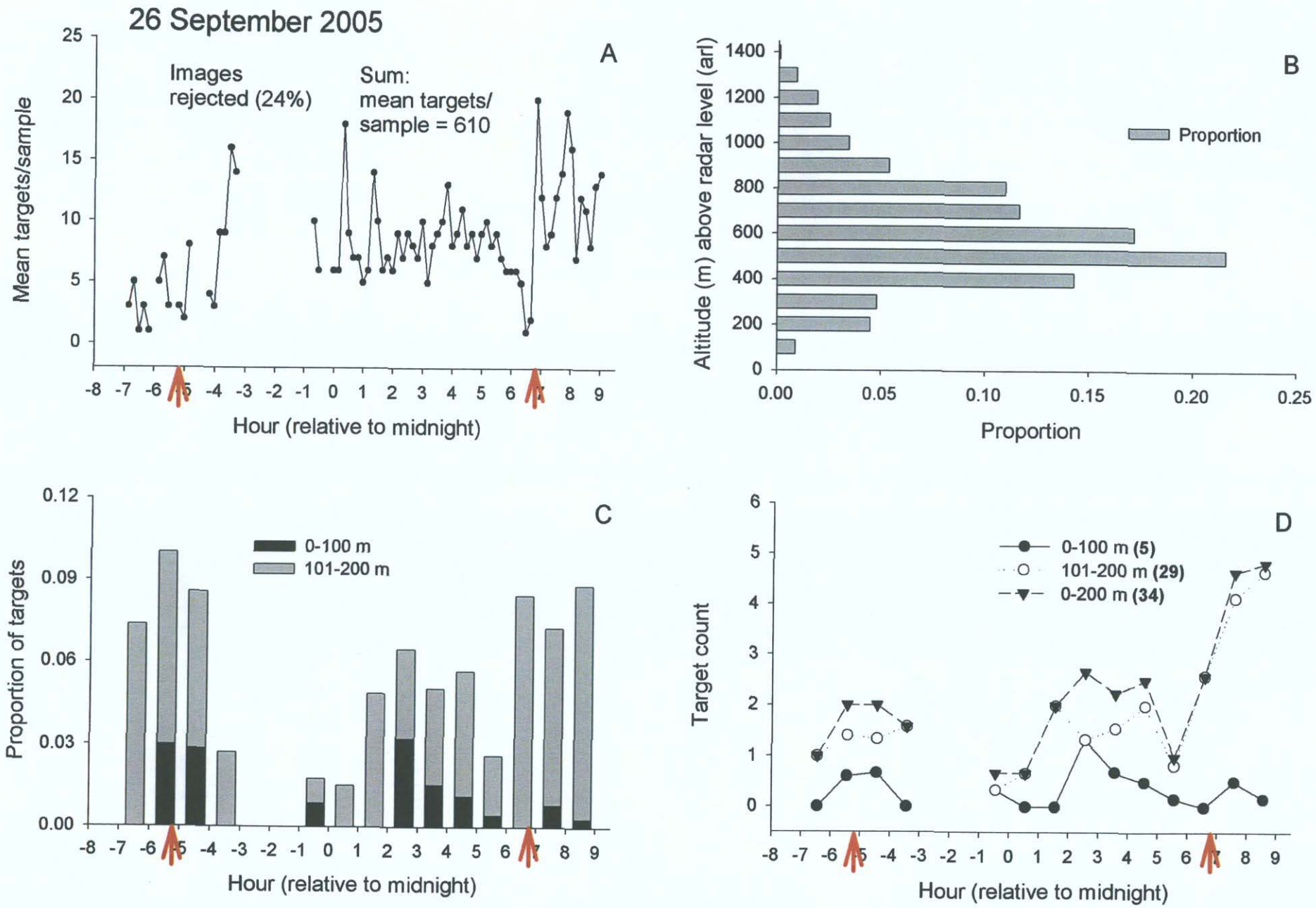

21 September 2005
A
Sum:
mean targets/
sample = 2,678
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (23)
101-200 m (187)
0-200 m (210)
Target count
Hour (relative to midnight)

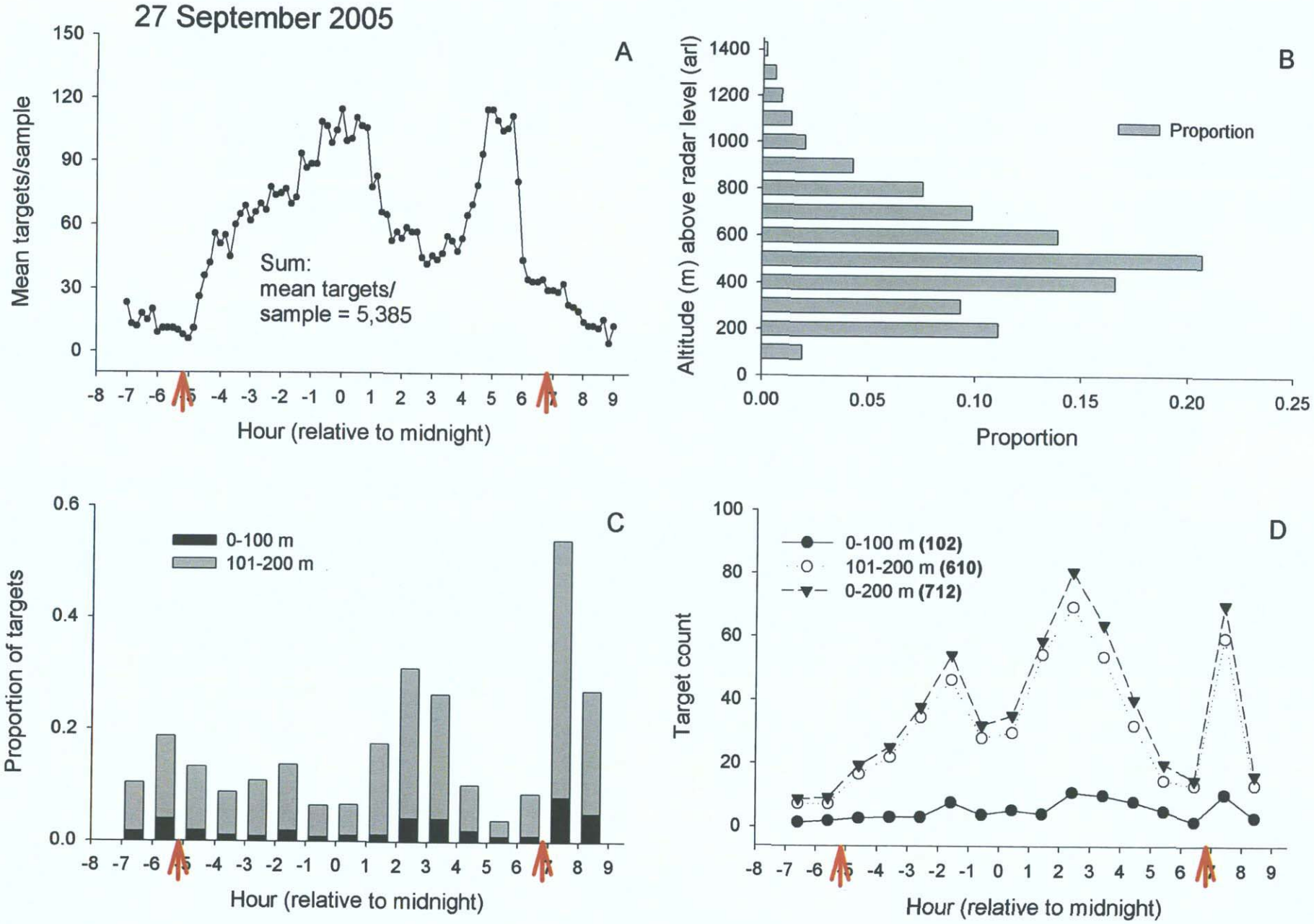

22 September 2005
A
Sum:
mean targets/
sample = 1,000
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (4)
101-200 m (49)
0-200 m (53)
Target count
Hour (relative to midnight)

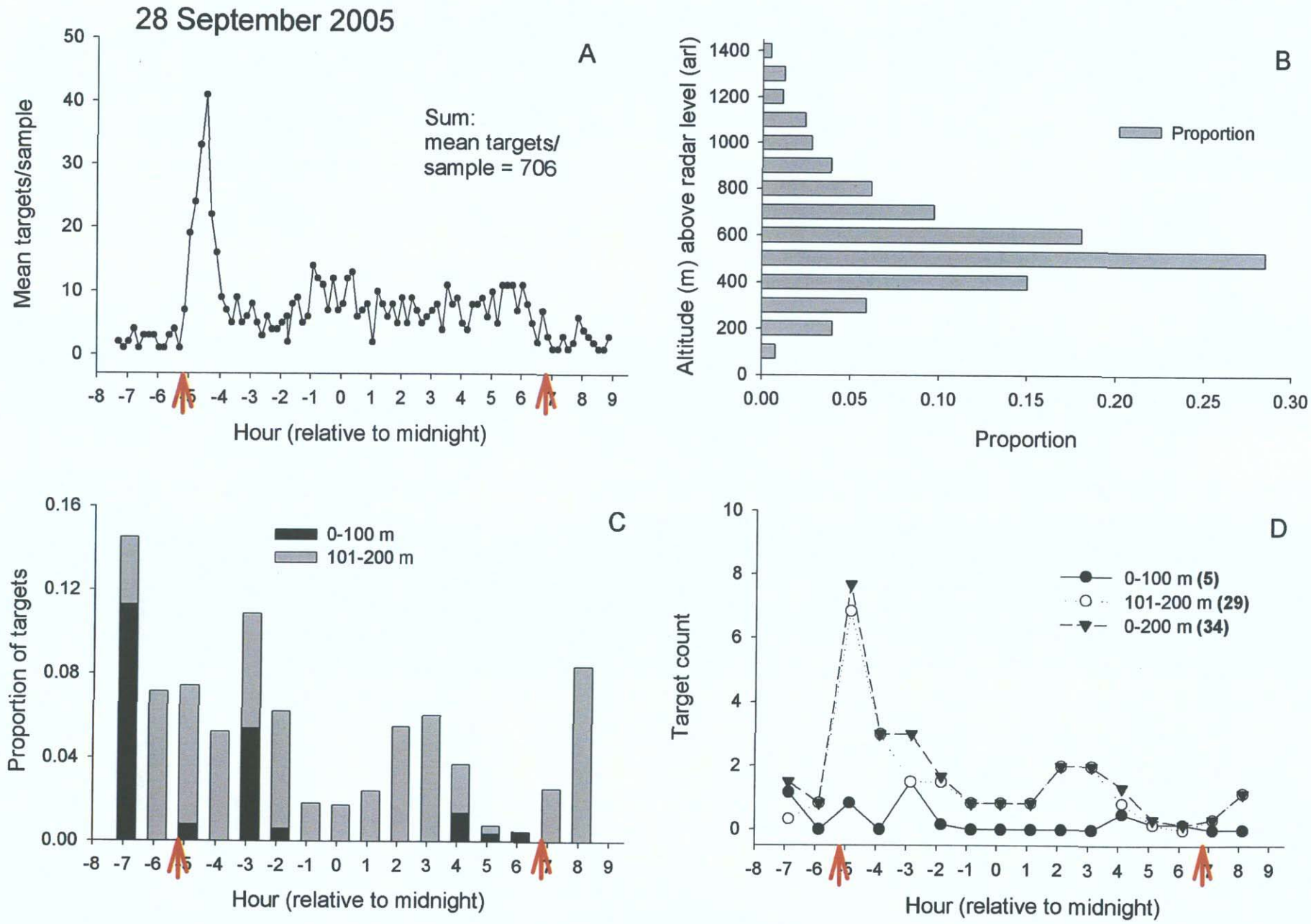

23 September 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 1,704
Images
rejected (44%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (22)
101-200 m (169)
0-200 m (191)
Hour (relative to midnight)

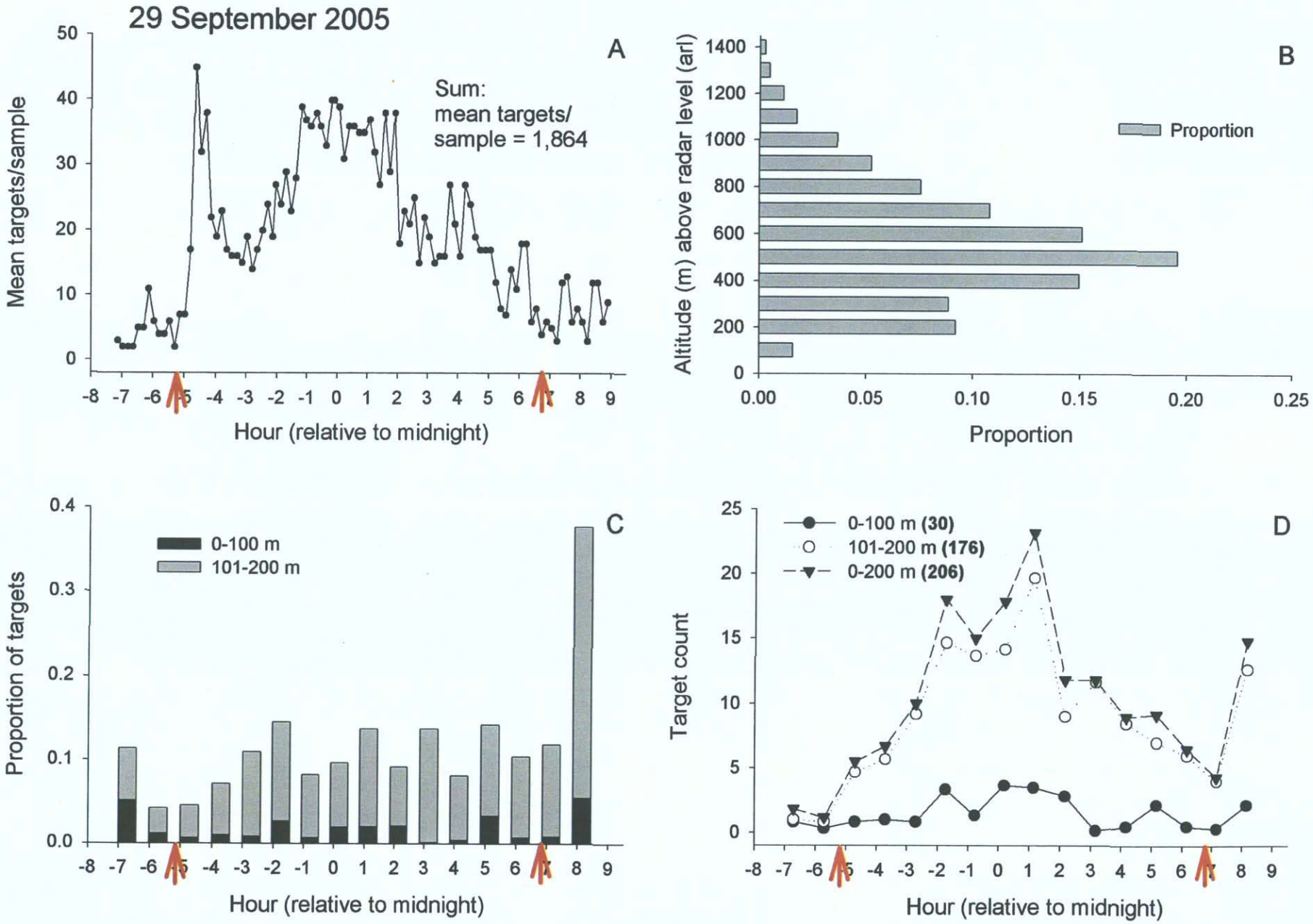

24 September 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 1,562
Images
rejected (2%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (48)
101-200 m (287)
0-200 m (335)
Hour (relative to midnight)

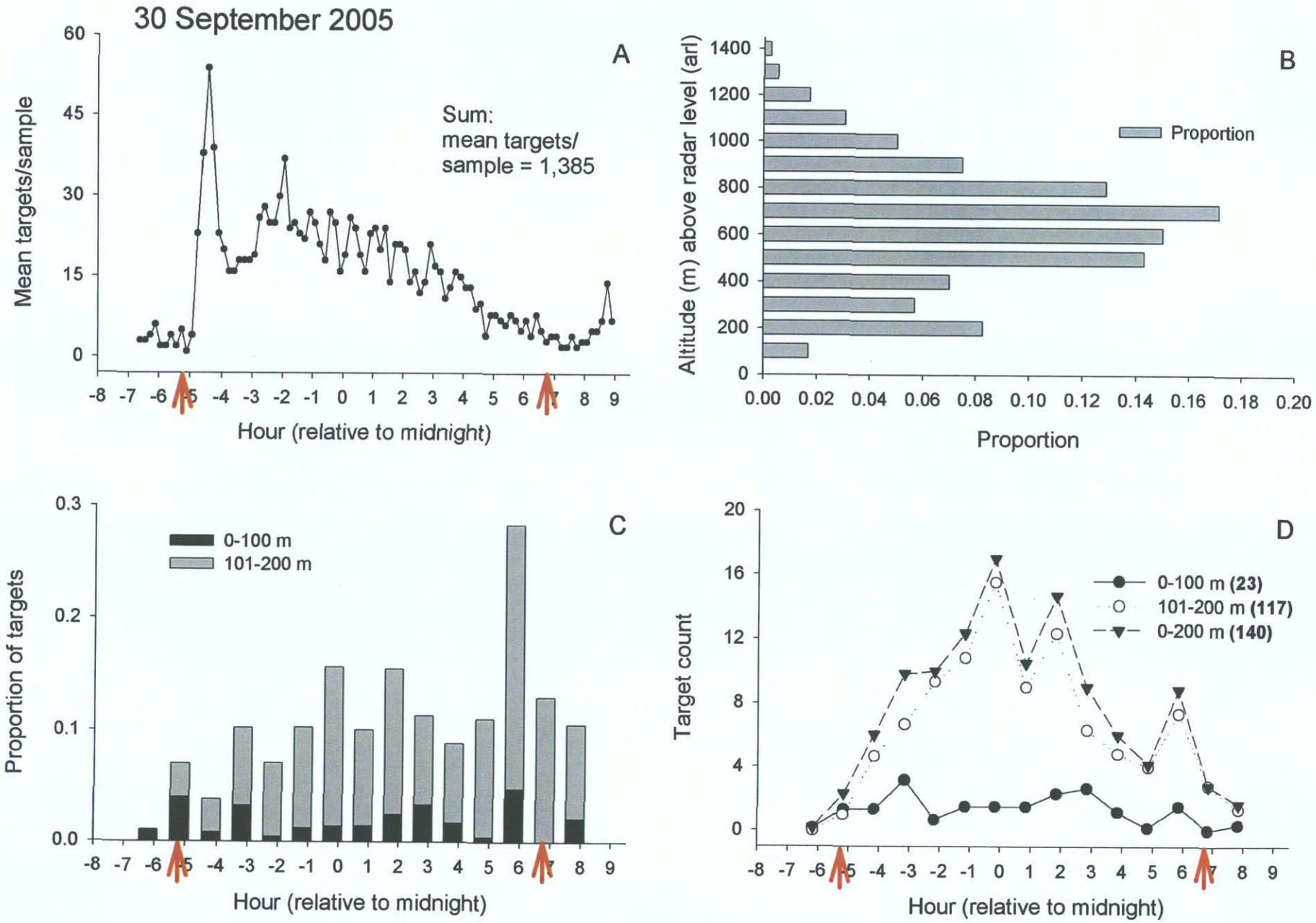

25 September 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 353
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (4)
101-200 m (22)
0-200 m (26)
Hour (relative to midnight)

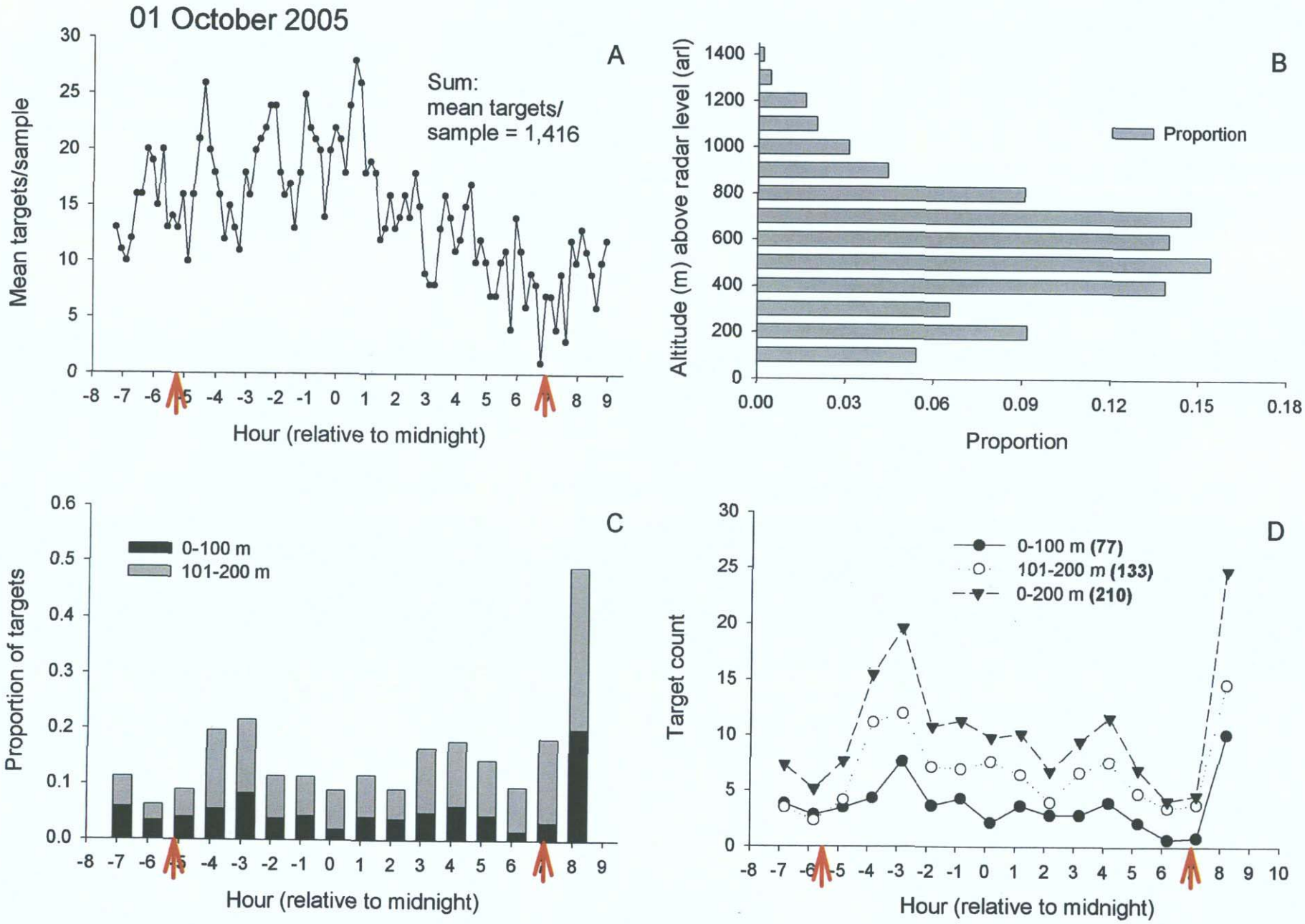

26 September 2005
A
Images rejected (24%)
Sum: mean targets/ sample = 610
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (5)
101-200 m (29)
0-200 m (34)
Target count
Hour (relative to midnight)

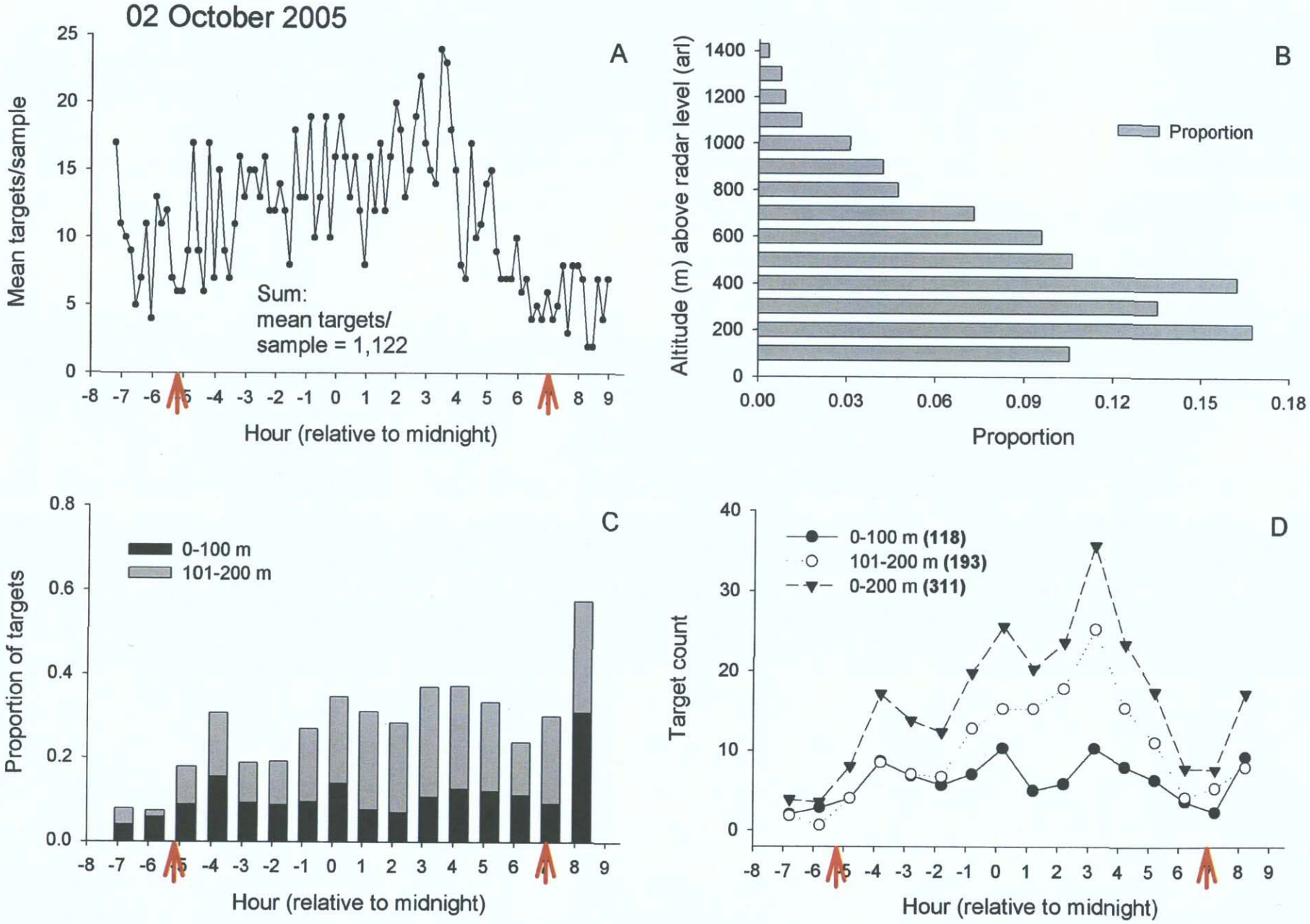

27 September 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 5,385
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (102)
101-200 m (610)
0-200 m (712)
Hour (relative to midnight)

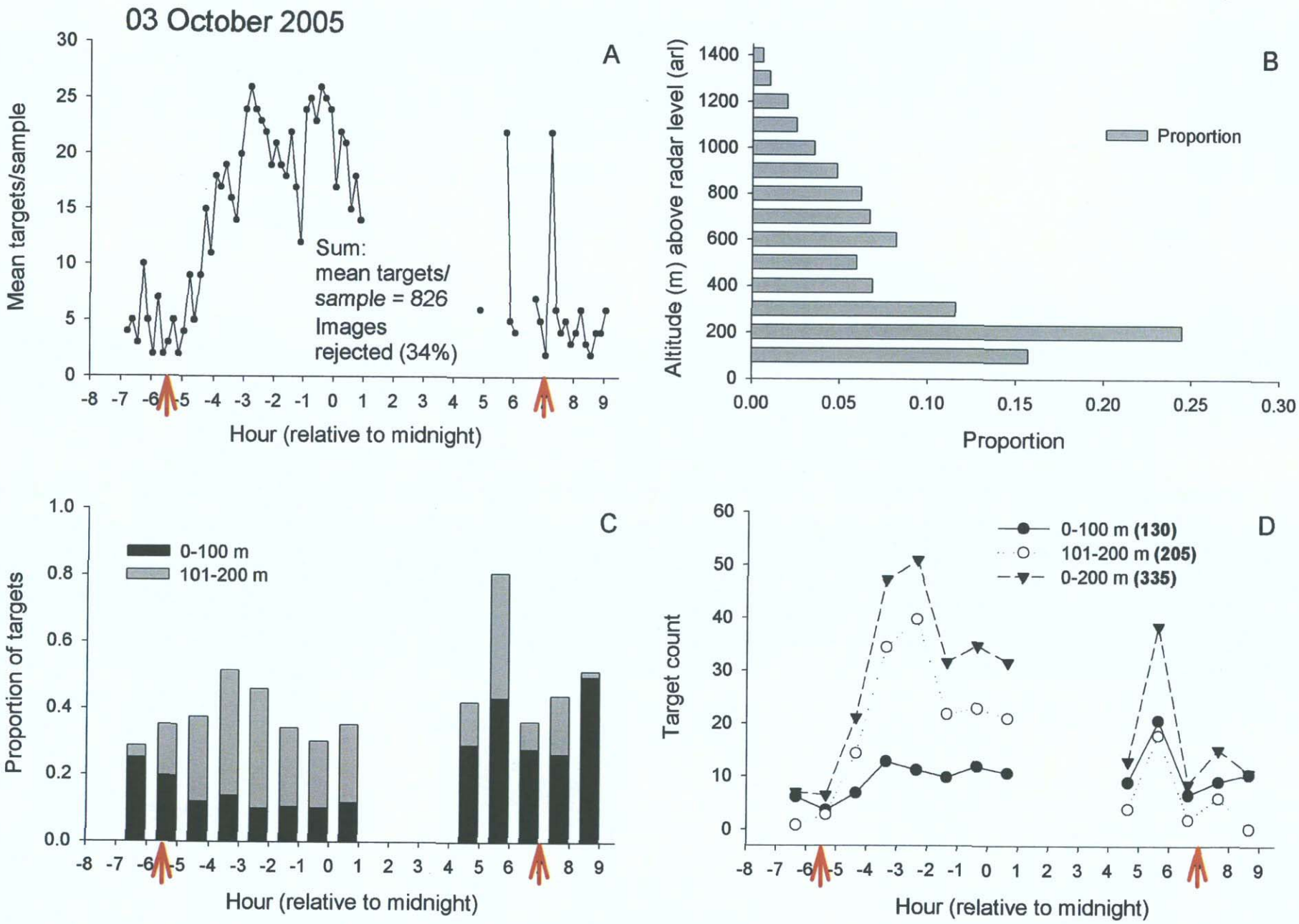

28 September 2005
A
Sum:
mean targets/
sample = 706
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (5)
101-200 m (29)
0-200 m (34)
Target count
Hour (relative to midnight)

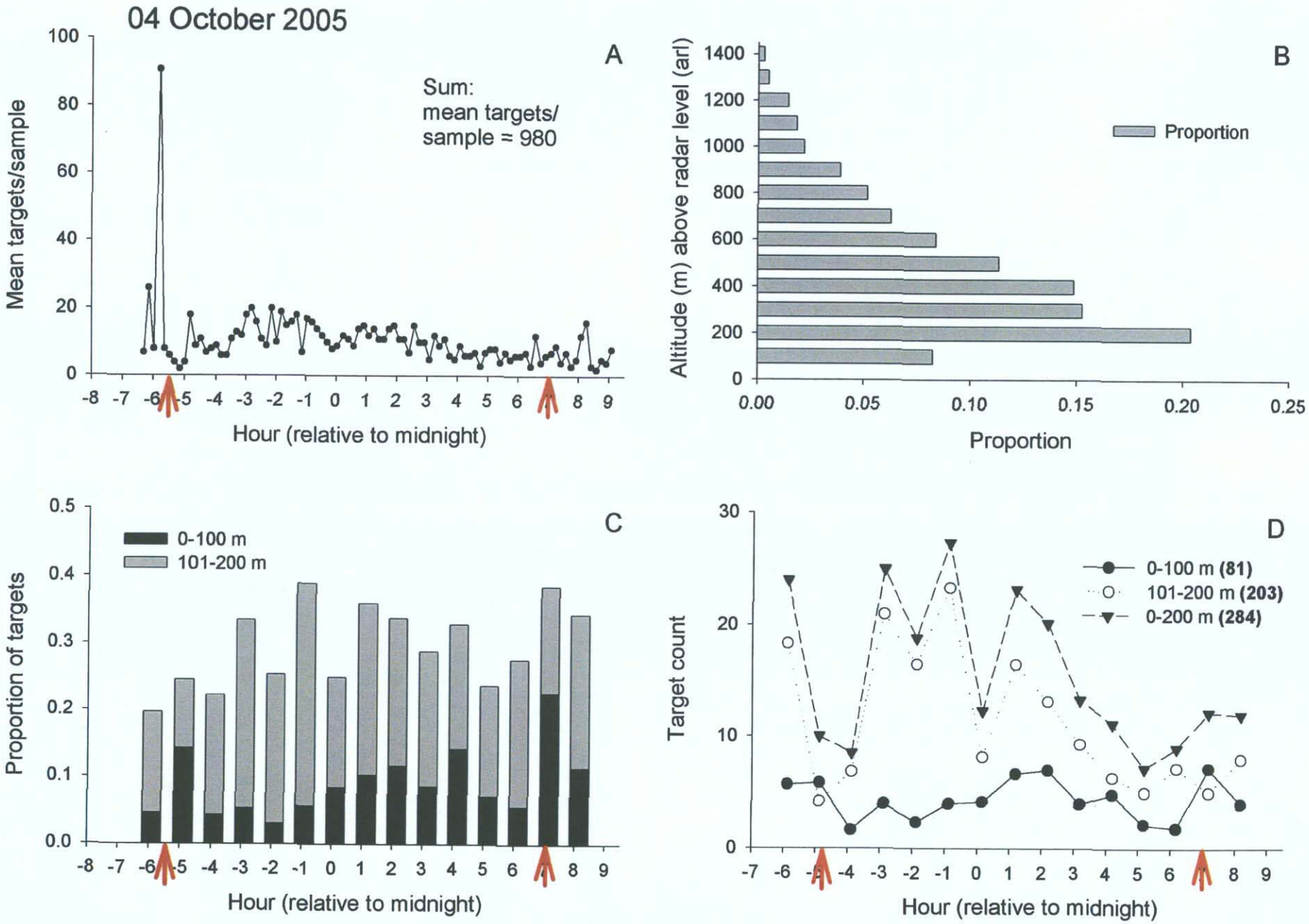

29 September 2005
A
Sum:
mean targets/
sample = 1,864
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (30)
101-200 m (176)
0-200 m (206)
Target count
Hour (relative to midnight)

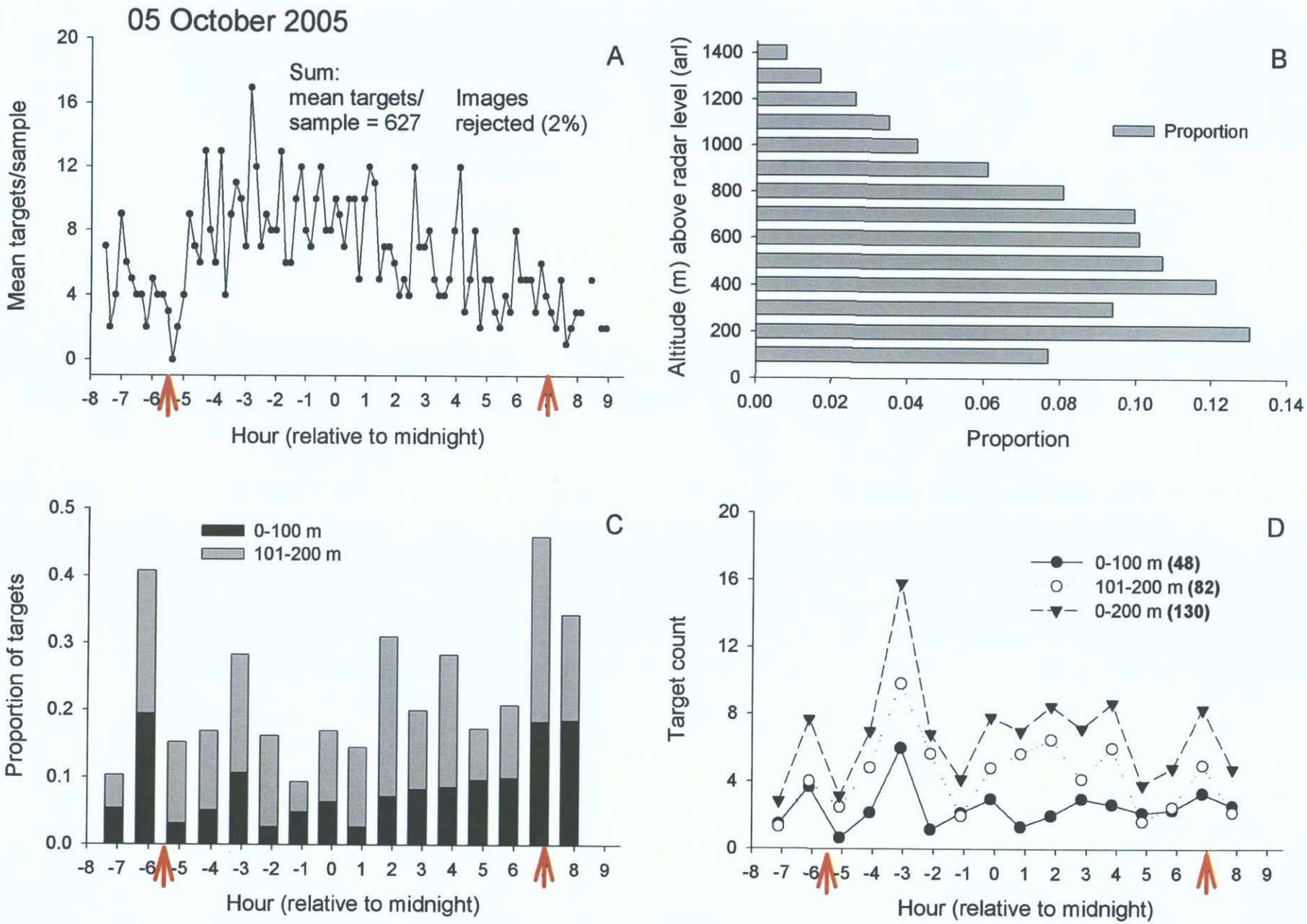

30 September 2005
A
Sum:
mean targets/
sample = 1,385
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (23)
101-200 m (117)
0-200 m (140)
Target count
Hour (relative to midnight)

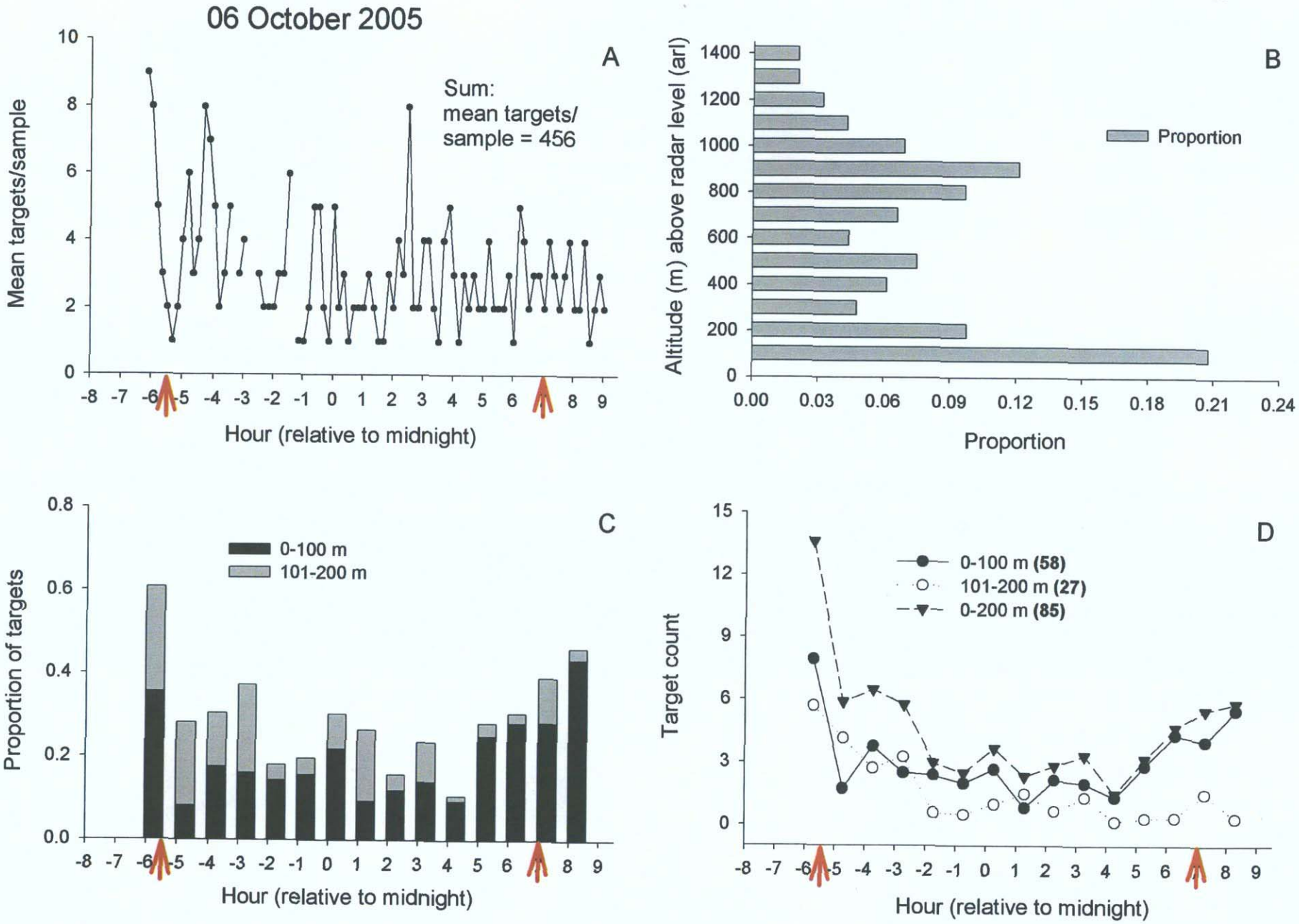

01 October 2005
A
Sum:
mean targets/
sample = 1,416
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (77)
101-200 m (133)
0-200 m (210)
Target count
Hour (relative to midnight)

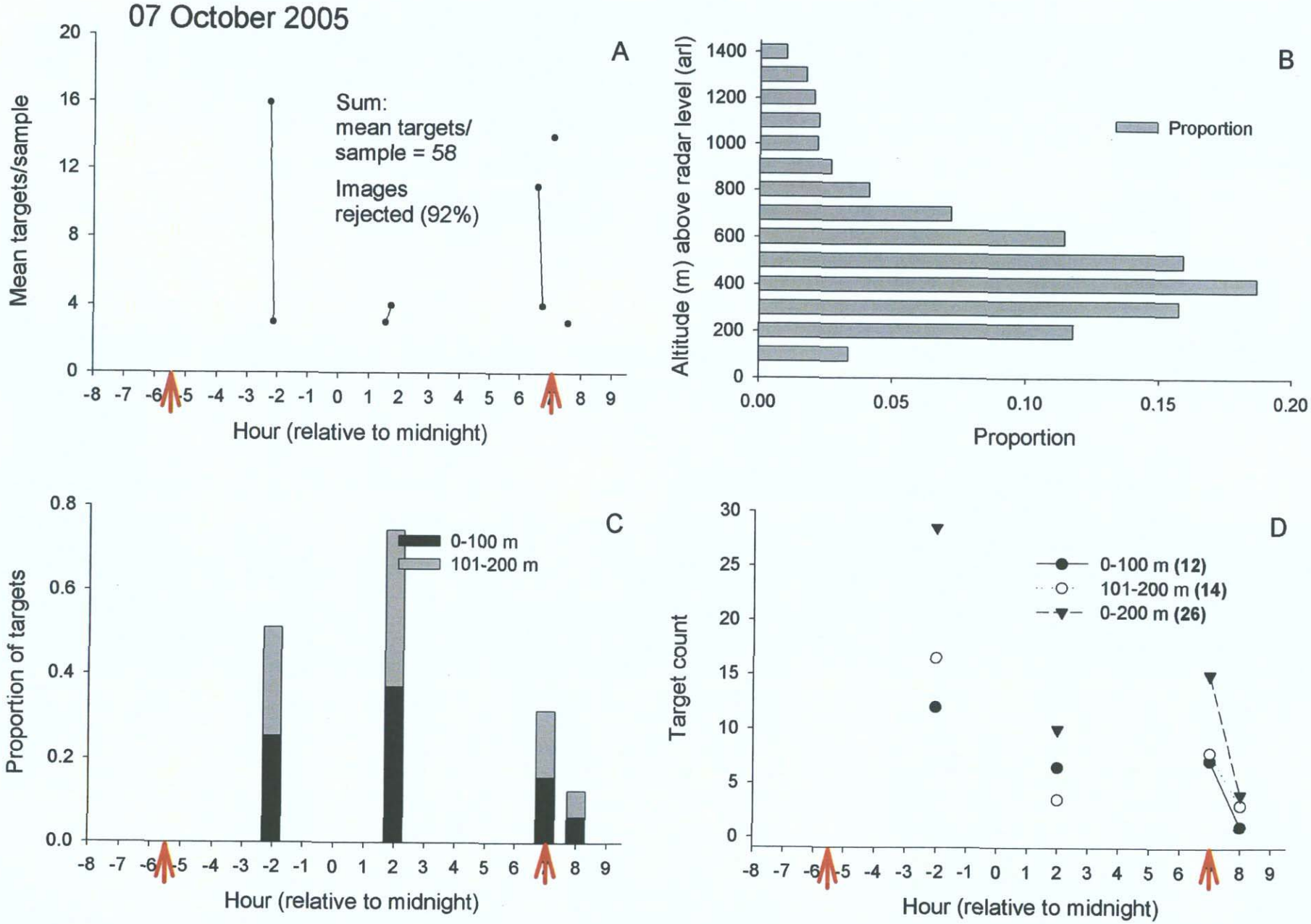

02 October 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 1,122
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (118)
101-200 m (193)
0-200 m (311)
Hour (relative to midnight)

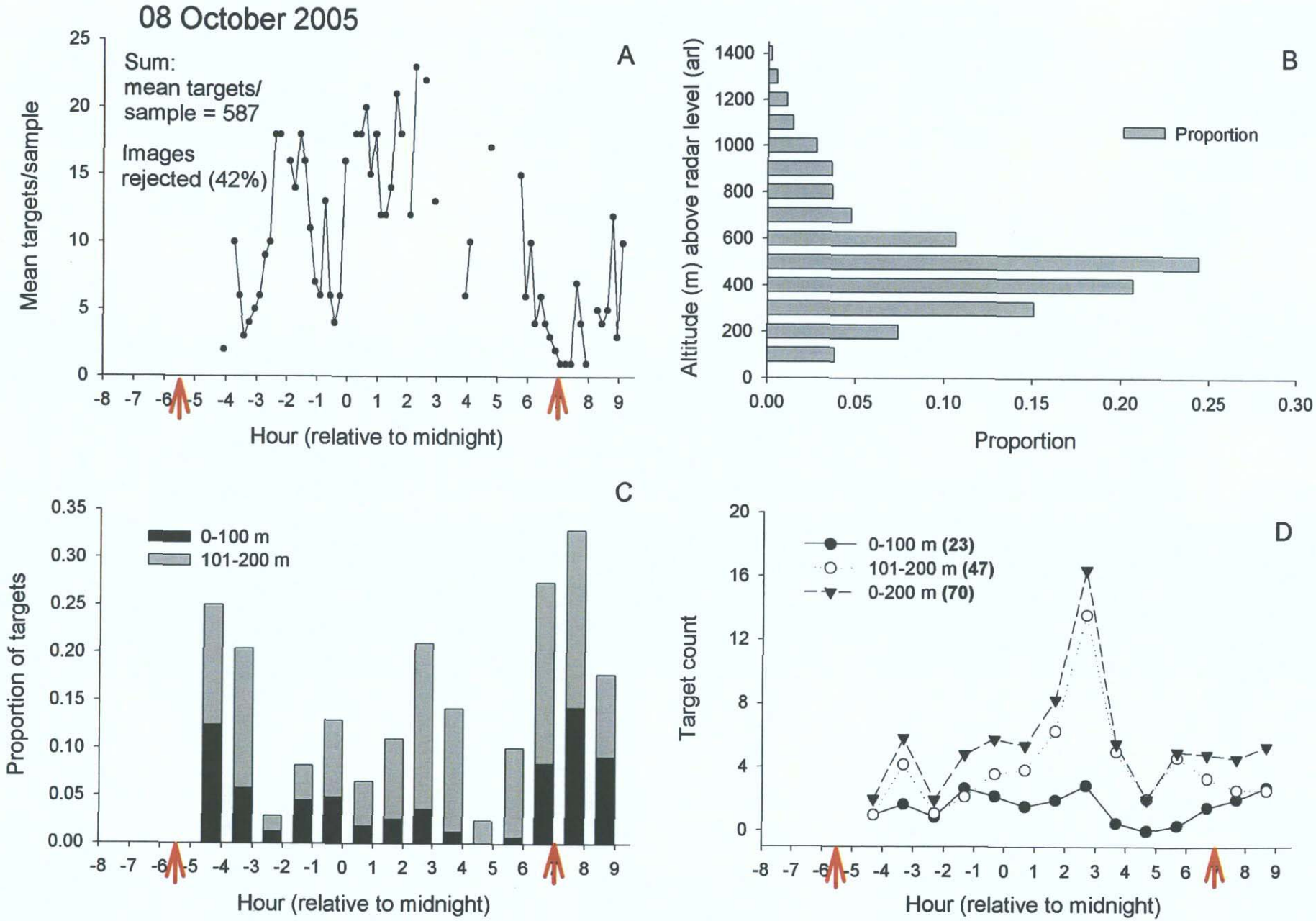

03 October 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 826
Images
rejected (34%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (130)
101-200 m (205)
0-200 m (335)
Hour (relative to midnight)

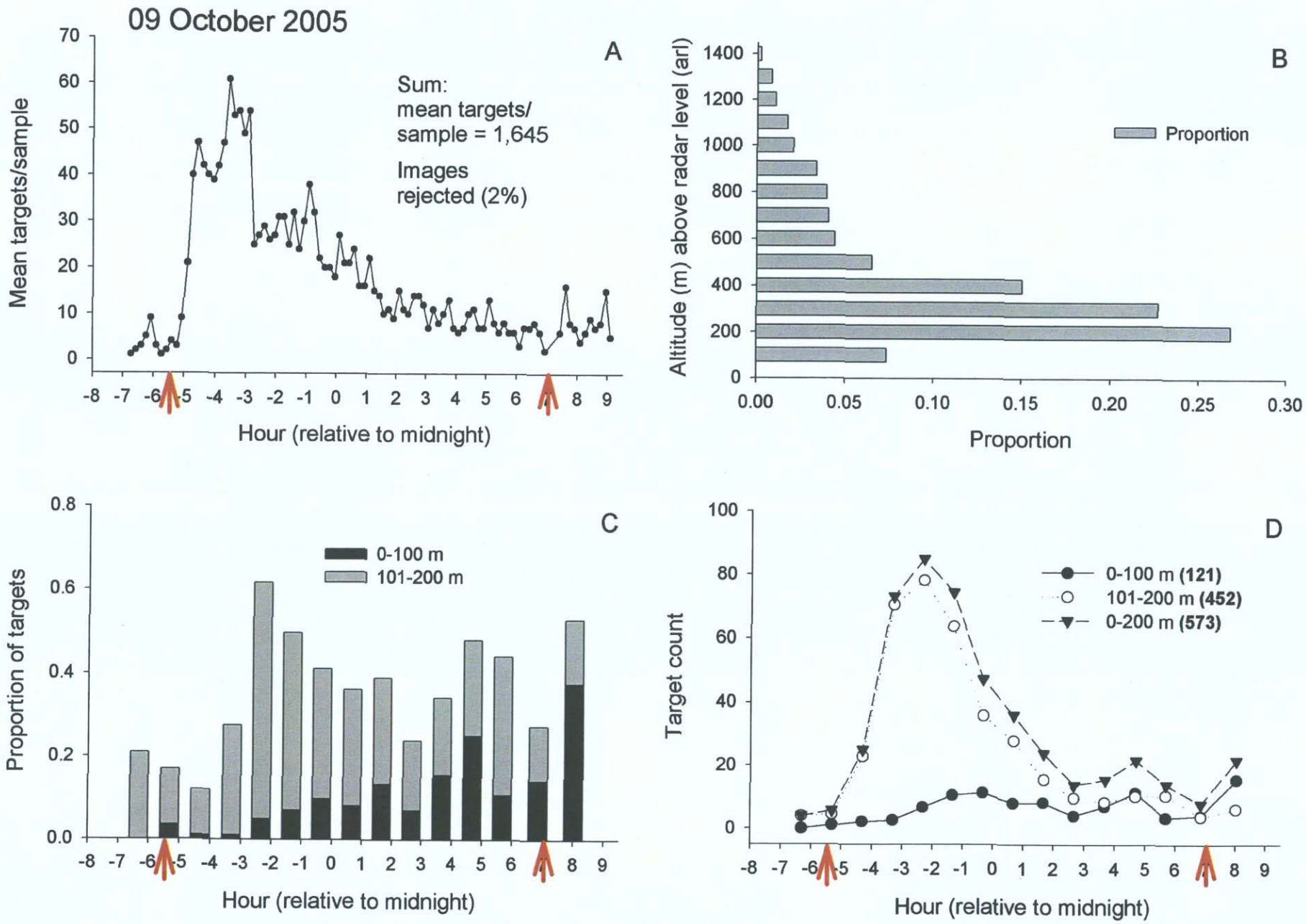

04 October 2005
A
Sum:
mean targets/
sample = 980
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (81)
101-200 m (203)
0-200 m (284)
Target count
Hour (relative to midnight)

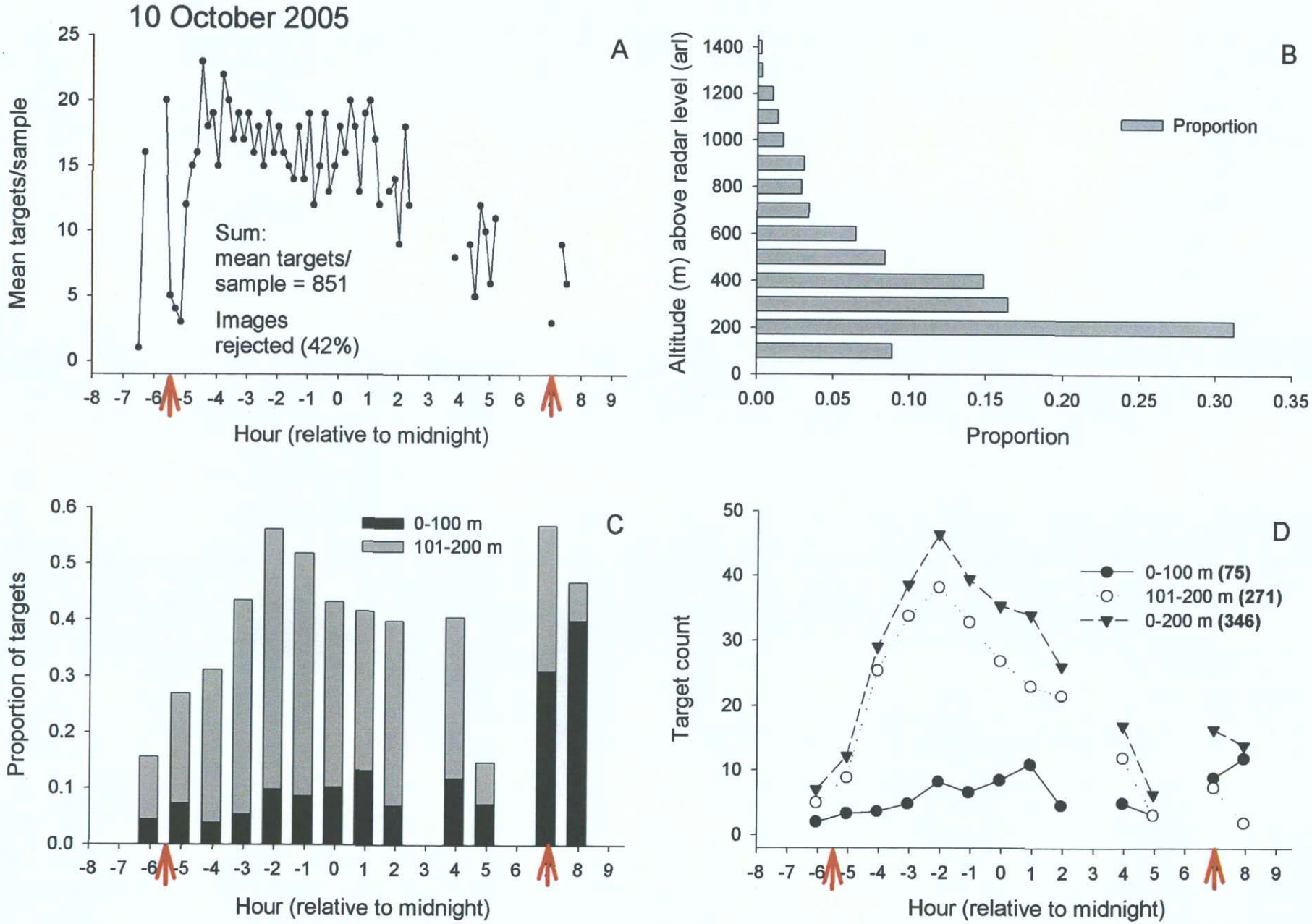

05 October 2005
A
Sum:
mean targets/
sample = 627
Images
rejected (2%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (48)
101-200 m (82)
0-200 m (130)
Target count
Hour (relative to midnight)

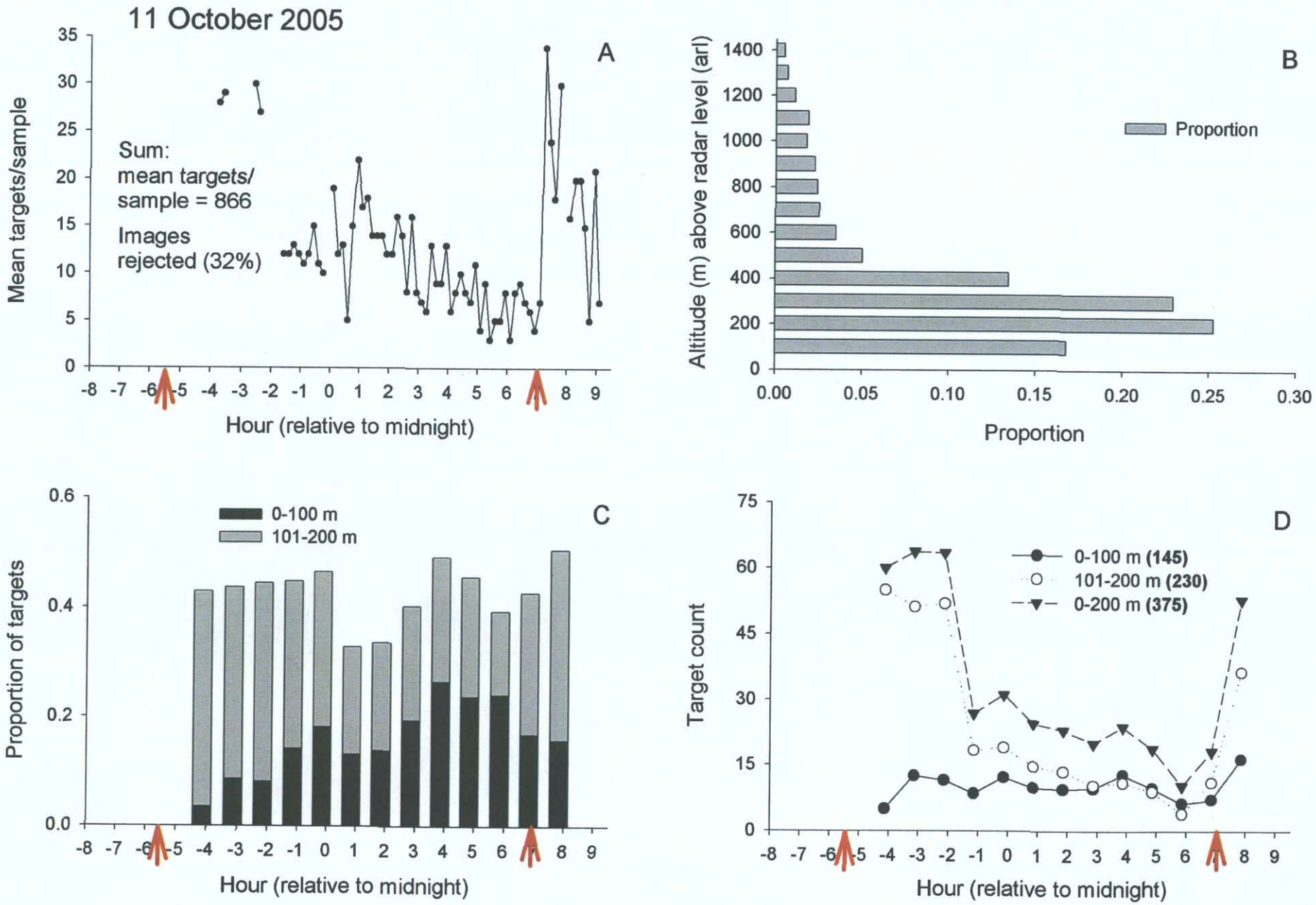

06 October 2005
A
Sum:
mean targets/
sample = 456
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (58)
101-200 m (27)
0-200 m (85)
Target count
Hour (relative to midnight)

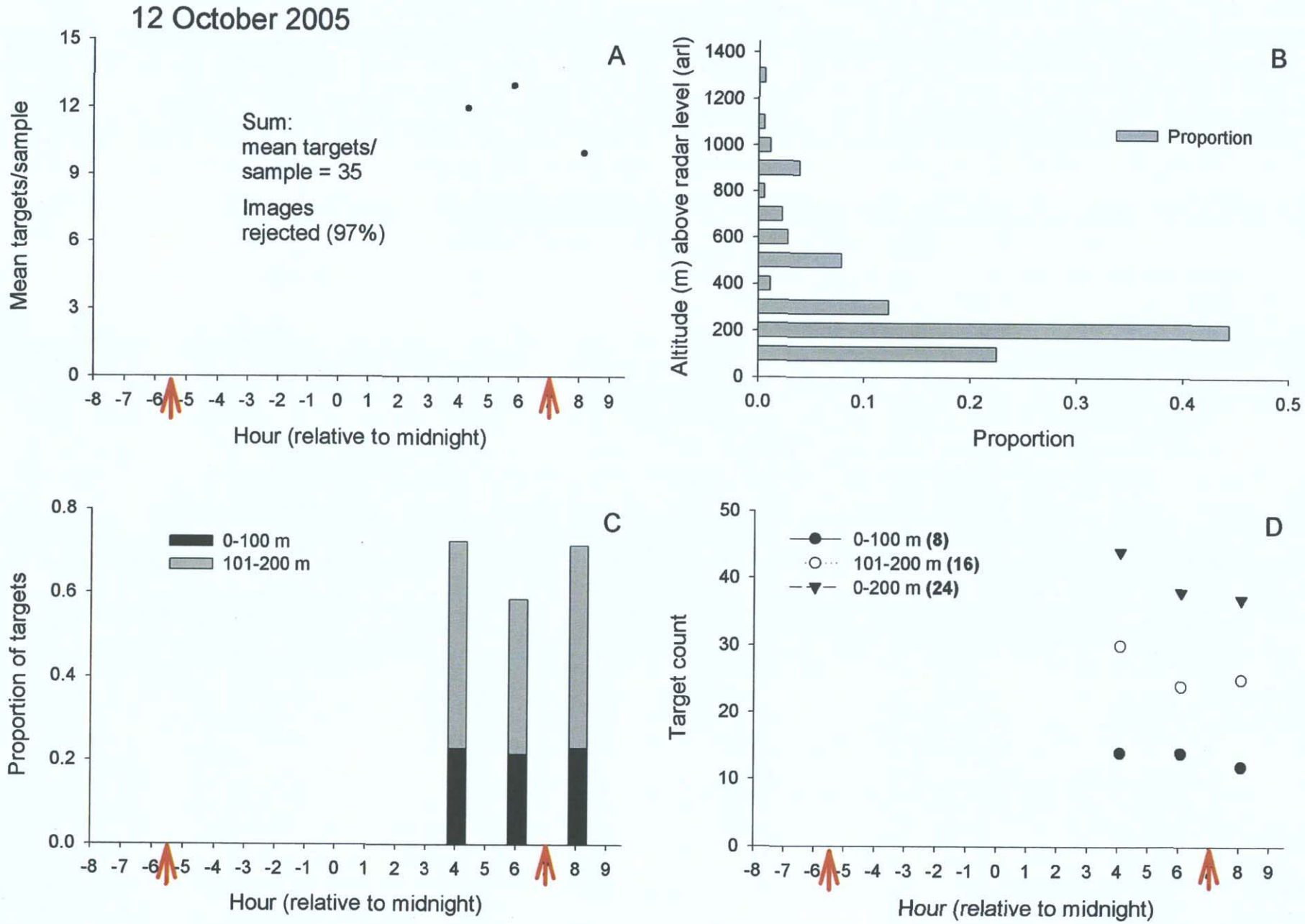

07 October 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 58
Images
rejected (92%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (12)
101-200 m (14)
0-200 m (26)
Hour (relative to midnight)

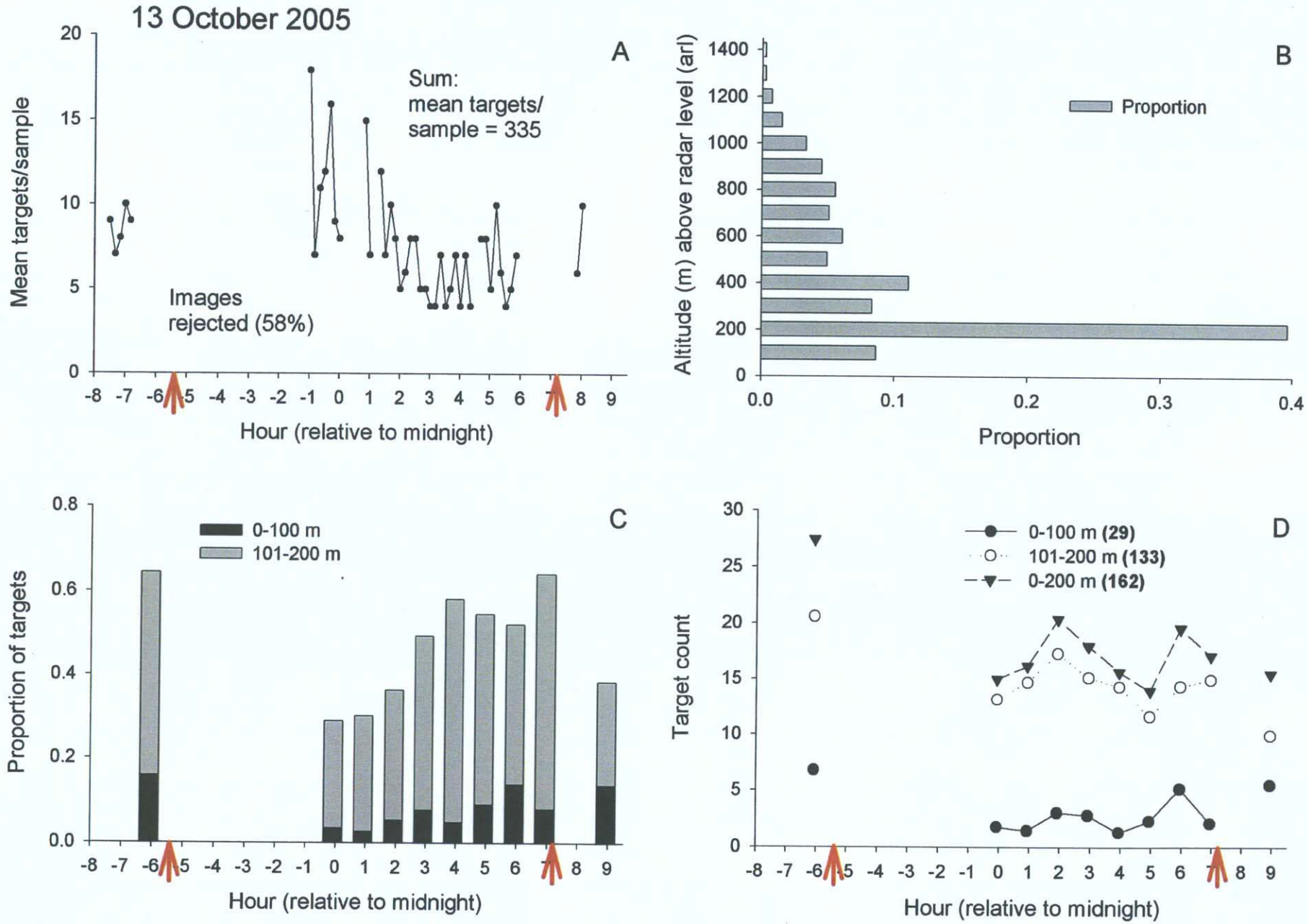

08 October 2005
A
Sum:
mean targets/
sample = 587
Images
rejected (42%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (23)
101-200 m (47)
0-200 m (70)
Target count
Hour (relative to midnight)

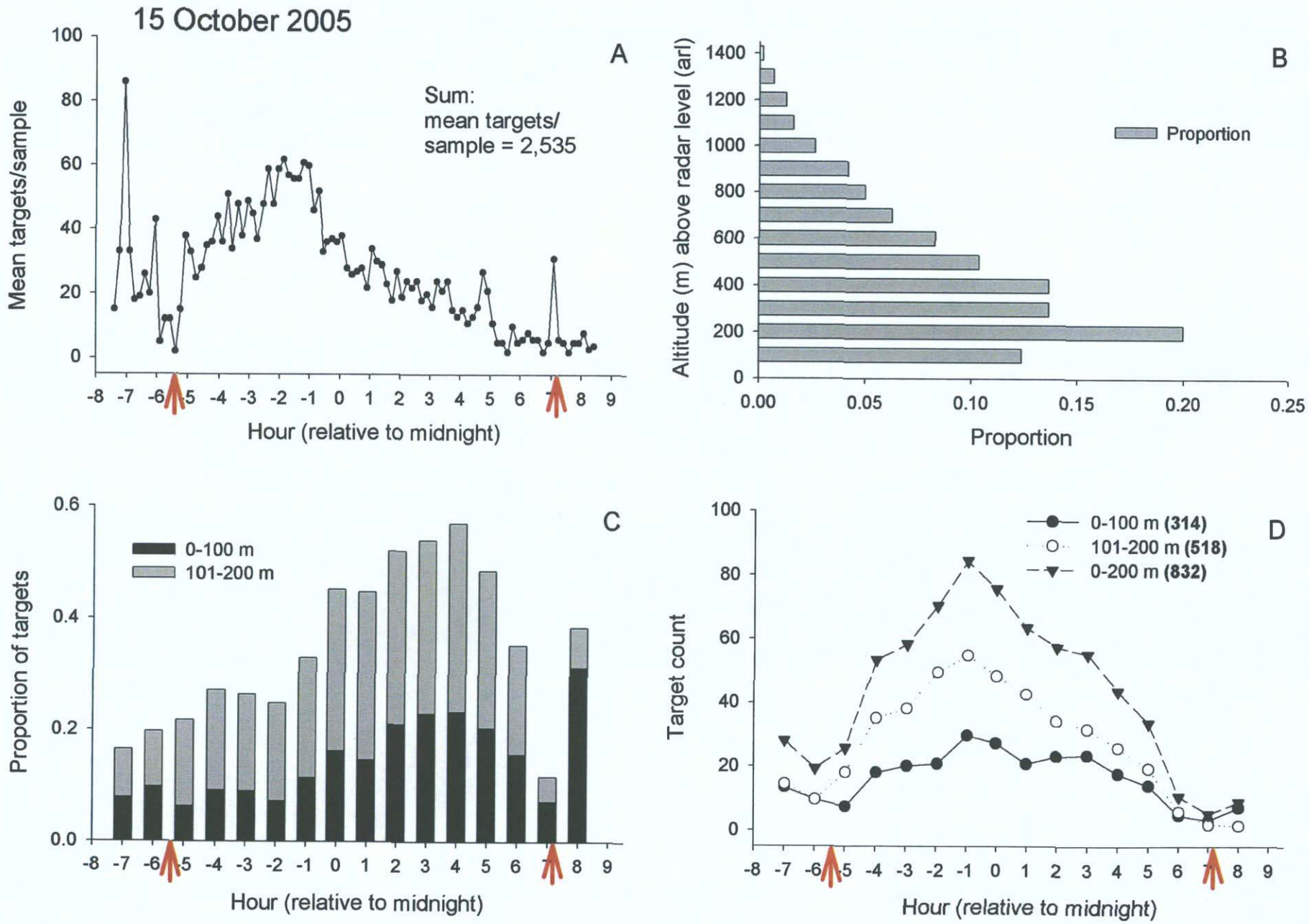

09 October 2005
A
Sum:
mean targets/
sample = 1,645
Images
rejected (2%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (121)
101-200 m (452)
0-200 m (573)
Target count
Hour (relative to midnight)

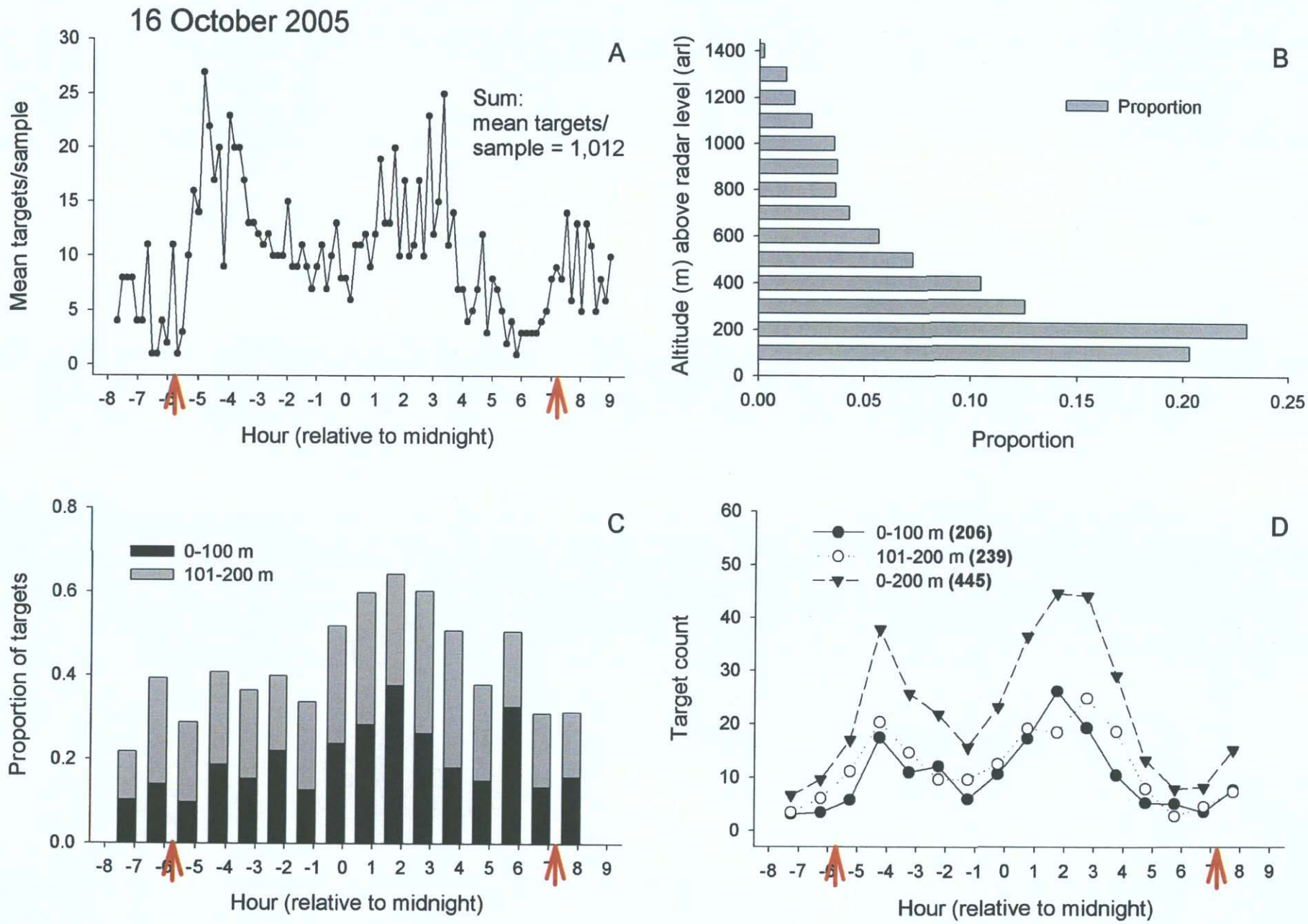

10 October 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 851
Images
rejected (42%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (75)
101-200 m (271)
0-200 m (346)
Hour (relative to midnight)

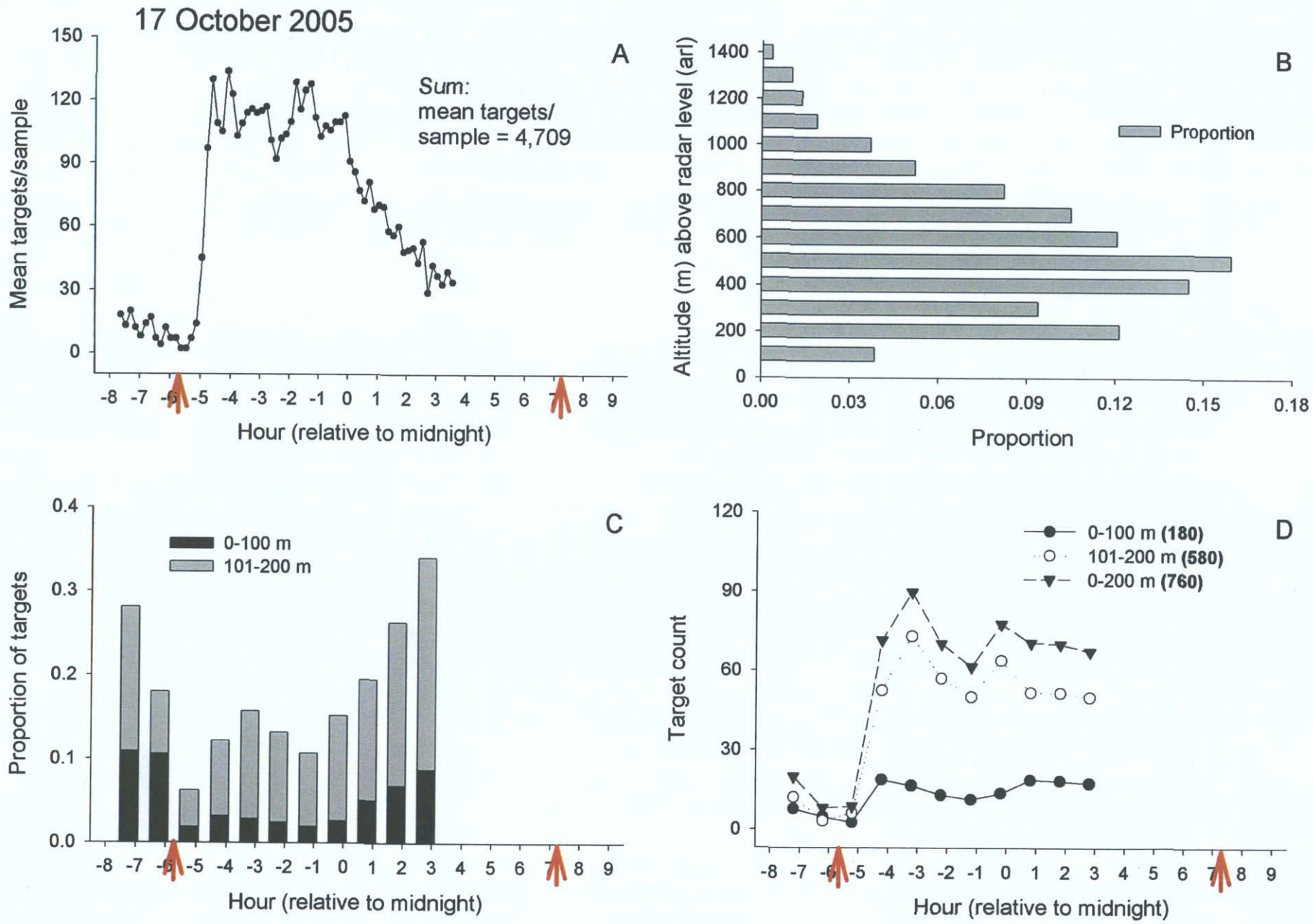

11 October 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 866
Images
rejected (32%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (145)
101-200 m (230)
0-200 m (375)
Target count
Hour (relative to midnight)

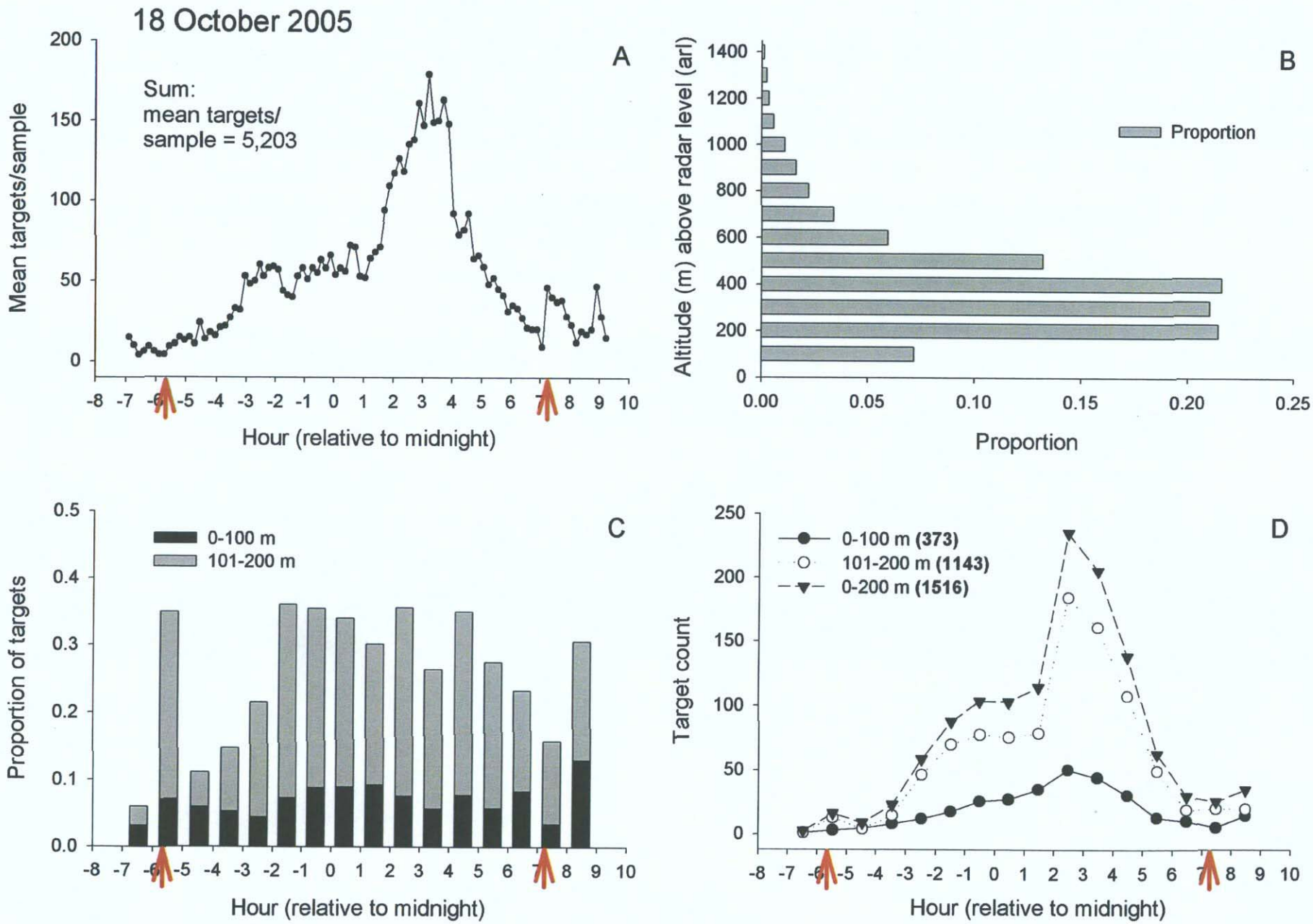

12 October 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 35
Images
rejected (97%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (8)
101-200 m (16)
0-200 m (24)
Hour (relative to midnight)

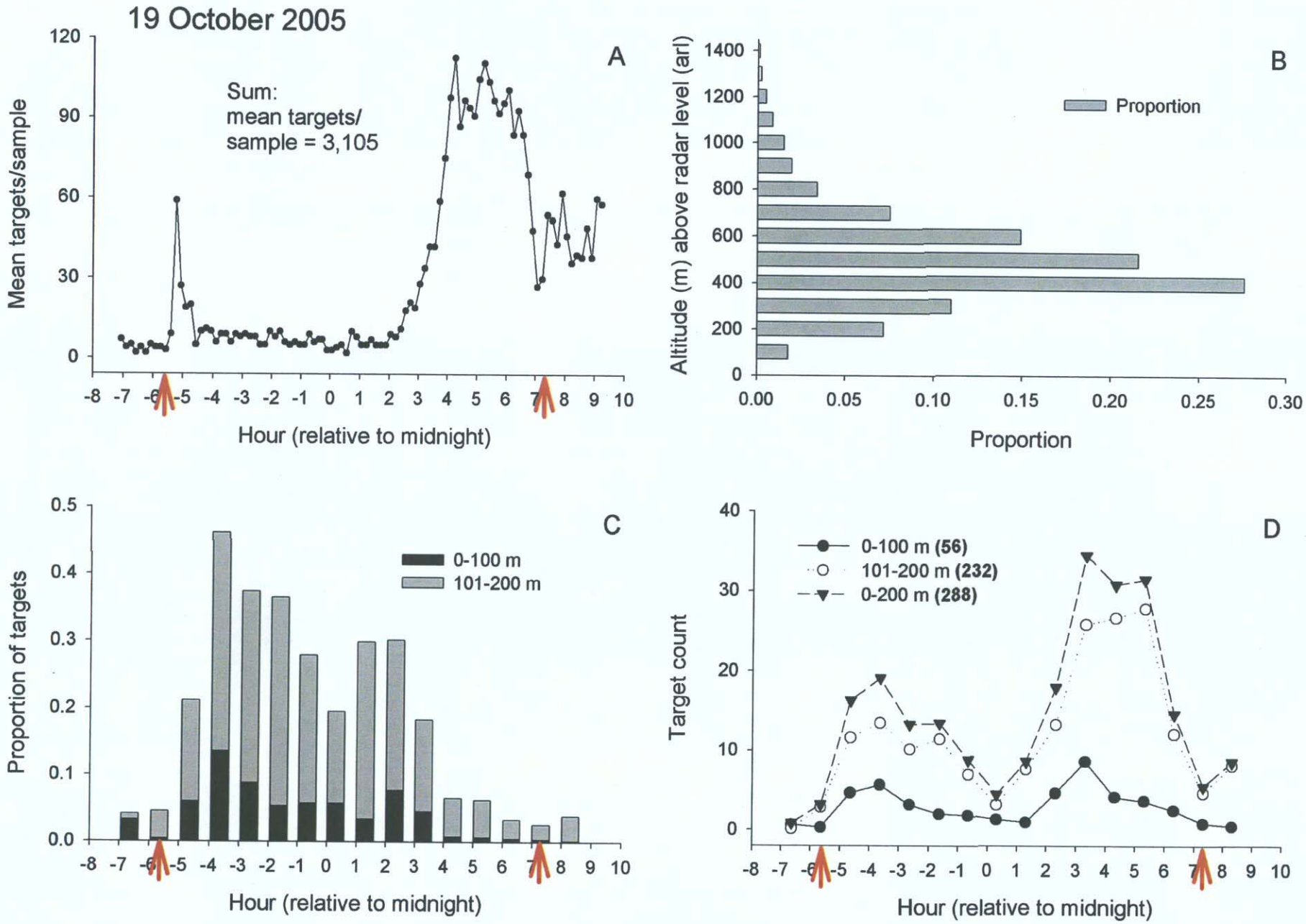

13 October 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 335
Images
rejected (58%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (29)
101-200 m (133)
0-200 m (162)
Hour (relative to midnight)

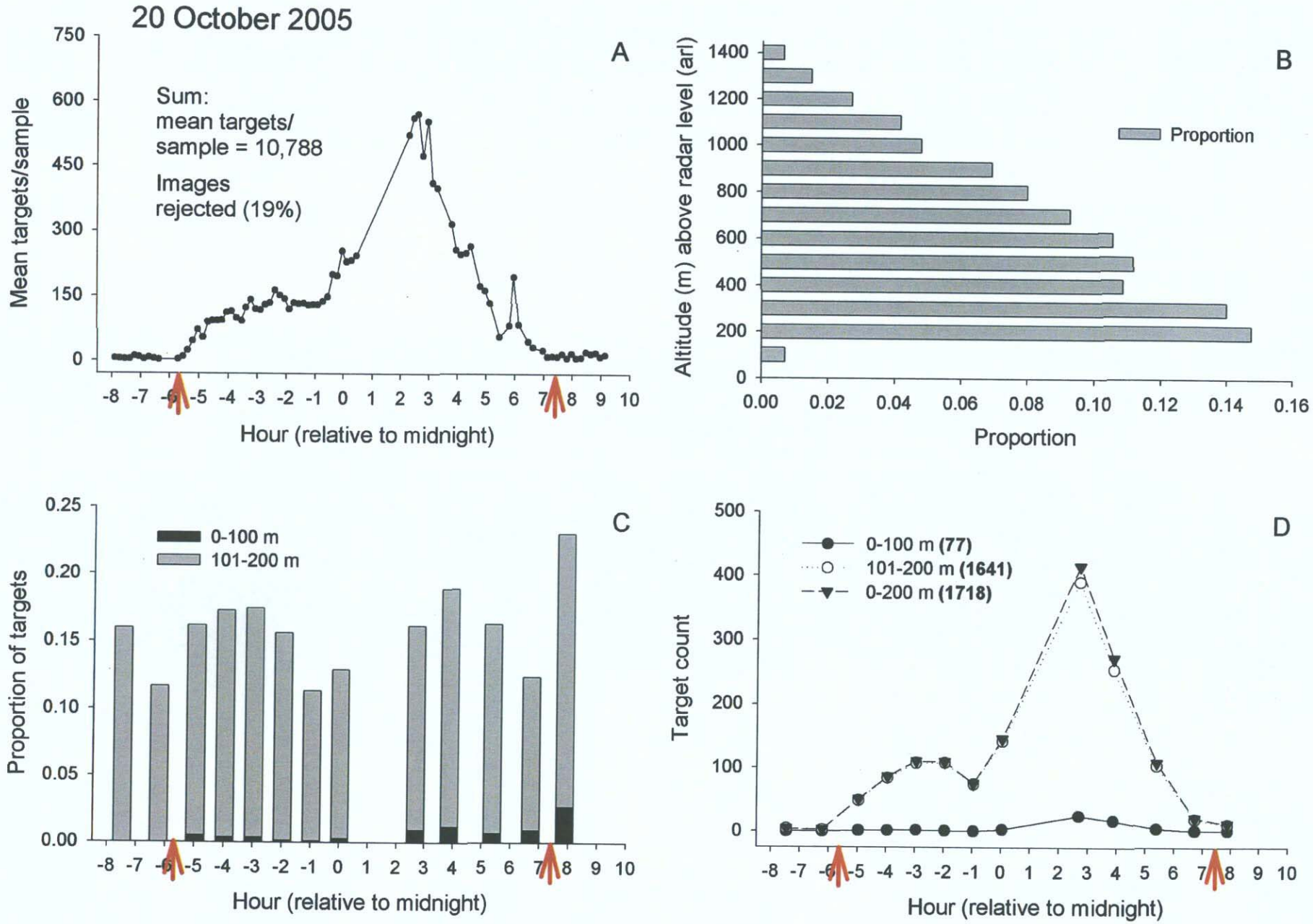

15 October 2005
A
Sum:
mean targets/
sample = 2,535
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (314)
101-200 m (518)
0-200 m (832)
Target count
Hour (relative to midnight)

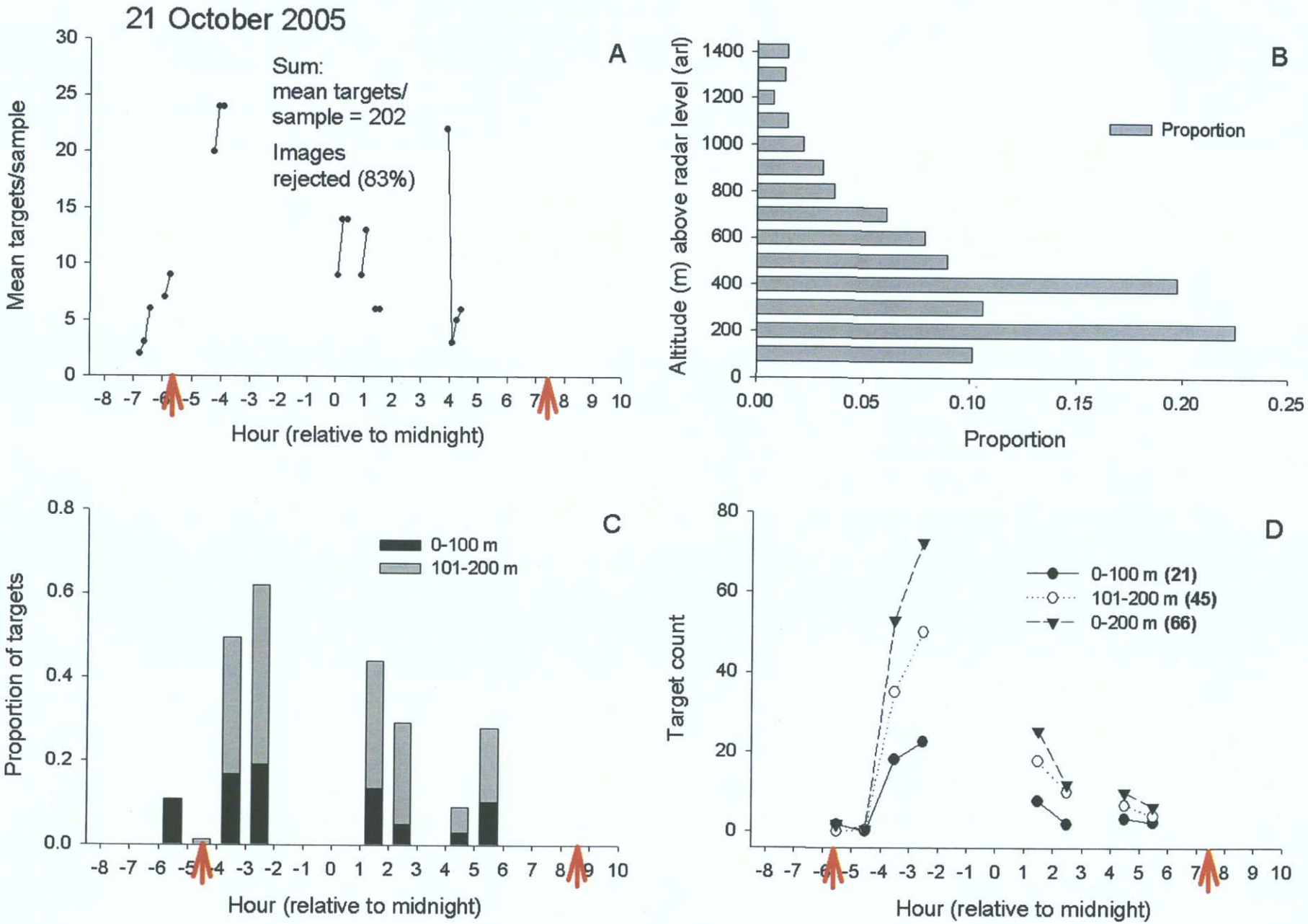

16 October 2005
A
Sum:
mean targets/
sample = 1,012
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (206)
101-200 m (239)
0-200 m (445)
Target count
Hour (relative to midnight)


17 October 2005
A
Sum:
mean targets/
sample = 4,709
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (180)
101-200 m (580)
0-200 m (760)
Target count
Hour (relative to midnight)

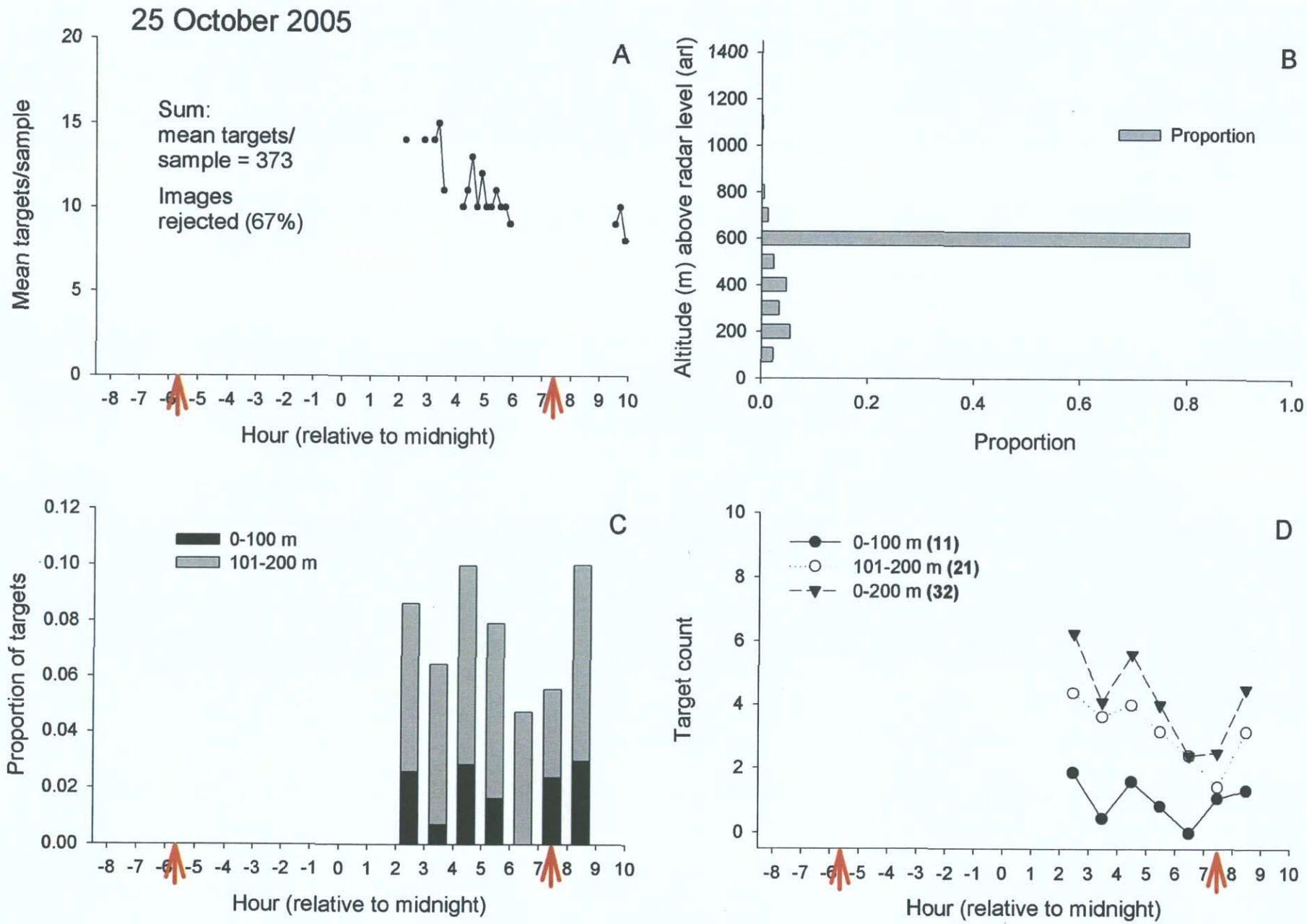

18 October 2005
A
Sum:
mean targets/
sample = 5,203
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (373)
101-200 m (1143)
0-200 m (1516)
Target count
Hour (relative to midnight)

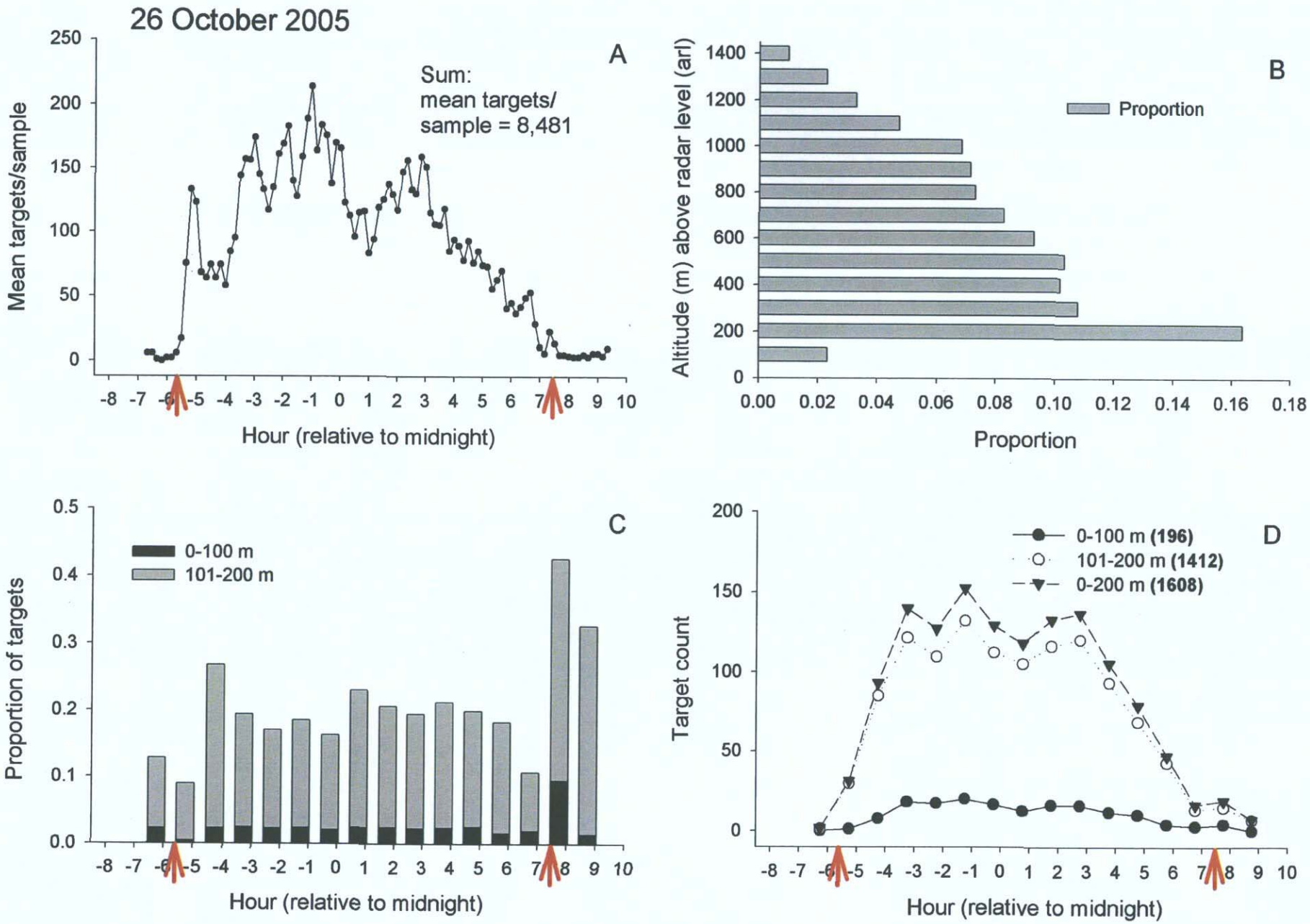

19 October 2005
A
Sum:
mean targets/
sample = 3,105
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (56)
101-200 m (232)
0-200 m (288)
Target count
Hour (relative to midnight)

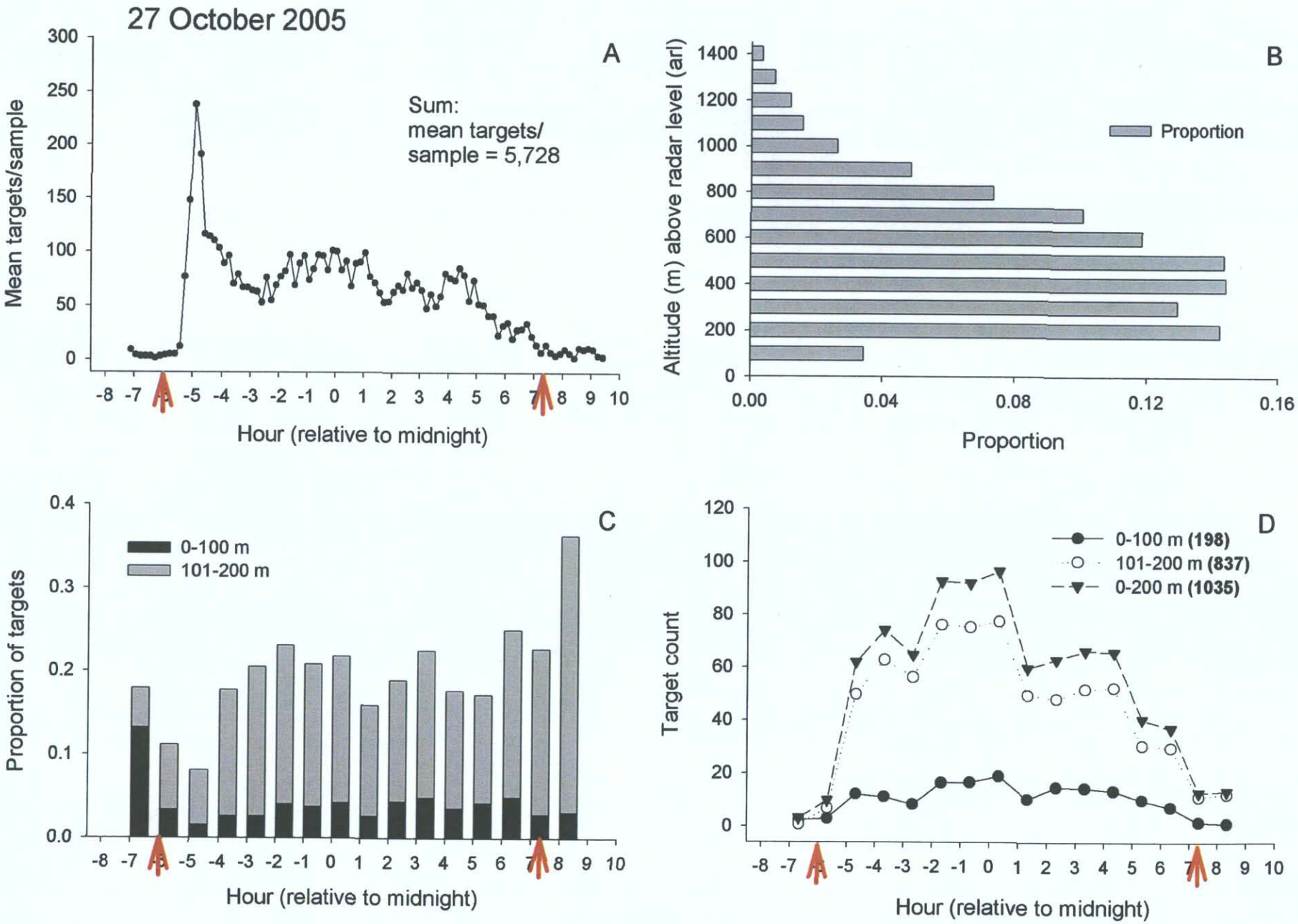

20 October 2005
A
Sum:
mean targets/
sample = 10,788
Images
rejected (19%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (77)
101-200 m (1641)
0-200 m (1718)
Target count
Hour (relative to midnight)

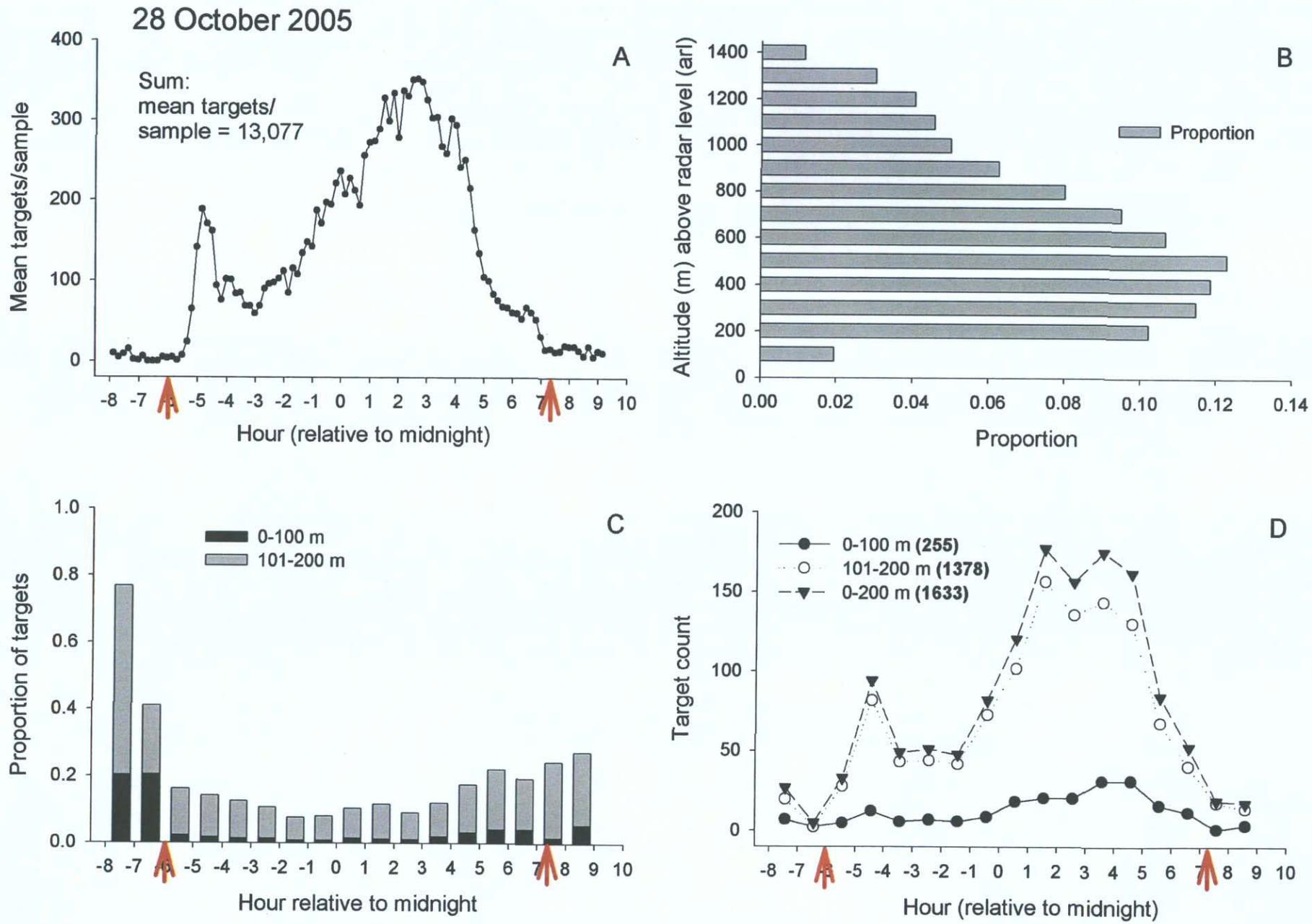

21 October 2005
A
Sum:
mean targets/
sample = 202
Images
rejected (83%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (21)
101-200 m (45)
0-200 m (66)
Target count
Hour (relative to midnight)

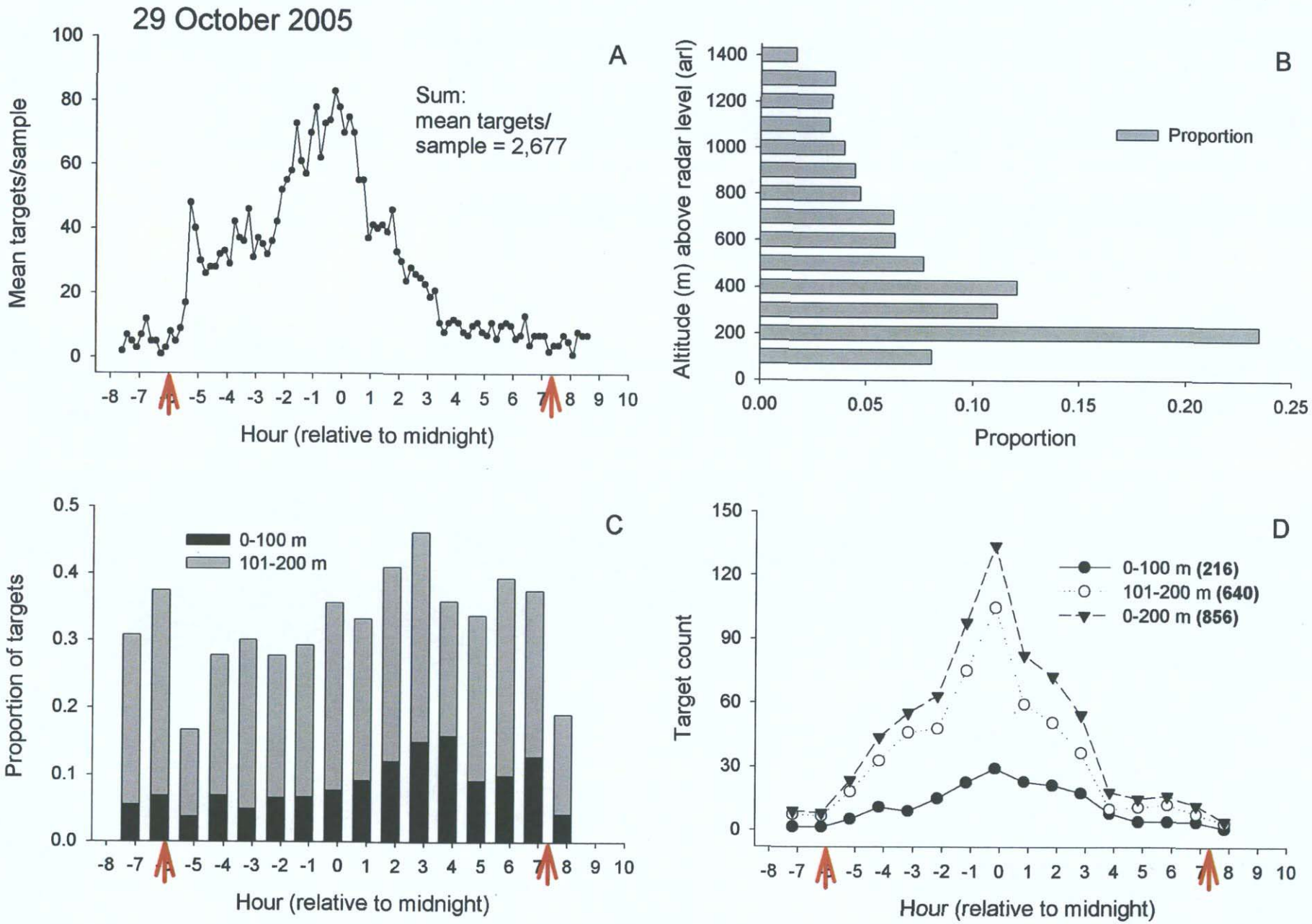
24 October 2005
No data
Rain throughout data collection period
1604 - 2354.
Power outage ended data collection 2354.
All rain until then.

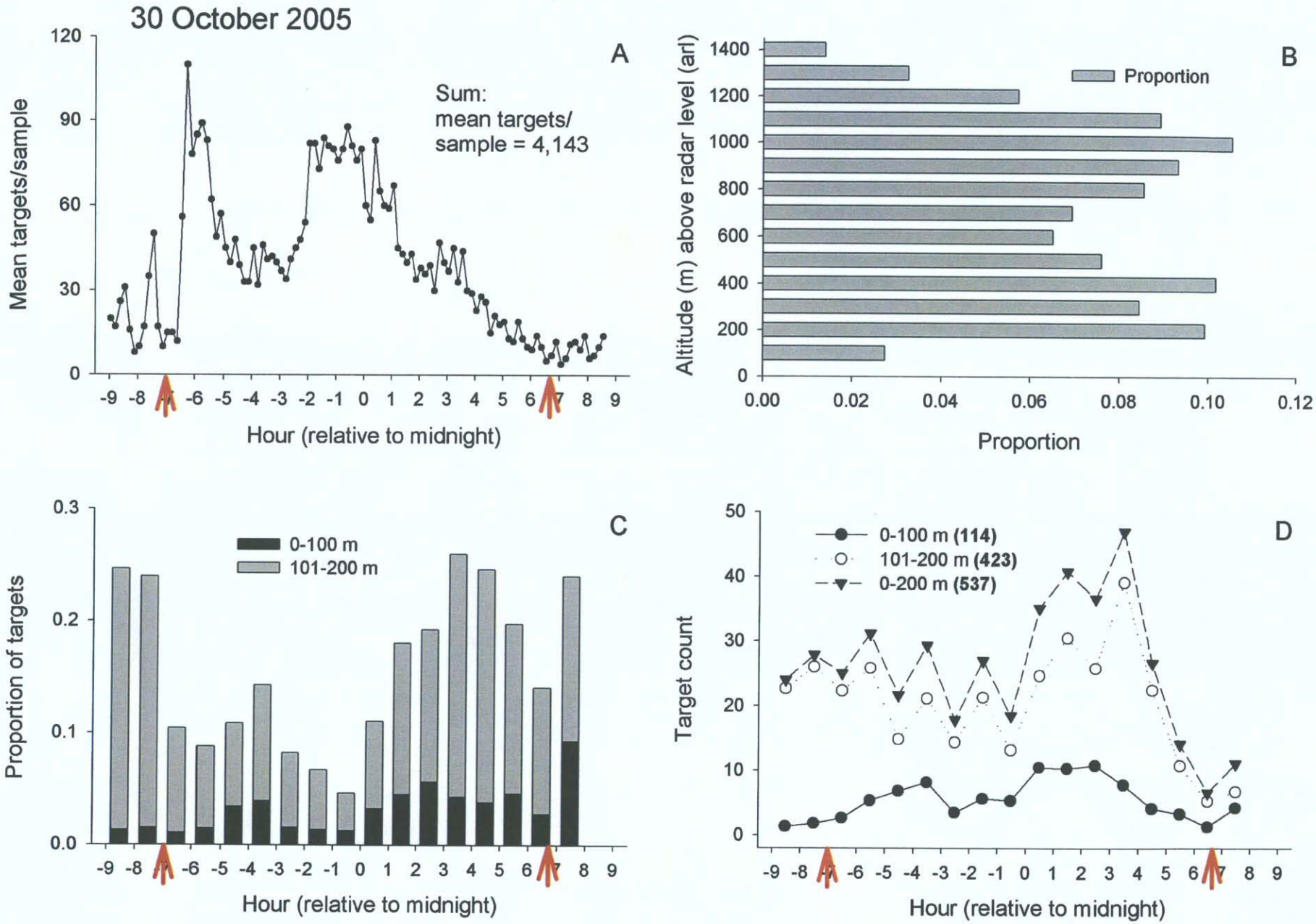

25 October 2005
A
Sum:
mean targets/
sample = 373
Images
rejected (67%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (11)
101-200 m (21)
0-200 m (32)
Target count
Hour (relative to midnight)

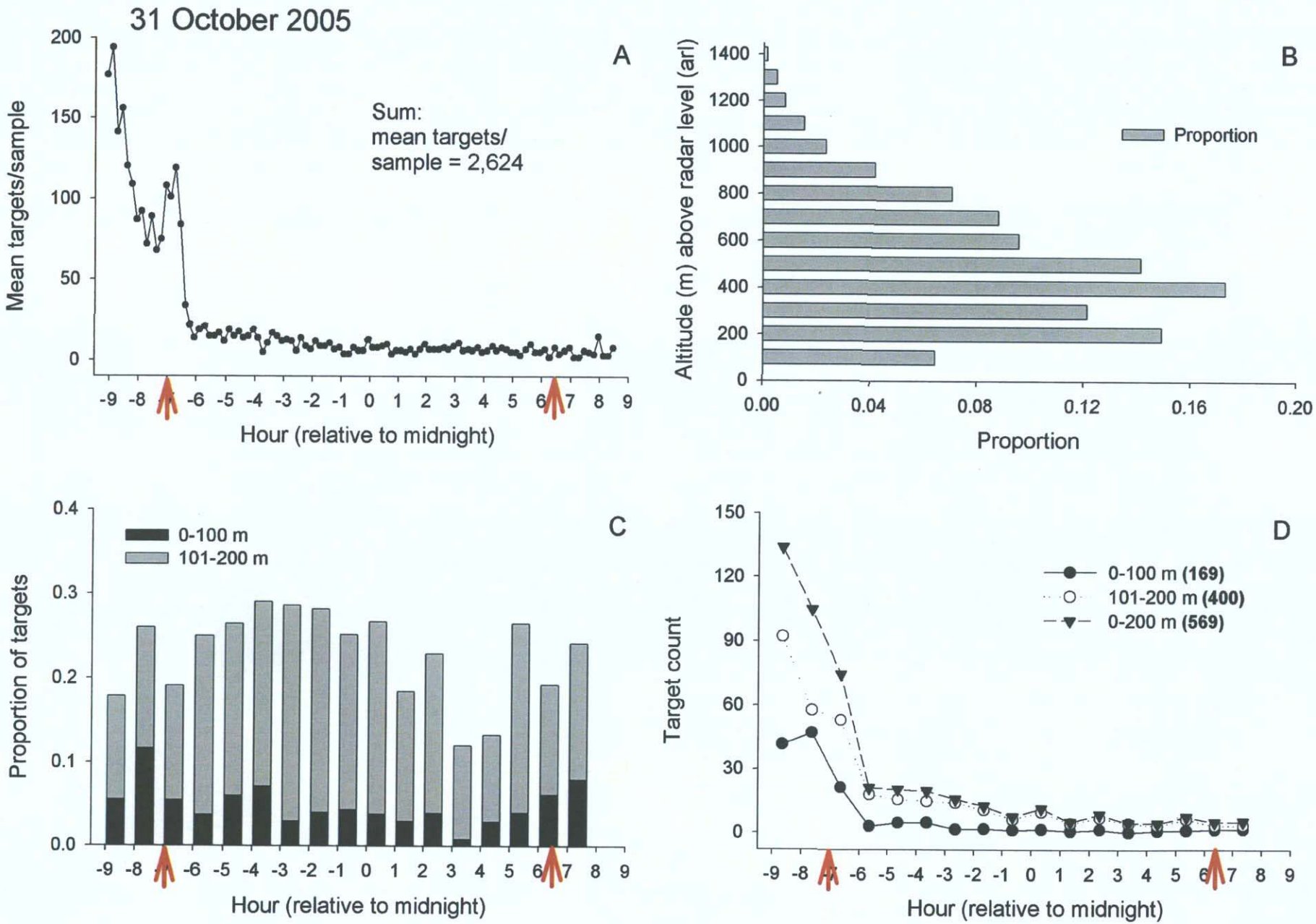

26 October 2005
A
Sum:
mean targets/
sample = 8,481
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (196)
101-200 m (1412)
0-200 m (1608)
Target count
Hour (relative to midnight)

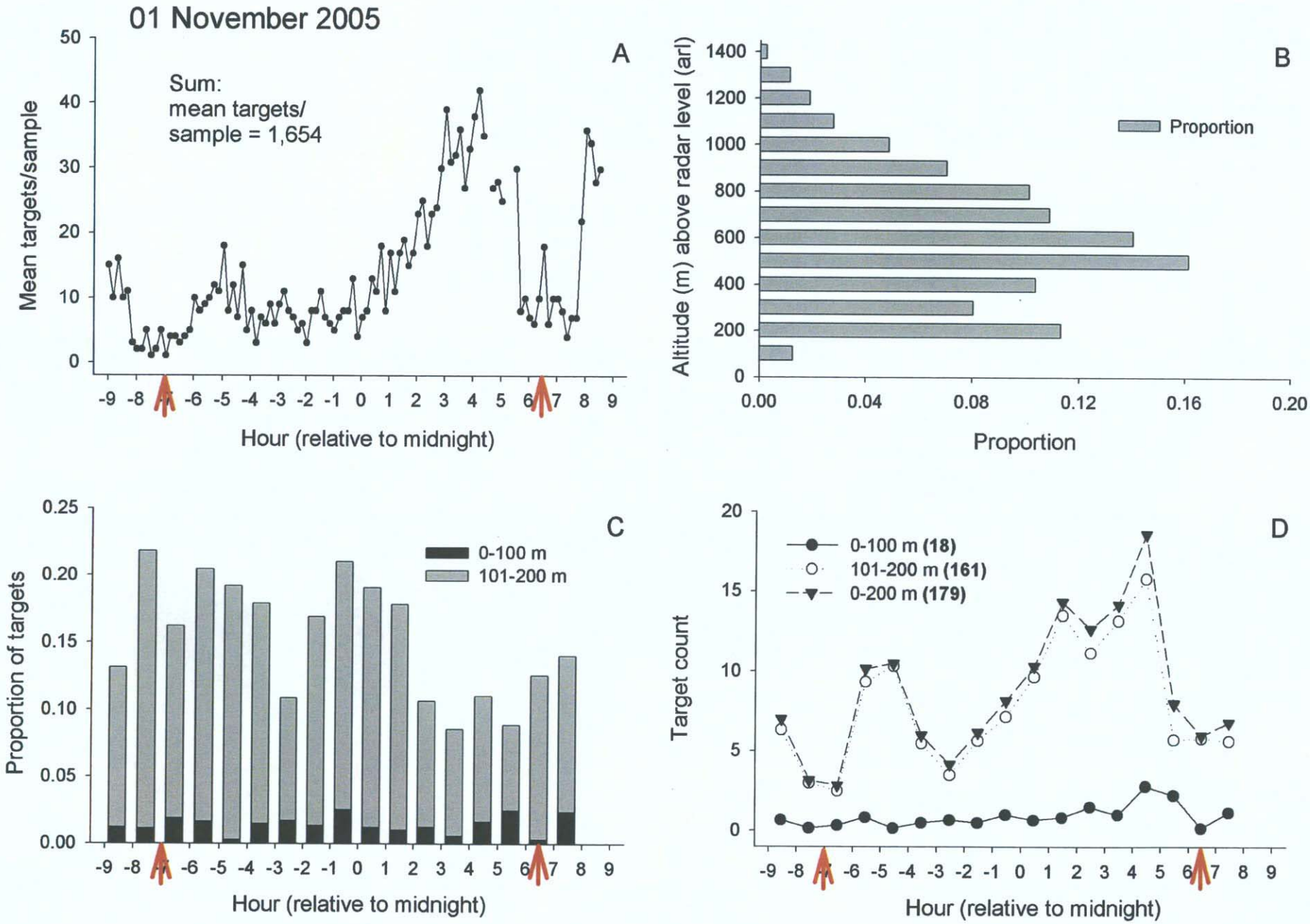

27 October 2005
A
Sum:
mean targets/
sample = 5,728
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (198)
101-200 m (837)
0-200 m (1035)
Target count
Hour (relative to midnight)

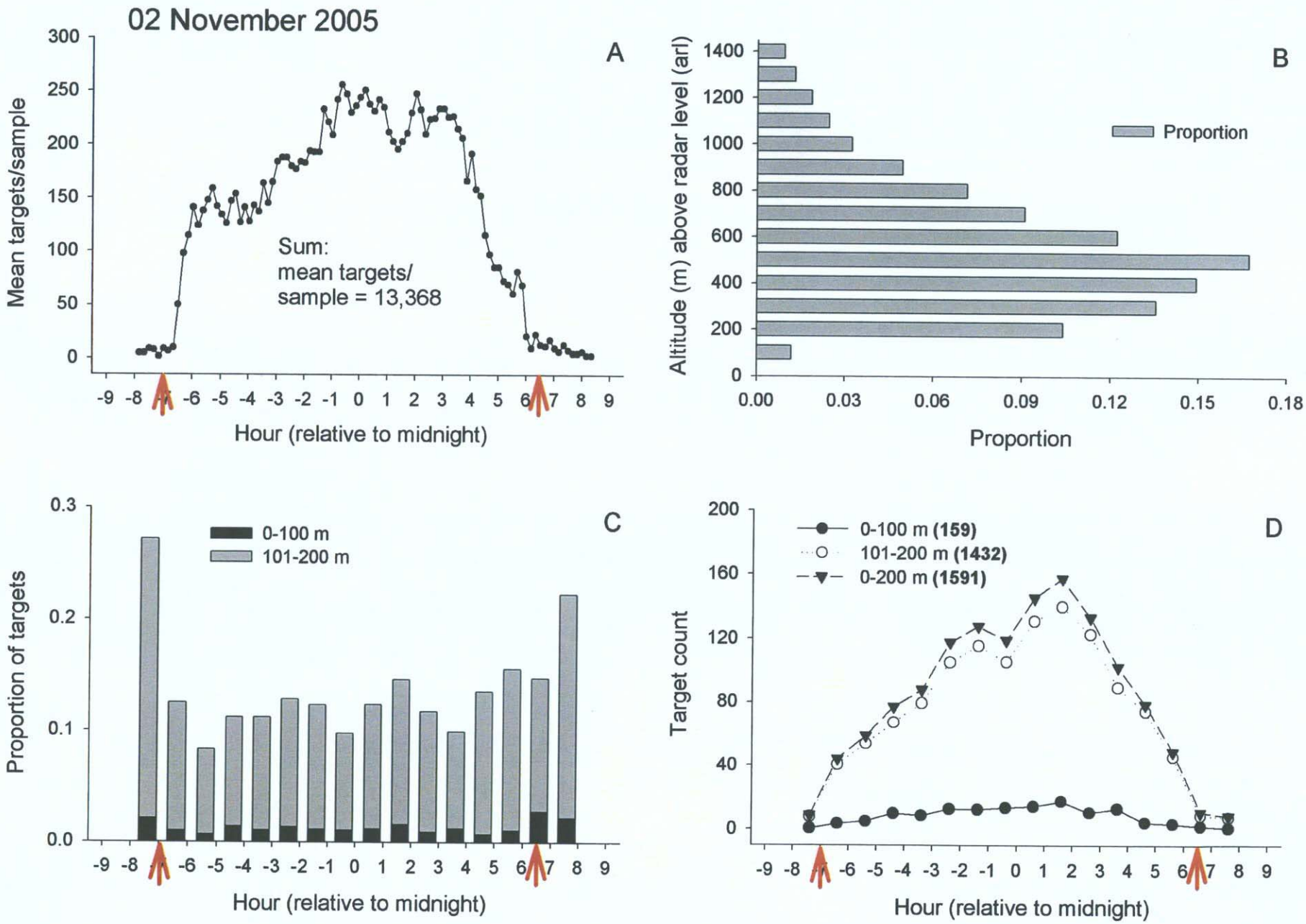

28 October 2005
A
Sum:
mean targets/
sample = 13,077
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (255)
101-200 m (1378)
0-200 m (1633)
Target count
Hour (relative to midnight)

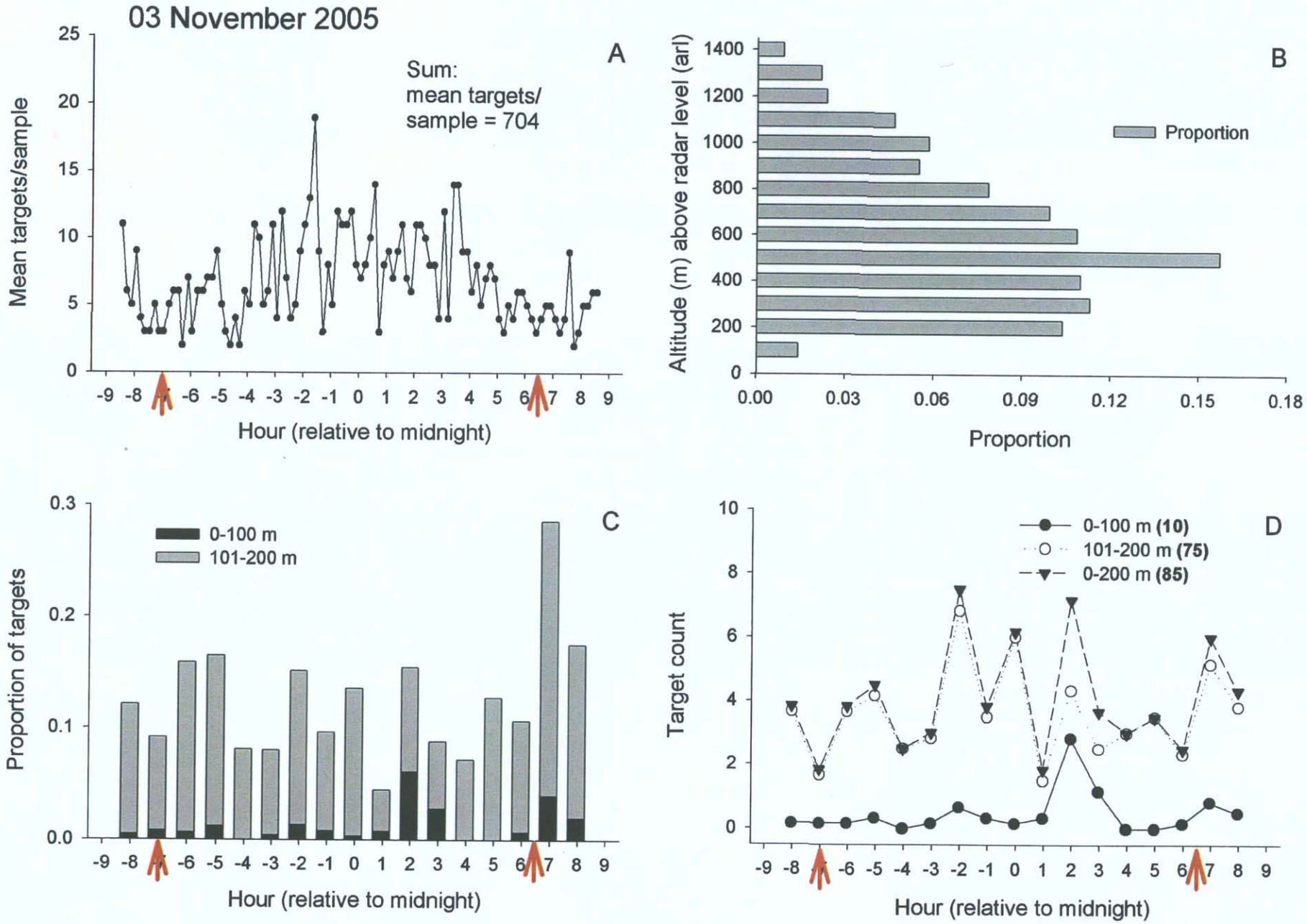

29 October 2005
A
Sum:
mean targets/
sample = 2,677
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (216)
101-200 m (640)
0-200 m (856)
Target count
Hour (relative to midnight)

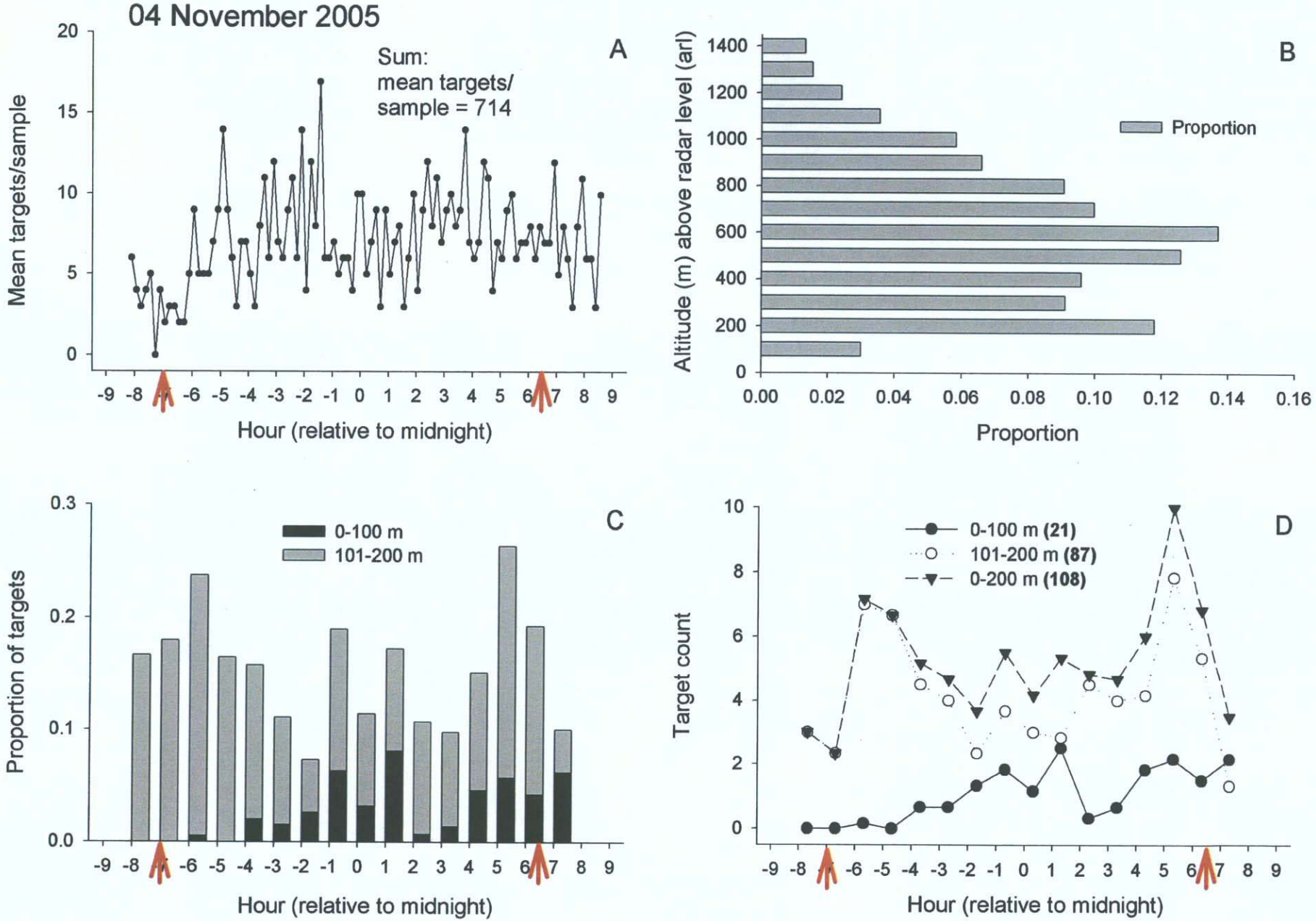

30 October 2005
A
Sum:
mean targets/
sample = 4,143
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (114)
101-200 m (423)
0-200 m (537)
Target count
Hour (relative to midnight)

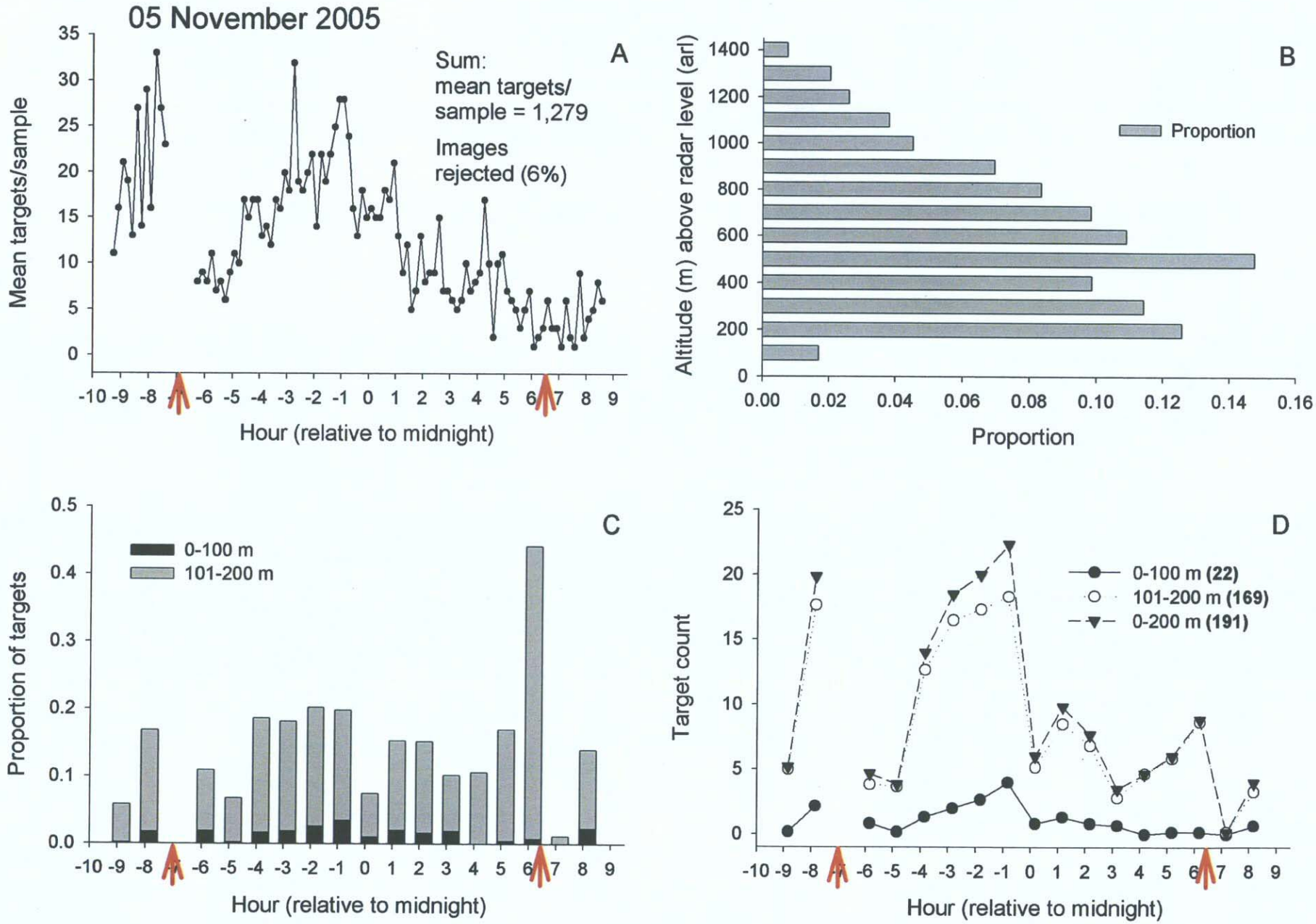

31 October 2005
A
Sum:
mean targets/
sample = 2,624
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (169)
101-200 m (400)
0-200 m (569)
Target count
Hour (relative to midnight)

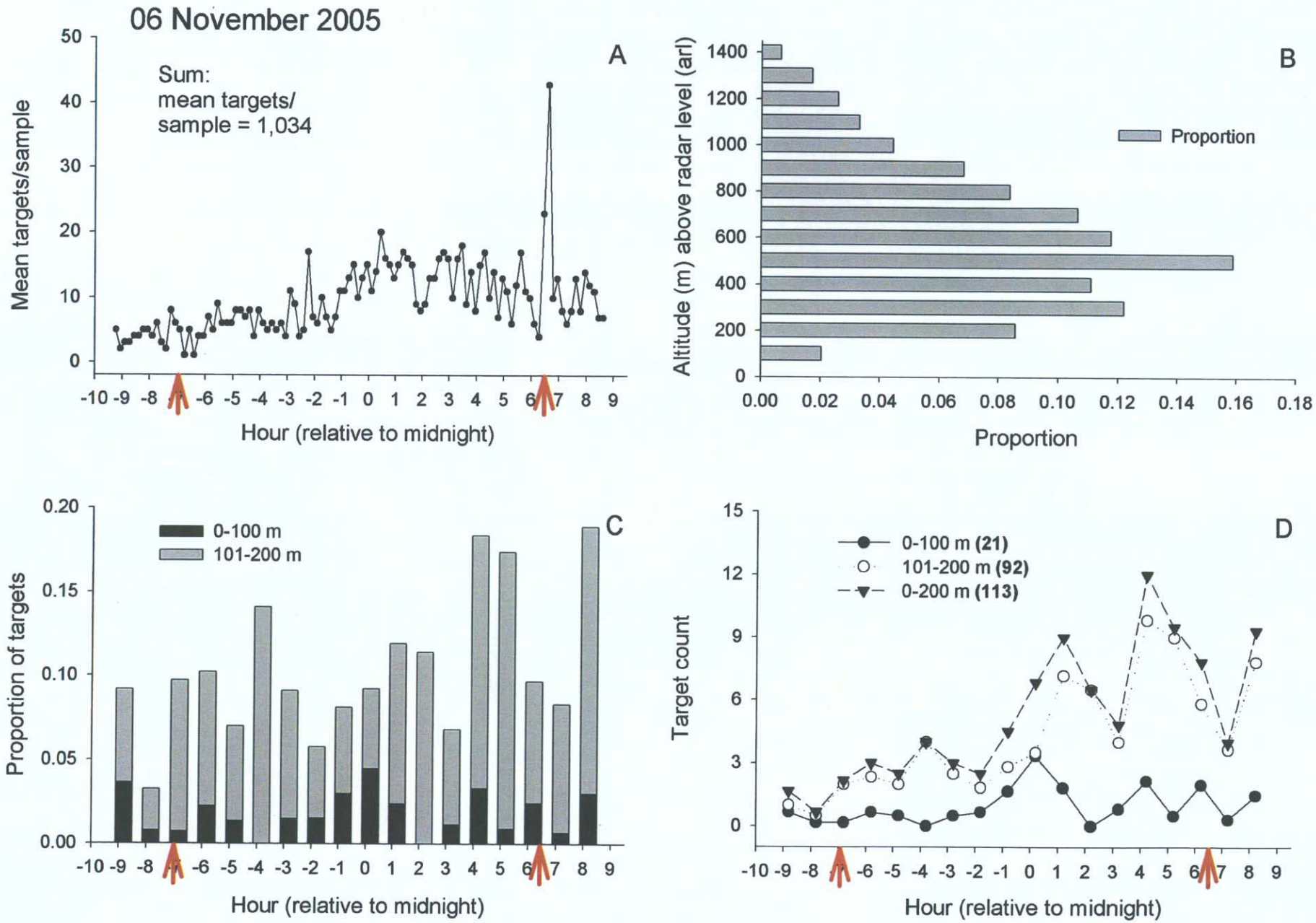

01 November 2005
A
Sum:
mean targets/
sample = 1,654
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (18)
101-200 m (161)
0-200 m (179)
Target count
Hour (relative to midnight)

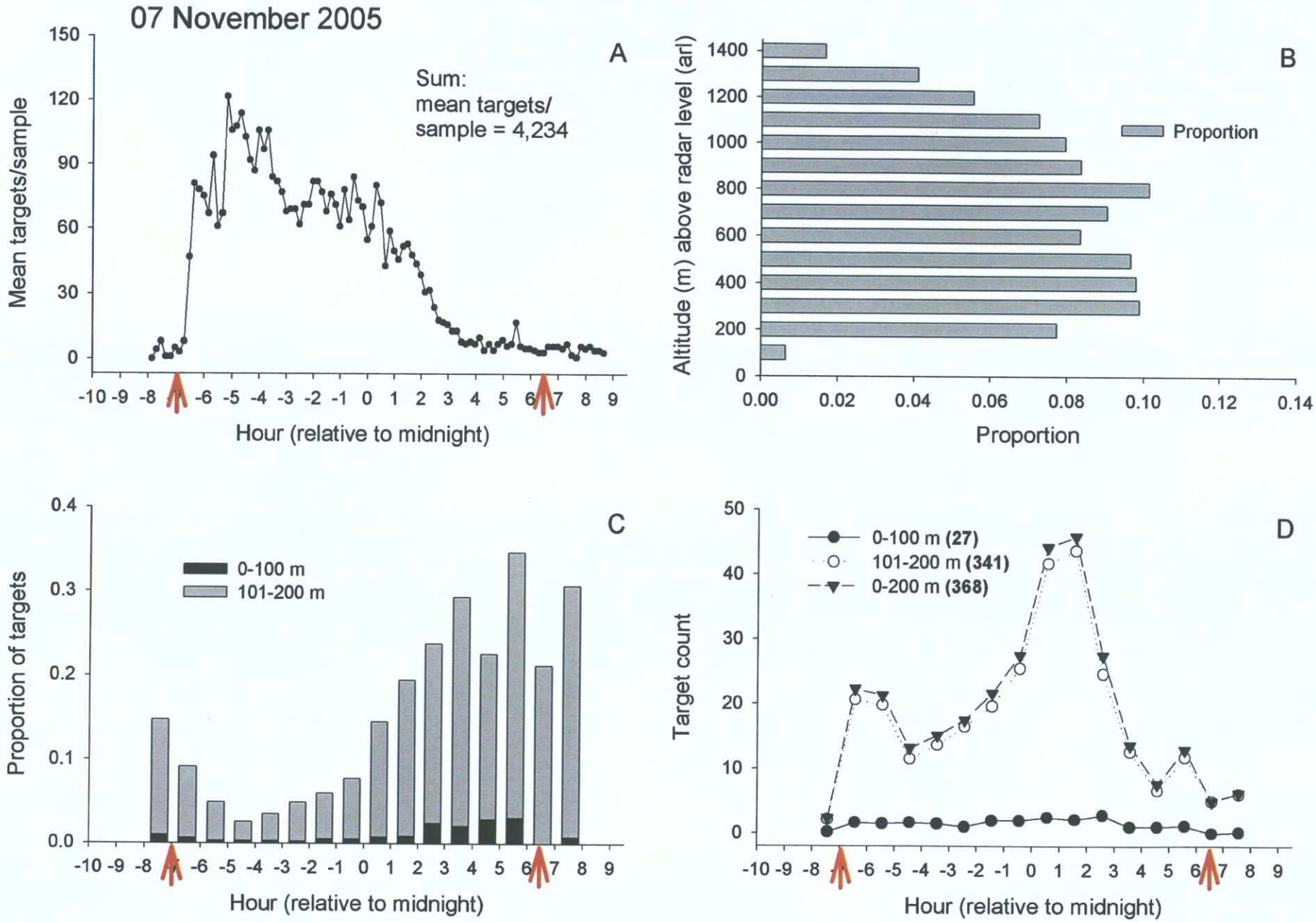

02 November 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 13,368
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (159)
101-200 m (1432)
0-200 m (1591)
Hour (relative to midnight)

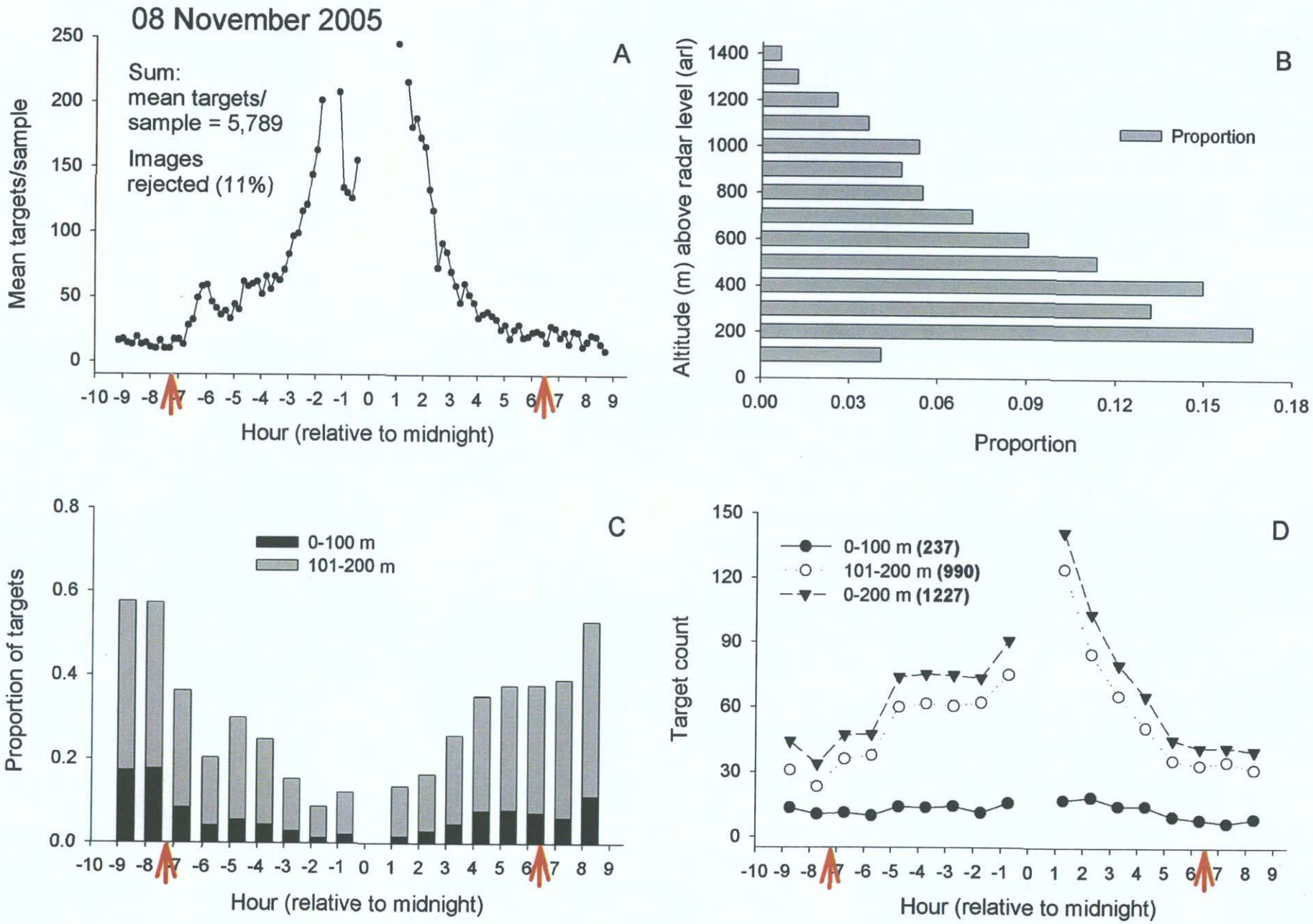

03 November 2005
A
Sum:
mean targets/
sample = 704
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (10)
101-200 m (75)
0-200 m (85)
Target count
Hour (relative to midnight)

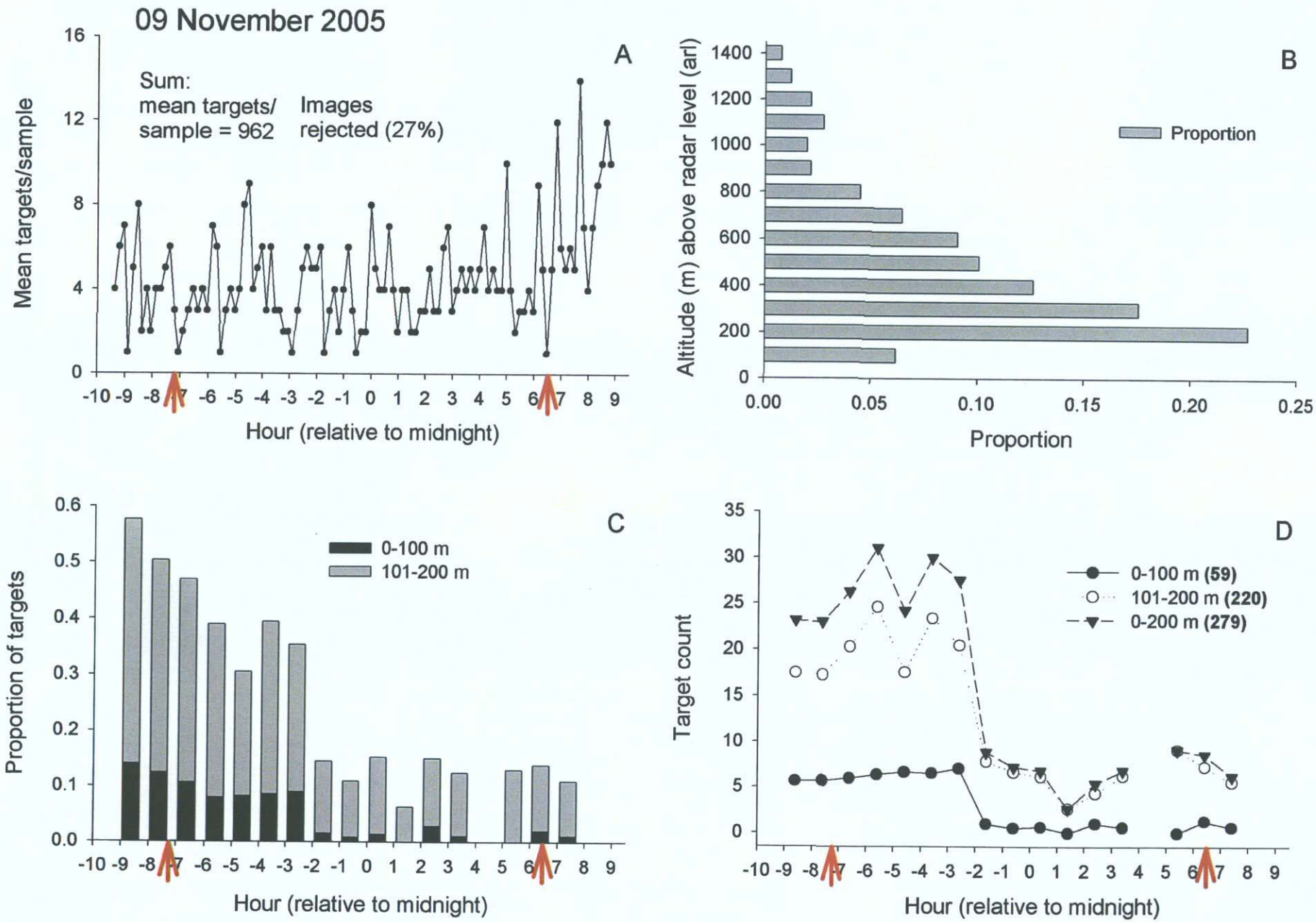

04 November 2005
A
Sum:
mean targets/
sample = 714
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (21)
101-200 m (87)
0-200 m (108)
Target count
Hour (relative to midnight)

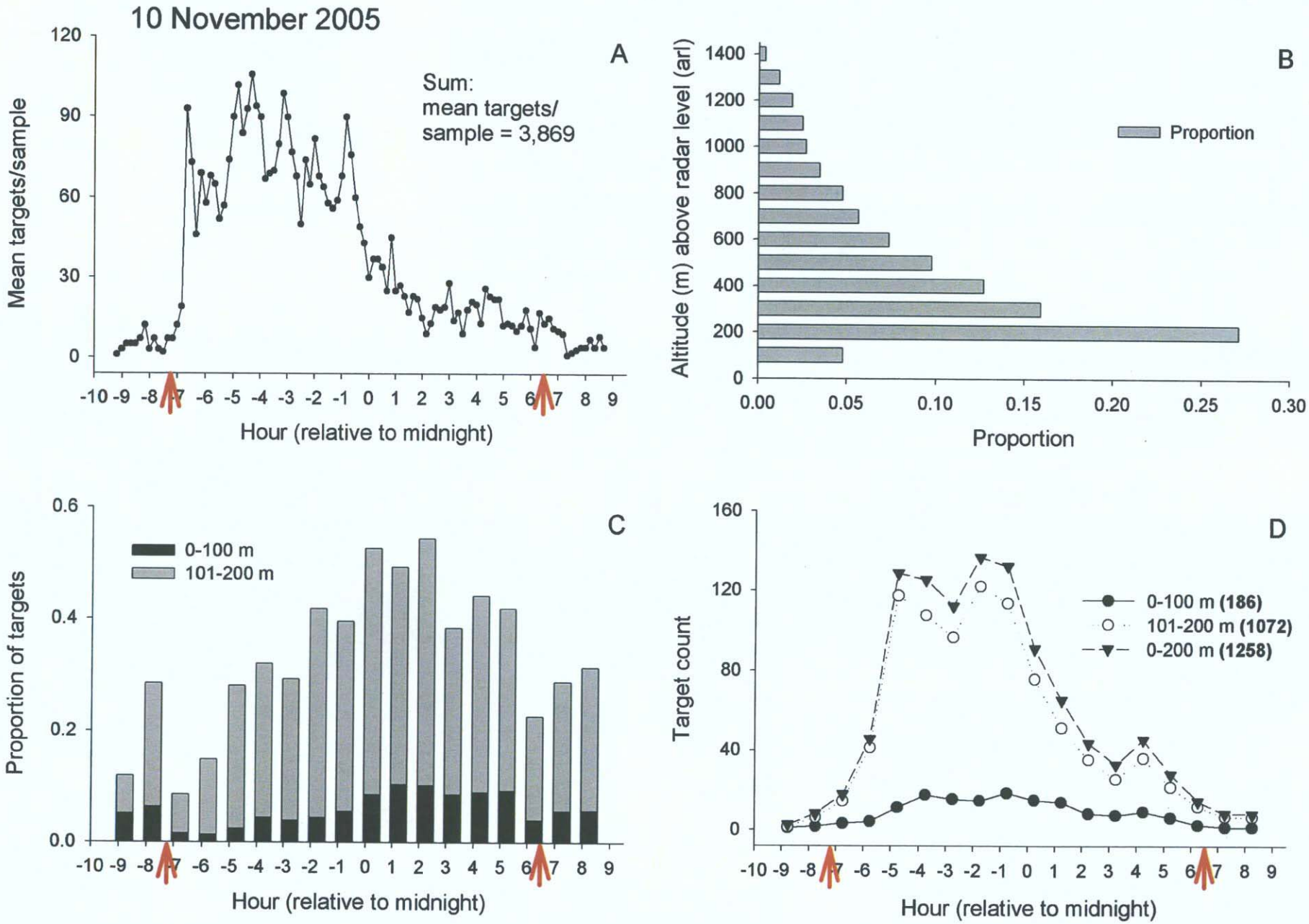

05 November 2005
A
Sum:
mean targets/
sample = 1,279
Images
rejected (6%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (22)
101-200 m (169)
0-200 m (191)
Target count
Hour (relative to midnight)

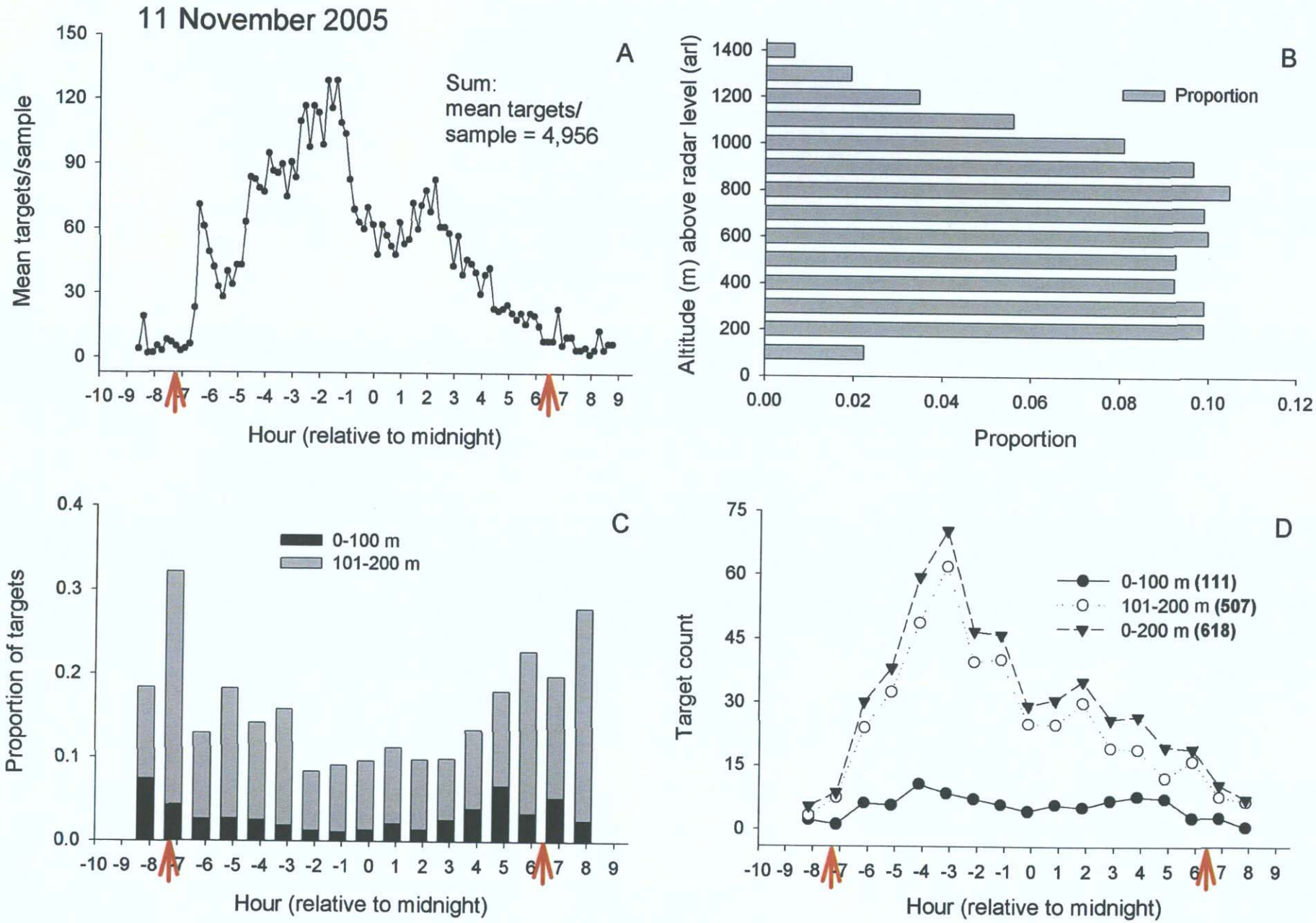

06 November 2005
A
Sum:
mean targets/
sample = 1,034
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (21)
101-200 m (92)
0-200 m (113)
Target count
Hour (relative to midnight)

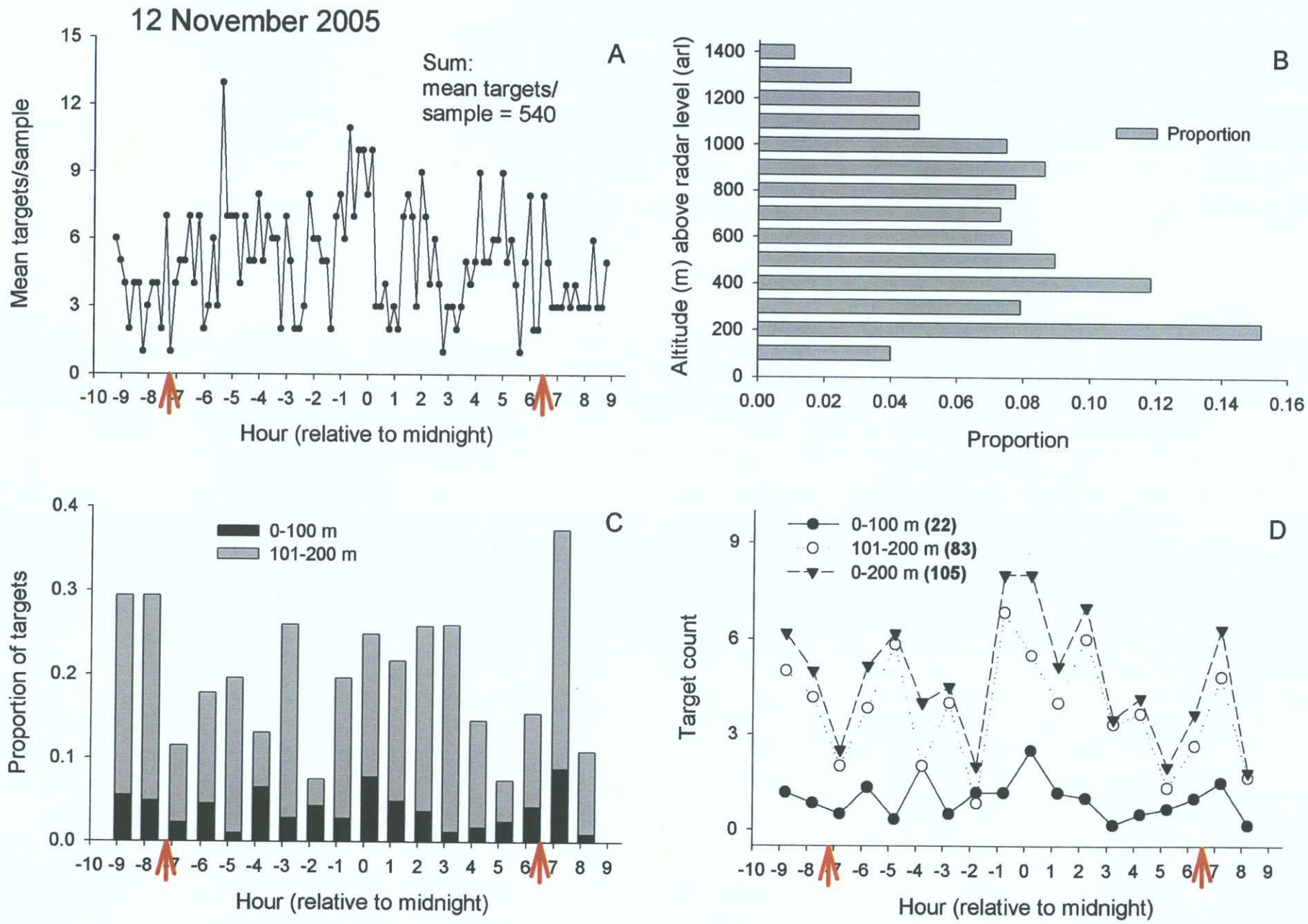

07 November 2005
A
Sum:
mean targets/
sample = 4,234
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (27)
101-200 m (341)
0-200 m (368)
Target count
Hour (relative to midnight)

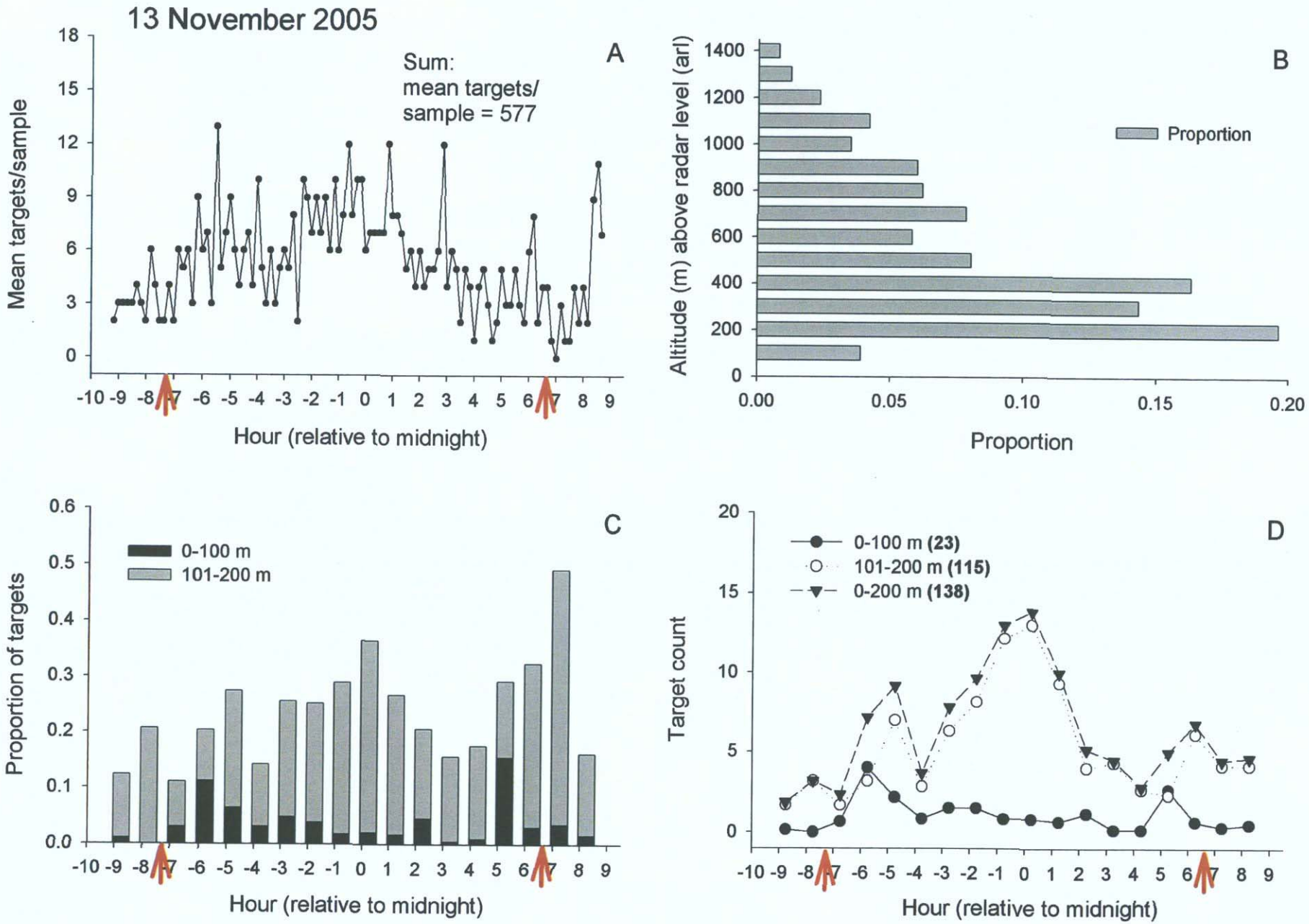

08 November 2005
A
Sum:
mean targets/
sample = 5,789
Images
rejected (11%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (237)
101-200 m (990)
0-200 m (1227)
Target count
Hour (relative to midnight)

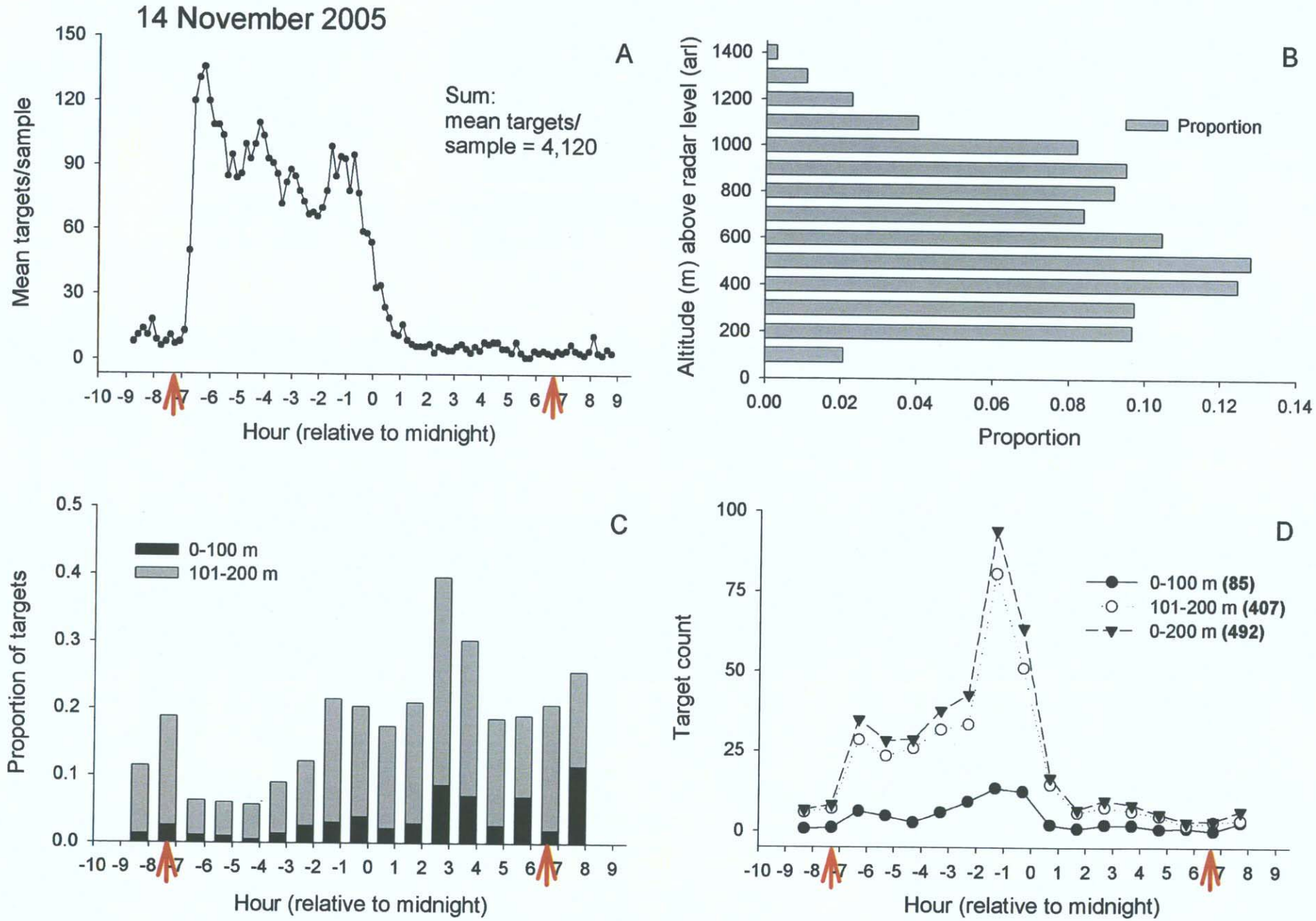

09 November 2005
A
Sum:
mean targets/ sample = 962
Images rejected (27%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (59)
101-200 m (220)
0-200 m (279)
Target count
Hour (relative to midnight)

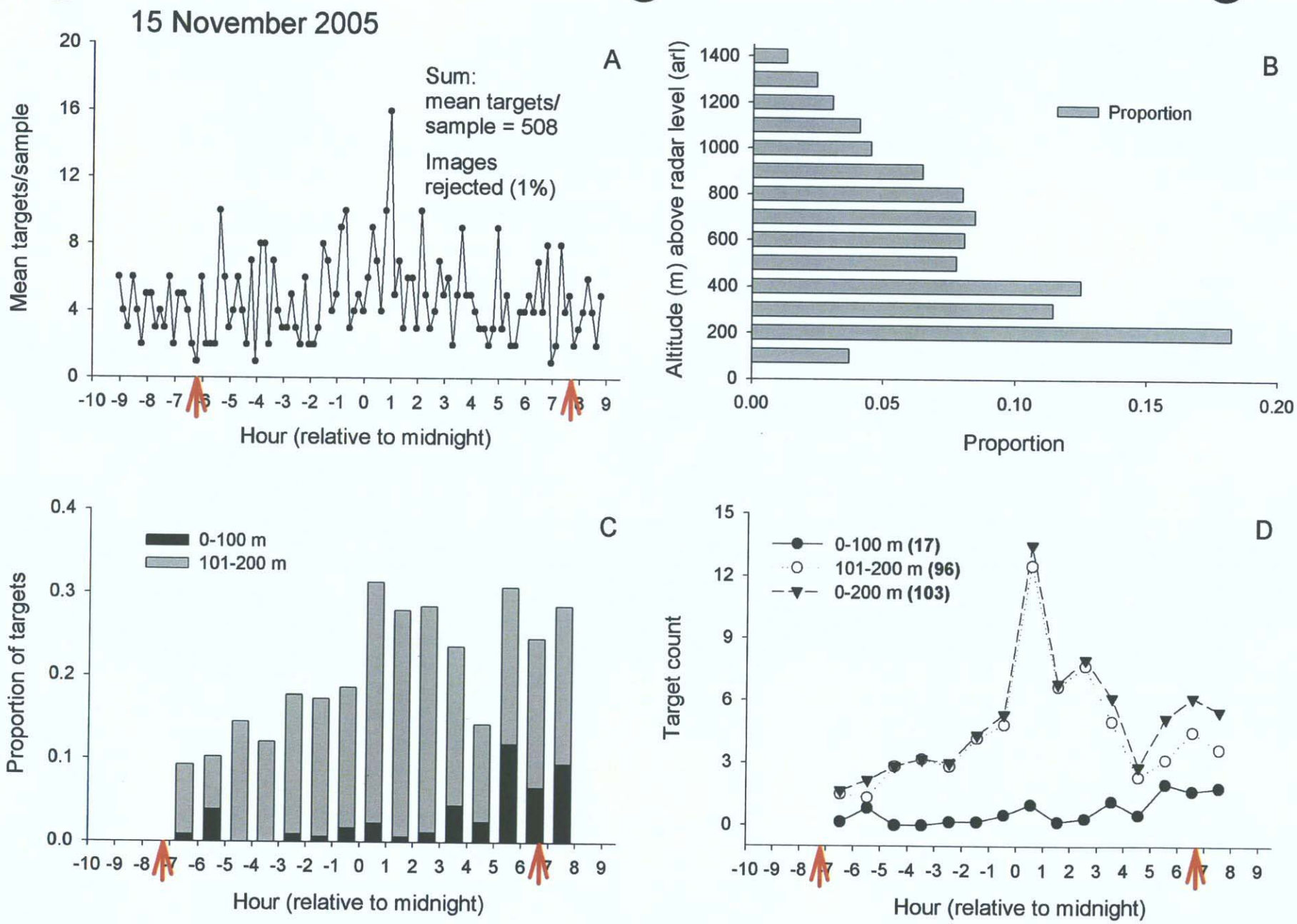

10 November 2005
A
Sum:
mean targets/
sample = 3,869
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (186)
101-200 m (1072)
0-200 m (1258)
Target count
Hour (relative to midnight)

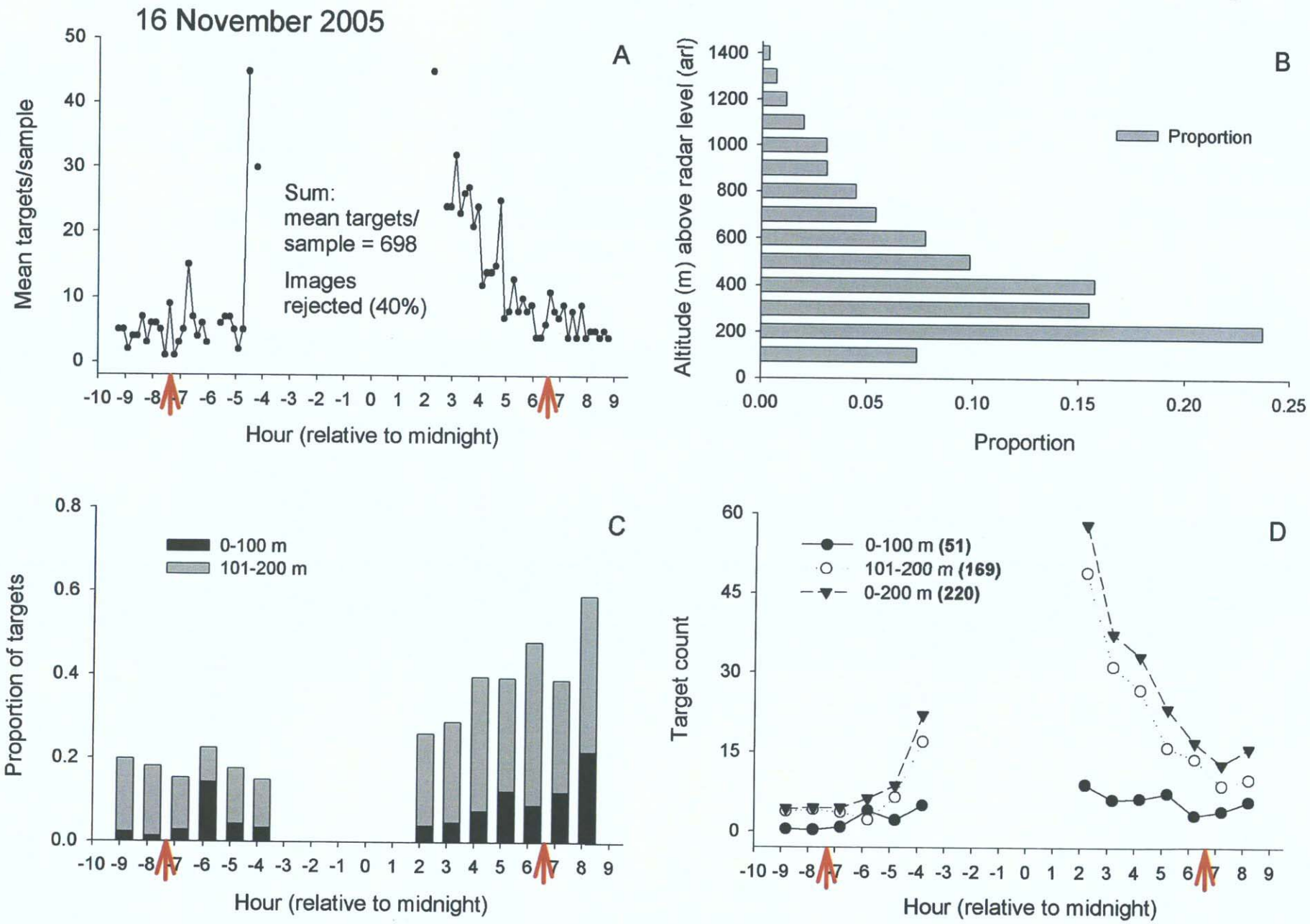

11 November 2005
A
Sum:
mean targets/
sample = 4,956
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (111)
101-200 m (507)
0-200 m (618)
Target count
Hour (relative to midnight)

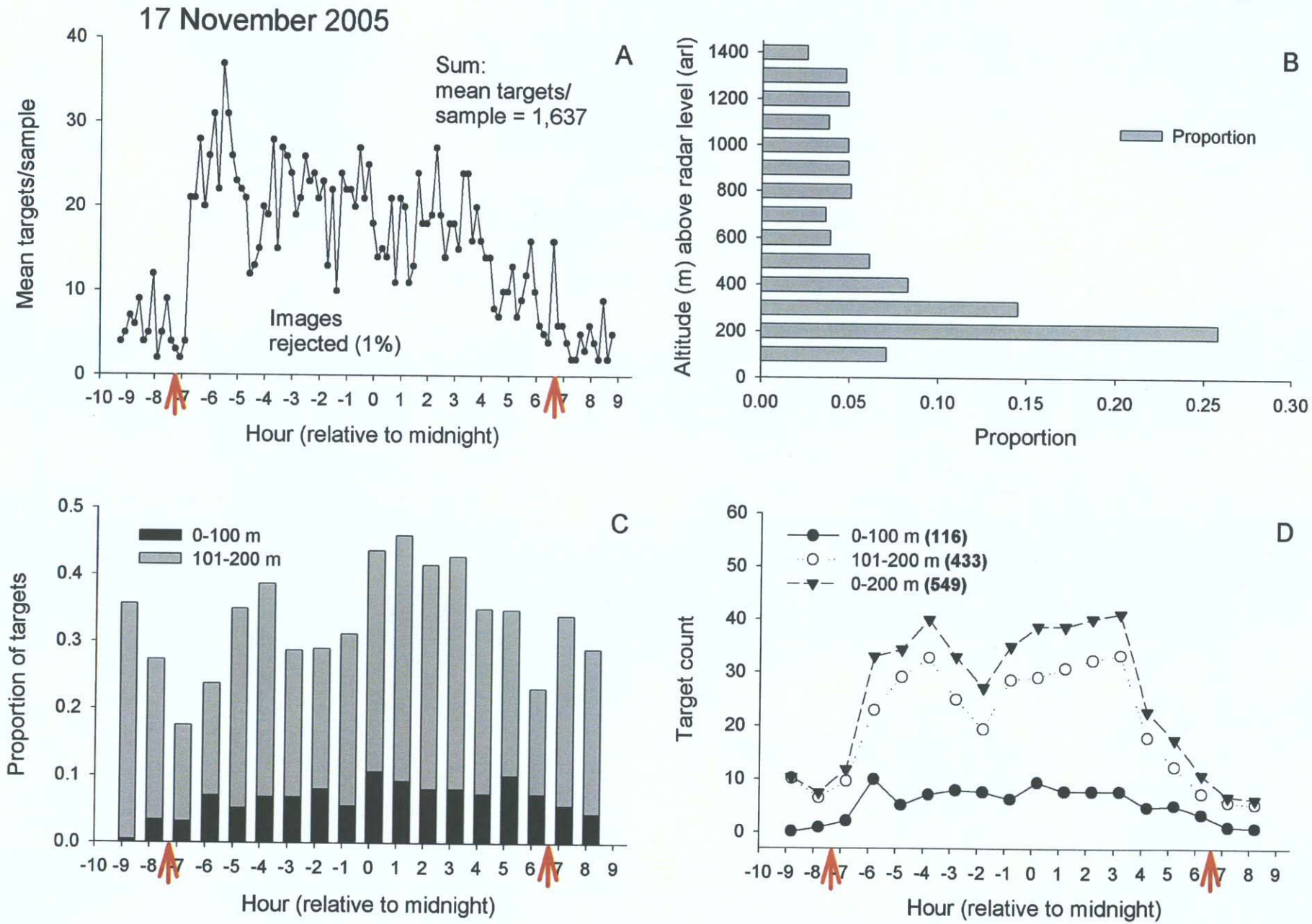

12 November 2005
A
Sum:
mean targets/
sample = 540
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (22)
101-200 m (83)
0-200 m (105)
Target count
Hour (relative to midnight)

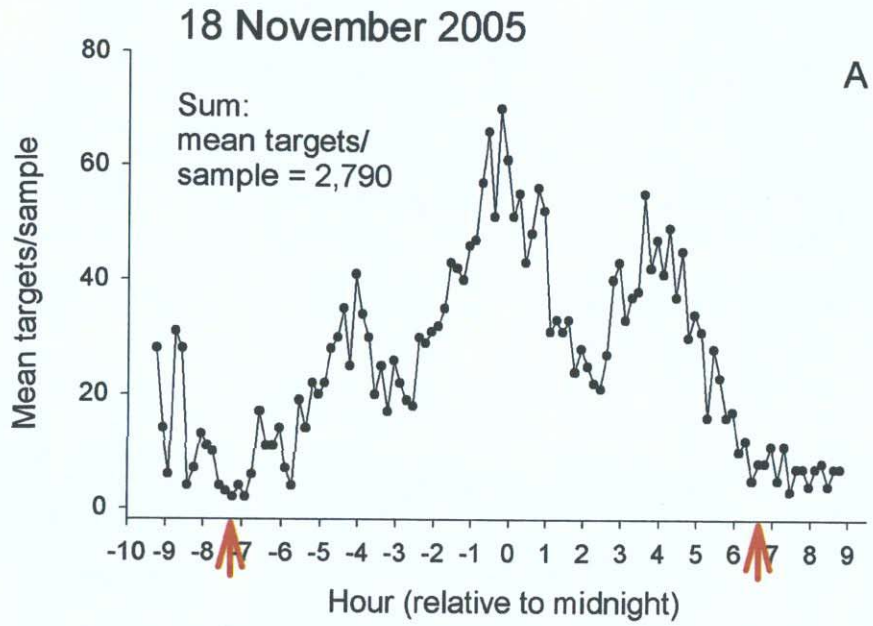

13 November 2005
A
Sum:
mean targets/
sample = 577
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (23)
101-200 m (115)
0-200 m (138)
Target count
Hour (relative to midnight)

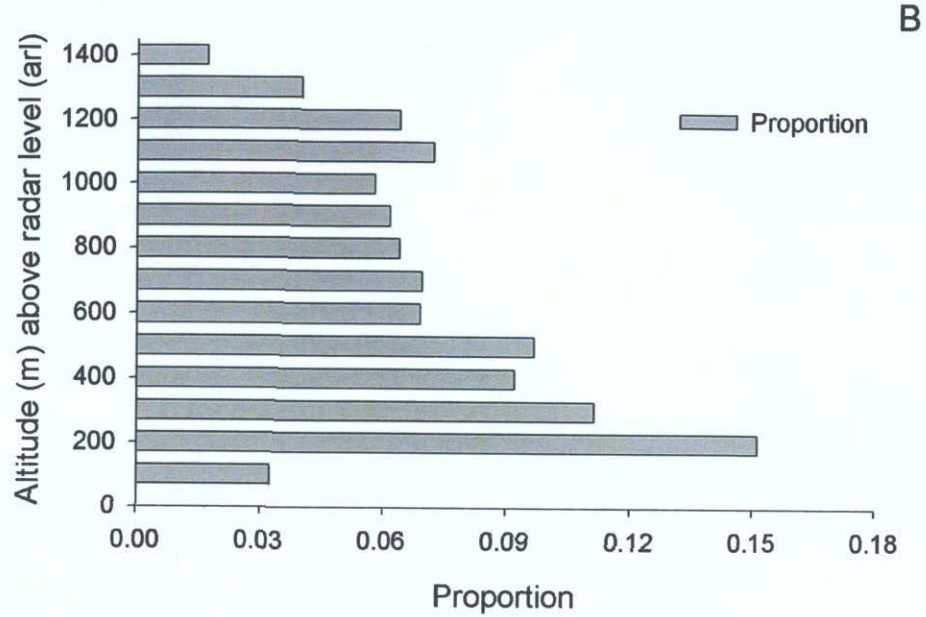

14 November 2005
A
Sum:
mean targets/
sample = 4,120
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (85)
101-200 m (407)
0-200 m (492)
Target count
Hour (relative to midnight)

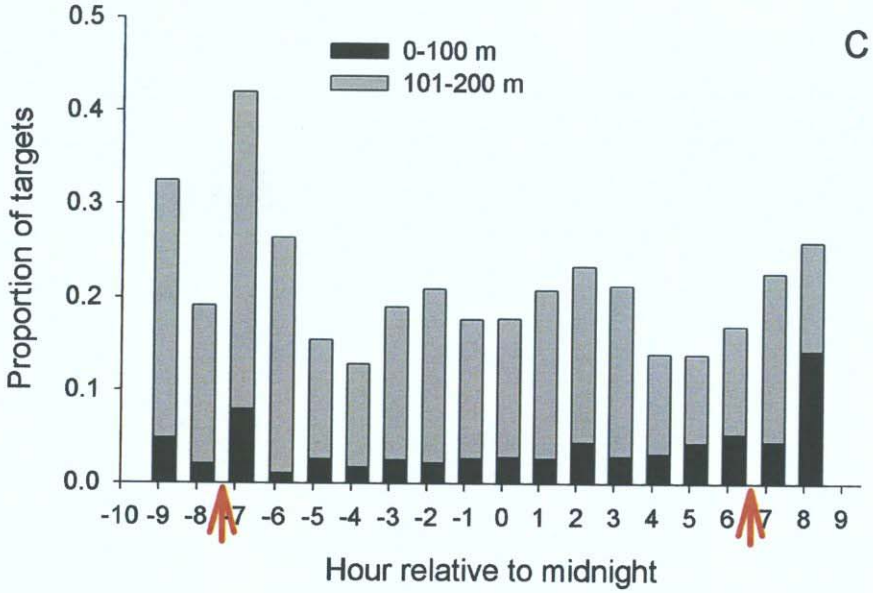

15 November 2005
A
Sum:
mean targets/
sample = 508
Images
rejected (1%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (17)
101-200 m (96)
0-200 m (103)
Target count
Hour (relative to midnight)

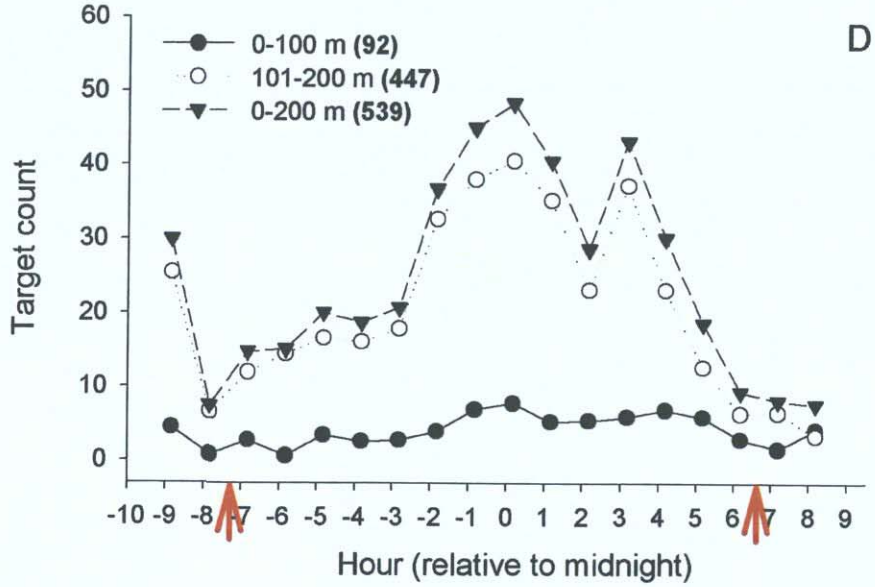

16 November 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 698
Images
rejected (40%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (51)
101-200 m (169)
0-200 m (220)
Hour (relative to midnight)

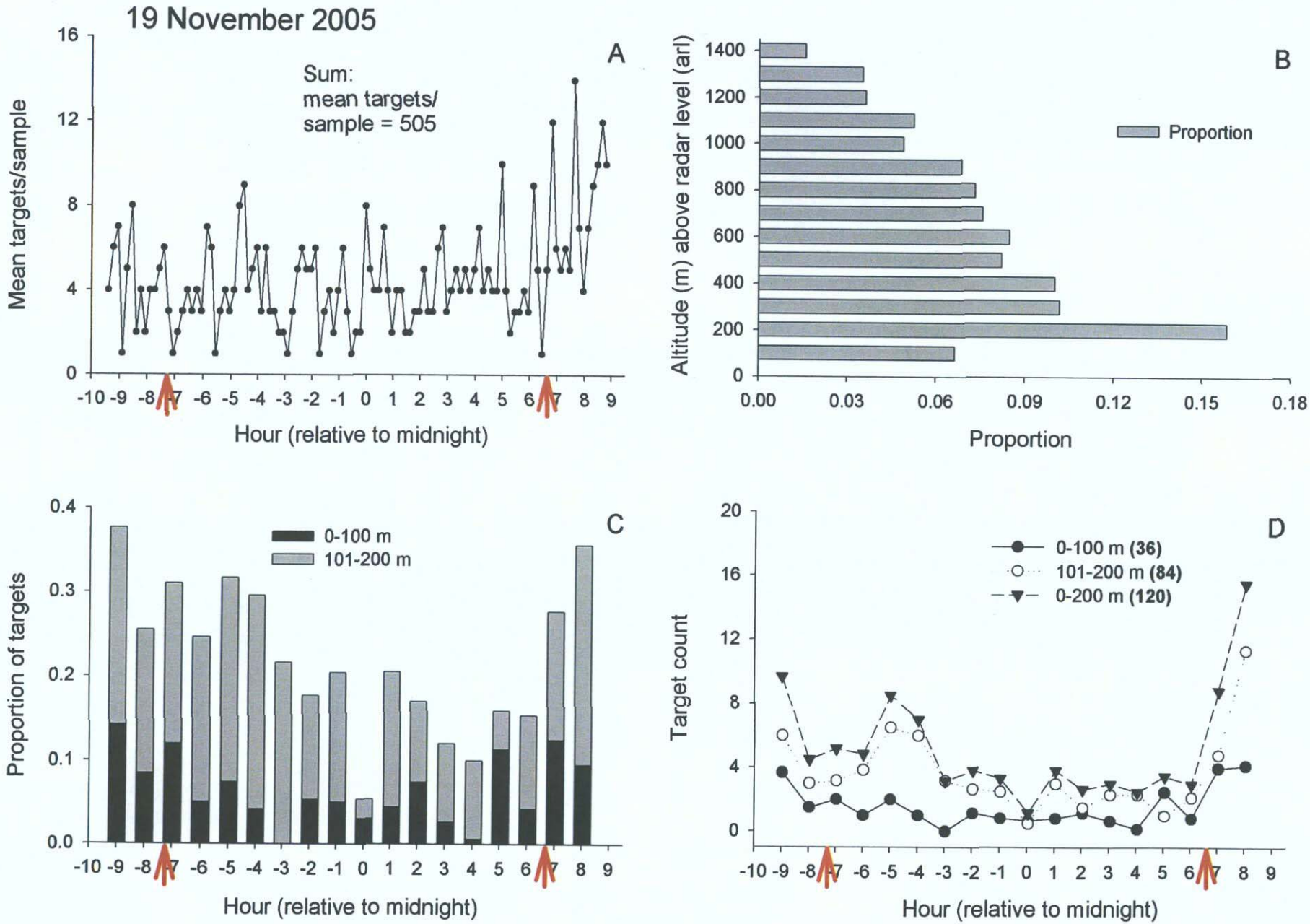

17 November 2005
A
Sum:
mean targets/
sample = 1,637
Images
rejected (1%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (116)
101-200 m (433)
0-200 m (549)
Target count
Hour (relative to midnight)

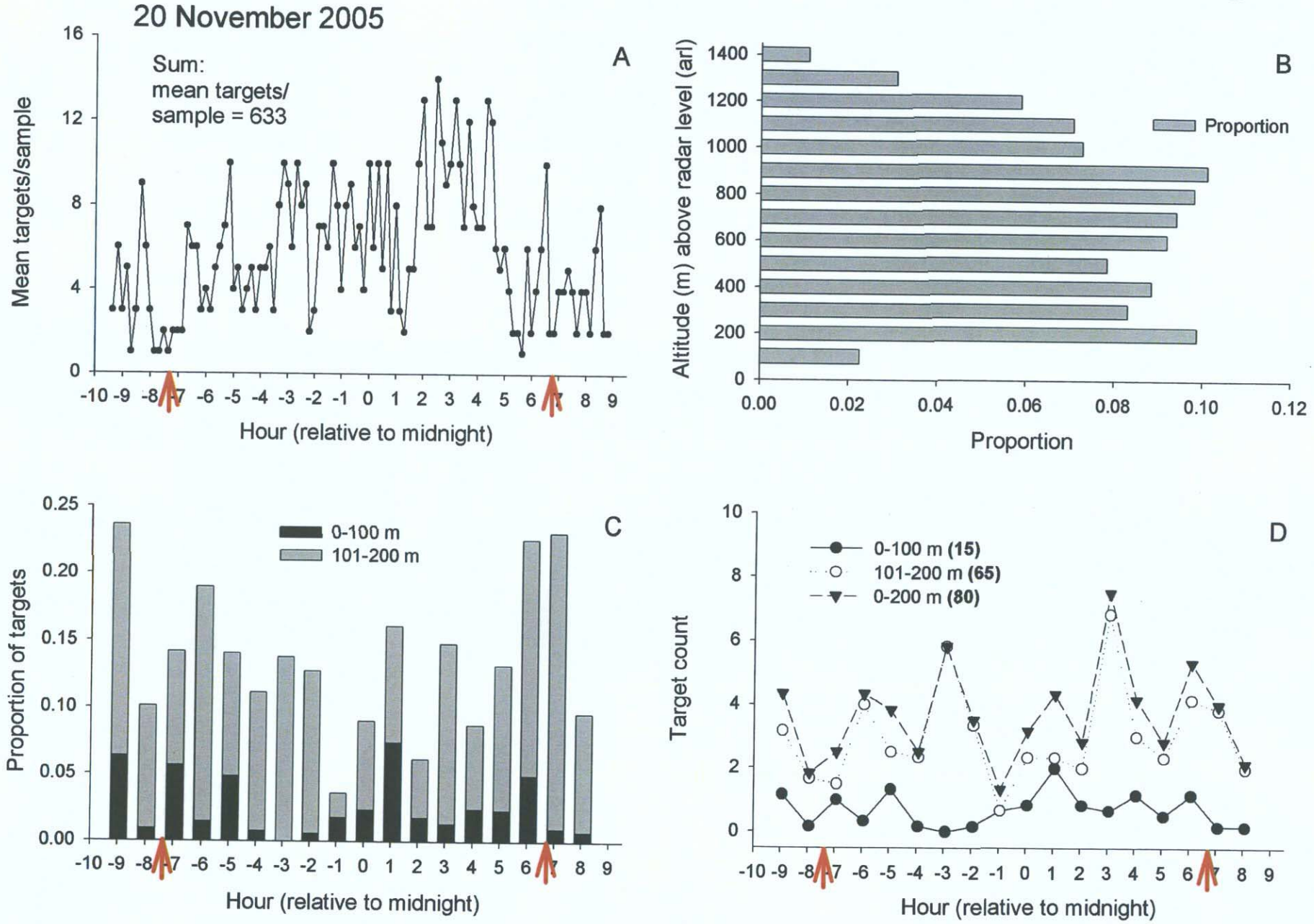

18 November 2005
A
Sum:
mean targets/
sample = 2,790
Mean targets/sample
Hour (relative to midnight)

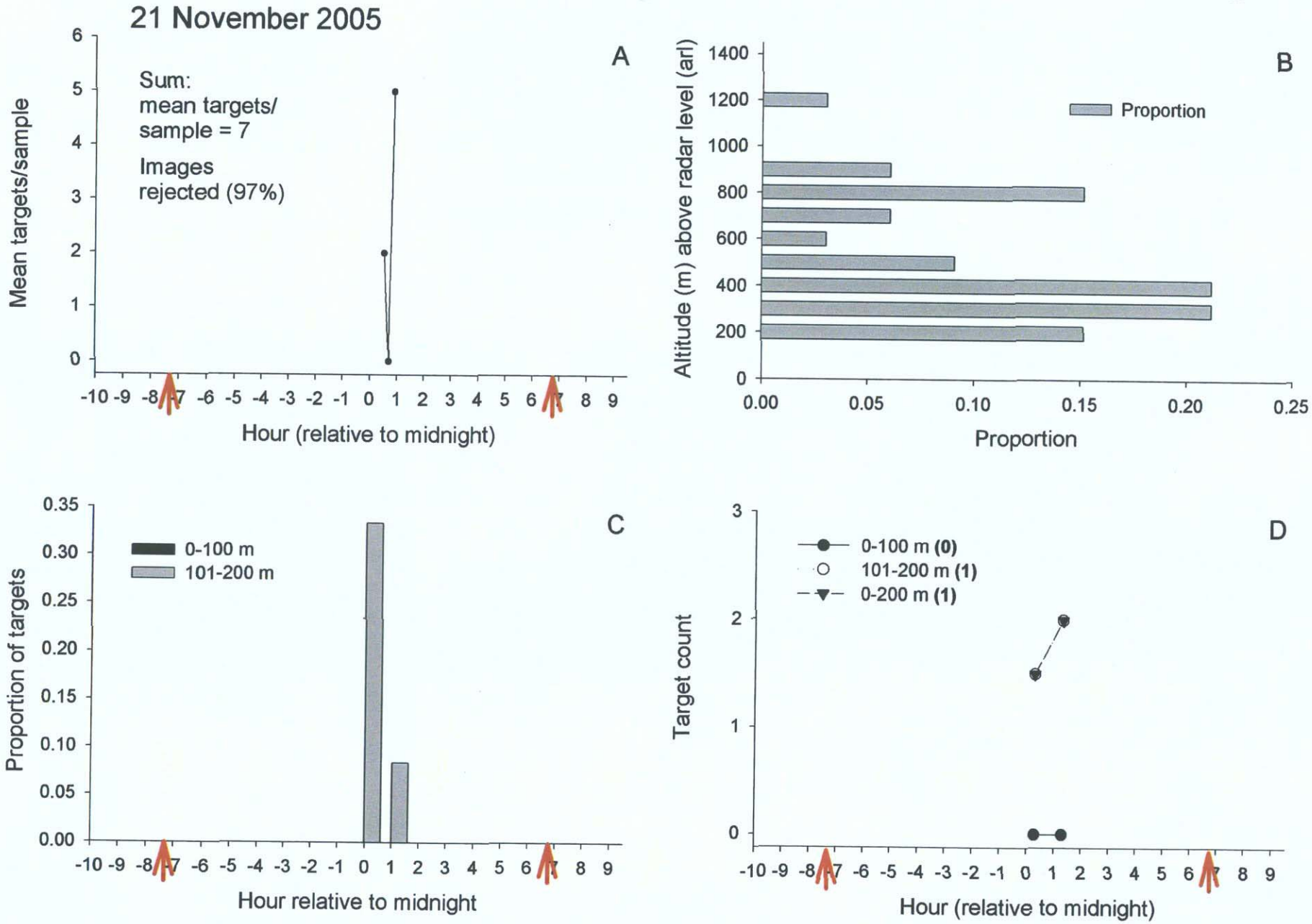

B
Proportion
Altitude (m) above radar level (arl)
Proportion

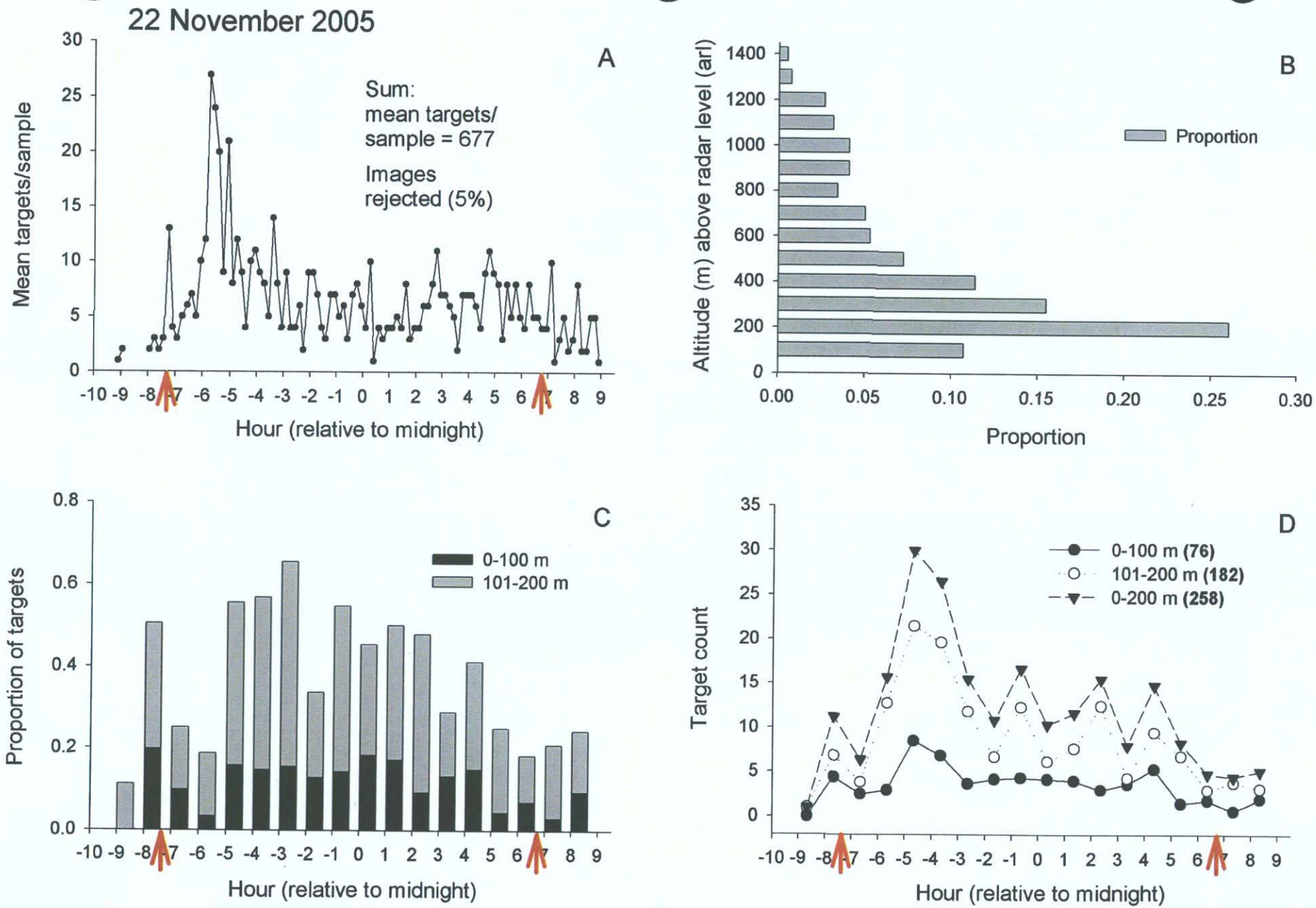

C
0-100 m
101-200 m
Proportion of targets
Hour relative to midnight

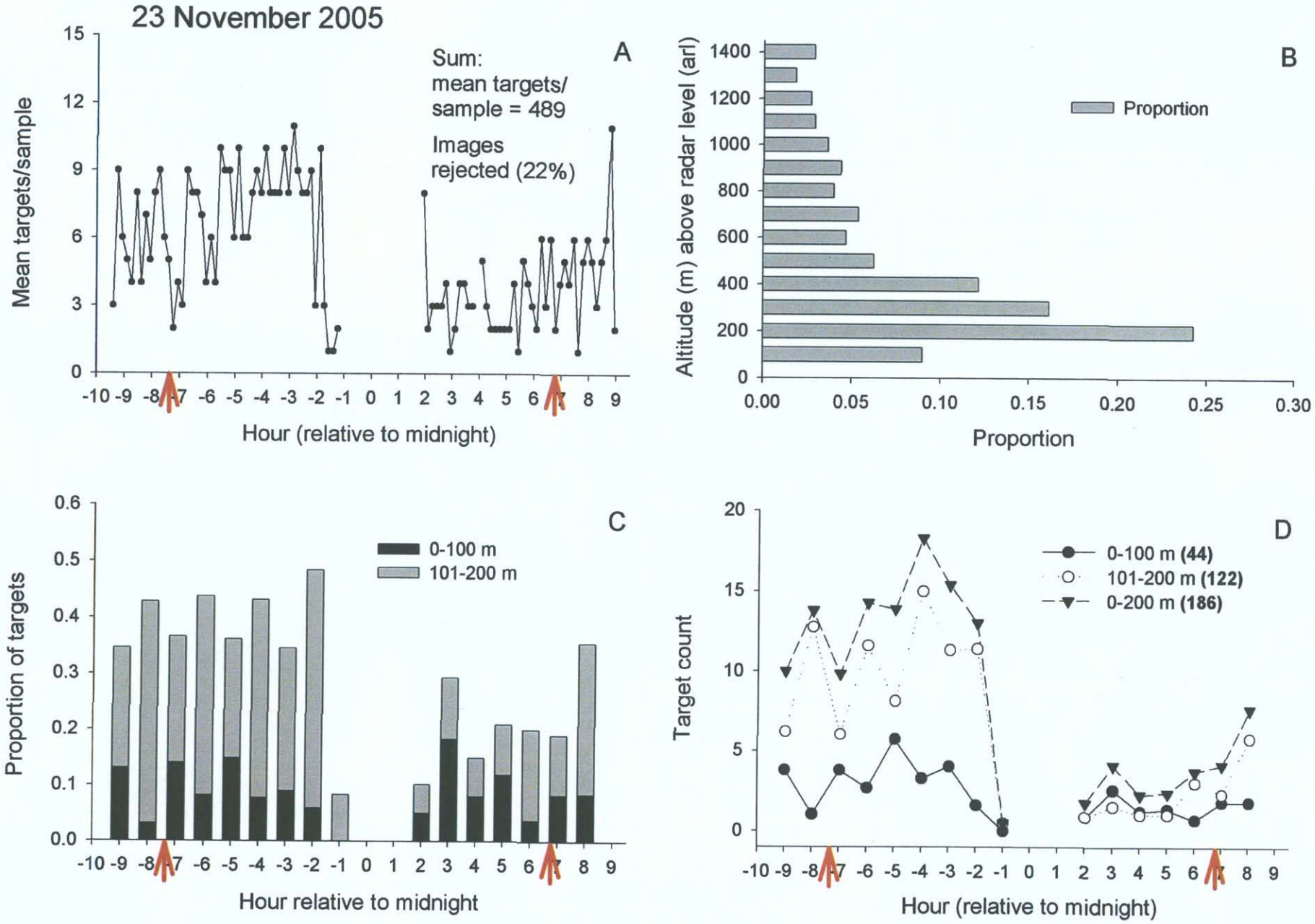

D
0-100 m (92)
101-200 m (447)
0-200 m (539)
Target count
Hour (relative to midnight)

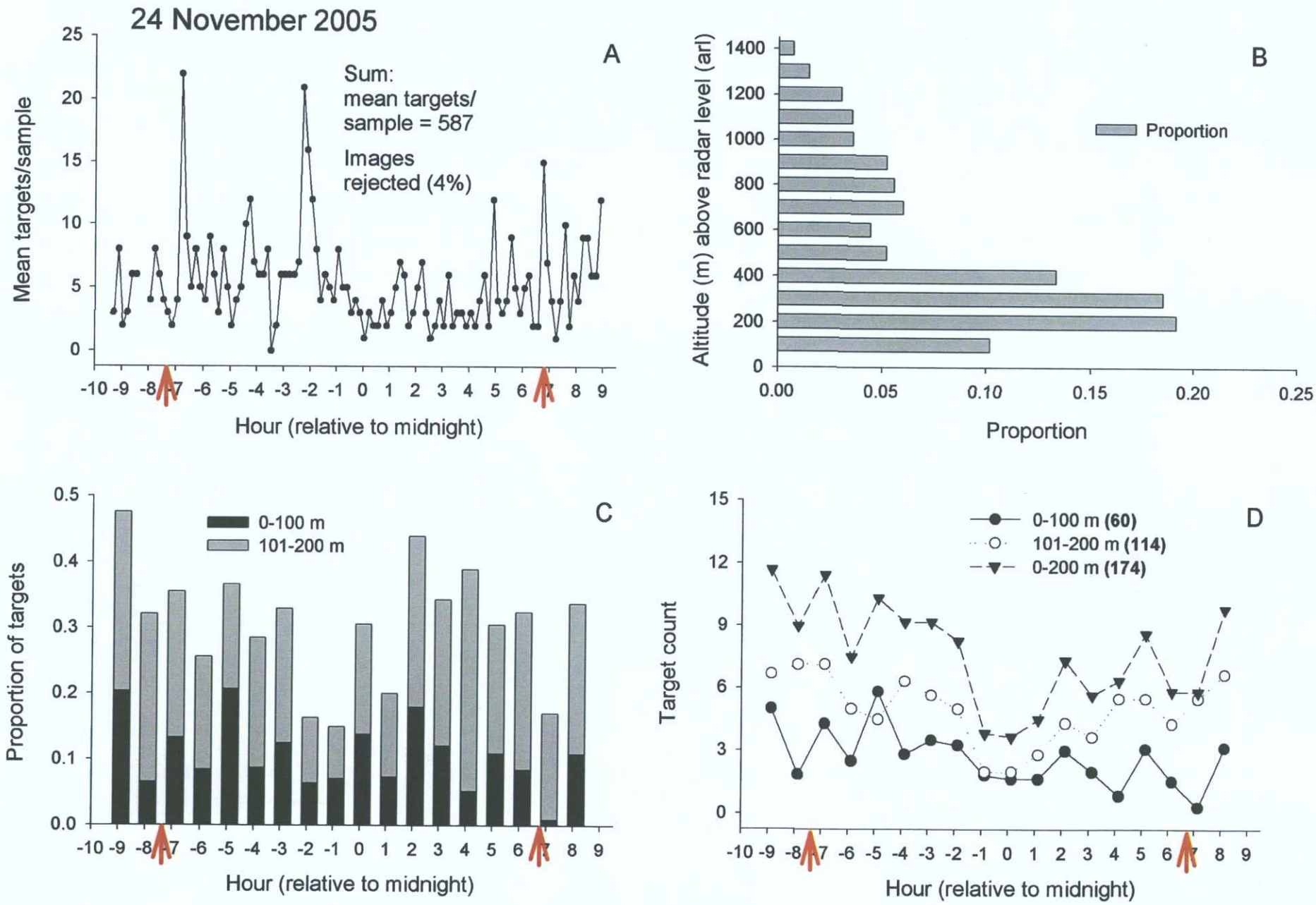

19 November 2005
A
Sum:
mean targets/
sample = 505
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (36)
101-200 m (84)
0-200 m (120)
Target count
Hour (relative to midnight)

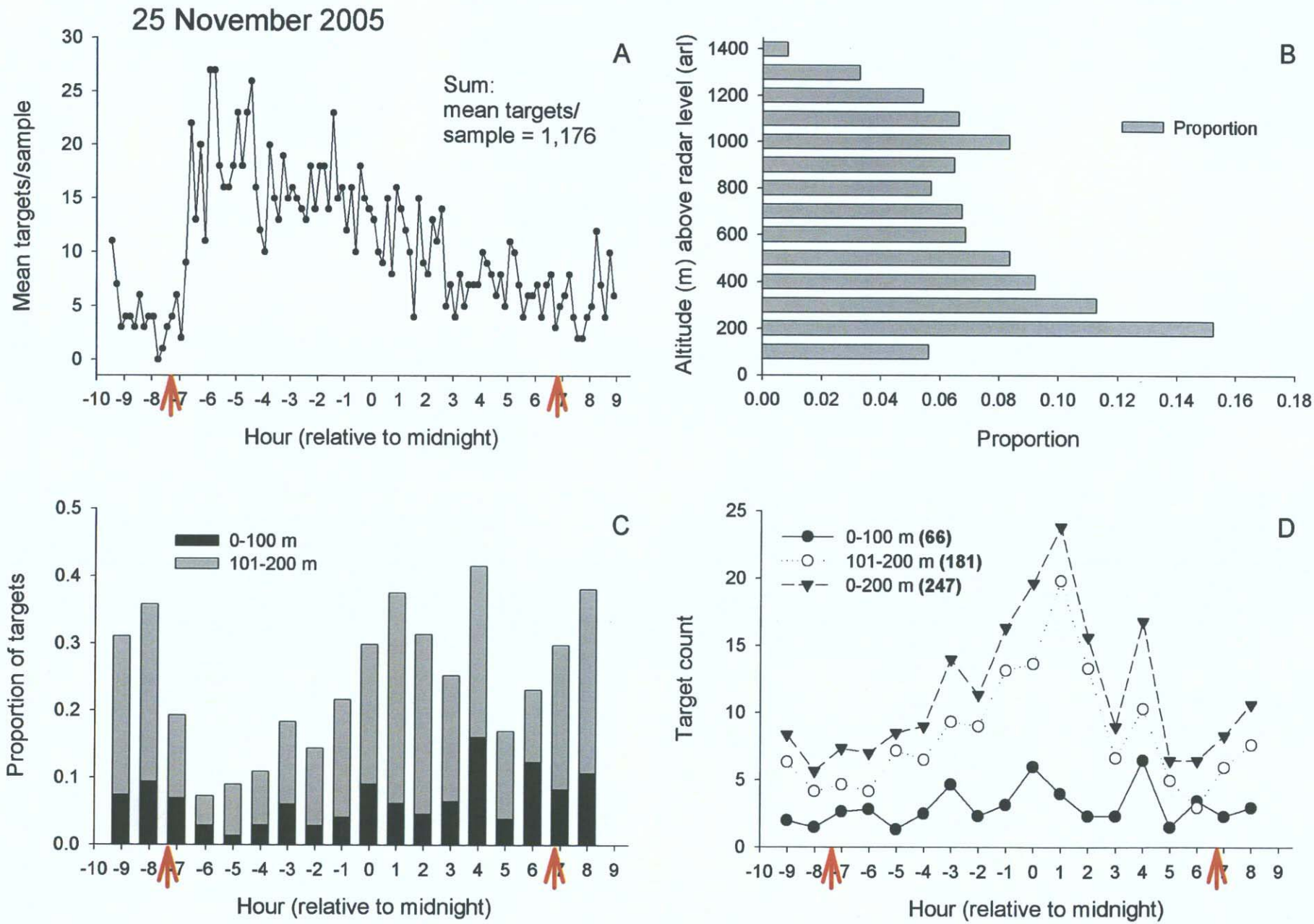

20 November 2005
A
Sum:
mean targets/
sample = 633
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (15)
101-200 m (65)
0-200 m (80)
Target count
Hour (relative to midnight)

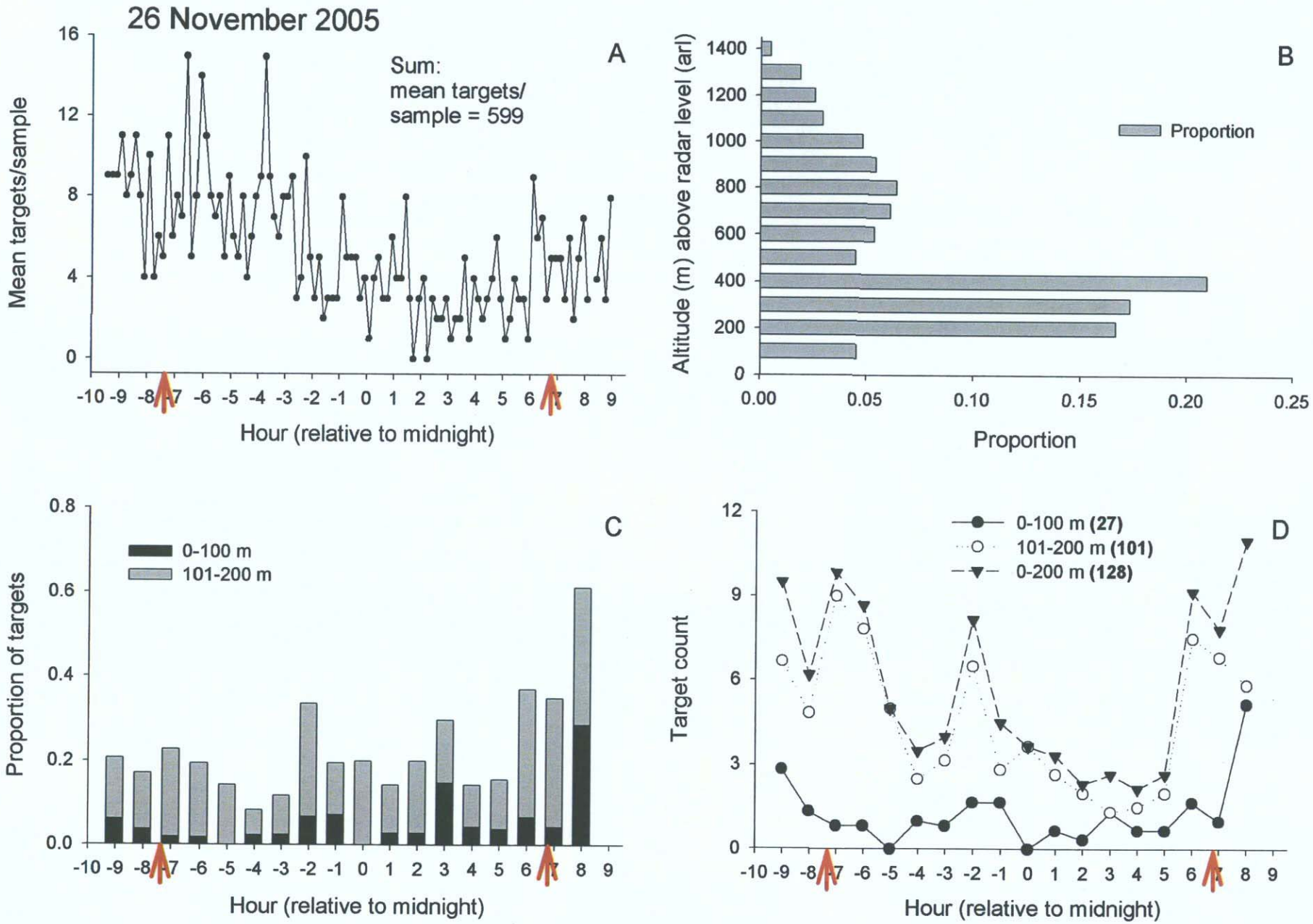

21 November 2005
A
Sum:
mean targets/
sample = 7
Images
rejected (97%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (0)
101-200 m (1)
0-200 m (1)
Target count
Hour (relative to midnight)

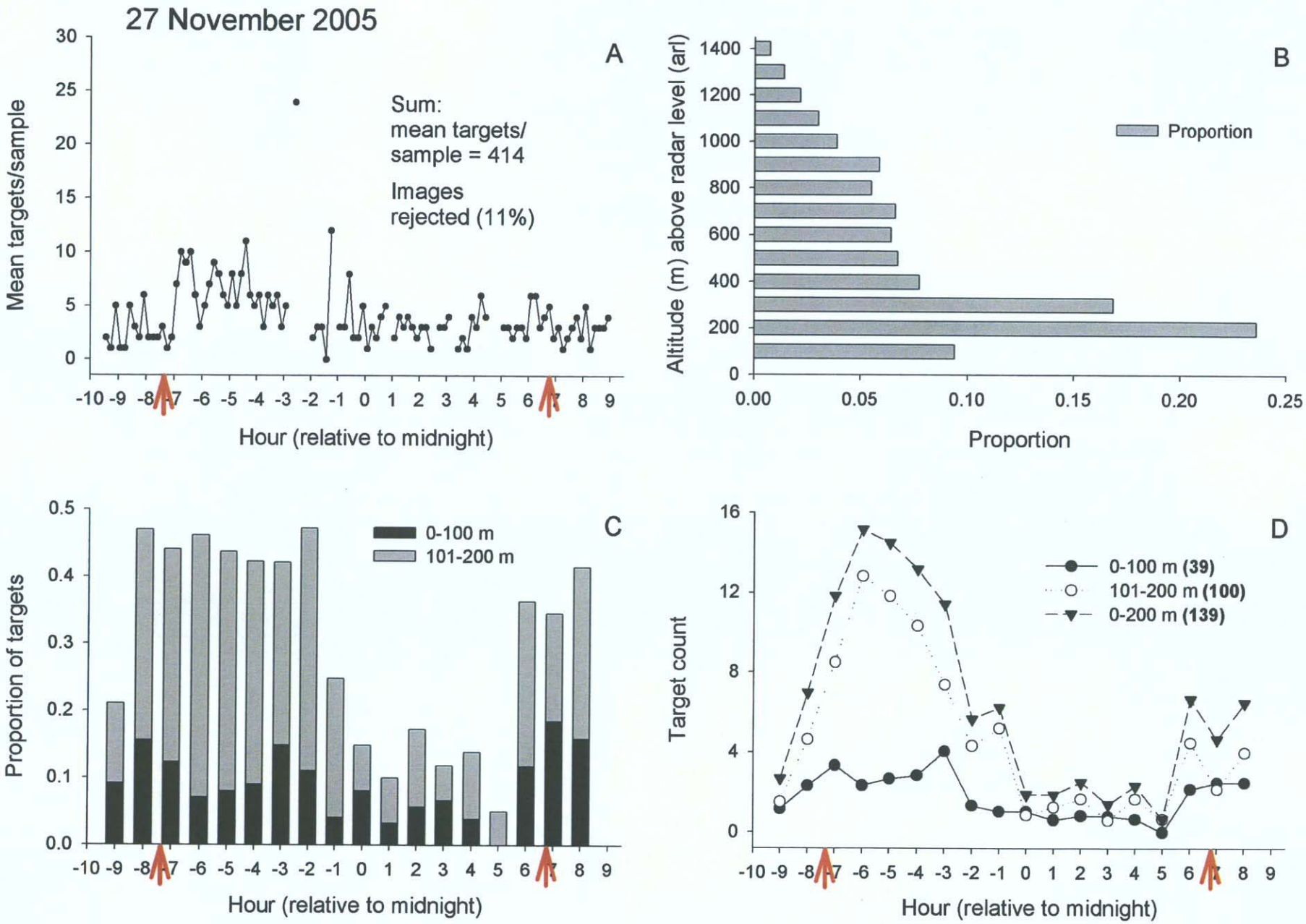

22 November 2005
A
Sum:
mean targets/
sample = 677
Images
rejected (5%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (76)
101-200 m (182)
0-200 m (258)
Target count
Hour (relative to midnight)

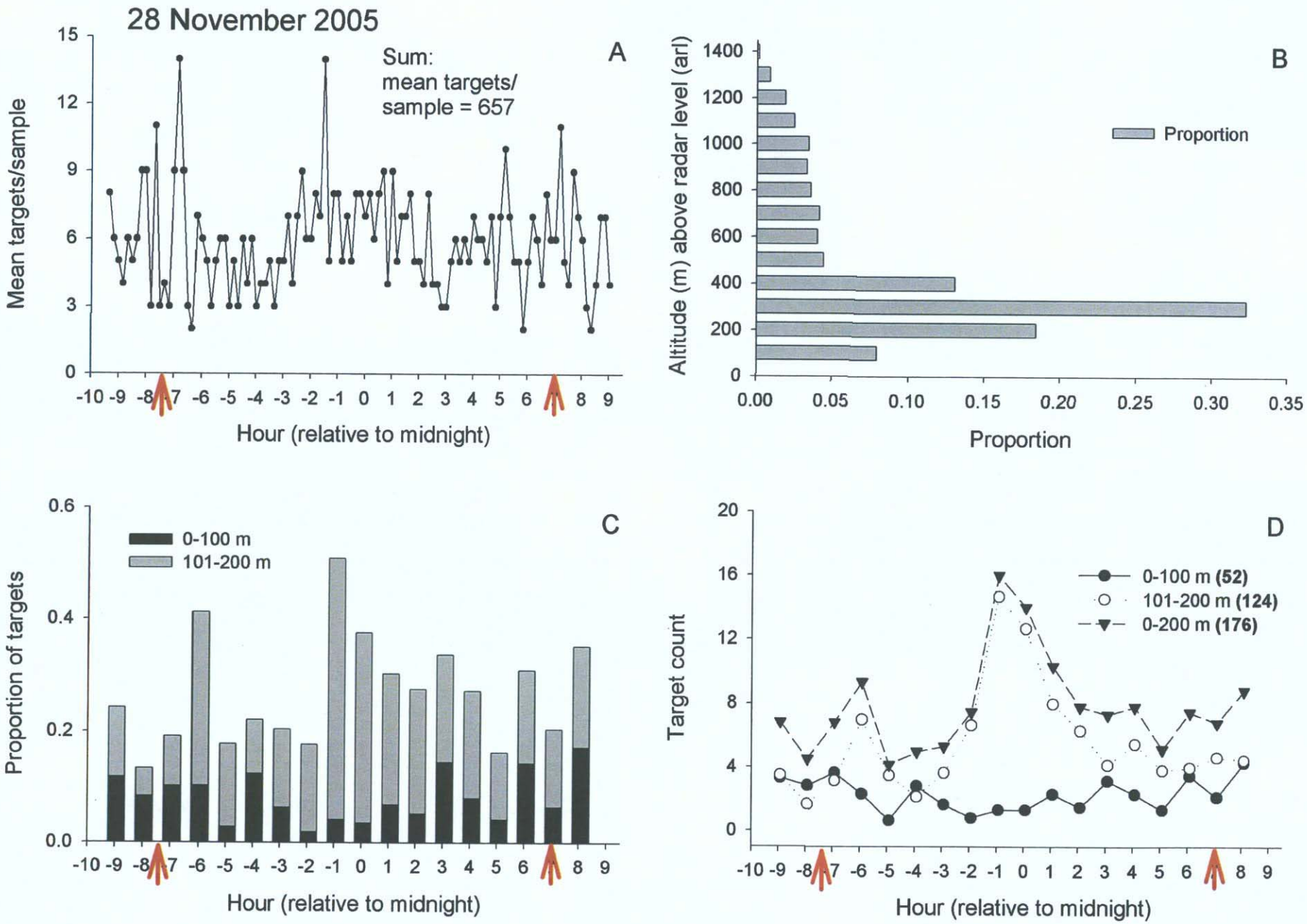

23 November 2005
A
Sum:
mean targets/
sample = 489
Images
rejected (22%)
Mean targets/sample
Hour (relative to midnight)
B
Proportion
Altitude (m) above radar level (arl)
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour relative to midnight
D
0-100 m (44)
101-200 m (122)
0-200 m (186)
Target count
Hour (relative to midnight)

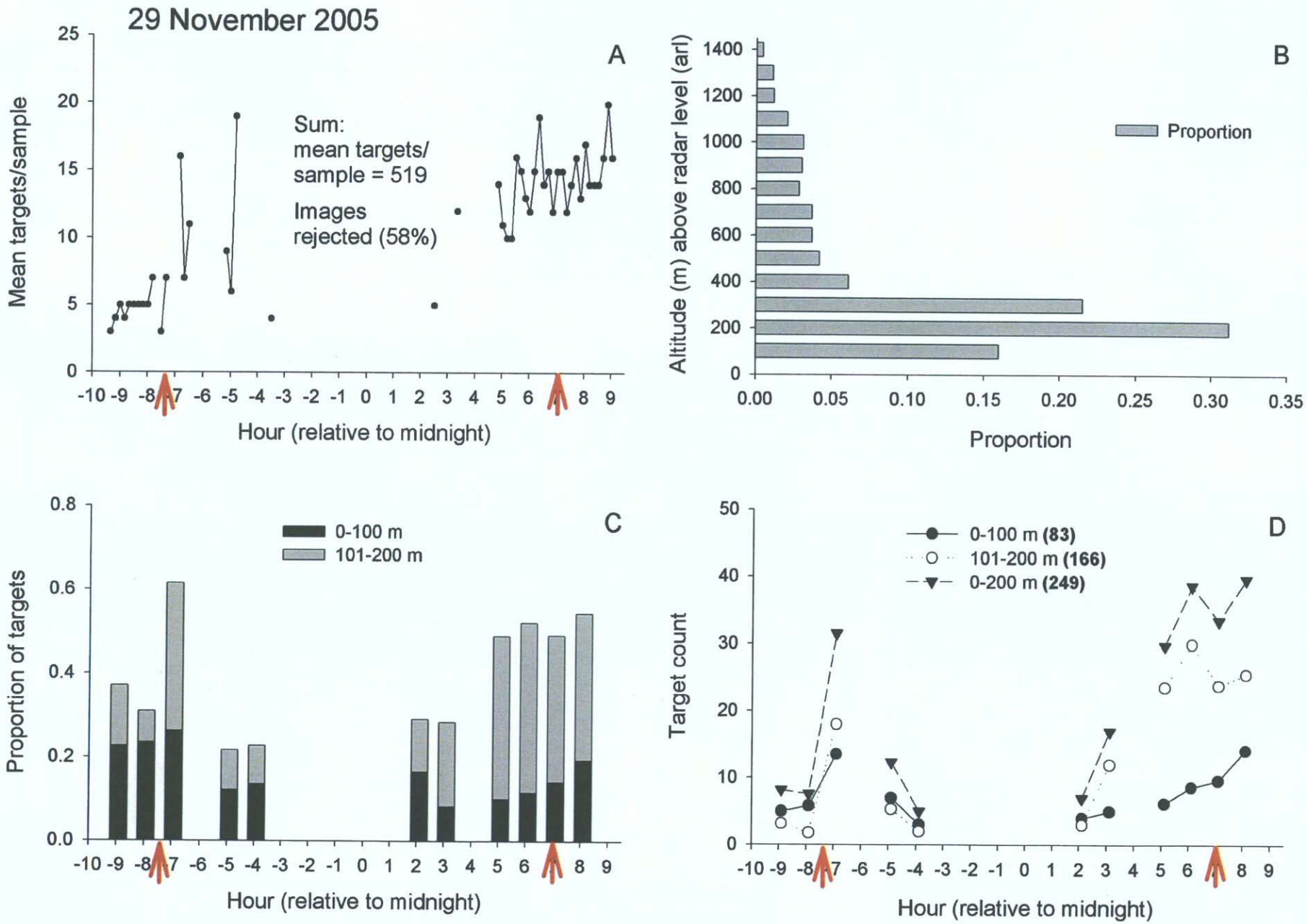

24 November 2005
A
Sum:
mean targets/
sample = 587
Images
rejected (4%)
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (60)
101-200 m (114)
0-200 m (174)
Target count
Hour (relative to midnight)

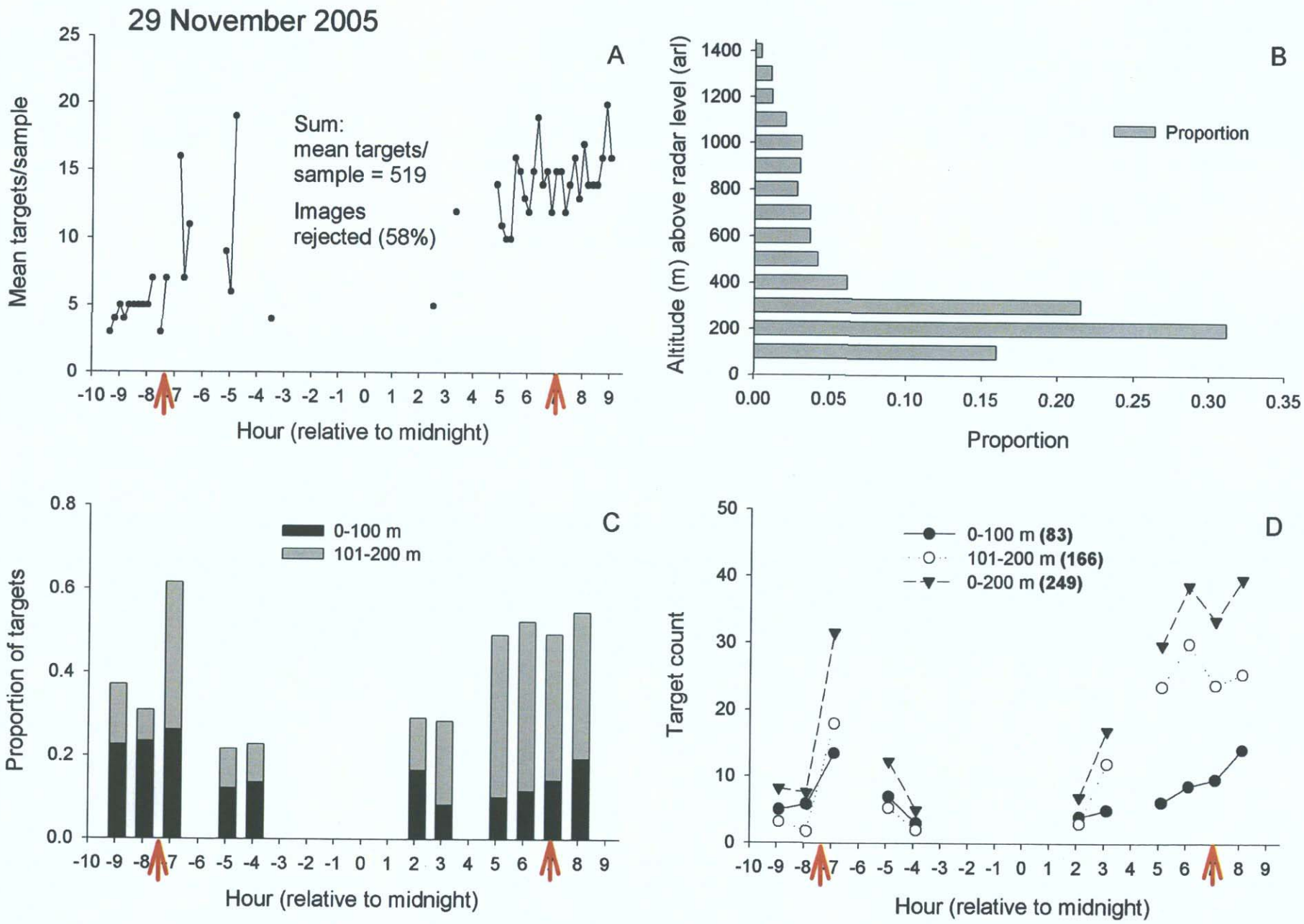

25 November 2005
A
Sum:
mean targets/
sample = 1,176
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (66)
101-200 m (181)
0-200 m (247)
Target count
Hour (relative to midnight)


26 November 2005
A
Sum:
mean targets/
sample = 599
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (27)
101-200 m (101)
0-200 m (128)
Target count
Hour (relative to midnight)


27 November 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 414
Images
rejected (11%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (39)
101-200 m (100)
0-200 m (139)
Hour (relative to midnight)


28 November 2005
A
Sum:
mean targets/
sample = 657
Mean targets/sample
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
0-100 m
101-200 m
Proportion of targets
Hour (relative to midnight)
D
0-100 m (52)
101-200 m (124)
0-200 m (176)
Target count
Hour (relative to midnight)


29 November 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 519
Images
rejected (58%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (83)
101-200 m (166)
0-200 m (249)
Hour (relative to midnight)


29 November 2005
A
Mean targets/sample
Sum:
mean targets/
sample = 519
Images
rejected (58%)
Hour (relative to midnight)
B
Altitude (m) above radar level (arl)
Proportion
Proportion
C
Proportion of targets
0-100 m
101-200 m
Hour (relative to midnight)
D
Target count
0-100 m (83)
101-200 m (166)
0-200 m (249)
Hour (relative to midnight)