

Use of Videography and Automated Counting Methods for Aerial Surveys of Seabird Colonies in California in 2008

Phillip J. Capitolo¹, Jeff N. Davis¹, W. Breck Tyler¹, and Gerard J. McChesney²

¹University of California, Institute of Marine Sciences,
100 Shaffer Road, Santa Cruz, California 95060

²U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex,
9500 Thornton Avenue, Newark, CA 94560

FINAL REPORT
May 2009

Prepared for: California Department of Fish and Game-Office of Spill Prevention and Response
Agreement No.: P0775011

Suggested Citation: Capitolo, P.J., J.N. Davis, W.B. Tyler, and G.J. McChesney. 2009. Use of videography and automated counting methods for aerial surveys of seabird colonies in California in 2008. Unpublished report, University of California, Institute of Marine Sciences, Santa Cruz, California. 19 p.

EXECUTIVE SUMMARY

Aerial photographic surveys of breeding colonies of Common Murres (*Uria aalge*), Brandt's Cormorants (*Phalacrocorax penicillatus*), and Double-crested Cormorants (*P. auritus*) in California have been conducted since 1979. These surveys have been important for assessing: a) oil spill response strategies in the absence (or prior to the availability) of real-time data; b) injuries to seabird populations caused by oil spills, gill-net fishing, human disturbance, and other anthropogenic factors; c) effects of El Niño and La Niña conditions and other oceanographic factors on seabird populations; and d) opportunities for and effectiveness of seabird restoration projects. In 2005, the University of California, Santa Cruz (UCSC) began using digital single lens reflex (SLR) cameras to photograph colonies and image analysis software to manually determine counts of nests and birds. Previously, surveys had been conducted with 35 mm film cameras, and counts of nests and birds had been determined from projected slides.

In 2008, with funding from the Scientific Study and Evaluation Program of the California Department of Fish and Game-Office of Spill Prevention and Response (OSPR), UCSC investigated ways to improve the efficiency of colony aerial surveys and counting methods. Specifically, we tested the use of videography and automated counting features of image analysis software. A high definition video camera was rented and used to survey selected seabird colonies. Captured video was in addition to complete colony coverage with digital still photography. Suitable image analysis software was purchased and automated counts of selected images were compared to manual counts of the same images.

Our results indicated that high definition video cameras are currently not suitable for aerial surveys of seabird breeding colonies in California. Close-up video of nesting areas was obtained with the optical zoom set high, but colony coverage was impossible to track during the survey because of the video camera's low-resolution display and small field of view. Further, the quality of still images captured from downloaded video was far inferior to the quality of images from digital SLR cameras. Use of video also did not reduce the time and effort needed for archival of survey imagery and selection of still images for counting. However, at lower optical zoom settings, the video camera was effective and in the future may be useful for recording: 1) overview coverage of colonies of interest (e.g., restoration sites); 2) behavioral responses of wildlife to aircraft overflights; and 3) oil spills and spill-response.

Automated counting features of image analysis software may increase the efficiency of counting surface-nesting seabirds from images, but more study is needed. Color thresholds and measurement filters were applied through trial and error, but these must be standardized for different species and image intensities (as affected by sky conditions, aircraft altitude, and camera focal length). Statistical comparisons of automated counts with manual counts will likely be needed in determining such thresholds and ranges. Indications are that automated counts similar to manual counts may be obtained consistently for colony areas of uniform habitat where predominantly one surface-nesting species occurs. Areas where two or more species are intermixed in relatively large numbers, or where pixel intensities of birds and background objects

are similar due to shadows, ledges, caves, boulders, rain-soaked soil, wave-washed areas, etc., appear to be best counted manually.

INTRODUCTION

The University of California, Santa Cruz (UCSC), currently conducts aerial photographic surveys of breeding colonies of Common Murres (*Uria aalge*), Brandt's Cormorants (*Phalacrocorax penicillatus*), and Double-crested Cormorants (*P. auritus*) in California. These surveys are conducted with funding from the California Department of Fish and Game-Office of Spill Prevention and Response (OSPR), and in cooperation with the U.S. Fish and Wildlife Service (USFWS) for northern and central California (Capitolo et al. 2008a). Similar surveys in California have been conducted in most years since 1979 (Carter et al. 2001). Recently, aerial photographic surveys in California also have been used to estimate breeding population sizes of colonies of gulls and terns (Capitolo et al. 2008b, 2009).

From 1985 to 2004, aerial photographic surveys were conducted with 35 mm single lens reflex (SLR) cameras and slide film. Whole-colony counts were determined by projecting selected slides onto 2'x3' white paper, marking (or "dotting") each bird, nest, and site with a felt pen, and subsequently tallying totals for each category (Takekawa et al. 1990, Carter et al. 1992, 1996, 2001, McChesney et al. 2007, Capitolo et al. 2008a). In 2005, UCSC began using digital SLR cameras to survey cormorant colonies in southern California. Since 2007, digital cameras also have been used for surveys in central and northern California, where all Common Murre colonies in California currently occur (Capitolo et al. 2008a). Use of digital cameras noticeably increased the efficiency of aerial photographic surveys because: 1) time spent loading film cameras, which often necessitated additional "circling" time by the pilot while observers prepared for the next pass over a colony, was eliminated; 2) image quality improved, enabling surveys to be conducted from higher altitudes and complete colony coverage to be obtained with fewer images; and 3) slide film processing was eliminated. In addition to reducing observer effort, use of digital cameras has reduced flight time and thereby aircraft fuel use.

Also in 2005, UCSC began using the image analysis software Image-Pro Express (Media Cybernetics, Silver Spring, Maryland) to increase the efficiency of the dotting process. With this software, birds, nests, and sites were manually marked on digital images in a convenient manner and all dotted images were saved with counting symbols and category totals shown. Categorical count data were automatically tallied by the software, substantially reducing the amount of time needed to determine whole-colony counts, compared to the earlier method of using hand-held counters to tally birds, nests, and sites marked on paper.

In 2008, with funding from the OSPR Scientific Study and Evaluation Program, we tested whether the efficiency of conducting surveys and determining whole-colony counts could be further increased by using a high-definition video camera (hereafter, "camcorder") and automated counting features of image analysis software. In this report, we present a preliminary assessment of whether these digital technologies are appropriate for use in aerial surveys of

seabird breeding colonies in California. Additional efforts to compare automated and manual counts also have been conducted by UCSC and USFWS. These data and further discussion of automated counting will be presented in a future report summarizing aerial photographic surveys in California in 2008-2009.

METHODS

Aerial Videography

We rented a Sony high definition camcorder (Model # HVR-V1U) that recorded high definition video (hereafter, “video”) to purchased mini DV tapes. Using Adobe Premier Elements 4.0, video was downloaded to a laptop computer plugged directly into the camcorder with a four pin-six pin IEEE 1394 (FireWire) cable.

Video of selected colonies was captured opportunistically during regularly scheduled aerial photographic surveys of seabird colonies in California (Capitolo et al. 2008a). All colonies were surveyed completely with digital still photography, and video was captured as time permitted. In southern California, we captured about nine min of video (1.65 GB) on 19 and 20 May 2008 at Sandpiper Pier, Bird Rock (San Clemente Island), West Anacapa Island, San Nicolas Island, and Gull Island (Santa Cruz Island). In central and northern California, we captured about 15 min of video (2.85 GB) on 2 and 5 June 2008 at South Farallon Islands, Steamboat Rock, and Castle Rock National Wildlife Refuge. Some video of the mainland coastline also was captured.

Video was recorded in the 1080i format using the default 60i frame rate. With the 60i frame rate, only half the lines of a frame are captured at any moment, with the other half captured 1/60 sec later. The fields are then interlaced (the “i” of 60i) by the camcorder to produce 30 complete frames/sec. In contrast, all lines are captured simultaneously using the 30p (“p” for progressive) frame rate. Temporal resolution and spatial resolution of video playback are thought to be favored by 60i and 30p, respectively. We used only 60i and did not determine which resolution was optimal for aerial surveys of seabird colonies. Video resolution was 1440 x 1080 pixels with a pixel aspect ratio (width:length of pixels) of 1.33. During playback, video resolution is “stretched” to 1920 x 1080 pixels (i.e., the number of pixels that make up the image), its current technological limit. The neutral density filter was set manually according to prompts by the camcorder based on lighting conditions. Other features (e.g., shutter speed, white balance) were left at default settings.

Adobe Premier Elements 4.0 also was used for playback of the MPEG video files and for capturing still images. Still images were exported as JPG files by pausing playback and exporting the frame, both with and without first deinterlacing the frame. Still images had a resolution of 1440 x 1080 pixels and appeared horizontally compressed in comparison to the paused video frame (see above); however, adjusting for a square pixel aspect ratio is possible

with Adobe Premier Elements 4.0 to avoid the horizontally compressed appearance. Capturing still images from video also was explored with Image-Pro software.

Image Analysis

Our original objective regarding automated counting was to investigate and summarize the automated counting capabilities of different image analysis software programs. However, through a review of related literature and conversations with Imaging Specialists from JH Technologies (San Jose, California), it became clear that the professional version of the software we had already been using was the most appropriate for pilot-testing. Image-Pro Plus (IPP) was then purchased separately with OSPR funding for colony surveys, and initial testing of automated counting methods was conducted.

For selected images, manual counts of birds and nests were made using the Manual Tag command of IPP and were compared to automated counts determined with the Count/Size command. Count comparisons were made for both Common Murres and Brandt's Cormorants. All images used for counting were taken with Canon 20D or 30D digital SLR cameras; no stills captured from video were used for counting. The detailed steps of determining automated counts are summarized below.

RESULTS AND DISCUSSION

Aerial Videography

Use of a camcorder did not improve the efficiency of aerial photographic surveys of seabird colonies for three main reasons. First, when the camcorder was zoomed in partially or completely (to obtain coverage comparable to still photography with a 200 mm telephoto lens), the low field of view of the camcorder and low resolution of its LCD display made it impossible for the observer to track the camera's coverage of large colonies. In contrast, the wider field of view and higher display resolution of digital SLR cameras during still photography results in more orderly surveys of large colonies and greater observer confidence that complete, high-quality coverage is obtained. However, at lower zoom settings the camcorder was effective for obtaining colony overview coverage.

Second, still images captured from video were of much lower quality than images from still photography. All still images captured from video appeared blurred to varying degrees, more so if the camcorder could not be held still due to aircraft motion. In some cases, images were so blurred that individual birds appeared as double-images (Fig. 1). Resolution of stills captured from video (1440 x 1080 pixels) was substantially lower than that of stills from SLRs; the image of Common Murres used in Figs. 3-5 was 3504 x 2336 pixels. We also attempted to deinterlace frames before capturing still images, but this did not result in improved image quality. Filming in

30p resolution and substantially increasing shutter speed also may have resulted in higher quality still-images, but we did not attempt these methods. Nevertheless, given the limitations of video resolution, stills captured from video will necessarily be of lower quality than images from still photography.

IPP also is capable of capturing stills from video, but the video file must first be converted from MPEG to AVI without compression. Quality of stills captured by Image-Pro Plus apparently should be the same as the video quality. However, even with some technical support from the software manufacturer, we were unable to open AVI files with IPP. The error code <-5> apparently indicated a missing codec (compressor-decompressor program) and the need to re-convert the file. Conversion was attempted three times, without success and causing one system crash.

Third, use of a camcorder apparently does not reduce the time and effort involved in archiving survey imagery or determining whole-colony counts. Downloading video from the camcorder occurred in “real time” (i.e., 15 min of video took 15 min to download), though downloading may be quicker with newer models that utilize memory cards. The time and effort needed to capture stills from video were similar to current methods of scrolling through JPG images to select the best for counting, but working with the video was much more demanding of computer memory and processing (and caused a computer crash), which ultimately could lead to increased time and effort. Additionally, the JPG file format used with still photography is more widely compatible with different image viewing and analysis software programs than is the MPEG format of video. For example, though IPP may work well for capturing high quality stills from video, video first must be converted to AVI, a time-consuming task that would further complicate archival procedures. With still photography, downloading, archiving, and maintaining images also requires considerable time, but all images from a survey can easily be backed-up and individual images can be rapidly scrolled through during dotting.

A further consideration of camcorders for aerial surveys of seabird colonies is their relatively large size compared to still cameras. The camcorder we rented did not fit through the aircraft’s window port during surveys designed for oblique photography, requiring passes to be flown farther offshore or with steeper banks. During surveys designed for vertical photography, camcorder use through the aircraft’s belly port was not difficult.

Though camcorders currently do not seem appropriate for aerial surveys of seabird colonies in California, they may be useful for other objectives such as: 1) documenting responses of birds and other wildlife to aircraft overflights; 2) periodically archiving video of colonies of interest (e.g., restoration sites); and 3) documenting activities associated with oil spills and spill response. Video segments also could be used for presentations because high video quality was retained when frames were paused during playback of the MPEG file (in contrast to low quality of captured JPG stills).



Figure 1. Sample still images captured from video of: 1) an object (the inside of the aircraft) not in relative motion; and 2) nesting cormorants at Gull Island, Santa Cruz Island, as the aircraft banked over the colony.

Image Analysis

Literature Review

A few previous studies have used small numbers of sample aerial photographs to demonstrate the potential to perform automated counts of wildlife, but we were not aware of any long-term application of standardized methods to complete surveys. Laliberte and Ripple (2003) summarized previous studies and provided a then-current review of the technical details of generating automated counts. Using ImageTool (University of Texas Health Science Center; <http://ddsdx.uthscsa.edu/dig/itdesc.html>), software similar to IPP that was developed for medical image analysis, they compared manual and automated counts of non-nesting groups of Canada (*Branta canadensis*) and Snow Geese (*Chen caerulescens*), and of a caribou (*Rangifer tarandus*) herd. As of this report, ImageTool apparently was still available for free download, but the site had not been updated since 2002.

Trathan (2004) used the Image Processing Toolbox of Matlab (MathWorks Inc., Natick, Mass.) to estimate population sizes of Macaroni Penguin (*Eudyptes chrysolophus*) colonies at Bird Island, South Georgia. Through regression analyses, he found automated and manual counts were highly correlated. The penguin colonies occurred on both level plateaus and steep, scree slopes, not dissimilar to terrain at some cormorant and murre colonies in California. However, penguins do not build nests (unlike cormorants) and average penguin nesting densities (< 1 nest/m²) were not comparable to murre nesting densities (as many as 20 breeding pairs /m²). A study of aerial infrared videography of night-roosting Sandhill Cranes (*Grus canadensis*) attempted automated counts from low-altitude (300 m) survey images but found they underestimated manual counts of cranes due to overlapping thermal signatures of individual birds. Manual counts were therefore used for calculating densities that were then used to estimate population sizes from higher-altitude (1200 m) surveys (Kinzel et al. 2006). The results of Laliberte and Ripple (2003) and Trathan (2004) were encouraging and these studies are referred to more in the Case Studies below.

Automated Count Methods

Using the Count/Size menu, we first chose the range of colors (or gray levels) IPP identified for a selected image, a process referred to as “segmentation”. Color, or intensity, values indicated the degree of gray of objects (i.e., pixels or groups of pixels), from zero (black) to 255 (white). Red, blue, and green intensity values for each pixel were displayed at the bottom of the IPP window as the cursor was moved through the image. After much trial and error, a roughly consistent approach to selecting a color range for a selected image was developed. In images with high contrast between birds and substrate, cormorants and murres appeared to be best identified by the software by segmenting an image toward the black end of the scale. The minimum color value was always set to zero, and the maximum value (often near 100) was adjusted until the software identified all pixels of the dark upperparts of all (or nearly all) birds.

Selecting colors such that gaps between identified pixels of the upperparts of each bird did not exist seemed to roughly standardize this step. Identified pixels (i.e., those within the color threshold and measurement filters [see below]) were counted as part of the same “object” if they shared an edge, referred to as the 4-Connect mode. In hindsight, counts using the 8-Connect mode also should be assessed. The 8-Connect mode also considers corner pixels and may help reduce numbers of background objects. Once this approach was developed, segmentation of images could be performed in just a few minutes.

Next, a measurement had to be chosen before a count of objects could be made. Again through trial and error, Area (in pixels) appeared to be the most straightforwardly useful measurement, but others such as Perimeter, Length, and Roundness may be useful for distinguishing standing cormorants from cormorants in incubation posture on well-built nests. Measurement ranges were then selected to filter out background objects with an Area that was well outside the range of Areas of bird-objects. Typically, the minimum value of the Area range (default value = 10 pixels) was adjusted to just less than a value at which birds began to be omitted from the count. Minimum selected values varied widely because Areas of birds depended on image intensity, which is affected by sky conditions, aircraft altitude, and camera focal length. The maximum value was left at the default setting (10 million pixels). An Area of Interest (AOI) was then defined to further restrict counting of objects to only a certain portion of the image.

Other methods, such as Classification (or Auto Classification) of objects according to measurements for cormorants (for which birds and nests are counted) and Watershed Split and Clusters analysis to distinguish individual murres in dense groups, are described in the Case Studies below. Additional methods, such as calibrating images with real distance data (e.g., bird lengths), calculating bird densities, or applying smoothing filters to adjust image intensities, may also be useful, but were not attempted for this report.

Case Study #1 - Roosting Cormorants

The small group of widely-spaced, roosting Brandt’s Cormorants counted in Fig. 2 is a simple case that helps illustrate how differences between automated and manual counts can arise. For the automated count, the maximum color value was set at 110, and the Area range was left at default settings. The AOI was indicated by the green line.

Though the total automated count (44 objects) was very similar to the manual count (45 birds), it actually represented 42 birds plus two background objects. Because the silhouettes of some of the roosting cormorants overlapped in the image, a gap in the pixels that met the color and measurement filter settings did not occur in three instances. In these instances, two birds were identified as only one object. Alone, this would have resulted in an automated count that underestimated the true count by three birds (7%). However, because two background objects also occurred within the chosen AOI, the total automated count underestimated the true count by only one bird (2%). The AOI could easily have been drawn to exclude these background objects;

and because numbers of background objects will vary among images, roughly standardized methods for defining an AOI need to be developed.

Case Study #2 - Common Murres

The issue of IPP identifying more than one bird as only one object was especially prominent when counting Common Murres. Whereas the Macaroni Penguins counted by Trathan (2004) occurred in low densities (< 1 nest/m²), murres occur in densities of up to 20 pairs/m², often with individual birds in physical contact with neighbors. Laliberte and Ripple (2003) encountered only small numbers of geese that occurred in groups, and used Classification methods (described further below) to assess numbers by dividing the Area of those larger objects by a defined maximum Area that represented one animal. For murres however, the number of individuals that may initially be included in an object may range from two birds to hundreds of birds (Fig. 3), so other methods are needed.

The following steps to address the clumped distribution of murres were developed by testing various methods on images with high contrast between birds and substrate across all areas. After colors and measurements were selected, the next step was to run a Watershed Split, where IPP erodes all objects and dilates them again so they do not touch. Typically, the Watershed Split reached a constant total after three iterations. The count from a Watershed Split usually was lower than the manual count of murres, with some smaller groups of murres remaining identified as just one object. Therefore, a Clusters analysis was conducted after the Watershed Split to assess numbers of murres in remaining un-split objects. The resulting count typically exceeded the manual count, so an average of the Watershed Split and the Clusters count also was determined.

To illustrate the importance of high contrast between birds and substrate, we describe for this report detailed results for just one sample image that did not have uniformly high contrast across all areas (Figs. 3-5). The manual count of murres for the sample image of Subcolony 2 at False Cape Rocks, Humboldt County, taken on 5 June 2008, was 4093 birds. For automated counts, the maximum color value was initially set (based on methods described above) at 100, the approximate value at which all pixels of the upperparts of murres were identified. Watershed Split and Clusters counts and their averages were then determined, and repeated with different color thresholds (Table 1).

Watershed Split counts exceeded the manual count by 2.6% to 11.0%. Clusters analysis counts greatly overestimated the number of murres, exceeding the manual count by 34.6% to 61.6%. Averages of the two automated counts exceeded the manual count by 19.5% to 36.3%. These results differ from the pattern of Watershed Split counts underestimating and Clusters analysis counts overestimating numbers of murres that was evident with other images. This difference was apparently due to wet, concave areas of substrate in the middle of murre groups. These areas were identified as objects because their intensities overlapped with the range of intensities selected as most appropriate for identifying murres, whereas white, guano-covered

rock was not identified as objects (Fig. 4). Laliberte and Ripple (2003) also noted that best results were obtained with images of high contrast, where animals were well differentiated from the background.

Table 1. Manual and automated counts (and % difference) of Common Murres from a sample image of False Cape Rocks. Objects with area < 25 pixels were excluded.

Color Range	Manual Count	Automated Counts		
		Watershed Split	Clusters	Average
0-100	4093	4276 (+4.5)	5507 (+34.6)	4892 (+19.5)
0-90	4093	4320 (+5.6)	5542 (+35.4)	4931 (+20.5)
0-80	4093	4544 (+11.0)	6614 (+61.6)	5579 (+36.3)
~150-255	4093	4198 (+2.6)	6302 (+54.0)	5250 (+28.3)

Due to the lack of uniformity of contrast, we would not consider these automated count data a valid assessment of the number of murres in the image. However, the relatively close Watershed Split counts (i.e., 2.6%-11% greater than the manual count) suggested that images with different degrees of contrast uniformity may require different automated routines. For images with non-uniform contrast, determining only a Watershed Split may be adequate, whereas the average of the Watershed Split and Clusters analysis counts may be best for images with uniformly high contrast. More work is needed to confirm best automated routines for counting Common Murres.

Case Study #3 - Nesting Cormorants

For nesting cormorants, Classification of object data was needed because population estimates typically are based on counts of nests (Carter et al. 1992) and an initial automated count estimated only the total number of birds. Cormorants attending a colony may include birds: 1) in incubation posture on well-built nests; 2) in various postures at nests under construction or with chicks; 3) standing next to incubating mates; and 4) standing at territorial sites.

We used a sample image of Brandt's Cormorant breeding at Vizcaino Point, San Nicolas Island, on 20 May 2008 to provide a simple example of Classification (Fig. 6). This particular group of cormorants was relatively synchronous. Most nests appeared to be in the incubation stage, but some poorly-built nests and territorial sites were evident. The manual count was: 124 well-built nests (WBN), 16 poorly-built nests (PBN), 4 territorial sites, and 14 other standing birds, for a total of 158 birds. Typically, the total number of nests is calculated as the sum of WBN and PBN (Capitolo et al. 2008a), 140 nests in this case.

The initial automated count (Color max.: 75; Area min.: 100) was 148 objects, 7% lower than the manual bird count. As with the example of roosting cormorants, this difference was due to pixel-connectivity of some adjacent birds. Next, a simple Auto Classification of objects was done. All objects were placed into one of two categories (16 “bins” are possible with IPP) based on similarity of Area measurements. This resulted in one category of 141 objects, with a mean area of 221 pixels, and a second category of seven objects, with a mean Area of 574 pixels. Upon inspection of the counted image, the Classified data could be interpreted as 141 nests and 7 objects that each represented two birds, for a total of 155 birds.

Classification may be done by using up to three different measurements, and this technique may be useful for colonies where murres and cormorant nests are intermixed. It should also be noted that images of cormorants in this report were taken obliquely. In images taken vertically through the belly port of the aircraft, as done in central and northern California, cormorants are less likely to overlap, and standing and incubating birds are more likely to have very different Areas, affecting Classification methods and interpretation.

Automated counting methods alone would result in the loss of some phenological data. Chicks of various sizes are often seen in nests in aerial photographs (especially in southern California), but would not be identifiable using automated methods because in almost all cases they would overlap with the pixels of an attending adult. Methods for accurately Classifying territorial sites also are still yet to be determined.

Image Analysis Conclusion and Recommendations

Like previous studies, our work to date has demonstrated clearly that under certain conditions automated counting features of software can generate counts of objects (e.g., seabirds) that closely approximate manual counts. It also is evident that individual users of automated counting methods will need to tailor specific methods to their unique tasks. The methods used by Trathan (2004) and Laliberte and Ripple (2003) were not directly applicable to counting murres and cormorants in California, and standardized methods that may be developed for seabirds in California would not be directly transferable to other objectives (e.g., counting hauled-out pinnipeds).

Automated counting methods may be especially suitable (i.e., more readily and consistently standardized) for surveys that are flown along fixed-altitude transects, using standard, mounted equipment for photography of flat areas. Under these conditions, image intensities may be predictable, and standardized values for color thresholds and measurement filters for use over time could be determined for a given combination of: 1) species to be counted; 2) aircraft altitude; and 3) sky condition. With standardized settings, macros also could be programmed in IPP for further efficiency. For surveys of seabird colonies in California, however, though focal length (200 mm) typically does not vary, colony topography, angle of aircraft approach to a colony, and aircraft altitude change often, resulting in changing image intensities at most colonies.

Regardless of whether image intensities can be predicted, the process of selecting color threshold and measurement filter settings needs to be standardized. The process we used was subjective. For example, we selected 100 as the maximum Color value for the Common Murre Case Study based on visual assessment that all upperparts of birds had been identified, but another observer might easily have selected a different value (e.g., 85 or 110, etc.). We recommend further consultation with Imaging Specialists for better understanding of histogram displays of intensities, and other features of IPP. Uses of Watershed Split, Clusters, and Classification commands also need to be refined and standardized.

Future efforts at standardizing automated counts should focus first on images of large, dense murre areas (e.g., portions of Castle Rock in northern California or the Farallon Islands in central California) and large, contiguous Brandt's Cormorant breeding areas (e.g., parts of Año Nuevo Island), for which time-savings may be substantial and for which standardized methods may be repeatable in different years. Large Western Gull colonies that occur over extensive areas of large, flat-topped islands in (e.g., Anacapa Island and Santa Barbara Island; Capitolo et al. 2008b) also would be appropriate. Secondary focus should be on images that feature large numbers of both species intermixed.

Given that whole-colony count data for murre and cormorant breeding colonies in California since 1985 have been collected in a standardized manner that aimed to census all birds in attendance (Takekawa et al. 1990, Carter et al. 1992, 1996, 2001, Capitolo et al. 2004, 2006), correlation of manual and automated counts should be assessed statistically to determine if automated counts can be used to accurately reflect population trends.

Further work to standardize automated methods is warranted because of the potential for substantial time savings for determining whole-colony counts. A dense colony area with several thousand murres that might require three hrs to count manually, might only require 20 min to count with automated methods. Other studies also have roughly quantified the time savings of automating counts (see Laliberte and Ripple 2003). However, with improved image quality of digital photography, and by using current computer equipment with large amounts of memory, fast processors, and large external monitors, manual dotting has become much more efficient in recent years and likely will remain preferable for small colonies and edge areas of larger colonies. For images with relatively small numbers of murres or cormorants, automated methods likely will save little time while sacrificing some data quality. Manual methods also would still be needed to determine phenological data for cormorants. Additional comparisons of automated and manual count data will be presented in a future report that summarizes aerial photographic surveys of seabird colonies in California in 2008-2009.

ACKNOWLEDGMENTS

Funding for this work was provided to the University of California, Santa Cruz (UCSC), by the California Department of Fish and Game-Office of Spill Prevention and Response (CDFG-OSPR), with assistance from Julie Yamamoto and Laird Henkel. Heather Sakai (JH Technologies, San Jose, California) provided valuable technical assistance. Administrative

assistance was provided by Robin Chace and Jeanne Moody (UCSC). Familiarity of Image-Pro Plus software also was gained by Capitolo during investigation for the Common Murre Restoration Project, with assistance from Rick Golightly (Humboldt State University, Arcata, California). Aerial surveys in 2008 were conducted under permit # MULTI-2008-02 with the National Oceanic and Atmospheric Administration (NOAA), with assistance from Danielle Lipski (NOAA, Santa Barbara, California). Aerial surveys were expertly piloted by Wayne Burnett, with scheduling assistance from Ron VanBenthuyzen (CDFG, Air Services, Sacramento, California).

LITERATURE CITED

- Capitolo, P.J., H.R. Carter, R.J. Young, G.J. McChesney, W.R. McIver, R.T. Golightly, and F. Gress. 2004. Changes in breeding population size of Brandt's and Double-crested Cormorants in California, 1975-2003. Unpublished report, Department of Wildlife, Humboldt State University, Arcata, California.
- Capitolo, P.J., G.J. McChesney, H.R. Carter, M.W. Parker, J.N. Hall, R.J. Young, and R.T. Golightly. 2006. Whole-colony counts of Common Murres, Brandt's Cormorants, and Double-crested Cormorants at sample colonies in northern and central California, 1996-2004. Humboldt State University, Department of Wildlife, Arcata, CA; and U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, Newark, California.
- Capitolo, P.J., J.N. Davis, L.A. Henkel, W.B. Tyler, and H.R. Carter. 2008a. Aerial photographic surveys of breeding colonies of Brandt's, Double-crested, and Pelagic Cormorants in southern California, 2005-07. Unpublished report, University of California, Institute of Marine Sciences, Santa Cruz, California.
- Capitolo, P.J., H.R. Carter, L.A. Henkel, K.K. Neuman, P.N. Hébert, and W.B. Tyler. 2008b. Comparison of 2007 and 1991 breeding population estimates for sample colonies of Western Gulls in southern California. Unpublished report, University of California, Institute of Marine Sciences, Santa Cruz, California.
- Capitolo, P.J., G.J. McChesney, H.R. Carter, and S.J. Rhoades. 2009. Breeding population estimates for sample colonies of Western Gulls, California Gulls, and Caspian Terns in northern and central California in 2006-2008. Unpublished report, Humboldt State University, Department of Wildlife, Arcata, California; and U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, Newark, California.
- Carter, H.R., G.J. McChesney, D.L. Jaques, C.S. Strong, M.W. Parker, J.E. Takekawa, D.L. Jory, and D.L. Whitworth. 1992. Breeding populations of seabirds in California, 1989-1991. Vols 1 and 2. Unpublished draft final report, U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, Dixon, California.

- Carter, H.R., G.J. McChesney, J.E. Takekawa, L.K. Ochikubo, D.L. Whitworth, T.W. Keeney, W.R. McIver, and C.S. Strong. 1996. Population monitoring of seabirds in California: 1993-1995 aerial photographic surveys of breeding colonies of Common Murres, Brandt's Cormorants and Double-crested Cormorants. Unpublished final report, U.S. Geological Survey, California Science Center, Dixon, California.
- Carter, H.R., U.W. Wilson, R.W. Lowe, M.S. Rodway, D.A. Manuwal, J.E. Takekawa, and J.L. Yee. 2001. Population trends of the Common Murre (*Uria aalge californica*). Pages 33-132 in D.A. Manuwal, H.R. Carter, T.S. Zimmerman, and D.L. Orthmeyer, editors. Biology and conservation of the Common Murre in California, Oregon, Washington, and British Columbia. Volume 1: Natural history and population trends. U.S. Geological Survey, Information and Technology Report USGS/BRD/ITR-2000-0012, Washington, D.C.
- Kinzel, P.J., J.M. Nelson, R.S. Parker, and L.R. Davis. 2006. Spring census of mid-continent Sandhill Cranes using aerial infrared videography. *Journal of Wildlife Management* 70:70-77.
- Laliberte, A.S. and W.J. Ripple. 2003. Automated wildlife counts from remotely sensed imagery. *Wildlife Society Bulletin* 31:362-371.
- McChesney, G.J., L.E. Eigner, T.B. Poitras, P.J. Kappes, N.M. Jones, D.N. Lontoh, P.J. Capitolo, R.T. Golightly, D. Le Fer, H.R. Carter, S.W. Kress, and M.W. Parker. 2007. Restoration of Common Murre colonies in central California: annual report 2006. Unpublished report, U.S. Fish and Wildlife Service, San Francisco Bay National Wildlife Refuge Complex, Newark, California.
- Takekawa, J.E., H.R. Carter, and T.E. Harvey. 1990. Decline of the Common Murre in central California, 1980-1986. Pp. 149-163 in S. G. Sealy, editor, *Auks at sea. Studies in Avian Biology* 14.
- Trathan, P.N. 2004. Image analysis of color aerial photography to estimate penguin population size. *Wildlife Society Bulletin* 32:332-343.

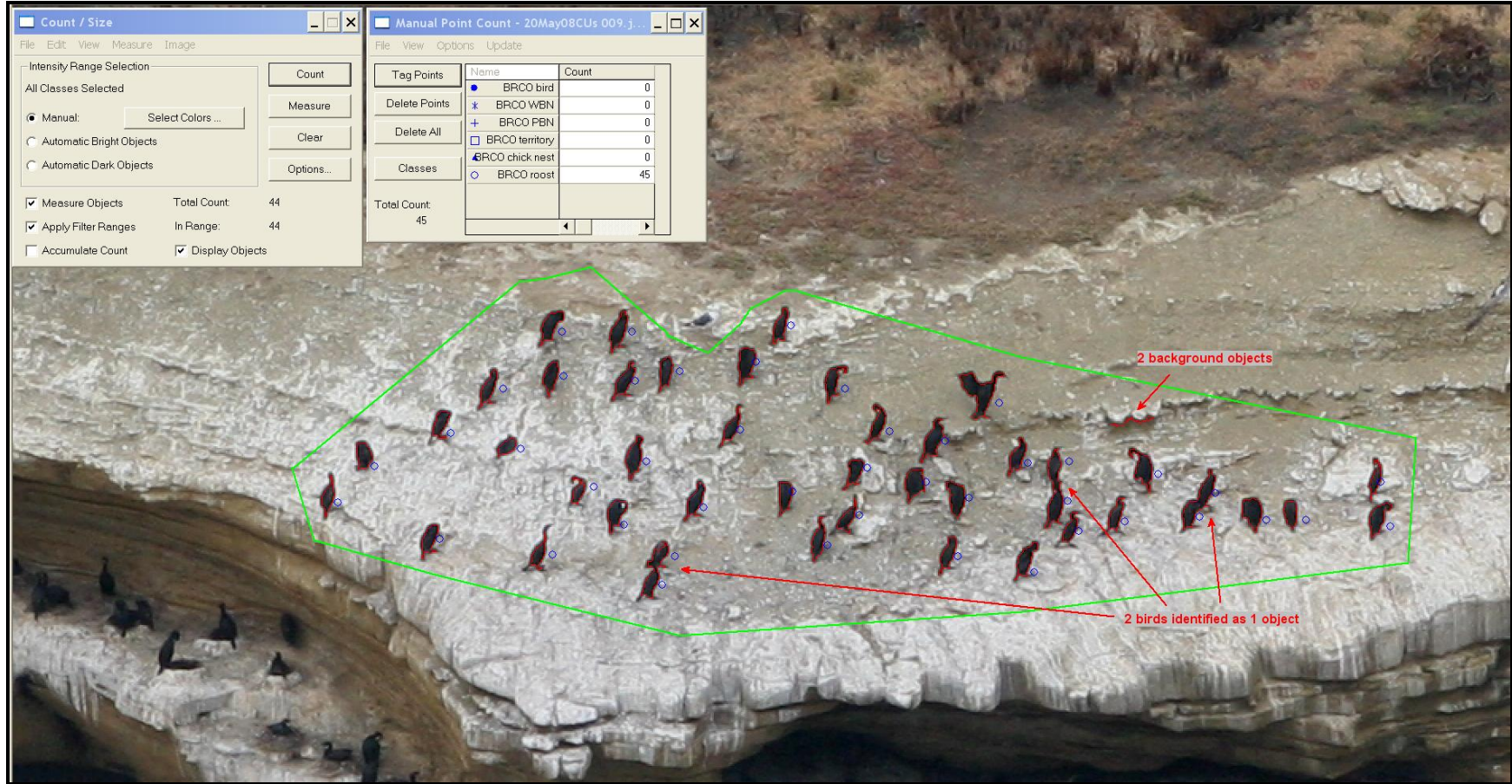


Figure 2. Manual (blue circles) and automated (red outlines) counts of roosting Brandt's Cormorants at San Nicolas Island, California. The automated total count (44 objects) differed from the manual count (45 birds) by just one, but included two background objects and excluded three birds.



Figure 3. A close-up image (zoomed to 200%) of Common Murres at Subcolony 02 of False Cape Rocks, Humboldt County, California. The red outlines indicate objects selected by the software according to color threshold and area filter settings. Note that most of the murres at the center of the image, as well as the wet concave areas between groups of murres, were considered part of a single large object (see Fig. 4).



Figure 4. A close-up image (zoomed to 400%) of Common Murres at Subcolony 02 of False Cape Rocks, Humboldt County, California. The red outlines indicate objects selected by the software according to color threshold and area filter settings, following a Watershed Split (see Fig. 3).

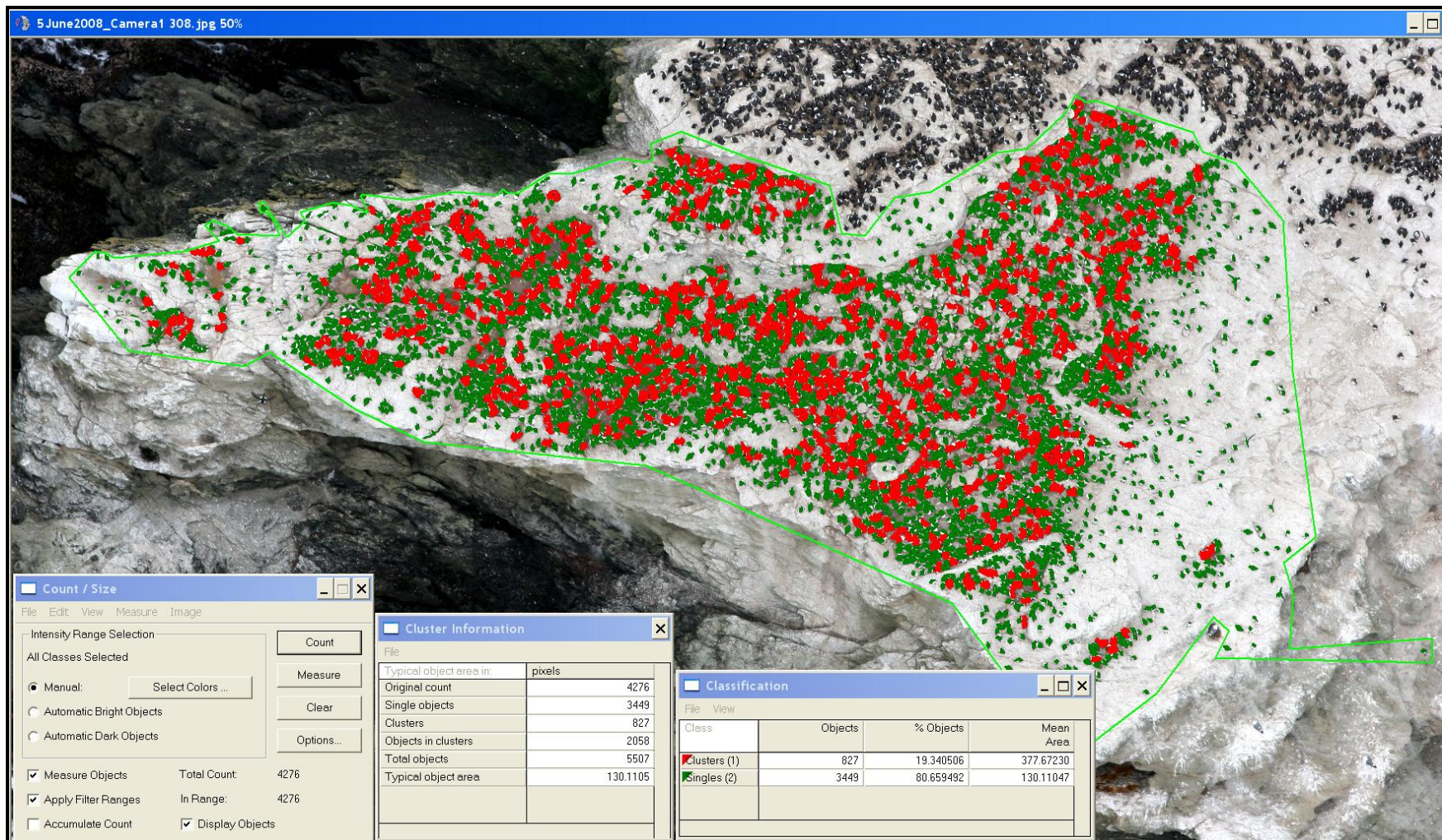


Figure 5. A close-up image (zoomed to 50%) of Common Murres at Subcolony 02 of False Cape Rocks, Humboldt County, California, showing results of Clusters analysis following Watershed Split (see Figs. 3,4).



Figure 6. A close-up image of nesting Brandt's Cormorants at Vizcaino Point, San Nicolas Island, 20 May 2008. The three boxes, from top to bottom, display: 1) Manual Tag data; 2) automated count total after color threshold and Area filter applications; and 3) Auto Classification of the automated total into two Area groupings.