Digital Photo-Identification Dataset Management and Analysis: Testing Protocols Using a Commercially Available Application

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2012

Canadian Technical Report of Fisheries and Aquatic Sciences 2978

Fisheries and Oceans Pêches et Océans

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

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Cat. No. Fs-97-6/2978E ISSN 0706-6457

Correct citation for this publication:

Towers, J.R., Ford, J.K.B., and Ellis, G.M. 2012. Digital photo-identification dataset management and analysis: Testing protocols using a commercially available application. Can. Tech. Rep. Fish. Aquat. Sci. 2978: iv + 16 p.

TABLE OF CONTENTS

ABSTRACT

Towers, J.R., Ford, J.K.B., and Ellis, G.M. 2012. Digital photo-identification dataset management and analysis: Testing protocols using a commercially available application. Can. Tech. Rep. Fish. Aquat. Sci. 2978: iv + 16 p.

The conversion from analogue to digital formats in scientific photography has created a need for new photo management and analysis tools for some large datasets. In order to maintain continuity with metadata working standards used for long time series of photo-identification data on film, we managed and analyzed a multi-year dataset of over 75,000 digital identification photos of killer whales using the program *Photo Mechanic*®. In this report, we provide detailed descriptions of our use of this application including setup, image filing, analysis and associated metadata input as well as metadata output, image searching and associated cataloguing. Additionally, we outline some of the *Photo Mechanic* options not used in our study but that may be worthy of consideration for use in other photo-identification projects.

RÉSUMÉ

Towers, J.R., Ford, J.K.B. and Ellis, G.M. 2012. Digital photo-identification dataset management and analysis: Testing protocols using a commercially available application. Can. Tech. Rep. Fish. Aquat. Sci. 2978: iv + 16 p.

Le passage de l'analogique au numérique en photographie scientifique soulève la nécessité de mettre en place de nouveaux outils de gestion et d'analyse photographique pour certains grands ensembles de données. Afin d'assurer la conformité avec les normes d'utilisation des métadonnées, suivies depuismps pour les ensembles de données d'identification photographique sur pellicule, nous avons géré et analysé un ensemble de données se rapportant à plus de 75 000 images d'identification photographique d'épaulards à l'aide du programme *Photo Mechanic*®. Dans le présent rapport, nous donnons des descriptions détaillées de l'utilisation que nous faisons de ce programme, y compris la mise en place, le classement des images, l'analyse et la saisie connexe des métadonnées, la sortie de données,la recerche d'images et le catalogage pertinent. De plus, nous décrivons certaines des options de *Photo Mechanic* qui n'ont pas servi à notre étude mais que l'on pourrait envisager d'utiliser dans d'autres projets d'identification photographique.

1.0 INTRODUCTION

The photo-identification of natural markings on individual wild cetaceans has been used as an important research method since the 1970s (Bigg et al. 1976; Würsig and Würsig 1977; Katona et al. 1979; Braham et al. 1980; Payne et al. 1981). Data collected using photo-identification have been essential for determining population sizes and demographic trends (Bigg et al. 1990; Katona and Beard 1990; Hammond 1990; Olesiuk et al. 1990; Payne et al. 1990), as well as the distribution, range and migration patterns of many cetacean species (Darling and McSweeney 1985; Stone et al. 1987; Calambokidis et al. 1990; Dorsey et al. 1990; Goley and Straley 1994). These studies were originally conducted using 35-mm film. In recent years, many datasets of cetacean images obtained using film have been expanded with the inclusion of digitally-obtained photographic data (Baird et al. 2008; Ellis et al. 2008; Calambokidis et al. 2009; Aschettino et al. 2011; Ellis et al. 2011). Other, recent studies on cetaceans have been undertaken using digital photographs exclusively (Jefferson et al. 2009; Tyurneva et al. 2009; Weir 2009; Auger-Méthé et al. 2010; Whooley et al. 2011).

Photo-identification datasets can be relatively large and therefore require a standardized approach for data collection and specialized methods for data analysis and management. Particular photo-identification methods vary by the species or population being studied (Lien and Katona 1990). Photo-identification data management and analysis procedures for all species, however, can consist of relatively similar stages. These stages usually include sorting or filing the images, identifying individuals within the frames and cataloguing the results (Mazzoil et al. 2004). The ways in which these stages are accomplished differ depending on whether film or digital photo-identification data are being analyzed (Meyer 2007). In either case, granular and structured metadata such as time, date, location, photographer, animal identity, photo rating and comments or keywords as they pertain to each identification photo need to be recorded in a consistent manner over the time series of the dataset. Implementation of a metadata working standard is of great use when working with photo-identification data. Applied to film, such a standard requires systematic use of data sheets that correspond to individual frames on a negative strip. When working with digital images, adoption of a metadata working standard requires the use of metadata container fields such as those developed by the IPTC (*International Press Telecommunications Council*) (Adobe Systems Inc. et al. 2010).

Adhering to a metadata working standard, particularly as it pertains to recording individual animal identities for each photographic frame, is important for our long-term photo-identification study of killer whales. This study was originally conducted using film. An average of 7,500 film-based identification photos were collected and analyzed each field season from 1973 to 2008. Due to this large volume of photographic data, efficient and consistent photo analysis techniques including the associated entry of metadata were developed early in the study and adhered to through its duration (Ellis, unpubl. data). With the advancement of digital photographic technology in the past decade, our use of film-based photo-identification data management and analysis protocols declined while our use of digitally-based methods increased. Although digital

photo-identification techniques were relatively simple to adopt (Ellis et al. 2011), subsequent digital data analysis and management methods required more rigorous development in order to progressively parallel analysis and management methods used for the corresponding film dataset.

In this report, we describe protocols that we developed to manage and analyze digital identification photos of killer whales with the application *Photo Mechanic*. These protocols were developed to enhance management of the digital photo-identification dataset and maintain consistency with methods we used for the analysis of over 200,000 identification photos of killer whales on film from 1973 to 2008. Details on setting up this application to accommodate these methods are provided. Management and analysis are broken down into stages. These stages consist of image organization, analysis and the associated application of metadata as well as metadata exporting, search techniques and subsequent image cataloguing. Screenshots are used to help portray these methods. We also discuss our use of this program and provide further tips on ways that *Photo Mechanic* could be useful for other photo-identification studies.

2.0 PROGRAM DISPLAY SETUP

Photo Mechanic (version 4.6.8) was installed on *Macintosh* computers. (This application runs almost identically on *Windows XP*® or *Windows 7*® operating systems). In the Contact Sheet window toolbar, thumbnails were set to display from 5 to 7 across depending on the size of the monitor screen being used. Also in this toolbar, thumbnails were set to appear sorted by Capture Time, ensuring that images were displayed in the order in which they were taken. From the Contact Sheet section of the Preferences window found under the *Photo Mechanic* menu, thumbnail labels were set to display the image Filename plus the contents of the standard IPTC metadata container field Caption by typing the variable for the Caption field in the space provided (Figure 1). (A table of all metadata variables can be found beginning on page 52 of the *Photo Mechanic* 4.6.3 Manual [Rains and Baker 2009].) This IPTC metadata container field was used for individual Animal ID(s) so that after analysis this information was displayed under each thumbnail in the Contact Sheet view along with its Filename.

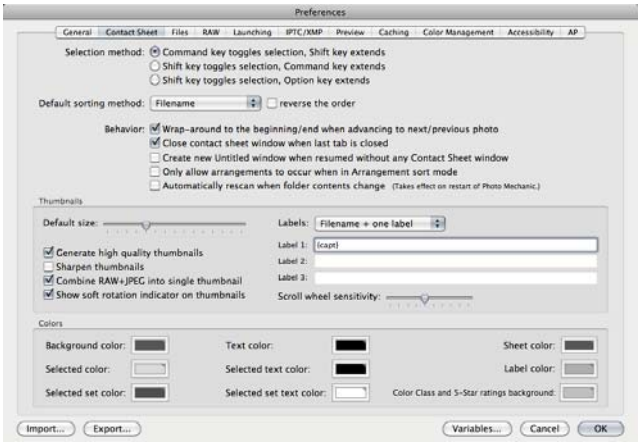

Figure 1. Setting thumbnail labels to display Filename plus Caption field contents.

Setting photo information text preferences allowed only relevant metadata to be displayed with each image. These preferences were set by opening the Set Info Text window in Settings under the Edit menu. Relevant existing metadata such as Date, Time, and camera settings as well as post-analysis metadata such as Photographer, Location, Animal ID(s), Photo Rating, Comments, Analyst and Date Analyzed were chosen to be displayed by providing the variable for each corresponding IPTC metadata container field (Figure 2). These metadata were shown in the Preview window (Figure 3). They could also be displayed in the Contact Sheet view upon placement of the cursor over a thumbnail by checking Show Info Tooltips found under the View menu.

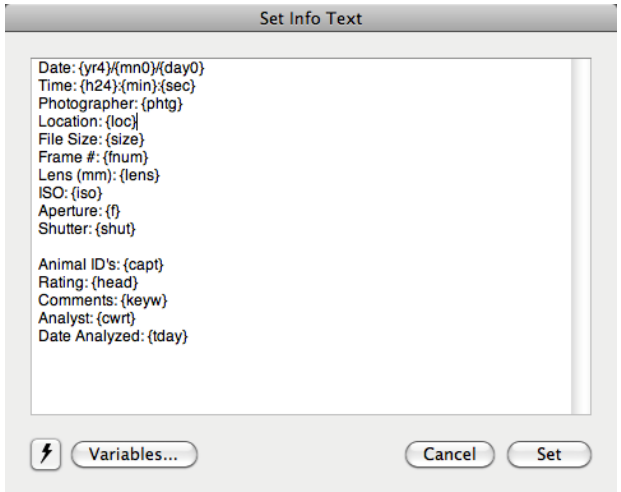

Figure 2. The Set Info Text window with existing and modified IPTC metadata container field headers and corresponding variables.

A Preview window was opened for a photo by double-clicking on a thumbnail. The Preview window was set to display one image only by selecting the appropriate icon from the toolbar (Figure 3). This display includes image metadata text and a zoom function on the right-hand side. A full view of one image excluding photo info text was also occasionally used by selecting the appropriate icon from the toolbar. Viewing images two at a time and having the ability to proceed forward or backward through the image set within the folder from either image on display was also an option in the toolbar but was not used. This option, however, could be very helpful in the process of manually matching individuals within an image set.

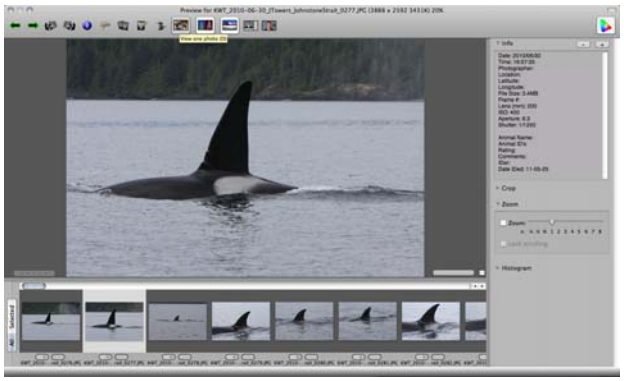

Figure 3. The Preview window.

3.0 DATASET MANAGEMENT AND ANALYSIS

3.1 IMAGE FILING

For filing purposes, all folders for images of each encounter were named using a string sequentially consisting of a Population Code, Date, Photographer and Location all separated by underscores (i.e., KWT_2010-06-30_JTowers_JohnstoneStrait). For consistency purposes, all folders containing identification images were stored on a secure server that is backed-up regularly. Any images that were not in jpeg format were converted to jpegs prior to analysis. Image files were renamed to reflect the folder name string followed by an underscore and the original file number. *Photo Mechanic* provided for the streamlining of this and other processes with its Ingest option. The Ingest window was set to open when *Photo Mechanic* detected an external source containing digital images. Alternatively, the Ingest window was occasionally opened manually and then applied to a selected folder. The folder and images inside were renamed during the Ingest process by providing the necessary strings in the necessary fields within the window (Figure 4). The original file numbers were extracted during this process by applying the appropriate variable to the end of the new Filename string (Figure 4). (Details on variable sub-string extraction can be found on page 51 of the *Photo Mechanic* 4.6.3 Manual [Rains and Baker 2009].) Alternatively, a new series of file numbers were created using the sequence variable when original file numbers were non-existent or inconsistent. Images were occasionally not renamed with Ingest. In these cases they were renamed after being displayed in the Contact Sheet window by selecting all photos and then opening the Rename Photos window from under the File menu.

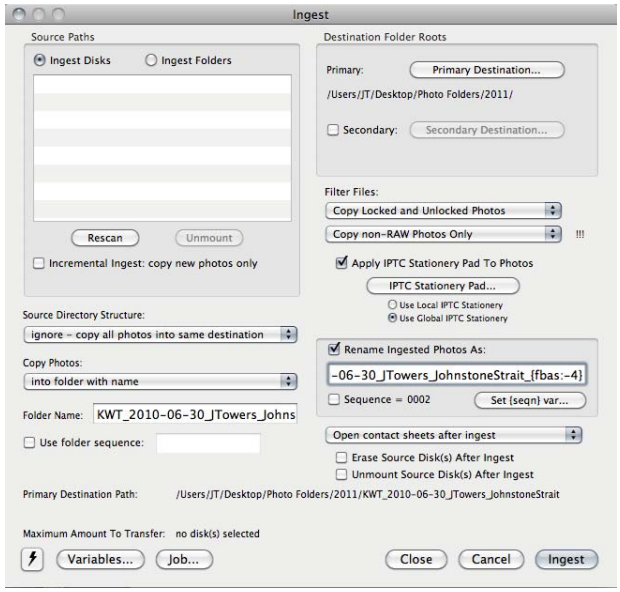

Figure 4. The Ingest window showing different settings, including folder name and image rename string followed by the variable used for retention of original file numbers.

3.2 METADATA INPUT AND IMAGE ANALYSIS

Batch entry of Photographer, Location and Analyst metadata to all photos in the encounter were also applied during Ingest or occasionally by selecting all images within the Contact Sheet window and opening the IPTC Stationary Pad from under the Image menu. Existing IPTC metadata container fields were used for these metadata with the exception of Analyst for which the field Caption Writer was used (Figure 5). Nominal Location names were entered, however, *Photo Mechanic* also allows for GPS coordinates to be applied to images. This can be done manually by opening the Set GPS Coordinates window under the Image menu and then using the *Google Earth*® application within to find coordinates and apply them to selected images as necessary. Alternatively, GPS coordinates can be added by selecting all images and then opening the Import GPS Coordinates window found under the File menu. In this window a GPX file can be imported, plotted, and the data within applied to images based on matching times between images and track points (Figure 6). Variables for latitude and longitude can then be added to the previously mentioned Info Text to display these metadata.

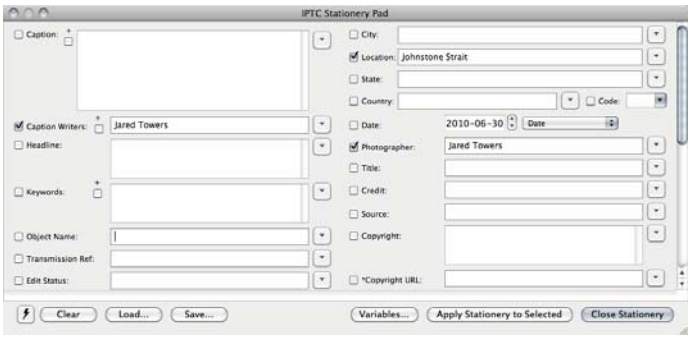

Figure 5. The IPTC Stationery Pad window showing metadata container fields including the 3 used for Analyst, Location and Photographer.

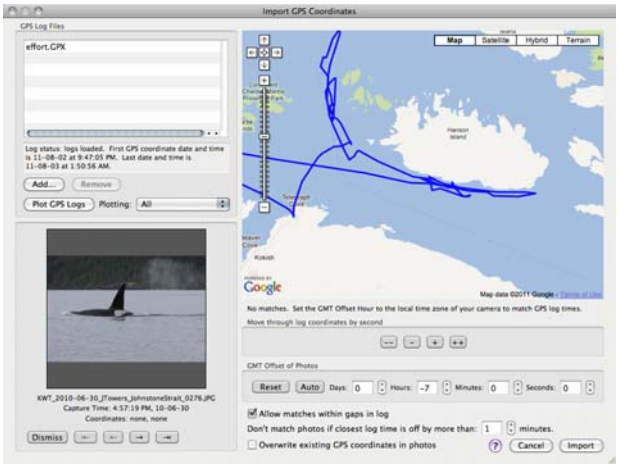

Figure 6. The Import GPS Coordinates window showing plotted GPX file.

It was sometimes necessary to edit existing Time and Date metadata if the source camera's Date and/or Time were incorrectly set. In these cases the Adjust Capture Dates and Times window from under the Tools menu was opened (Figure 7). A new Date or Time was then set and applied to selected images as necessary.

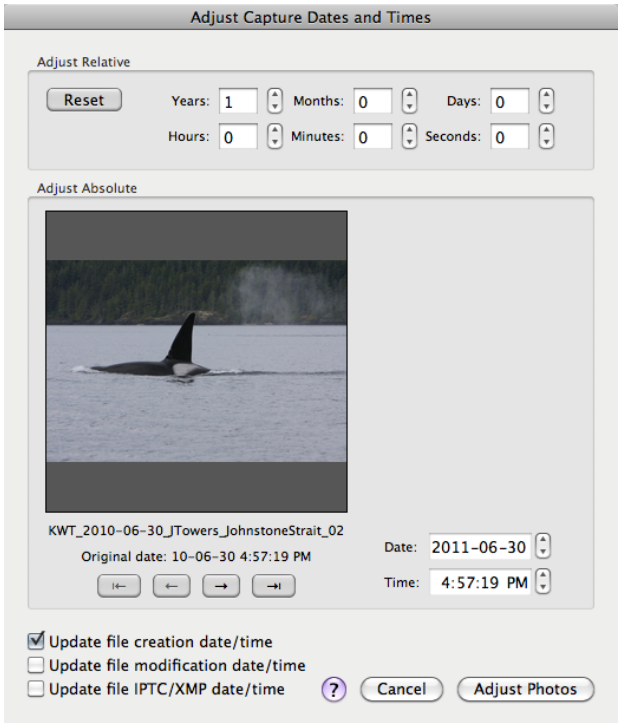

Figure 7. The Adjust Capture Dates and Times window.

Other metadata such as Animal ID(s), Photo Rating and Comments were applied respectively to the Caption, Headline and Keywords IPTC metadata container fields. Any photos that shared common characteristics noticeable at the thumbnail size were selected for batch entry of such metadata. Multiple images of the same individual were commonly selected for batch metadata entry of Animal ID. As killer whales in British Columbia have historically been monitored and identified from photographs of individuals' left sides (Bigg et al. 1987; Ford et al. 1994; Ford and Ellis 1999; Ford et al. 2000; Ellis et al. 2007; Ellis et al. 2008; Ellis et al. 2011), it was assumed in the metadata that images were of left sides unless otherwise stated. Therefore, images of right sides were also commonly selected for batch entry of these metadata in the Comment field. All other metadata were applied manually one frame at a time. This was done by selecting the Edit IPTC Information icon from the Preview window toolbar, thereby opening the IPTC Info data application and display window over top of the existing Preview window (Figure 8). Animal ID(s) were applied to the Caption field of every image containing one or more identifiable animals (Figure 8). Identification names of more than one animal in a single frame were applied separated by a space. A quality rating of 1 to 4 (with 4 being best) was applied to the Headline field only to images that were of a quality sufficient to be used as reference material (Figure 8). Comments were applied in the Keywords field of any images containing specific subjects or features. (Figure 8). Multiple Comments in a single frame were applied separated by a comma and a space. Comments were not made for descriptive markings on animals in our study, however, if a consistent vocabulary for these traits

were used during the metadata input and image searching stages, *Photo Mechanic* could be utilized as a non-metric based matching program. After metadata were applied, the Save and Move to Next Photo command was selected from the icon or by using a keyboard shortcut (Keyboard shortcuts can be found beginning on page 159 of the *Photo Mechanic* 4.6.3 Manual [Rains and Baker 2009].)

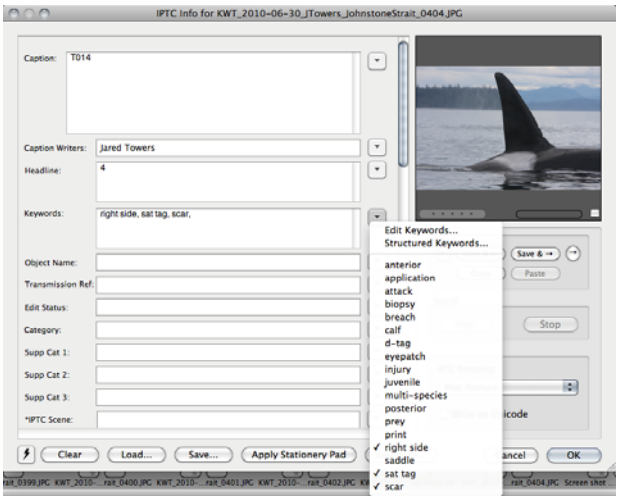

Figure 8. The IPTC Info metadata application window showing the Comment list and other metadata applied to various container fields.

3.3 METADATA OUTPUT

After analysis and metadata embedding were completed for each photo obtained during an encounter, all images were selected for export of their embedded metadata. The desired IPTC metadata container field variables separated by tabs were entered into the Export Code field within the Exporter window selected from under the File menu (Figure 9). The following code:

{filenamebase}{tab}{yr4}{tab}{mn0}{tab}{day0}{tab}{h24}:{min}{tab}{location}{tab}{photographer}{tab}{caption}{tab}{head}{tab}{keyw}{tab}{cwrt}{tab}{tday}

yielded Filename, Date, Time, Location, Photographer, Animal ID(s), Photo Rating, Comments, Analyst, and Date Analyzed for all images within an encounter folder selected for metadata text export. Each export file was renamed with the same string as the encounter folder from which it was derived and then stored in a folder including all other export files from that year. Export files were then opened with the database application *FileMaker Pro*®. (Export files could also be opened with *Microsoft Access*®). Visual scans for erroneous data were performed on the files immediately after completion of encounter analysis and export. When erroneous metadata were encountered, they were immediately corrected manually and then re-exported to overwrite the existing erroneous file. All files were ultimately imported into a master

external database for all digital image metadata from all encounters with killer whales. The master database was used as an external metadata library. Individual or multiple fields could be queried to aid in finding data totals or specifics. Additionally, it provided for the safe-keeping of metadata in an organized manner.

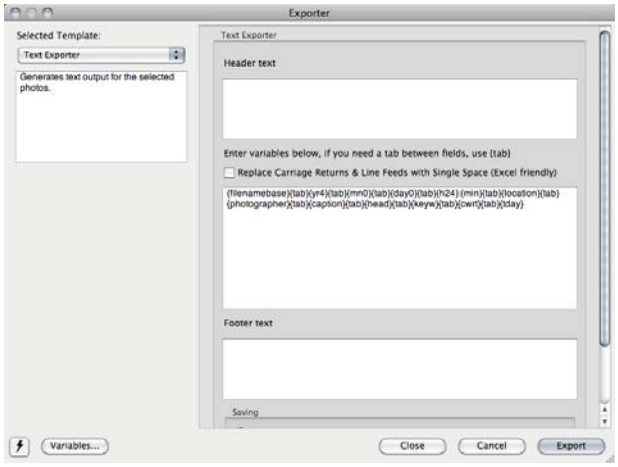

Figure 9. The Export window showing Export Code consisting of individual tab separated IPTC metadata container field variables.

3.4 IMAGE SEARCHING AND CATALOGUING

For image cataloguing purposes, searches for embedded metadata were performed when all photos to be searched could be found on one or more hard drives or servers. Searches were conducted for specific metadata in IPTC metadata container fields by using the Search window under the Edit menu in *Photo Mechanic* (Figure 10). All resulting images were provided in a new folder. This process represented an improvement over external metadata searches, as it negated the need to follow the path to each image location manually in order to verify its potential as high quality reference material in comparison to others. Selected search results were saved into folders containing only high quality identification images of individual whales. These folders, each named with the identity of the whale, were created for every individual and provided for quick future reference of the best identification images for each animal. Filenames inside were edited to begin with the name of each whale. For quick reference of all individuals in the population, the single best image of each whale could be copied to a population folder that when opened with *Photo Mechanic* and sorted by Filename could provide a Contact Sheet view of all individuals in alphanumeric sequence.

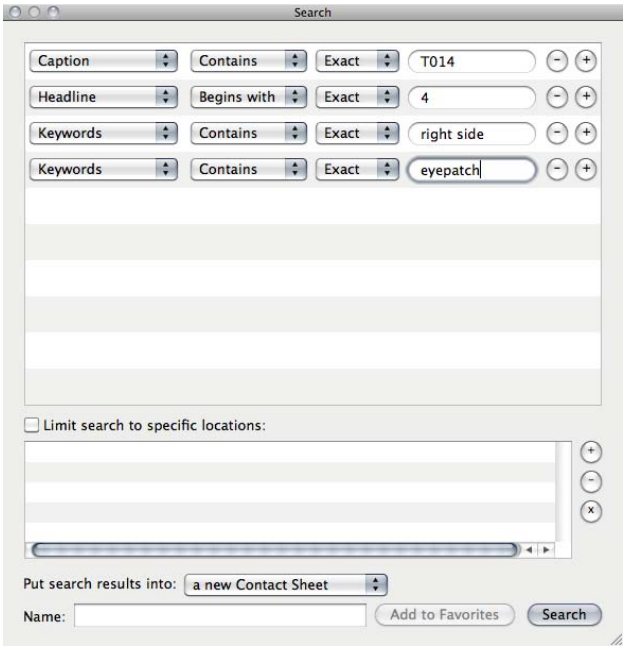

Figure 10. The Search window showing IPTC metadata container field search criteria.

A more restricted search could be applied to multiple IPTC metadata container fields of images within a single folder by using the Find window selected from under the Edit menu when the desired folder is open. The Find and Replace window also found under the Edit menu could be used to locate and correct erroneous data from any IPTC metadata container field(s) of images within the encounter. Similar functions could also be performed to the externalized metadata text within the master database using *Filemaker Pro*.

4.0 DISCUSSION

The complete transition from film to digital methodology for our long-term photo-identification studies of killer whales off the west coast of North America was inevitable due to the many advantages that digital technology offers over film. Standardizing the use of digital technology and the management and analysis of digital data were critical steps in undertaking the shift between the two analogous methods. In order for any analysis methods used for digitally-sourced data to correspond with those used traditionally with film-based data, we required an application that could be used to apply different metadata to individual images. Finding a program that accelerated workflow, was regularly updated, could rename files and be used to edit, export and search for metadata were also important criteria for us to consider during the transition to digital technology for our photo-identification studies.

A total of 76,448 digital identification photos from 1,689 encounters with killer whales from 2001 to 2010 were managed and analyzed with *Photo Mechanic* using the protocols outlined in this report. Our use of digital cameras and digital photo-identification data management and analysis protocols gradually increased over these years while our use of film for the photo-identification of killer whales gradually decreased until ceasing altogether in 2008. When compared to the multiple steps and associated time needed to manage and analyze photo-identification data from film we found that managing and analyzing digital photo-identification data with *Photo Mechanic* greatly expedited and streamlined the entire process. While doing so, this application still allowed for consistency of baseline analysis protocols between the two mediums to be maintained.

The idea of using metadata as a means to better organize and find images is not new. Metadata working procedures are in use in many industries today and are paramount to keeping image copyright, caption and keyword data intact across platforms and during transport and edit. The adoption or creation of a metadata working standard for the maintenance of a dataset consisting of cetacean photo-identification images allows for its safe-keeping and long-lasting preservation, and helps to ensure that the dataset can be mined for specific results with ease. Many digital image programs on the market today cater towards users wishing to implement metadata working standards. The program *Photo Mechanic,* however, fit our requirements better than other programs that we tested such as *ACDSee*®, *iPhoto*®, *Photoshop*®, *Lightroom*®, *Aperture*® and *IMatch*®.

Although much of what is described in this report can be gleaned by filtering through *Photo Mechanic* software features as described by Rains and Baker (2009) and applying them accordingly to a dataset of identification photos, the concept and benefit of doing so may not be immediately apparent. Various publications explain the use of digital photography (Mazzoil et al. 2004) and specially designed matching programs (Mizroch et al. 1990; Whitehead 1990; Araabi et al. 2000; Huele et al. 2000; Hillman et al. 2003; Mazzoil 2004; Gope et al. 2005; Adams et al. 2006; Kniest et al. 2010) for studies of cetaceans. Further publications provide examples of digital photo dataset management and metadata working techniques (Krogh 2009; Nozères 2011). Few, however, provide thorough examples of the management and analysis of a dataset of digital cetacean identification images that complements protocols used historically for film.

The methods and protocols outlined in this report can also be helpful for other studies when modified or adapted to suit the needs of the user and the dataset. For example, descriptive metadata from a pre-determined vocabulary of keywords used to flag specific physical features of an animal can be applied to various IPTC metadata container fields, similar to protocols outlined by Harting et al. (2004). Searches can then be made in those metadata container fields for such keywords, thereby providing non-metric based potential matches. Using metadata in similar ways can also be helpful in studies that are not based on digital photo-identification. The concepts and

protocols described in this report can be adapted and modified for application to datasets of video and acoustic files as well.

5.0 ACKNOWLEDGEMENTS

The individuals who have collected identification photographs of killer whales and contributed them to our studies over the years are too numerous to list. We wish to thank them all. In particular, we would like to extend our thanks to the many individuals who have diligently forwarded us all of their digital identification images of killer whales over the last decade. We also thank Robin Abernethy for input on the setup of *Photo Mechanic* and Christie McMillan for a review of the manuscript.

6.0 REFERENCES

Adams, J. D., Speakman, T., Zolman, E., Schwacke, L. H. 2006. Automating image matching, cataloging, and analysis for photo-identification research. Aquatic Mammals 32(3): 374-384

Adobe Systems Inc., Apple Inc., Canon Inc., Microsoft Corp., Nokia Corp., and Sony Corp. 2010. Guidelines For Handling Image Metadata, Version 2.0 Metadata Working Group www.metadataworkinggroup.org

Araabi, B.N., Kehtarnavaz, N., McKinney, T., Hillman, G. and Würsig, B. 2000. A string matching computer-assisted system for dolphin photoidentification. Ann Biomed Eng. 28:1269-1 279.

Aschettino, J.M., Baird, R.W., McSweeney, D.J., Webster, D.L., Schorr, G.S., Huggins, J.L., Martien, K.K., Mahaffy, S.D. and West, K.L. 2011. Population structure of melon-headed whales (*Peponocephala electra*) in the Hawaiian Archipelago: Evidence of multiple populations based on photo identification. Mar. Mam. Sci. doi: 10.1111/j.1748- 7692.2011.00517.x

Auger-Méthé, M., Marcoux, M. and Whitehead, H. 2010. Nicks and notches of the dorsal ridge: Promising mark types for the photo-identification of narwhals. Mar. Mam. Sci. 26(3): 663-678

Bigg, M.A., Ellis, G. and Balcomb, K.C. 1986. The photographic identification of individual cetaceans. Whalewatcher (J. Amer. Cetacean Soc.) 20: 10-12.

Bigg, M.A., Ellis, G.M., Ford, J.K.B., and Balcomb, K.C. 1987. Killer Whales: A Study of Their Identification, Genealogy and Natural History in British Columbia and Washington State. Phantom Press and Publishers, Nanaimo, BC. 79 p.

Bigg, M.A., MacAskie, I.B. and Ellis, G. 1976. Abundance and movements of killer whales off eastern and southern Vancouver Island with comments on management. Unpubl. Rep., Arctic Biological Station, Dept. of Fisheries and Environment, Ste Anne-de-Bellevue, Quebec.

Bigg, M.A., Olesiuk, P.F., Ellis, G.M., Ford, J.K.B., and Balcomb, K.C. III. 1990. Social organization and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Rep. Int. Whal. Commn. Special Issue 12: 383-405.

Braham, H.W., Krogman, B.D., Johnson, J.H. et al 1980. Population studies of the bowhead whale (*Balaena mysticetus*): results of the 1979 spring research season. Rep. Int. Whal. Commn. 30: 391-404

Baird, R.W., Webster, D.L., Mahaffy, S.D., McSweeney, D.J., Schorr, G.S. and Ligon, A.D. 2008. Site fidelity and association patterns in a deep-water dolphin: Rough-toothed dolphins (*Steno bredanensis*) in the Hawaiian Archipelago. Mar. Mam. Sci. 24(3): 535-553.

Calambokidis, J., Steiger, G.H., Cubbage, J.C., Balcomb, K.C., Ewald, C., Kruse, S., Wells, R. and Sears, R. 1990. Sightings and movements of blue whales off central California 1986-88 from photo-identification of individuals. Rep. Int. Whal. Commn. Special Issue 12: 343-348

Calambokidis, J., Barlow, J., Ford, J.K.B., Chandler, T.E. and Douglas, A.B. 2009. Insights into the population structure of blue whales in the eastern North Pacific from recent sightings and photographic identification. Mar. Mam. Sci. 25(4) 816-832

Darling, J.D. and McSweeney, D.J. 1985. Observations on the migrations of North Pacific humpback whales (*Megaptera novaeangliae*). Can. J. Zool. 63(2): 308-314

Dorsey, E.M., Stern, S.J., Hoelzel, A.R. and Jacobsen, J. 1990. Minke whales (*Balaenoptera acutorostrata*) from the west coast of North America: Individual recognition and small-scale site fidelity. Rep. Int. Whal. Commn. Special Issue 12: 357-368

Ellis, G.M., Ford, J.K.B. and Towers, J.R., 2007. Northern Resident Killer Whales in British Columbia: Photo-Identification Catalogue 2007. Pacific Biological Station, Nanaimo.

Ellis, G.M., Towers, J.R. and Ford, J.K.B. 2008. Transient Killer Whales of British Columbia and Southeast Alaska: Photo-Identification Catalogue 2008. Pacific Biological Station, Nanaimo.

Ellis, G.M., Towers, J.R., and Ford, J.K.B. 2011. Northern resident killer whales of British Columbia: Photo-identification catalogue and population status to 2010. Can. Tech. Rep. Fish. Aquat. Sci. 2942: vi + 71 p.

Ford, J.K.B., and G.M. Ellis. 1999. Transients: Mammal-Hunting Killer Whales. UBC Press, Vancouver, British Columbia. 96 pp.

Ford, J.K.B., Ellis, G.M., and Balcomb, K.C. 1994. Killer Whales: The Natural History and Genealogy of Orcinus orca in British Columbia and Washington State. UBC Press and University of Washington Press, Vancouver, BC and Seattle, WA. 102 p.

Ford, J.K.B., Ellis, G.M., and Balcomb, K.C. 2000. Killer Whales: The Natural History and Genealogy of Orcinus orca in British Columbia and Washington, Second edition. UBC Press and University of Washington Press, Vancouver, BC and Seattle, WA. 104 p.

Goley, D.P., and Straley, J.M. 1994. Attack on gray whales (*Eschrichtius robustus*) in Monterey Bay, California, by killer whales (*Orcinus orca*) previously identified in Glacier Bay, Alaska. 1994. Can. J. Zool. 72(8): 1528-1530.

Gope, C., Kehtarnavaz, N., Hillman, G., and Würsig, B. 2005. An affine invariant curve matching method for photo-identification of marine mammals. Pattern Recognition 38: 125-132.

Hammond, P.S. 1990. Capturing whales on film - estimating cetacean population parameters from individual recognition data. Mammal Rev. 20(1): 17-22

Harting, A., Baker, J., and Becker, B. 2004. Non-metrical digital photo-identification system for the Hawaiian monk seal. Mar. Mam. Sci. 20(4): 886-895.

Hillman, G.R., Würsig, B., Gailey, G.A., Kehtarnavaz, N., Drobyshevsky, A., Araabi, B.N., Tagare, H.D., and Weller, D.W. 2003. Computer-assisted photo-identification of individual marine vertebrates: A multi-species system. Aquatic Mammals, 29(1): 117-123.

Huele, R., Udo de Haes, H.A., Ciano, J.N., and Gordon, J. 2000. Finding similar trailing edges in large collections of photographs of sperm whales. J. Cetacean Res. Manage. 2(3): 173-176.

Jefferson, T.A., Olson, P.A., Kieckhefer, T.R., and Rojas-Bracho, L. 2009. Photo-identification of the vaquita (*Phocoena sinus*): The world's most endangered cetacean. Lat. Amer. J. Aqua. Mam. 7(1-2): 53-56.

Katona, S.K., and Beard, J.A. 1990. Population size, migrations and feeding aggregations of the humpback whale (*Megaptera novaeangliae*) in the western North Atlantic Ocean. Rep. Int. Whal. Commn. Special Issue 12: 295-305

Katona, S., Baxter. B., Brazier. O., Kraus. S., Perkins. J.S., and Whitehead, H. 1979. Identification of humpback whales by fluke photographs. (*Megaptera novaeangliae*) Behavior of Marine Animals: Current perspectives in research Vol. 3: Cetaceans, 33-44. Plenum Press, N.Y.

Kniest, E., Burns, D., and Harrison, P. 2010. Fluke Matcher: A computer-aided matching system for humpback whale (*Megaptera novaeangliae*) flukes. Mar. Mam. Sci. 26(3): 744-756.

Krogh, P. 2009. The DAM Book: Digital Asset Management for Photographers. Second Edition. O'Reilly Media Inc. Sebastopol CA. xv + 476pp

Lien, J., and Katona, S. 1990. A guide to the photographic identification of individual whales based on their natural & acquired markings. American Cetacean Society. San Pedro, CA. 77pp

Mazzoil, M., McCulloch, S. D., Defran, R. H., and Murdoch, M. E. 2004. Use of digital photography and analysis of dorsal fins for photo-identification of bottlenose dolphins. Aquatic Mammals, 30(2): 209-219.

Meyer, E.T. 2007. Socio-technical perspectives on digital photography: Scientific digital photography use by marine mammal researchers. Ph.D. Thesis, Indiana University, Bloomington, Indiana, U.S.A. xx + 340 p.

Mizroch, S.A., Beard, J.A., and Lynde M. 1990. Computer assisted photo-identification of humpback whales (*Megaptera novaeangliae*). Rep. Int. Whal. Commn. Special Issue 12: 63-70.

Nozères, C. 2011. Managing image data in aquatic sciences: an introduction to best practices and workflows. Can. Tech. Rep. Fish. Aquat. Sci. 2962: xii + 171 p.

Olesiuk, P.F., Bigg, M.A., and Ellis, G.M. 1990. Life history and population dynamics of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. Rep. Int. Whal. Commn. Special Issue 12: 209-242.

Payne, R., Brazier, O., Dorsey, E.M., Perkins, J.S., Rowntree, V.J., and Titus, A. 1981. External features in southern right whales, *Eubalaena australis* and their use in identifying individuals. Final report for Contract No. MM6AC017. NTIS Publ. PB81-161093. U.S. Marine Mammal Commission, vii + 77pp.

Payne, R., Rowntree, V., Perkins, J.S., Cooke, J.G., and Lankaster, K. 1990. Population size, trends and reproductive parameters of right whales (*Eubalaena australis*) off Peninsula Valdes, Argentina. Rep. Int. Whal. Commn. Special Issue 12: 271-278

Rains, N., and Baker, K. A. 2009. Photo Mechanic User Guide, version 4.6.3. Camera Bits Inc. http://www.camerabits.com/site/downloads.html

Saunders, S. 2011. Image Metadata Planning: A guide for business users. Centre of the Picture Industry and the IPTC Photometadata Working Group. Berlin, Germany. 25 pp

Stone, G.S., Katona, S.K., and Tucker, E.B. 1987. History, migration and present status of humpback whales *Megaptera novaeangliae* at Bermuda. Biol. Cons. 42(2): 133-145.

Tyurneva, O.Y., Yakolev, Y.M., and Vertyankin, V.V. 2009. Photographic identification of the Korean-Okhotsk gray whale (*Eschrichtius robustus*) offshore northeast Sakhalin Island and southeast Kamchatka Peninsula (Russia), 2008. Unpub. paper to the IWC Scientific Committee. 9 pp. Madeira, Portugal, June 2009 (SC/61/BRG26)

Weir, C.R. 2009. Distribution, behaviour and photo-identification of Atlantic humpback dolphins (*Sousa teuszii*) off Flamingos, Angola. 2009. Afr. J. Mar. Sci. 31(3): 319-331.

Whitehead, H. 1990. Computer assisted individual identification of sperm whale flukes. Rep. Int. Whal. Commn. Special Issue 12: 71-77.

Whooley, P., Berrow, S., and Barnes, C. 2011. Photo-identification of fin whales (*Balaenoptera physalus* L.) off the south coast of Ireland. Mar. Biodiv. Rec. 4: e8

Würsig, B., and Würsig, M. 1977. The photographic determination of group size, composition, and stability of coastal porpoises. (*Tursiops truncatus*) Science (Washington D.C.) 198(4318): 755-756.