AUTOMATED AND COLORIMETRIC CALIBRATED VIDEO-IMAGING PROTOCOL FOR THE DAY-NIGHT COUNTING OF FISHES AT A CABLED OBSERVATORY

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Abstract: We describe a new automated and colorimetric calibrated video-imaging protocol for the 24-h continuous counting of fishes. Images of approximately 2 x 2 m methacrylate red panel with a chromatic chart were acquired at 30 min frequency with the cabled observatory OBSEA (www.obsea.es), installed at 20 m depth off Vilanova (Spain). The spectral reflectance value for each patch was measured between 400 to 700 nm and then converted in standard RGB, and used as a reference for all following calibrations. All image analysis was carried out within a standardized Region Of Interest, using the recently implemented "3D Thin-Plate Spline" warping approach. That operation was repeated on a subset of 500 images as a training set, manually selected since acquired under optimum visibility conditions. All images plus those for the training set were ordered together through Principal Component Analysis, allowing the selection of 614 images (67.6%) out of 908 (as a total corresponding to 18 days at 30 min frequency). The Roberts Operator was used to highlights regions of high spatial colour gradient corresponding to fishes' bodies. Time series in manual and visual counts were compared together for efficiency evaluation.

Keywords: Coastal fishes, cables observatories, OBSEA, automated video-imaging, colorimetric calibration, swimming rhythms, 3D Thin-Plate Spline warping

INTRODUCTION

The field measurements of swimming activity rhythms of rocky fishes are scant for the difficulty of counting individuals at a high frequency over a large period of time [1]. Poor access to repeated sampling at statistically relevant frequencies limits temporal studies of fauna, impeding to establish a solid linkage between perceived local biodiversity and species behavior [2]. Such kinds of studies are of relevance for the development of models predicting fish community changes in spite of changing environmental conditions.

Unfortunately, major drawbacks in using still cabled observatories cameras chiefly refers to the need of a manual processing of very large sets of images for animals detection, counting and when required, classification [3]. That drawback can be overcome only by implementing suitable automated-video imaging protocols [3] [4].

In this study, we describe the customization and functioning of a new automated video-imaging protocol for the day-night continuous counting of fishes (with no classification) within a standardized field of view.

MATERIAL AND METHODS

2.1. The platform and the panel

The expandable SEAfloor OBservatory (OBSEA; www.obsea.es) is a multiparametric cabled video-platform located at 20 m depth, 4 km off Vilanova i la Geltrú (Catalonia, Spain). It is endowed with a OPT-06 Underwater IP Camera (OpticCam; Ocean Presence Technologies, Santa Cruz, California, USA). The OBSEA was implemented with a nocturnal lighting system consisting of 2 white light LEDs, in order to allow fish counting over the 24-h cycle in a continuous fashion.

The camera always aimed at 45º angle toward a red methacrylate red panel of 220 X 220 cm (Fig. 1). Its presence and uniform colouring were required to standardize automated video-imaging within a constant homogeneous Region Of Interest (ROI) up to a maximum extent. A 9-colour chromatic chart was also installed in order to allow image calibration for Red, Green and Blue (RGB). RGB calibration was required for the image thresholding.

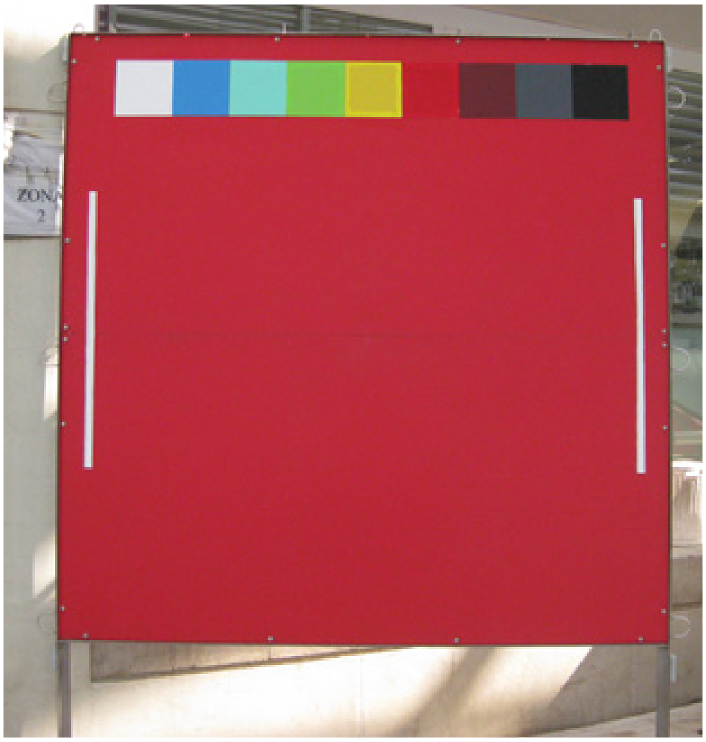

Figure 1. The methacrylate red panel used for automated RGB colorimetric calibration of images taken by OBSEA. White vertical lines (100 cm length) can be used as general size bars for fish length determination.

2.2. The automated video-imaging protocol for fish counting

We acquired images over 30-min periods during 18 days (22 Oct. to 09 Nov. 2011). All automation procedures were implemented in a Matlab 7.0 environment (Image Processing Toolbox). The spectral reflectance values for each of the 9-colour chart patches of the panel was measured in the visible range (between 400 to 700 nm wavelengths) prior immersion, using a Portable Integrated-Sphere D50/2 Spectrocolorimeter. The obtained reflectance of each patch was then converted in standard RGB (sRGB) value, using the Matlab OptProp Freeware Toolbox.

All the images were calibrated using the recently implemented "3D Thin-Plate Spline" warping approach [5]. All images were ordered altogether through Principal Component Analysis (PCA). In order to verify if calibration could be automatically used to classify good from bad images.

Fish automated counting was then carried out only on the 614 images within a ROI encompassing the central portion of the panel. On all the RGB channels a Euclidean distance was calculated from each pixel with respect of the background (i.e., the mean value for the 100×100 pixels panel central area). Basing on these distances the Roberts edge detection segmentation algorithm has was applied [6]. In the output, pixel values at each point represent the estimated absolute magnitude of the spatial gradient of the input image for that point. Fishes were then counted in resulting 2-bit images.

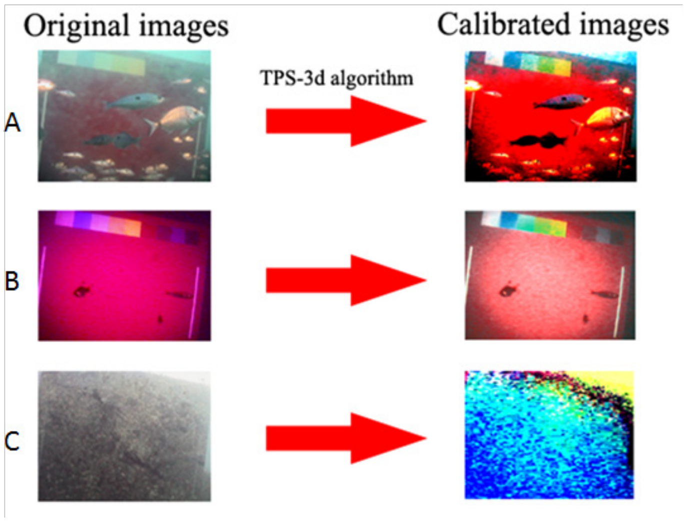

Figure 2. Example of three images with different illumination conditions (A, day, B, night; C, day with turbidity), before and after the calibration.

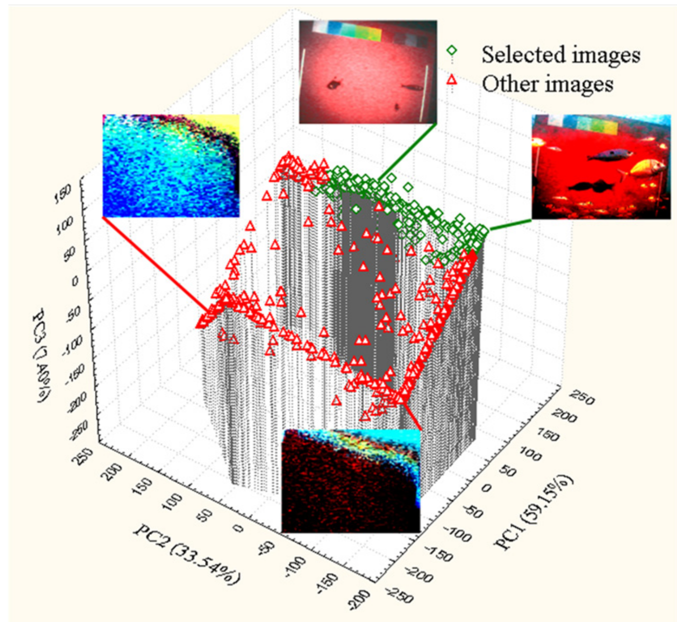

Figure 3. PCA outputs on the mean calibrated RGB values of a 100 x 100 pixels area in the centre of the panel. In green the selected images; in red the discarded images. Around the graph are represented four examples of calibrated images (selected and discarded according to their relative positioning in the PCA output (clockwise: nighttime good, daytime good; night bad, day bad).

2.3. Data treatment of video-imaging fish counts

Fish count time series were screened by Chi-Square periodogram analysis between 660 and 1500 min (equals to 11-h and 25-h, respectively). Periodogram analysis was run with El Temps software (Díez-Noguera; University of Barcelona; www.el-temps.com). In the periodogram output plots, the highest peak crossing the significance ($p<0.05$) threshold, represented the maximum percentage of total data variance explained by the inherent dominant periodicity. Periodicity was indicated by that peak value. Data were treated by waveform analysis according to the Midline Estimating Statistic of Rhythm (MESOR) method. We also considered the intensity variations of the Green channel (G) of the green colour chart patch in order to compare automated video-imaging performance with local conditions of illumination and turbidity.

RESULTS

We successfully acquired 908 images (i.e. 18 days at 30 min frequency). 614 images were selected for the further analyses according to the "3D Thin-Plate Spline" the calibration procedure. The PCA ordination of the mean calibrated RGB values of a 100 x 100 pixels area in the center of the panel is reported in Fig. 2.

In Fig. 3. Four examples of images processed with the automated protocol were reported. It is possible to observe how the 2 images on the A block were processed with good performances of object extraction, meanwhile the B block reported images processed with fair performances (i.e. object overlapping on the upper side and object as not recognized on the bottom side).

The comparison between automated and manual fish count sets can be used to generally evaluate the goodness of the developed method. Automated time series showed a similar phasing in fish count increases (at daytime) than manual ones, although for different fluctuation levels. In fact, total detected fishes are equals to 678 for the automated protocol versus 4751 for the manual counting.

Periodogram screening of both automated and manually-generated data sets (Fig. 5A,B) indicated very similar and significant periodicities. According to differences in reported abundances by the two methods, the rhythmicity in time series showed also a differential strength as indicated by the peak amplitude: automated, 19.1%; manual, 26.2%.

The automated processing showed to be influenced by turbidity, which was more apparent in daytime images (Fig. 5). The Green content of images was used as a proxy of dissolved particulate matter. That factor increased during the day for the effect of downward incoming solar light enhancing the reflection of the dissolved matter. At night times, such an effect was consistently diminished under the action of the two lights, which strongly illuminated the ROI but in the horizontal plane. Accordingly, overall detections were more different during the day, as timing coinciding with the larger augments of fishes in the OBSEA area.

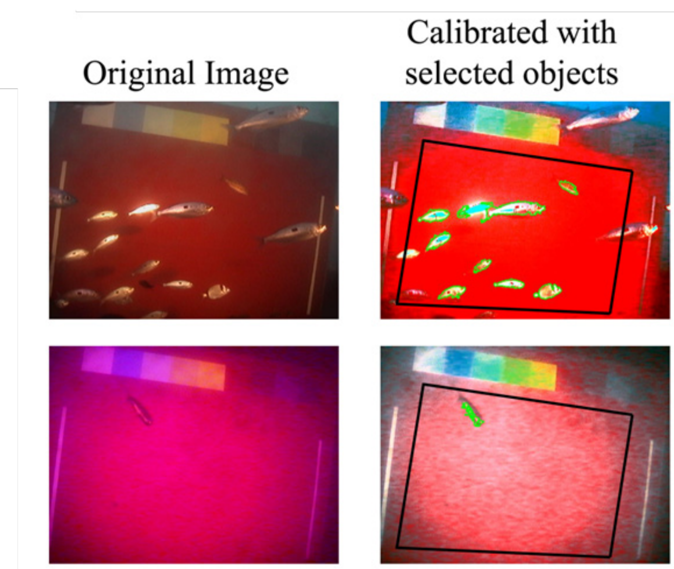

Figure 4. Examples automated processing of time-lapse images acquired by the OBSEA. Two examples of original images (on the left; above day, below night) and their chromatically calibrated outputs (on the right) were reported as an example of fish identification performance. The black polygon represents the ROI and selected object selected by the Roberts edge algorithm within it are evidenced with a green outline.

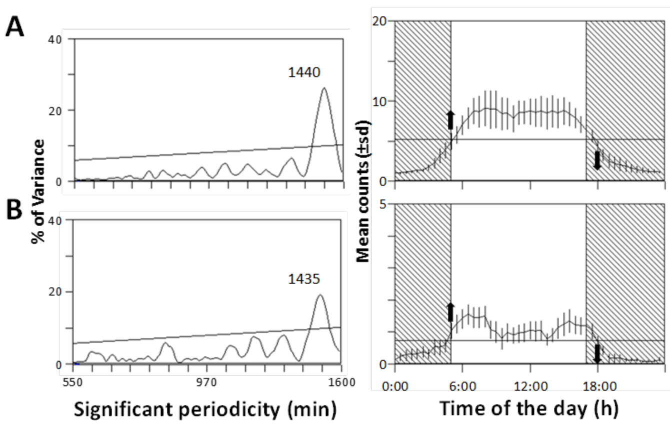

Figure 5. Periodograms (right) and waveforms (left) for visual (A) and automated (B) fish counts time series as reported at OBSEA. The dashed vertical rectangle depicts the average night duration during the whole video sampling period. MESOR is the horizontal bar in waveforms (A= 5.21; B= 0.74) along with ONSET (upper arrow; the first values above MESOR) and OFFSET (lower arrow; the first value below MESOR) timings.

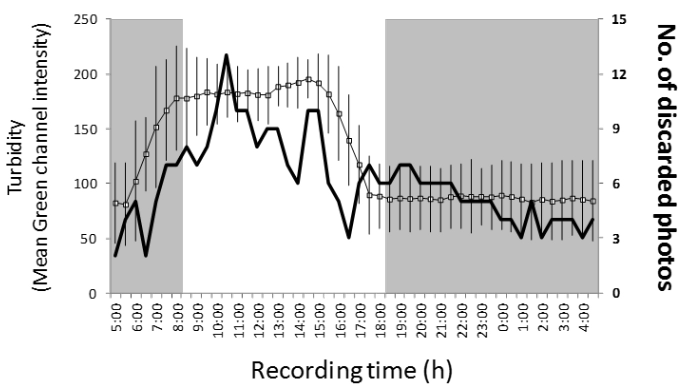

Fig. 6. The influence of turbidity on the elaborated automated video-imaging protocol over a standard 24-h cycle, as indicated by turbidity as quantified through the averaged Green content (green-channel) and total discharged photos. Grey area is the night.

CONCLUSIONS

In this study, we customized a new automated video-imaging protocol to cunt fishes at day and night in a continuous fashion over a standardized ROI. We implemented a colorimetric calibration procedure that could efficiently discriminate suitable images for fish counting.

Periodogram and waveform analysis outputs for automated and manual data sets are similar, although quantified parameters in relation to the strength of respective rhythms were different. Clearly, data sets derived from manual counting presented the larger day-night fluctuations being reported rhythms stronger in comparison to those derived from automation. This comparison indicates that our video-imaging protocol subestimate fish numbers but it is anyway suitable for the study of community rhythmic behavior.

Here, we tried to standardize our automated video processing to a maximum extent, by adding a constant and colorimetric uniform ROI. In that manner, fish counts are at least homogenized in relation to the depth of the field of view. Under these conditions, activity patterns were anyway resolvable in a fashion similar to outputs provided by manual counting. This indicates that activity rhythms in the community can be studied by automated video-imaging because image discarding and the derived counting subestimation are constantly occurring through consecutive days.

Marked variations in coastal fish counts were detected at a diel periodicity through the use of an automated video-monitoring protocol. This fact alone justifies the effort of developing increasingly more efficient methods for the remote, autonomous, and long-lasting monitoring of marine animal communities by still cameras of cabled observatotries. In this monitoring, automation in video imaging plays a key role, since cameras are the only sensor allowing the extraction of biological information at the complex ecological scale of animals. Suitable automation may contributes to transform cabled observatories into permanent ecosystem monitoring tools, fulfilling the goals of major ongoing infrastructural projects of the future of European marine research.

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REFERENCES

1. Azzurro, E.; Aguzzi, J.; Maynou, F.; Chiesa, J.J.; Savini, D. Diel rhythms in shallow Mediterranean rocky-reef fishes: a novel chronobiological approach. J. Mar. Biol. Ass. U.K. 2013, 93, 461-470.

2. Aguzzi, J.; Costa, C.; Menesatti, P.; Fujiwara, Y.; Iwase, R.; Ramirez-Llorda, E. A novel morphometry-based protocol of automated video-image analysis for species recognition and activity rhythms monitoring in deep-sea fauna. Sensors 2009, 9, 8438-8455.

3. Aguzzi, J.; Costa, C.; Robert, K.; Matabos, M.; Antonucci, F.; Juniper, K.; Menesatti, P. Automated video-imaging for the detection of benthic crustaceans and bacterial mat coverage at VENUS cabled network. Sensors 2011, 11, 10534-10556.

4. Doya, C.; Aguzzi, J.; Pardo, M.; Matabos, M.; Company, J.B.; Costa, C.; Milhaly, S. Diel behavioral rhythms in the sablefish (Anoplopoma fimbria) and other benthic species, as recorded by deep-sea cabled observatories in Barkley canyon (NEPTUNE-Canada). J. Mar. Syst. 2013, In Press.

5. Costa, C.; Angelini, A.; Pallottino, P.; Antonucci, A.; Aguzzi, J.; Menesatti, P. RGB color calibration for quantitative image analysis: the "3D Thin-Plate Spline" warping approach. Sensors 2012, 12, 7063-7079.

6. Senthilkumaran, N.; Rajesh, R. Edge detection techniques for image segmentation: A survey of soft computing apprаches. Int. J. Recent Tren. Engineer. 2008, 1, 250-254.