Automated Quantification of Crown-of-Thorns Starfish (*Ancanthaster planci*) and Long-Spined Sea Urchin (*Diadema antillarum*) on Underwater Videos and Panoramic Images using YOLOv8

RAMOS, John Peter M., ECE
College of Engineering
Electronics Engineering Department
Technological University of the Philippines-Manila

GALERA, Adrian Darren S.
College of Engineering
Electronics Engineering Department
Technological University of the Philippines-Manila

MONTEJO, Paulo Jr. M.
College of Engineering
Electronics Engineering Department
Technological University of the Philippines-Manila

PACOMA, Niña Marie B.
College of Engineering
Electronics Engineering Department
Technological University of the Philippines-Manila

ROSETE, Charles L.
College of Engineering
Electronics Engineering Department
Technological University of the Philippines-Manila

SEBASTIAN, Franchesca Ann A.
College of Engineering
Electronics Engineering Department
Technological University of the Philippines-Manila

***Abstract*—Coral reefs are crucial marine ecosystems supporting biodiversity and providing valuable benefits to human societies. However, Crown-of-thorns starfish (COTS) outbreaks, defined as 15 or more COTS per hectare, pose a significant threat to coral reefs, leading to a reduction in coral cover and macroalgal grazers, such as long-spined sea urchins, which helps control algal growth, facilitating coral recovery. A YOLOv8-based detection and counting system was proposed to address the need for effective monitoring systems. The system aimed to assess the presence of coral health indicators, specifically COTS and Long-Spined Sea Urchins. The system underwent initial testing in a saltwater environment, achieving mean accuracy results of 93.89% for counted COTS, 93.61% for counted long-spined sea urchins, and 70.97% for mixed class. The system was deployed in Marine Protected Areas (MPAs) in Balayan Bay in San Juan and Taal, Batangas, and Tayabas Bay in Sariaya, Quezon. The proposed system proved efficient in counting COTS and long-spined sea urchins, with the deployment results achieving an average accuracy of 80% for counting underwater videos and 90.91% for counting on panoramic images. Overall, the system offers promising capabilities for improving coral reef monitoring, with implications for conservation efforts.**

***Keywords*— YOLOv8, Crown-of-Thorns Starfish, Long-Spined Sea Urchin, Marine Protected Areas (MPAs), panoramic image**

I. INTRODUCTION

Coral reefs, renowned for their biodiversity and ecological significance, face threats ranging from natural occurrences like mass bleaching to anthropogenic factors such as pollution and overfishing. Among these challenges, the outbreak of COTS or crown-of-thorns starfish (*Ancanthaster planci*), defined as 15 or more COTS per hectare, has become a significant contributor to coral destruction, posing a severe threat to the health and sustainability of coral reef ecosystems [1]. Meanwhile, marine invertebrates such as Long-Spined Sea Urchin (*Diadema antillarum*), maintained at a population of 5 per sqm, play a vital role as grazers that significantly contribute to the health of coral reef by eliminating seaweed and microalgae, which are the main competitors of corals for space and resources [2]. Thus, monitoring COTS and long-spined sea urchin is crucial for devising appropriate strategies for identifying COTS outbreaks, planning COTS population control, and mitigating their impact on coral reefs. With a reliable means of determining COTS and long-spined sea urchin count and analyzing their behaviors, it becomes easier to monitor population trends and evaluate the effectiveness of management interventions.

To better understand the dynamics of coral reef ecosystems, a YOLOv8-based counting system, integrated with Byte Track and Supervision, has been developed as an innovative tool to aid in identifying COTS outbreaks, mitigate its impact on the coral reef ecosystem, and monitor the population of long-spined sea urchins. To ensure the reliability of the detection and counting system, the accuracy of COTS and long-spined sea urchin counting is verified by comparing the results from the videos to the generated panoramic image of the entire surveyed area.

Additionally, the actual count of COTS and long-spined sea urchins and count results were validated by the accompanying divers. These validation techniques enhance confidence in the accuracy and reliability of the monitoring system, thereby facilitating effective coral reef management and conservation efforts.

II. BACKGROUND OF THE PROBLEM

Elston and Dallison [3] named crown-of-thorns starfish (COTS, Acanthaster spp.) as one of the most efficient predators of corals, known to be with 20-35 cm diameter and predation rates of 150 to 250 cm^2 per day. Throughout the years, researches have been made to maintain the balance in the COTS population so as not to trigger an outbreak that leads to these harmful effects in coral reefs.

Ludevese-Pascual et al. [4] developed a study to provide updated reports on crown-of-thorns starfish sightings across various collection sites in Sogod Bay, Philippines. Results show that the surveyed locations exceeded the threshold of 0.25 COTS per 100 square meters, indicating an outbreak. Given the recurrent nature of COTS outbreaks in Sogod Bay, it was recommended to conduct periodic monitoring to assess the damage to coral reefs and the cleanup efforts to be initialized.

Campos et al. [5] proposed a semi-autonomous drone with coral reef monitoring and pollution detection using YOLOv4 and Faster-RCNN to detect COTS and underwater garbage. However, the study needs validation methods to ensure the reliability and accuracy of the detection system. To address the gap in the study, the current study proposes automated quantification of crown-of-thorns starfish and long-spined sea urchins on underwater videos and panoramic images using YOLOv8. The study intends to provide validation techniques to verify the data gathered by the system from the underwater videos and panoramic images generated, ensuring a reliable system to help in coral reef monitoring.

III. OBJECTIVES

This study aims to develop an Automated Crown-of-Thorns Starfish and Long-Spined Sea Urchin Quantification using YOLOv8 with Panoramic Image Stitching. This incorporates the YOLO algorithm into underwater video and panoramic images for its object detection and counting capabilities. Specifically, it aims to achieve the following:

1. to test and evaluate the functionality of the counting system using test images in saltwater and in coral reef environment;
2. to test and evaluate the reliability of the counting system based on underwater videos and panoramic images; and
3. to assess the overall performance of the counting system.

IV. METHODOLOGY

A. *Initial Testing in Saltwater*

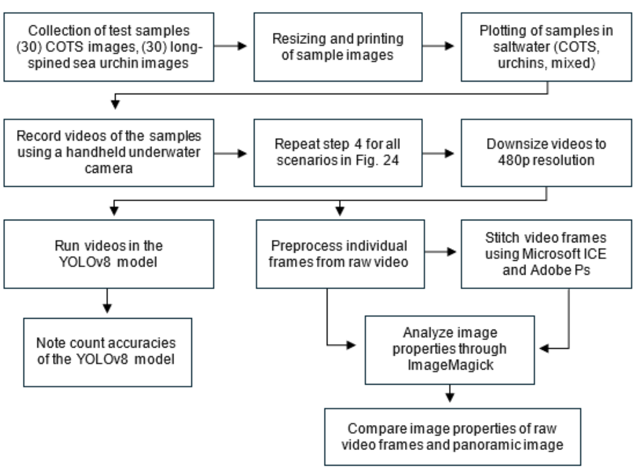

Fig. 1. Overall Functionality Testing Procedure in Saltwater

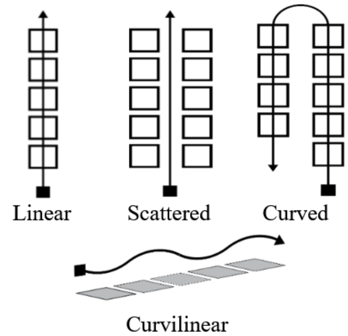

Fig. 2. Scenarios for Testing in Saltwater

The initial trial of the system in an actual marine environment took place in Taal, Batangas. The trial utilized 30 pictures of COTS and long-spined sea urchins submerged 5 feet in the seawater. The testing scenarios applied were distributed, clustered, curved, linear, and curvilinear using a GoPro Hero 11 camera, with a resolution of 1080p downsized to 480p processed by the YOLOv8 detection and counting model.

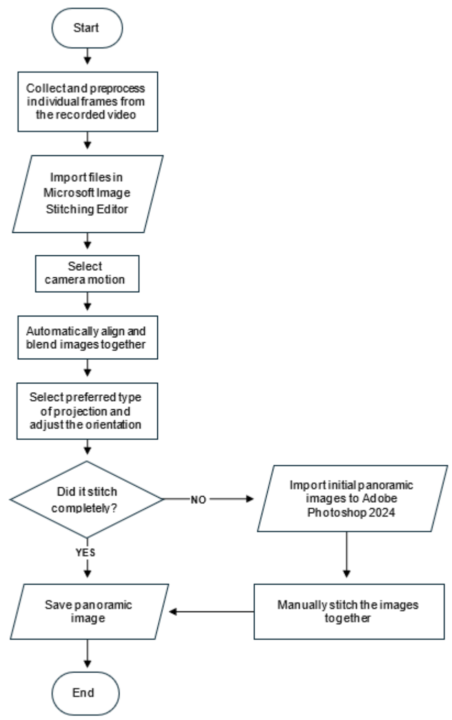

Fig. 3. Concept Diagram of the Processes in Stitching the images to form a Panoramic Image

Fig. 3 illustrates the image stitching process to generate panoramic images. Individual frames were extracted from the live video recording captured by the drone. The collected images then underwent image stitching using Microsoft Image Composite Editor. The selected images were automatically matched, and their features aligned depending on the chosen camera motion. The preferred projection type could be adjusted once the images were stitched together. The process involved enhancing the quality of panoramic images and eliminating uneven edges and unwanted areas. Suppose it cannot stitch all the frames altogether in the panoramic image, the stitched image is then imported to Adobe Photoshop for manual stitching before enhancing the quality of the panoramic image.

B. Deployment on Marine Protected Areas

The accuracy and efficiency of the counting system were tested in an actual marine environment, specifically in Marine Protected Areas in Balayan Bay, San Luis and Taal, Batangas, and Tayabas Bay, Sariaya, Quezon.

Fig. 4. Experimental Setup using Handheld Underwater Camera

The proponents, with the assistance of the local divers and representatives from the Department of Environment and Natural Resources (DENR), tested the system by recording videos using handheld underwater cameras, such as GoPro and DJI Osmos, to survey the areas with presence of COTS and long-spined sea urchin shown in Fig. 4.

For additional deployment data, outsourced videos were collected from the surveys of local divers in Pasacao, Camarines Sur, and Taal, Batangas. These videos were downsized to 480p and processed by image stitching applications. The recorded videos and panoramic images were run into the YOLOv8 model to verify if the actual count of COTS and long-spined sea urchins, which were verified by the divers, matched the count of the system.

C. Statistical Treatment of Data

The data gathered from TRITON underwent statistical treatment using descriptive analysis. Descriptive statistics were applied to interpret the data more simply, aiding in analyzing the significant differences in object counting accuracy across varying test scenarios.

For the output results, the mean average (1) of the three trials during testing was computed to show the average accuracy of object counting in saltwater.

$$m = \frac{sum\ of\ terms}{number\ of\ terms} \quad (1)$$

This analysis provides insights into the accuracy and reliability of TRITON's system.

D. Technical Evaluation

An evaluation was conducted by the proponents through a survey of the divers who assisted in the deployment of the system. This aimed to assess various aspects of TRITON Software, including its functionality, effectiveness, usability, compatibility, security, reliability, maintainability, and portability.

The data gathered from TRITON Software underwent analysis following the Likert-Scale Description. The means from all the responses per category were calculated for the primary analysis. The means were interpreted as follows: Strongly disagree in the point range of 1.00 - 1.80, Disagree for 1.81 - 2.60, Neutral for 2.61 – 3.40, Agree for 3.41 - 4.20, and Strongly Agree for 4.21 - 5.00 [6].

V. RESULTS AND DISCUSSION

A. Results from Initial Testing in Saltwater

TABLE I. COUNTED OBJECTS ON VIDEOS CONTAINING 30 COTS IMAGES

Present Classes	Scenarios	COTS Count		
		Trial 1	***Trial 2***	***Trial 3***
30 Urchins	**Scattered**	29	28	28
	Curved	29	28	29
	Linear	27	27	28
	Curvilinear	30	25	26

TABLE II. AVERAGE COUNT AND PERCENT ERROR OF THREE TRIALS FROM TABLE I

Present Classes	Scenarios	Accuracy
30 Urchins	**Scattered**	94.44%
	Curved Path	95.56%
	Linear	91.11%
	Curvilinear	93.33%
Average Accuracy		**93.61%**

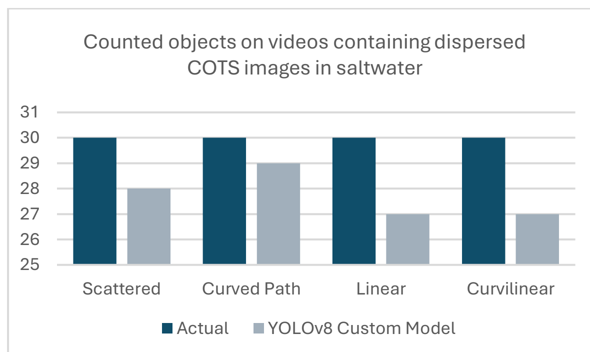

Fig. 5. Counted objects on videos containing dispersed COTS images in saltwater

Tables I-II and Fig. 5 illustrate the counting accuracy in three trials of the YOLOv8 Model in terms of counting COTS on videos containing 30 COTS images in saltwater. The model exhibited an average accuracy of 93.61%.

TABLE III. COUNTED OBJECTS ON VIDEOS CONTAINING 30 URCHIN IMAGES

Present Classes	Scenarios	Urchin Count		
		Trial 1	***Trial 2***	***Trial 3***
30 Urchins	**Scattered**	27	30	30
	Curved Path	28	28	28
	Linear	28	29	27
	Curvilinear	28	29	26

TABLE IV. AVERAGE COUNT AND PERCENT ERROR OF THREE TRIALS FROM TABLE III

Present Classes	Scenarios	Accuracy
30 Urchins	**Scattered**	96.67%
	Curved Path	93.33%
	Linear	93.33%
	Curvilinear	92.22%
Average Accuracy		**93.89%**

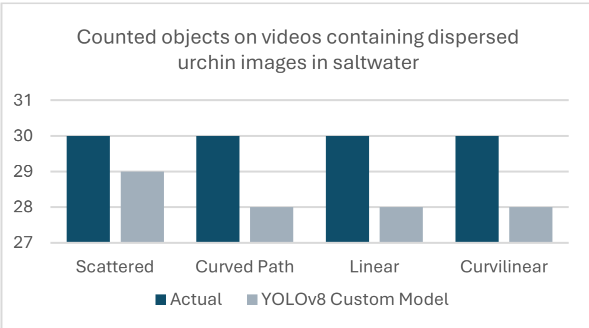

Fig. 6. Counted objects on videos containing dispersed urchin images in saltwater

Tables III-IV and Fig. 6 illustrate the YOLOv8 Model in terms of counting long-spined sea urchins on videos containing 30 urchin images in saltwater. The model exhibited an average accuracy of 93.89%.

TABLE V. COUNTED OBJECTS ON VIDEOS CONTAINING 30 COTS AND URCHIN IMAGES

Present Classes	Scenarios	COTS			Urchin		
		Trial 1	*Trial 2*	*Trial 3*	*Trial 1*	*Trial 2*	*Trial 3*
30 COTS 30 Urchins	**Scattered**	22	25	29	20	22	16
	Curved	18	25	15	18	17	21
	Linear	27	22	28	19	16	21
	Curvilinear	23	22	20	19	24	22

TABLE VI. AVERAGE COUNT AND PERCENT ERROR OF THREE TRIALS FROM TABLE V

Present Classes	Scenarios	COTS	Urchin
30 COTS 30 Urchins	**Scattered**	84.44%	64.44%
	Curved Path	64.44%	62.22%
	Linear	85.56%	62.22%
	Curvilinear	72.22%	72.22%
Average Accuracy		**76.67%**	**65.28%**
Average Accuracy for COTS and Urchin		**70.97%**	

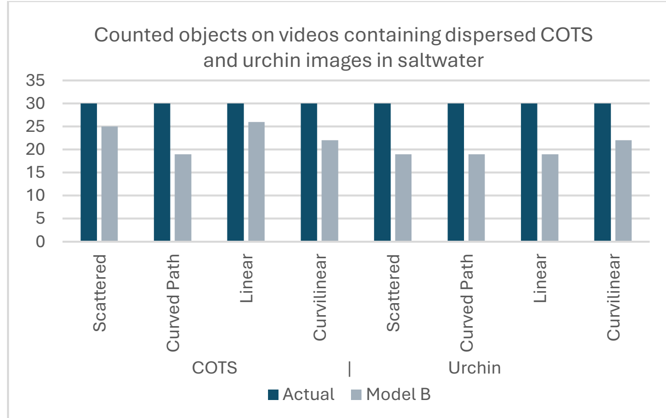

Fig. 7. Counted objects on videos containing dispersed COTS and urchin images in saltwater

Tables V-VI and Fig. 7 illustrate the YOLOv8 Model in terms of counting objects on videos containing 30 COTS and 30 urchin images. The model achieved an average accuracy of 76.67% for COTS and 65.28% for urchin. On average, the model showed 70.97% accuracy for counting COTS and urchins in images under saltwater.

Fig. 8. Panoramic image in linear scenario of mixed classes in saltwater

Fig. 8 shows the panoramic image generated from the recorded video comprising 30 COTS and 30 urchins using stitching software, Microsoft ICE and Adobe Photoshop.

B. Results from Deployment on Marine Protected Areas

The system was tested by recording videos of Crown-of-Thorns Starfish and Long-Spined Sea Urchins on different MPAs using the underwater cameras, GoPro and DJI Osmo. Outsourced videos were also collected from local divers. All videos were downsized to 480p resolution before running them in the custom YOLOv8 model.

1) Summary of results from deployment on MPAs

TABLE VII. COUNT ACCURACIES FROM TESTING IN MPAS

Location	Present Class	Actual Count	Counting Model	
			Video	***Panoramic Image***
Balayan Bay, San Juan, Batangas	Urchin	52	41	47
Balayan Bay, Taal, Batangas	COTS	2	2	2
Tayabas Bay, Sariaya, Quezon	COTS	1	1	1
Total count		55	44	50
Accuracy			**80.00%**	**90.91%**

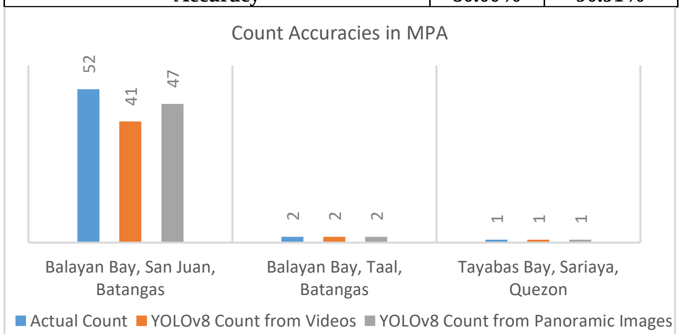

Fig. 9. Summary of results from deployment on MPAs

2) Summary of results from outsourced videos

TABLE VIII. COUNT ACCURACIES FROM TESTING ON OUTSOURCED VIDEOS

Location	Present Class	Actual Count	Counting Model	
			Video	**Panoramic Image**
Pasacao, Camarines Sur	COTS	400	24	72
Balayan Bay, Taal	COTS	6	2	6
Total count		406	26	78
Accuracy			**6.40%**	**19.21%**

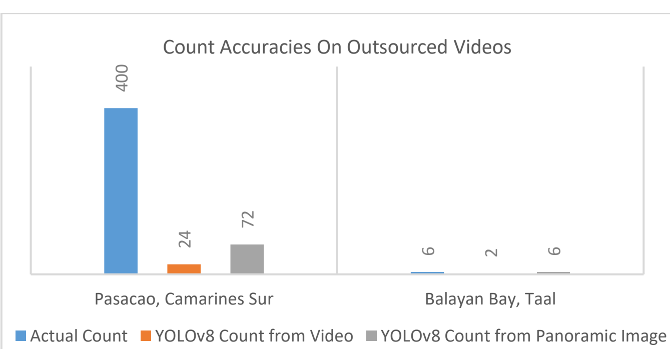

Fig. 10. Summary of results from outsourced videos

Tables VII-VIII present the counting accuracies from the testing in Marine Protected Areas and outsourced videos from volunteer divers. Results in Table 10 show average accuracies of 80% for counting underwater videos and 90.91% for counting on panoramic images. The results in Table 10 show average accuracies of 6.40% for counting on underwater videos and 19.21% for counting on panoramic images.

Overall, the system was able to detect and count Crown-of-Thorns Starfish and Long-Spined Sea Urchins on underwater videos and generated panoramic images. The miscounts on the testing are attributed to unstable camera recording, clustered species, and corals blocking the camera's view of the species, resulting to difficulty for the model in recognizing the present classes.

C. Evaluation Results

The system was evaluated by the divers who volunteered for the deployment and testing of the model via a survey questionnaire.

TABLE IX. OVERALL SUMMARY OF RESPONSES

Quality Characteristics	Total Mean	Likert-Scale Description
Functionality and Effectiveness	4.5	**Strongly Agree**
Usability and Compatibility	4.19	**Agree**
Security and Reliability	4.17	**Agree**
Maintainability and Portability	4.17	**Agree**
Total Average	**4.26**	**Strongly Agree**

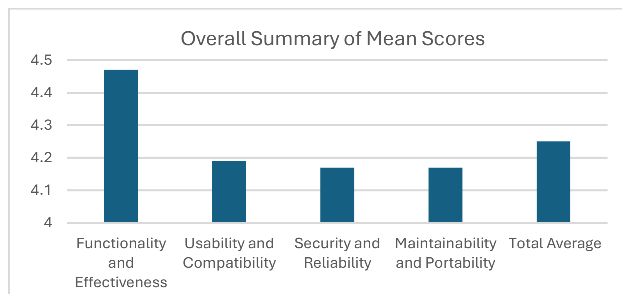

Fig. 11. Overall Summary of Mean Scores

Table IX and Fig. 11 present the results from the evaluation survey. The system evaluation revealed high ratings across several categories. The functionality and effectiveness received a mean score of 4.50. Usability and compatibility were rated positively with a mean of 4.19. Security and reliability received a mean score of 4.17, as did maintainability and portability, indicating favorable evaluations from respondents in all areas.

The average of the mean per category was also computed to determine the overall evaluation of the system. After assessing the participants' responses, the system received a mean score of 4.26, corresponding to an evaluation of "Strongly Agree" and indicating a positive evaluation for the overall performance of the system.

VI. CONCLUSION

In this study, a system was developed to assess the presence of coral health indicators, specifically COTS and Long-Spined Sea Urchins. The system underwent initial testing in a saltwater environment, achieving mean accuracy results of 93.89% for counted COTS, 93.61% for counted long-spined sea urchins, and 70.97% for mixed class. The system was deployed in Marine Protected Areas (MPAs) in Balayan Bay in San Juan and Taal, Batangas, and Tayabas Bay in Sariaya, Quezon. The proposed system proved efficient in counting COTS and long-spined sea urchins, with the deployment results achieving an average accuracy of 80% for counting underwater videos and 90.91% for counting on panoramic images. Favorable ratings were gathered from the system's evaluation from the divers who were able to use the system. Overall, the system offers promising capabilities for improving coral reef monitoring, with implications for conservation efforts.

VII. REFERENCES

[1] Naturevolution. (2022, December 14). Crown-of-thorns starfish and COTS outbreaks. Retrieved from Naturevolution: https://www.naturevolution.org/en/crown-of-thorns-starfish-cots-outbreaks/

[2] Manuel, O., Williams, S., Weil, E., & Cruz-Motta, J. (2021). Corrigendum to "Experimental evaluation of D. antillarum herbivory effects on benthic community assemblages" [Journal of experimental marine biology and ecology. Volume 541 (2021)]. Journal of Experimental Marine Biology and Ecology, 544, 151612. https://doi.org/10.1016/j.jembe.2021.151612

[3] Elston, C. & Dallison, T. (2019). Brief communication on the Crown-of-thorns Seastar (Acanthaster spp.) densities in the municipalities of San Francisco, Liloan and Pintuyan, Southern Leyte, Philippines. Coral Cay Conservation, 3.

[4] Ludevese-Pascual, G., Napala, J. J., Tomol, R., Oyong, L. J., Alfante, J. M., & Lumain, J. P. (2022). Crown-of-Thorns starfish (COTS) outbreak in Sogod Bay, Southern Leyte, Philippines. Journal of Ecosystem Science and Eco-Governance, 24-30. https://doi.org/10.54610/jeseg/4.1.2022.003

[5] Campos, F., Dueñas, E., Gecana, K., Lazaro, J., & Marcellana, M. (2022). Layag: A Semi-Autonomous Underwater Drone With Coral Reef Monitoring And Pollution Detection Via Machine Learning. Technological University of the Philippines Manila.

[6] Pimentel, J. L. (2010). A note on the usage of Likert Scaling for research data analysis. USM R&D Journal, 18(2), 109-112.