Received: 24 February 2023 | Accepted: 5 April 2023

DOI: 10.1002/inc3.20

PRACTICE AND POLICY

INTEGRATIVE CONSERVATION XTBG WILEY

The power of academic and public opinion in conservation: The case of Ayyalon Cave, Israel

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Funding information

Biodiversa+, Grant/Award Number: project DarCo. (S.M.); SYNTHESYS+, Grant/Award Number: Supported S.M. visit to Israel

Abstract

While pessimism dominates discussions on biodiversity loss, it is increasingly recognized that for the long-term success of conservation programs, we also need hope. One way to foster hope is to celebrate the positive outcomes of conservation efforts. Here, we report on a successful step in the conservation efforts of Ayyalon cave, a unique subterranean ecosystem discovered in 2006 as a result of mining activities in a quarry in central Israel. Ayyalon cave is one of the few known fully sustained subterranean autotrophic sulfur-based food webs, in turn supporting a diverse, specialized endemic fauna. Upon the discovery of the cave, its isolation from the surface was compromised, resulting in colonization of alien species and changes in environmental conditions. In May 2021, the cave was put at additional risk following a plan to inject millions of cubic meters of fresh, cold, and oxidized water into the quarry. A team of Israeli scientists decided to take action, starting a highly mediatic campaign to save the cave. This campaign involved cooperation among domestic and foreign academics, the general public sector, and diverse stakeholders. Despite strong economic interests, the conservation campaign succeeded in pushing the National Infrastructure Committee to rectify the plan to inject water into the cave. Stemming from this success, we discuss important take-home messages that are paramount for the broader conservation science community.

KEYWORDS

autotrophic ecosystem, conservation, media, professional opinion letters, public perception, sentiment analysis, subterranean biology

Plain language summary

While biodiversity loss is a major concern, it's important to have hope and celebrate successes in conservation efforts. Ayyalon Cave (central Israel) is a unique subterranean ecosystem located in an active quarry, home to a diverse and specialized endemic fauna. Since its discovery in 2006, this fragile ecosystem has been threatened by alien species and changes in environmental conditions. In May 2021, a plan to inject millions of cubic meters of water into the quarry put the cave at critical risk. A team of Israeli scientists launched a media campaign to save this cave, which involved academics, the public sector, and different stakeholders. Despite strong economic interests, the conservation campaign succeeded in pushing the National Infrastructure Committee

to rectify the plan. By reporting on this successful conservation story, we aim to highlight the importance of celebrating positive outcomes in conservation efforts and the need for cooperation among diverse stakeholders to protect our planet's biodiversity.

"We are experiencing a sixth mass extinction of biological diversity," "Biodiversity is being eroded globally," "Species are going extinct at an unprecedented rate"—these sentences may sound familiar as they are often used as the opening lines in scientific papers on ecology and conservation. Pessimism dominates our specialized literature and media discourse on the environmental crisis (Swaisgood & Sheppard, 2010), and rightly so (Ripple et al., 2017). However, for the long-term success of conservation programs, we need to balance this with hope (Park et al., 2020; Swaisgood & Sheppard, 2010). Positive conservation outcomes should be widely celebrated because the failure to do so may discourage the public, stakeholders, and policy-makers from addressing environmental problems that have no immediate or apparent solution [Balmford & Knowlton, 2017; Cvitanovic & Hobday, 2018; see also the "Love, Not Loss" campaign by the Commission on Education and Communication of the International Union for Conservation of Nature (IUCN)].

Caves and other subterranean ecosystems host unique biodiversity that is globally threatened by the combined effects of multiple anthropogenic stressors, including habitat loss, pollution, and climate change (Mammola et al., 2019). Worryingly, we currently have poor quantitative knowledge of effective conservation measures for subterranean ecosystems (Mammola et al., 2022). With the majority of subterranean biodiversity lacking formal protection (Sánchez-Fernández et al., 2021), there are limited examples of positive stories regarding successful outcomes in the conservation of subterranean ecosystems. Surfing the wave of celebrating positive conservation stories (e.g., Bolam et al., 2021; Knowlton, 2021), we here report on a successful 'battle' in the conservation of a unique subterranean ecosystem: Ayyalon cave (Frumkin et al., 2023; Por et al., 2013; Por, 2007, 2012).

The Ayyalon cave was discovered in April 2006 during quarrying activities in the Nesher-Ramla quarry located in the center of Israel, approximately 20 km east of the Mediterranean coast, within the late Cretaceous (Turonian) limestone (Por, 2007). The cave had been isolated from the external environment for over 5 million years by approximately 100 m of impervious cap rocks above the cave (Frumkin et al., 2023), which no longer exist due to years of quarrying. Inside the cave, the Ayyalon Saline Anomaly, which is brackish warm water rich in hydrogen sulfide (H_2S), with no oxygen, creates a sulfuric warm water pool (Figure 1a) with temperatures reaching up to 30°C within the Yarqon-Tanninim freshwater aquifer (Frumkin et al., 2022, 2023; Por, 2007). These environmental conditions, coupled with the cave's long isolation from the surface, gave rise to a unique food web in the context of subterranean ecosystems (Frumkin et al., 2023; Por, 2007; Por et al., 2013).

Practitioner points

- Successful conservation campaigns often require close cooperation among multiple actors, for example, conservation scientists, the media, the public, and decision-makers.
- Conservation campaigns should build upon sound scientific knowledge of the target species or ecosystems and its importance and/or uniqueness should be transferred to the public and decision-makers clearly and simply.
- A thorough understanding of the legislative and administrative procedures and their effective utilization may be key to successful conservation campaigns.

The ecosystem found in the cave has been described as a unique biome called Ophel, which is completely disconnected from the surface (Por, 2007), and includes at least six species endemic to this cave (Por et al., 2013). The aquatic species live in the sulfuric pool. This sulfuric pool is covered by floating microbial biofilms of chemoautotrophic sulfide-oxidizing bacteria (Figure 1b). The entire ecosystem of the cave, which had no external food source until it accidentally opened, depends on the primary production of these chemoautotrophic biofilms (Frumkin et al., 2023; Por, 2007). The next trophic levels found in groundwater are amoeboids, ciliophorans, and crustaceans (Frumkin et al., 2023; Por et al., 2013), including the copepod *Metacyclops longimaxillis* Defaye & Por, 2010, the thermosbaenacean *Tethysbaena ophelicola* Wagner, 2012, and the blind prawn decapod *Typhlocaris ayyaloni* Tsurnamal, 2008, the latter of which acts as the top predator in the aquatic food-web (Figure 1c). The terrestrial food-web includes blind scorpions (*Akrav israchanani* Levy, 2007; Figure 1d), blind pseudoscorpions (*Ayyalonia dimentmani* Ćurčić, 2008), and collembolans of the genus *Troglopedetes* (not yet described), all of which are indirectly dependent on the biomass of the sulfide-oxidizing bacteria

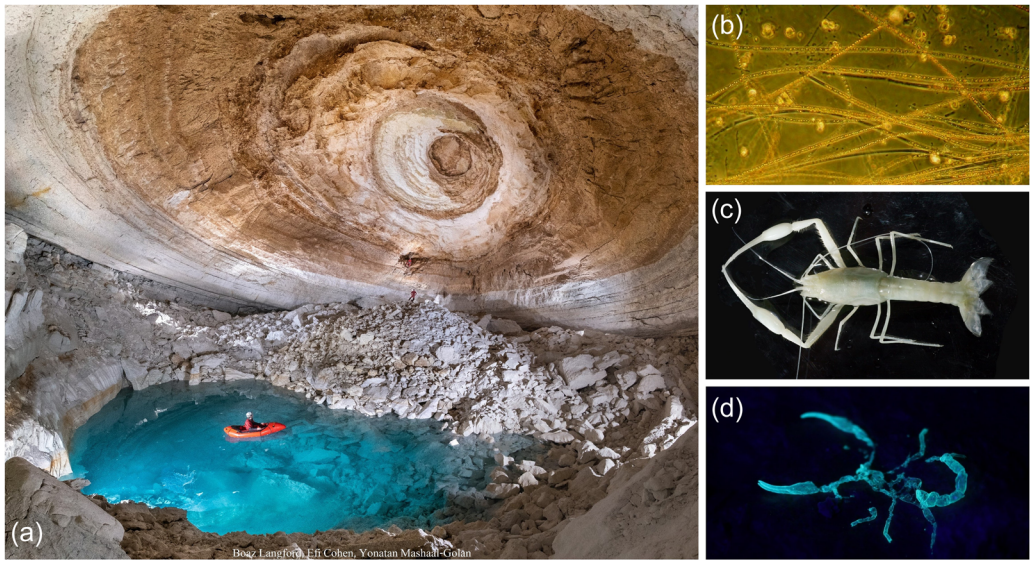

FIGURE 1 Ayyalon cave and its endemic fauna. (a) Sulfuric water pool (Pic: B. Langford). (b) Chemoautotrophic bacteria (Pic: A. Oren). (c) *Typhlocaris ayyaloni* Tsurnamal, 2008 (Pic: S. Tiram). (d) *Akrav israchanani* Levy, 2007 (Pic: S. Aharon).

(Frumkin et al., 2022, 2023; Por et al., 2013). All of these species show high subterranean specialization and are endemic to the Ayyalon cave system (Frumkin et al., 2022; Por et al., 2013).

In March 2021, 15 years after the discovery of Ayyalon cave, The Hebrew University released a statement with an opinion by Prof. Amos Frumkin about the threats to the cave. The location of the cave within an open quarry poses a significant threat to this unique ecosystem. The excavation of impervious rock formations above the cave and exposure of karstified rock has resulted in changes in airflow circulation and infiltration of run-off from the quarry's basin. In addition, the future land uses planned for the quarry's area after the depletion of resources may introduce additional risks to the groundwater. Furthermore, the opening of the cave has resulted in the colonization of alien species and changes in environmental conditions and trophic inputs (Frumkin et al., 2023), which threaten the endemic fauna (see Nicolosi et al., 2023). For example, since 2018, several individuals of the invasive spider *Eidmannella pallida* (Emerton, 1875) have been found in the cave, as well as numerous bats entering the cave from crevices in the walls. This invasive spider was found under rocks in the deepest part of the cave, the preferred niche of the blind pseudoscorpion *A. dimentmani*, which seemingly disappeared (or became rarer) as a result of competition or predation. When the cave was first discovered, and again in 2015, it was suggested that quarrying activities in the area should be stopped, and the entire site should be declared a protected area. The cave and the surrounding area were approved as a nature reserve, a key step in the process of protected areas declaration. However, the status of protected areas has not received final approval from the Minister of the Interior yet, which would be the last step to achieve effective legal protection under the "National Parks, Nature Reserves, National Sites and Memorial Sites" law.

In late May 2021, the cave faced an additional high risk due to a plan (plan TTL/33/A) to divert upstream water from the Ayyalon river basin into the Nesher-Ramla quarry to deal with seasonal flooding. The Ayyalon river is a seasonal stream that overflows once every few years (up to 6 million cubic meters per event) and blocks a major intercity trunk road through Tel-Aviv, the Ayyalon highway, the busiest road in Israel. Additionally, Israel's key railroad tracks run adjacent to the Ayyalon riverbed within Tel Aviv. The construction of an additional railroad track is planned along this route in the near future, and finding a robust solution to the risk of flooding has been defined as a prerequisite. The planned solution was to use the quarry in which the Ayyalon cave is found as a stormwater reservoir.

A team of Israeli biologists and geologists took action, warning the authorities that injecting millions of cubic meters of fresh, cold, and oxidized water with a high content of suspended matter would cause an irreversible change in the properties of the groundwater, threatening the integrity of Ayyalon's food-web and its endemic fauna. The plan was authorized by the National Committee for Planning and Construction of Infrastructure (NIC) in 2021, but was open to objections from the public, governmental entities and other organizations before final approval. NIC is a committee established by the power of the Israeli "Planning and Construction Law," aiming to centralize and expedite planning of national infrastructure. It includes representatives of 10 ministries, municipalities, the Israel Land Authority, a representative of NGOs dealing with environmental protection, the public, and a professional planner. The public hearing took place during July 2021, led by a small NIC-appointed objections' committee, during which all objections that had been submitted were presented

and discussed. At the end of this process, the objections' committee submits recommendations to the broader forum of the NIC; these recommendations are usually accepted.

The researchers launched a broad public campaign to save the cave, calling on academic colleagues to oppose the plan by writing opinion letters to the NIC, the Israeli Water Authority, and the Yarkon River Authority. They also encouraged the public to write letters, submit objections to the plan, and sign petitions to save the unique fauna of Ayyalon. Within a week, local newspapers and radio stations became involved in the campaign, a website dedicated to Ayyalon cave was established, and three petitions were opened, securing public awareness. After a week, local environmental organizations joined the struggle, and letters from foreign specialists and global organizations began to accumulate.

In the same week in which the scientists initiated the campaign, five different media outlets in Israel published articles about the threat to Ayyalon cave [Yediot Modi'in, Ynet, Kan news, N12 (Mako), Makor Rishon]. In addition, one of the leading TV channels made an extensive report (N12, 2021; Figure 2), just before the committee's meeting to discuss the issue. Coordination among multiple organizations to oppose the plan took place, including the Society for Nature Protection in Israel (SPNI), Adam Teva V'Din (a major non-profit public interest association of lawyers, scientists, urban planners, and communications experts), and the Green Course (a student organization for sustainable environmental and social policy). A range of stakeholders, from local councils to farmer organizations, were invited to join, and each contributed their own unique viewpoint. Four academic Israeli societies (the Israeli Chapter of the Society for Conservation Biology; The Israel Cave Research Center; The Zoological Society of Israel; and The Israel Society for Evolutionary Biology), the representatives of three (out of nine) Israeli universities [The Hebrew University of Jerusalem (HUJI: National Natural History Collections, & EEB dept.); Tel Aviv University (TAU: Zoology School, & School of the Environment and Earth Sciences); Ben Gurion University of the Negev (BGU: The Ecology dept.)], and 14 individual researchers (from HUJI, TAU, BGU, Ariel University, Bar Ilan University, Haifa University, and Tel-Hai College) submitted their objections. Approximately 11,000 scientists and nonscientists from the general public signed three different petitions, in Hebrew and Arabic. Finally, the researchers contacted organizations and researchers specialized in the study of caves from abroad. This act yielded 21 letters from UNESCO, the Union Internationale de Spéléologie, different working groups from the IUCN and the European Reference Genome Atlas, national speleological societies (Croatia, Italy, Slovenia, and the USA), as well as biologists and geologists from three continents (Argentina, Australia, Germany, Italy, New Zealand, Slovenia, and the USA).

FIGURE 2 Interviewing Prof. Amos Frumkin (right) and Mr. Boaz Langford (left) before entering the Ayyalon cave to film the extensive report by N12 TV channel (Picture by S. Aharon). (https://www.mako.co.il/news-science/2021_q3/Article-0d82cfafb4a3b71026.htm).

BOX 1. A conservation agenda for Ayyalon cave.

For the long-term conservation of Ayyalon cave, several important monitoring and management actions should be implemented. These include:

(a) Finalize the declaration procedure of the nature reserve and prepare a concrete and cost-effective management plan.
(b) Implement isolation measures to protect the cave from the surface using suitable materials to seal the holes created by quarrying. This should prevent the penetration of new species (particularly bats and arthropods) and minimize seepage of pollutants and organic matter that is alien to this ecosystem.
(c) Develop a long-term monitoring scheme to track changes in the cave fauna due to environmental changes. This will supplement the occasional monitoring of the terrestrial fauna and the existing monitoring of the aquatic fauna.
(d) Supervise quarrying activities in the vicinity of the cave to identify additional caves of the Ophel biome to which Ayyalon cave belongs. These additional caves should be included in the preservation plan upon discovery.

BOX 2. Key lessons learned relevant to conservation science.

While the successful conservation story of Ayyalon cave represents a specific case, we can distill general principles that are valid for conservation science more broadly. These include:

(a) The need for solid scientific knowledge. Conservation campaigns require sound information about the importance of species and/or ecosystems under threat to leverage public opinion and convince decision-makers to act.
(b) The importance of cooperation and coordination between multiple sectors. To succeed, conservation campaigns need close cooperation between scientists (generating and providing information), the media and the public (facilitating information flow), and decision-makers (translating information into action).
(c) The importance of well-functioning laws and institutions. Successful conservation campaigns rely on well-functioning bureaucratic systems.
(d) The benefits of engaging in a constructive and positive way. Conservation campaigns may be more effective when focusing on the positive aspects of conservation rather than solely despairing about what is (or will be) lost.

The researchers leading the conservation campaign submitted all objections and letters to the NIC and were invited to present their arguments to the committee in July 2021, along with the Israel Nature and Parks Authority (INPA), the Israeli Water Authority, the Yarkon River Authority, the Ministry of Environmental Protection, the regional municipality, several environmental organizations, and the public. In September 2021, the NIC reached the decision to alter plan TTL/33/A, requiring that the project's contractor prepare a new plan for dealing with the Ayyalon stream's potential overflow that will not include Nesher-Ramla quarry and Ayyalon cave. The head of the committee emphasized the importance of the professional opinions of the Israeli biologists and geologists, as well as those of the foreign specialist letters, as key factors in his decision. After this announcement, the INPA requested to re-establish the monitoring scheme for the aquatic fauna of Ayyalon cave (monitoring of the fauna was initially started in 2006). In July 2022, the committee met again to open the discussion regarding the alternative plan of run-off management, and it now seems that Ayyalon cave has been saved from the risk of flooding—at least for the time being (see Box 1 for a long-term conservation agenda).

Notwithstanding the uniqueness of the Ayyalon cave system, one might argue that this story represents a very specific case of little relevance for conservation more broadly. To us, however, this story highlights important take-home messages that are paramount to conservation science (Box 2). First, even in the face of severe threats to ecosystems exerted by forceful economic powers (in this case by the contractor company, whose representatives argued that changes or delay in

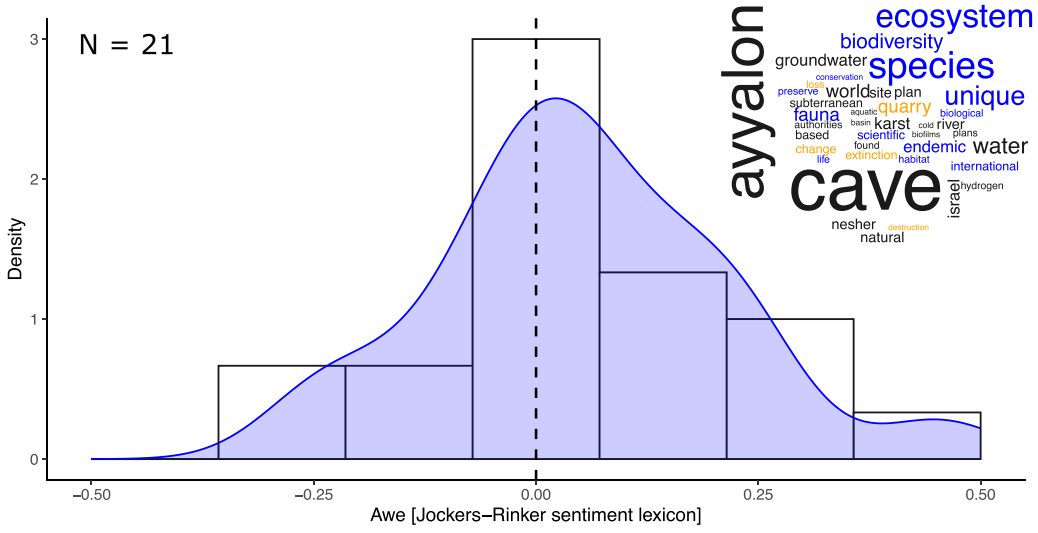

FIGURE 3 Aggregated sentiment scores (awe) of the 21 letters sent by international experts in subterranean biology, based on the Jockers-Rinker sentiment lexicon (Rinker, 2021). The sentiment score for each letter is the average of the sentiment of all the sentences, as calculated with the R package "sentimentr" v. 2.9.0 (Rinker, 2021). The word cloud (inset) illustrates the most frequently used 40 words across all letters. Text size is proportional to the frequency of each word. Blue-colored words are often used to describe the uniqueness of subterranean biodiversity ecosystems, orange words are mostly referring to anthropogenic threats and impacts.

the execution of the original plan would cost millions of dollars), there is hope that well-explained, decisive, and coordinated actions can prevail. In this, cooperation among different sectors, calling in a diverse set of stakeholders, was crucial and complementary to action along other fronts such as the media and among politicians. Second, as opposed to common sentiment, there is hope in the bureaucratic system. The bureaucracy functioned well in this case, and the system of receiving objections from the public and considering them seriously through professional discussion proved to be constructive. Understanding the intricacies of how this system works, engaging in positive discussion with the officials, and appealing both to common sense and to due process and the formal procedure was pivotal in this battle for the protection of Ayyalon cave. Finally, and perhaps most importantly, this case study offers hope: hope for one unique ecosystem, and hope that conservation actions may bear fruit. The content of the letters sent by experts from abroad exemplifies this, with most texts being neutral-to-positive in content and making explicit reference to the uniqueness of the endemic species inhabiting Ayyalon cave and the important ecosystem services associated with groundwaters (Figure 3). The fight for nature conservation cannot be driven solely by despair and sorrow for what is lost, but rather by hope for what the future may hold (Swaisgood & Sheppard, 2010); that by making the right choices today, we may leave our children a richer world, fascinating and diverse, with caves to explore and wonderful creatures to discover.

AUTHOR CONTRIBUTIONS

Efrat Gavish-Regev: Conceptualization; data curation; project administration; writing—original draft. **Amos Frumkin**: Project administration; validation; writing—review and editing. **Israel Na'aman**: Validation; writing—review and editing. **Boaz Langford**: Validation; writing—review and editing. **Shlomi Aharon**: Validation; visualization; writing—review and editing. **Shemesh Ya'aran**: Writing—review and editing. **Oren Kolodny**: Validation; writing—review and editing. **Stefano Mammola**: Conceptualization; data curation; formal analysis; project administration; visualization; writing—original draft.

ACKNOWLEDGMENTS

We thank the many volunteers and activists, from academia and the general public, that have dedicated hours, days, and weeks to the protection and study of Ayyalon cave; thanks to their work, we maintain the hope to conserve this unique ecosystem for future generations. Special thanks to Ariel Chipman for proofreading the manuscript. S. M. acknowledges support from the Biodiversa+ project DarCo. S. M.'s visit to Israel was supported by the 2021 SYNTHESYS+ project "Morphological traits as a tool to infer eco-evolutionary processes in subterranean environments."

CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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How to cite this article: Gavish-Regev, E., Frumkin, A., Na'aman, I., Langford, B., Aharon, S., Ya'aran, S. et al. (2023) The power of academic and public opinion in conservation: the case of Ayyalon Cave, Israel. *Integrative Conservation*, 2, 73–79. https://doi.org/10.1002/inc3.20