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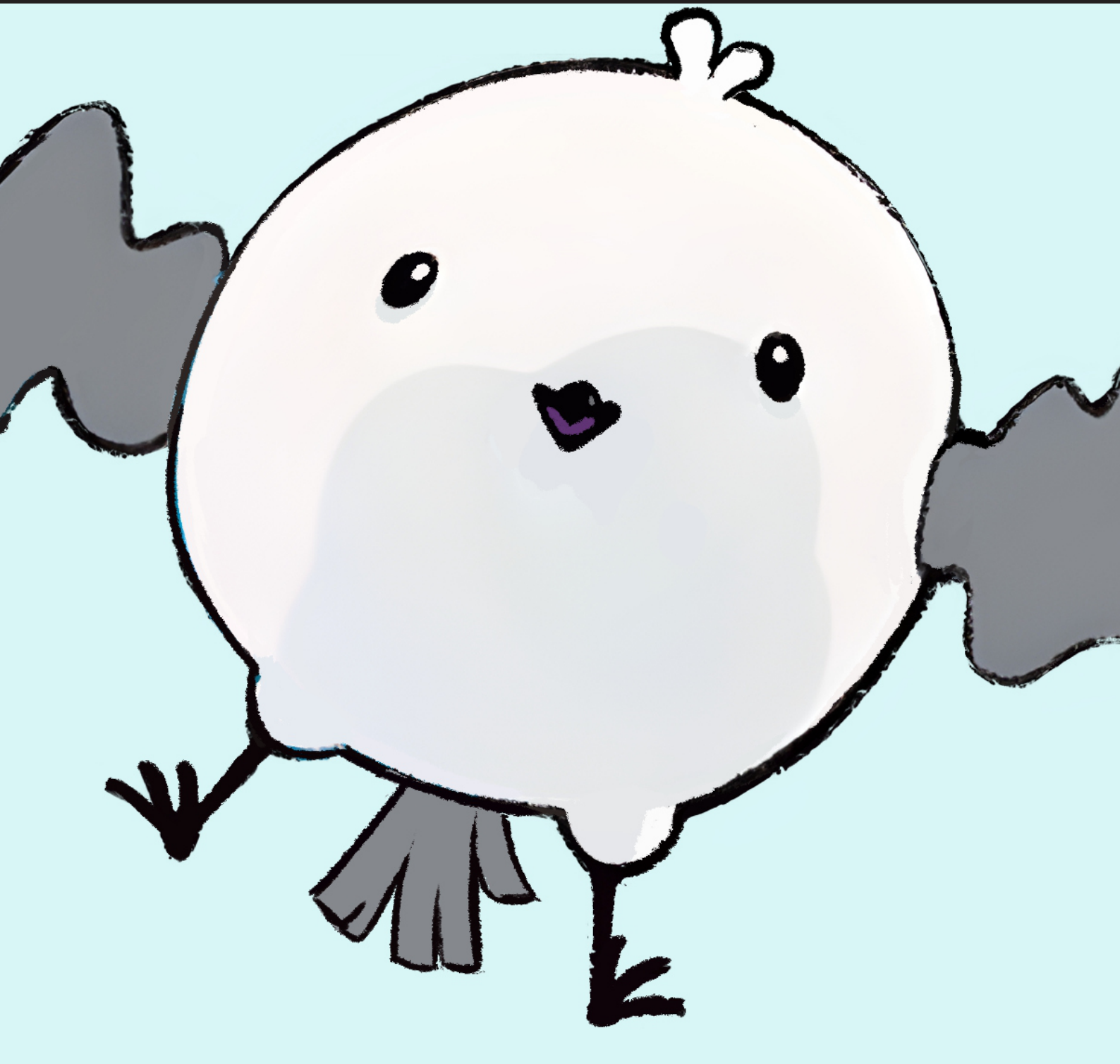

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Predicting competitive Pokémon VGC leads using Latent Semantic Analysis: a data-driven approach to team matchups

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Competitive Pokémon battles often hinge on the initial selection of Pokémon leads. Anticipating an opponent's lead choice offers a tactical edge, particularly in high-stakes matches. In this paper, I explore the use of Latent Semantic Analysis (LSA), a natural language processing algorithm, applied to over 5,000 Pokémon Showdown battle logs, to predict likely lead pairs based on team compositions. Evaluated against the Top 8 bracket of the North America International Championships (NAIC) 2025, the model achieved promising results, showcasing the potential of unsupervised learning in strategic game prediction.

POKÉMON VGC

The Video Game Championships (VGC) are the official competitive format organized by The Pokémon International and Play! Pokémon organizations. These events culminate in the annual Pokémon World Championships, which bring together top players from around the globe in various formats including the video games, the trading card game, and select spin-off titles.

In VGC, battles are conducted in a Double Battle format where each player brings six Pokémon, but selects only four to battle. Two are sent out as leads, and two remain in the back for switching. The game begins with a team preview phase, during which players see their opponent's six Pokémon and their move sets and held items (Bulbapedia, 2025).

LATENT SEMANTIC ANALYSIS

Latent Semantic Analysis (LSA) is a technique from natural language processing used to discover relationships between documents and terms by mapping them into a lower-dimensional space via Singular Value Decomposition (SVD). In this transformed space, documents can be compared based on the semantic similarity of their content. Originally developed for text retrieval and indexing, LSA (or LSI when used in information retrieval contexts) works by converting documents into a term-document matrix and reducing it to capture the most important relationships (Foltz, 1996; Wikipedia, 2025).

WHY IS A GOOD LEAD SELECTION RELEVANT IN VGC?

This question defines the core intention of this study. The fact is that all matches start in the team preview phase where each player has to decide which Pokémon will participate in the battle, leaving two of

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them out of the battle. This is an important decision because the four selected Pokémon must be solid and concise to overwhelm the opponent's team. Selecting a good pair of Pokémon with synergy will put pressure on the opponent side of the board, if the player makes the right call on the opponent's leads and selects two Pokémon that are able to counter and check them, thus gaining some advantage on the match.

As well stated by (Zheng, 2020), "picking the proper Pokémon in team preview can give you a major advantage before the game even starts", so the team preview holds a decisive part in the match. It is one of the most difficult parts of the game and there's no easy answer or cookbook to a perfect choice that will always work; not even the best players get it right 100% of the time.

Aaron Zheng emphasized that an effective lead not only applies early pressure but also aligns with the broader strategic intent of the team. Through mental flowcharts and recognition of synergy-based combinations (e.g., Speed control + Attacker, Redirection + Setup), players can anticipate the likely opposing leads and respond with countermeasures that tilt the battle in their favor. Also, the attempt to anticipate the opponent's strategy (particularly their most threatening combinations) forms the basis of lead prediction.

This capacity to predict an opponent's decisions is foundational for algorithmic approaches aimed at narrowing viable options and improving the player's lead selection. Leads are not merely chosen in isolation, but evaluated in the context of synergy, threat coverage, and their role in the broader battle plan (Zheng, 2020).

The predictive paradigm is reenforced by Traylor (*apud* Zheng, 2020) as an important part of the game, thus supporting the idea of proposing a narrative-based framework, in which players simulate possible match leads during team preview.

METHODOLOGY

Data collection

Data was sourced from publicly available battle logs hosted in an online battle simulator used extensively by the competitive community to test and train teams. The replay logs can be accessed via a URL trick: appending ".log" to the end of a replay page reveals the raw text file containing detailed information about each battle. This includes: (1) the complete teams for each player (six Pokémon each); (2) the two initial Pokémon (leads) sent out at the start of battle (Pokémon Showdown, 2025).

A scraping script was written in Python using the requests library to collect over 5,000 logs to extract team and lead data (available in Carli, 2025a).

Data filtering

To match a real-world competitive context, logs were filtered to include only those where at least one team used six Pokémon from the set of species seen in the NAIC 2025 Masters Top 8 bracket (Figs. 1, 2). This produced a refined dataset of 1,174 battle logs. While Figure 3 lists the top 30 most frequent Pokémon in the train set, all the Pokémon frequencies from the teams used by top cut players are listed in Figure 4 (data from LabMaus, 2025).

Model input format

As stated by Zheng (2020), the team preview is heavily influenced by the team each player is using. So, in order to find a pattern of the selected lead a structure containing both teams in the match must be provided so each battle instance is represented as a string: "poke1 poke2 poke3 poke4 poke5 poke6 VS poke1 poke2 poke3 poke4 poke5 poke6".

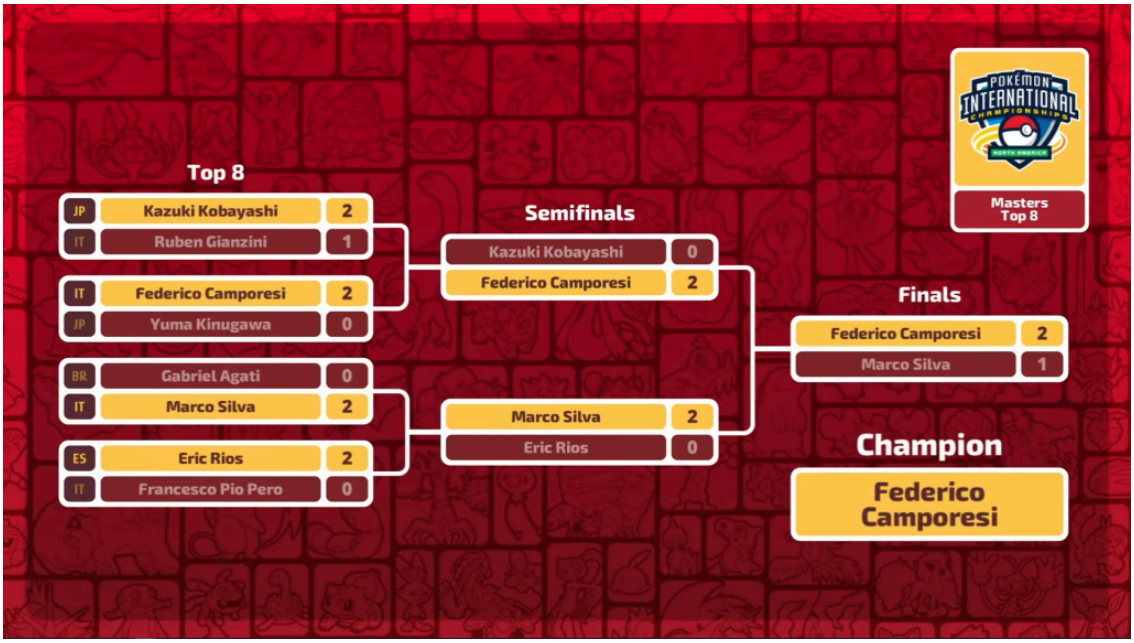

Figure 1. NAIC 2025 Top 8 Bracket. Source: Núñez (2025).

#	Swiss	Flag	Player	Prize	Team	OTS	EVs
1	10-2		Federico Camporesi (FedeCampoVGC)	2025 Worlds 500 CP $15,000			
2	10-2		Marco Silva (marcofiero)	2025 Worlds 480 CP $10,000			
3	11-1		Kazuki Kobayashi (CRYMAX)	2025 Worlds 420 CP $7,000			
4	10-2		Eric Rios (AEsir)	2025 Worlds 420 CP $7,000			
5	11-1		Francesco Pio Pero (CICCIOTT)	380 CP $5,000			
6	11-1		Yuma Kinugawa (スカーレット)	380 CP $5,000			
7	10-2		Ruben Gianzini (Sedia)	380 CP $5,000			
8	10-2		Gabriel Agati (Ash)	380 CP $5,000			
9	11-1		Behzad Muntazir (Saten)	300 CP $3,000			
10	10-2		Justin Knox (Justin)	300 CP $3,000			
11	10-2		Carson Confer (Carson)	300 CP $3,000			
12	10-2		Luca Ceribelli (Yume)	300 CP $3,000			

Figure 2. NAIC 2025 Top 8 cut results, with teams listed teams. Source: Núñez (2025).

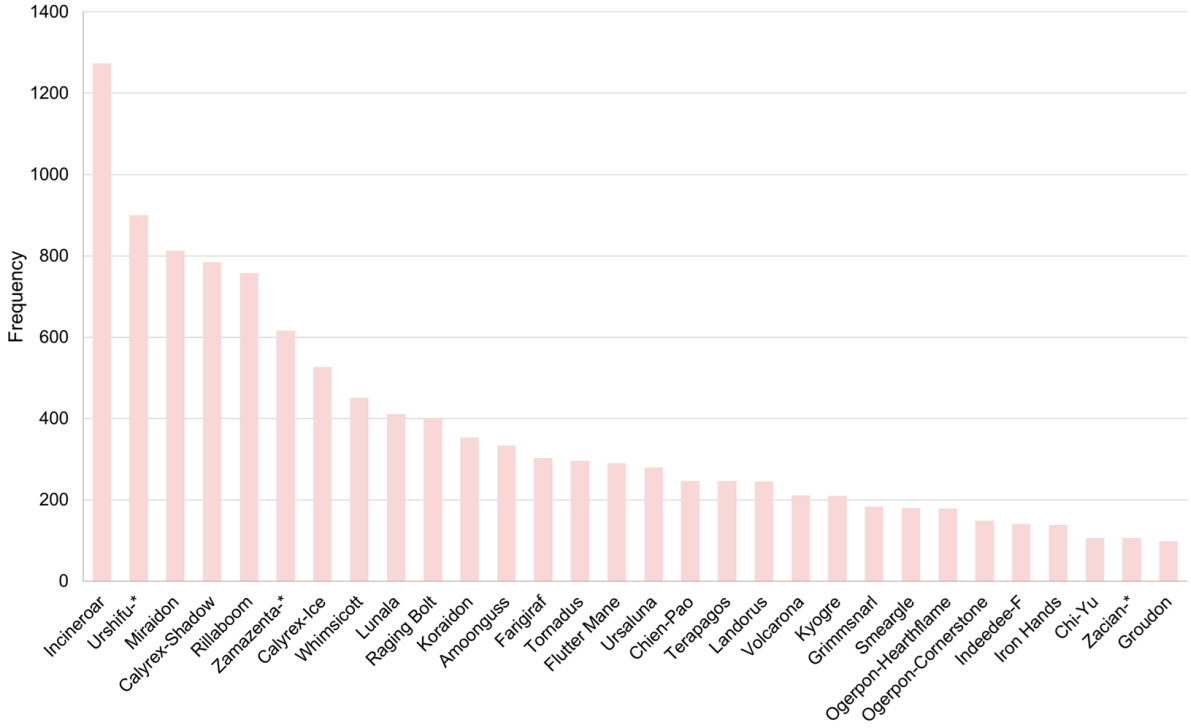

Figure 3. The 30 most frequent Pokémon on train sets.

Here, the left side of the 'VS' represents the user's team and the right side represents the opponent. The model is trained to predict the opponent's most likely two-Pokémon lead.

Implementation

The model was implemented using Gensim's LSI model with a Bag-of-Words representation. Lead prediction was based on

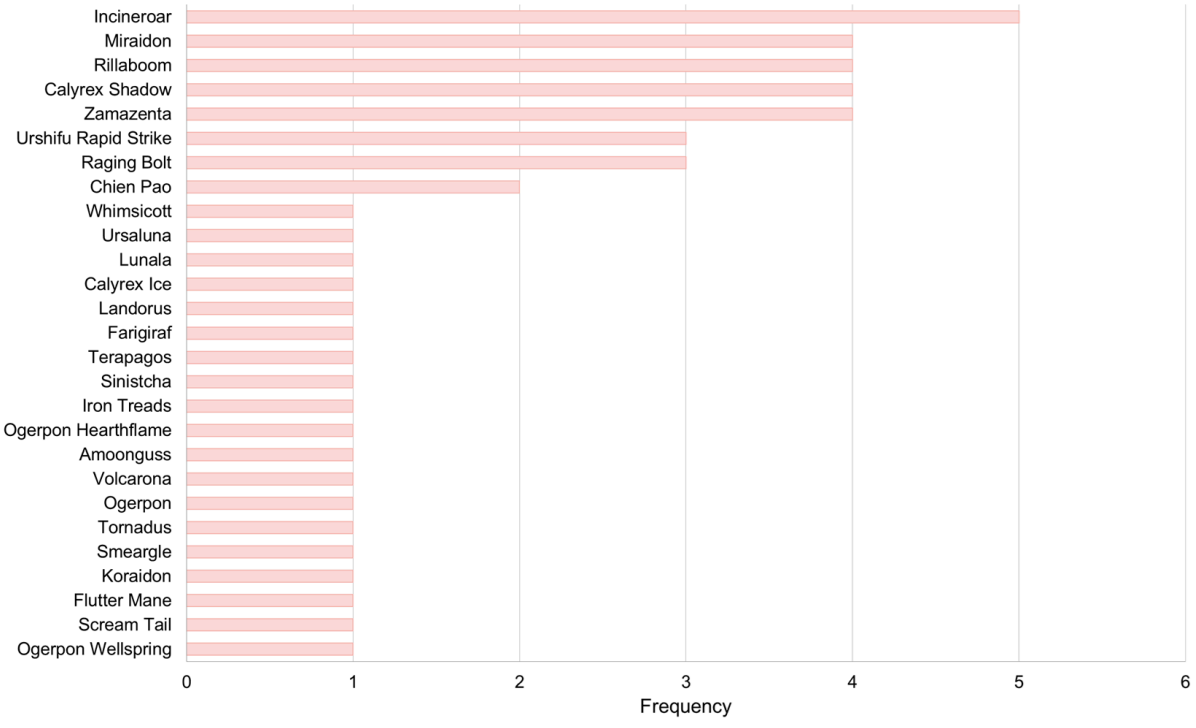

Figure 4. The most frequent Pokémon in NAIC 2025 Top 8. Source: LabMaus (2025).

Figure 5. Print Screen from NAIC 2025 streamed game between Federico Camporesi and Yuma Kinugawa (Round 1). Source: Núñez (2025).

vector similarity (cosine distance) between the input battle string and those seen during training.

The model may return a set of predictions by configuring a parameter named *max_preds* on the wrapper function that invokes the model. This parameter will inform the model how many possibilities of combination the opponent side can select and return a number of predictions equivalent to the value defined as argument to the parameter. Using this approach, it is possible to test the performance based on how many possibilities predicted by the model were necessary to correctly predict the real lead a player has selected, in other words it is expected that with more prediction possibilities the more biased might be the model.

For example, let's suppose that before a final match of the tournament (the match that will crown a champion) both players are practicing with their teammates at the hotel in order to get prepared for the ultimate decisive battle. If the algorithm was configured to predict three possible combinations of lead based on their teams and battle over and over with his teammates using those predicted leads so the player can get more prepared for what's to come, is an acceptable threshold for this player to go with. But if the algorithm was configured to predict eight or ten possible combinations, the player will be less likely to accomplish all sorts of possibilities in time. So, evaluation of the model over a range of possibilities can reveal the margin of error the model can perform by predicting less possibilities with higher accuracy.

Evaluation method

Predictions were evaluated by comparing model outputs with real-world leads from the NAIC 2025 Top 8 bracket. Since the leads used by each player are not explicitly shown in the website data, this information was collected by watching the live stream record available on YouTube (via Núñez, 2025).

The author watched the start of every match from the top cut bracket and taken notes of each lead used by the players that was included in the source code validation test set. Figure 5 shows an example of how the author identified the lead of each player on a match to set up the evaluation test set.

There were two possible ways to achieve a quantitative value for evaluation: (1) predicting correctly both lead Pokémon of a player; (2) predicting at least one lead Pokémon of a player.

In order to achieve this, it was defined one metric for each of these possibilities: **Hard Prediction**: a score of 1 if both predicted leads match the real leads (order-independent) otherwise 0. **Soft Prediction**: a score of 1 if both predicted leads match the real leads (order-independent) or a score of 0.5 if only one predicted lead matches, otherwise 0.

This approach makes it possible to evaluate the model from two points of view: (1) a perfect prediction that implies on a hard complexity level; (2) a more likely possible prediction that implies flexibility to the analytical context.

The main goal of using the data of a real competition as evaluation metric is to bring the theoretical implication of data science over a real-world problem. This brings more insightful ways to obtain a reliable proof of concept to computational abstract algorithms, which creates a more meaningful solution context for the application. Final performance metrics are the mean average of these values across all tournament matches for a set of parameter range of configurations. The source code and implementation are available online (see Carli, 2025b).

RESULTS

The model's performance was evaluated on each of the 32 battles from the NAIC Top 8 bracket and tested with the parameter configuration in a range of values from one to ten. Table 1 lists the evaluation of the model on each parameter. It is visible that the higher the number of predictions, the higher the score obtained, implying that the model was able to find a combination that matches with the lead used by the player in the tournament (Fig. 6).

Considering the most likely three possible lead Pokémon the opponent will bring, the overall Hard Prediction (correctly predict both leads) scored 62.50% while the overall Soft Prediction (correctly predict one of the leads) scored 81.25%. As the number of predictions grows, the algorithm is more likely able to find a pattern that matches with the leads used in almost every game, reaching a Hard Prediction score of 90.63% accuracy and Soft Prediction 95.31%.

Table 2 describes the middle term (five predictions) for every match in the NAIC 2025 Top 8 bracket scores: Hard Prediction = 68.75%; Soft Prediction = 84.38%. In the finals, where players have the most time to prepare and study opponent teams, the scores were highly accurate even for the three most likely leads (Table 3), scoring: Hard Prediction = 83.33%; Soft Prediction = 91.66%.

These results suggest that even a simple unsupervised algorithm can provide meaningful insights in a competitive context.

Table 1. Model performance on increasing number of predictions.

Nr	Hard prediction	Soft prediction
1	21.88%	53.13%
2	56.25%	75.00%
3	62.50%	81.25%
4	68.75%	84.38%
5	68.75%	84.38%
6	68.75%	84.38%
7	75.00%	87.50%
8	81.25%	90.63%
9	81.25%	90.63%
10	90.63%	95.31%

DISCUSSION

While the model does not capture all the nuance of VGC gameplay (e.g., movesets, synergy, in-game momentum), it offers a surprising amount of strategic value simply by analyzing team compositions from pre-

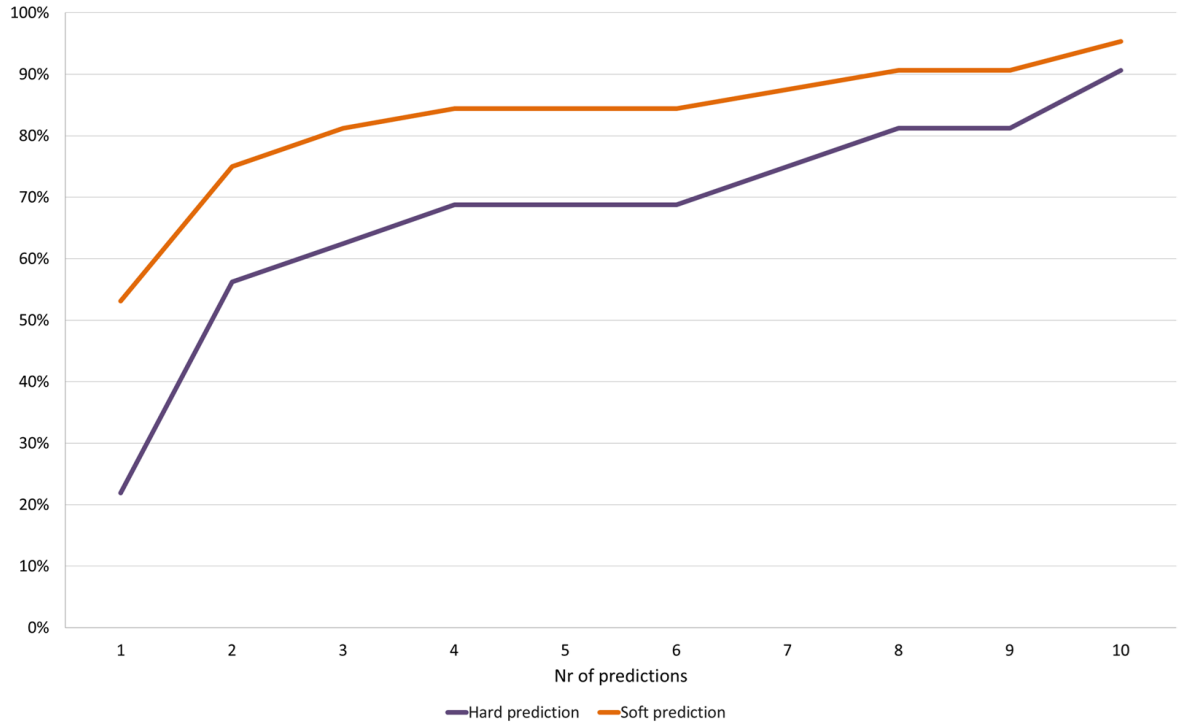

Figure 6. Model performance on increasing number of predictions.

vious matches played in simulation games and confirming the existence of a pattern that describes the more likely lead players choose to pick based on the matchup. It can serve as a scouting tool or sparring assistant.

Furthermore, the methodology avoids trying to model the data around the entire dataset from the initial number of logs collected from the data source, instead focusing on a specific set of Pokémon existent in the teams used by the players classified for the top cut resulting in an impactful decision point: the lead selection. This narrow focus keeps the modeling tractable and meaningful, demonstrating capability of pattern recognition on well-defined matchups when predicting a higher number of combinations.

But of course, it's true that Pokémon VGC is very challenging and complex in many ways, considering the skills and experience of the players, as well as the mind games involved in tricking the opponents with unpredictable choices, which are parameters the algorithm still does not understand. But competitions are overwhelming even for most experienced players and scouting tools like this are here to help the players to start to identifying common plays without stressing too much, especially in the finals where players have more knowledge of their opponents and more time to practiceand prepare.

By grounding the evaluation in a real-world tournament with known outcomes and high stakes, this study demonstrates practical relevance and not just theoretical performance. The application has potential to become a promising tool for preparation before matches in the future.

CONCLUSION

This study presented an innovative application of LSA to the Pokémon VGC context, demonstrating that unsupervised semantic models can support competitive decision-making in eSports. While not state

Table 2. NAIC 2025 Top 8 Bracket games with original leads and model results.

Players	Opponent	Lead	Hard prediction	Soft prediction
Gianzini VS Kobayashi	Kobayashi	Calyrex-Ice, Incineroar	1	1.0
Gianzini VS Kobayashi	Gianzini	Rillaboom, Zamazenta-Crowned	1	1.0
Gianzini VS Kobayashi	Kobayashi	Calyrex-Ice, Incineroar	1	1.0
Gianzini VS Kobayashi	Gianzini	Calyrex-Shadow, Zamazenta-Crowned	1	1.0
Gianzini VS Kobayashi	Kobayashi	Miraidon, Urshifu-Rapid-Strike	0	0.5
Gianzini VS Kobayashi	Gianzini	Calyrex-Shadow, Zamazenta-Crowned	1	1.0
Camporesi VS Kinugawa	Camporesi	Lunala, Incineroar	1	1.0
Camporesi VS Kinugawa	Kinugawa	Smeargle, Calyrex-Shadow	1	1.0
Camporesi VS Kinugawa	Camporesi	Urshifu-Rapid-Strike, Whimsicott	0	0.5
Camporesi VS Kinugawa	Kinugawa	Smeargle, Calyrex-Shadow	1	1.0
Agati VS Marco	Marco	Ogerpon-Hearthflame, Calyrex-Shadow	0	0.5
Agati VS Marco	Agati	Calyrex-Shadow, Flutter Mane	1	1.0
Agati VS Marco	Marco	Zamazenta-Crowned, Calyrex-Shadow	1	1.0
Agati VS Marco	Agati	Calyrex-Shadow, Flutter Mane	1	1.0
Rios VS Pio Pero	Pio Pero	Iron Treads, Miraidon	0	0.5
Rios VS Pio Pero	Rios	Rillaboom, Volcarona	0	0.5
Rios VS Pio Pero	Pio Pero	Urshifu-Rapid-Strike, Incineroar	1	1.0
Rios VS Pio Pero	Rios	Rillaboom, Volcarona	0	0.5
Camporesi VS Kobayashi	Kobayashi	Landorus, Miraidon	1	1.0
Camporesi VS Kobayashi	Camporesi	Miraidon, Incineroar	1	1.0
Camporesi VS Kobayashi	Kobayashi	Landorus, Miraidon	1	1.0
Camporesi VS Kobayashi	Camporesi	Miraidon, Incineroar	1	1.0
Rios VS Marco	Marco	Zamazenta-Crowned, Calyrex-Shadow	1	1.0
Rios VS Marco	Rios	Miraidon, Ogerpon-Teal	0	0.5
Rios VS Marco	Marco	Rillaboom, Calyrex-Shadow	0	0.5
Rios VS Marco	Rios	Miraidon, Zamazenta-Crowned	0	0.5
Camporesi VS Marco	Marco	Calyrex-Shadow, Zamazenta-Crowned	0	0.5
Camporesi VS Marco	Camporesi	Miraidon, Lunala	1	1.0
Camporesi VS Marco	Marco	Rillaboom, Zamazenta-Crowned	1	1.0
Camporesi VS Marco	Camporesi	Lunala, Incineroar	1	1.0
Camporesi VS Marco	Marco	Rillaboom, Zamazenta-Crowned	1	1.0
Camporesi VS Marco	Camporesi	Lunala, Incineroar	1	1.0

Table 3. NAIC 2025 Finals with original leads and model results.

Players	Opponent	Lead	Hard prediction	Soft prediction
Camporesi VS Marco	Marco	Calyrex-Shadow, Zamazenta-Crowned	0	0.5
Camporesi VS Marco	Camporesi	Miraidon, Lunala	1	1.0
Camporesi VS Marco	Marco	Rillaboom, Zamazenta-Crowned	1	1.0
Camporesi VS Marco	Camporesi	Lunala, Incineroar	1	1.0
Camporesi VS Marco	Marco	Rillaboom, Zamazenta-Crowned	1	1.0
Camporesi VS Marco	Camporesi	Lunala, Incineroar	1	1.0

of the art in terms of algorithmic sophistication, the work is novel in its domain adaptation and bridges data science with strategic gameplay.

FURTHER WORK

Future improvements may include supervised refinement, incorporation of moves/item metadata, and broader meta-context generalization. Predicting not only the lead but the four picks for a match is also a good improvement for more complex analysis of game matchups. Another creative and helpful point of view is to predict the most likely Pokémon a player decides **not** to bring to a game according to its disadvantage. One last useful analytical variance of the model application is to look for strengths and weakness among team compositions in order to optimize the coverage and synergy between the six Pokémon formation in teambuilding process which was well mentioned by Zheng (2020) when pointing that "stronger teams will allow you to have more options during team preview. Bad match-ups will lead to more difficult team preview phases, and you'll occasionally be in situations where you don't have any good leads. Selecting a strong team will make team preview easier for you."

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Molluscs of the Multiverse: molluscan diversity in *Magic: The Gathering*

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In our plane of existence, molluscs are the second most diverse animal phylum in sheer number of species, losing only to arthropods. They are, however, perhaps the most diverse animal groups in body plans and shapes. The better-known molluscan groups include forms as disparate as snails and slugs (class Gastropoda), octopuses and squids (class Cephalopoda), and oysters and mussels (class Bivalvia). The lesser-known molluscs go from the worm-like aplacophorans to the armadillo-like chitons and the fang-shaped tusk shells. Also, molluscs come in all sizes, from species smaller than 1 mm all the way to the largest invertebrate alive, the giant squid that can reach over 15 m and is the origin of the legendary Kraken (Salvador & Tomotani, 2014).

As arcane specialists on Mollusca and eternal inhabitants of museum galleries and catacombs, we are constantly pondering the existence of molluscan life (intelligent or otherwise) on planes other than our own. Thus, we have discussed squid kids, pixel molluscs, and many others. One of us (Carnall, 2018) has even explored cephalopod diversity across the multiverse of *Magic: The Gathering* (MTG).

Since then, the MTG's multiverse has witnessed an explosion of molluscan diversity, notably in the cephalopod and gastropod fronts. The kinship of disparate molluscan classes has even been recognised across the multiverse, as seen in the flavour text of Nightwhorl Hermit, which brings bivalves and snails together: "*He etches his secrets onto the shimmering shells of mussels, saving them to share with the Great Snail*". To us, that sounded as a call to arms to ~~spend money on cards~~ study all these new life forms.

SLUGS AND SNAILS

Perhaps the largest increase in molluscan diversity in MTG took place among the terrestrial gastropods, with a notable contribution from the Bloomburrow set of 2024. Of all the peoples of the Bloomburrow plane, the ratfolk have achieved the pinnacle of enlightenment, with a culture that revolves around gastropods, including worshipping a being known as The Great Snail. Such advanced sensibilities have only one parallel in our plane's history: the rise of Lord Helix during the *Twitch Plays Pokémon* event – though the Cult of the Helix involved a fossil cephalopod (Salvador, 2014).

Snails

The legendary rat warlock Wick, the Whorled Mind grew up in the village of Conch and developed a psychic bond with his companion, the sapient snail Grotgyre –

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Figure 1. Snail creature token and an amber snail (*Succinea* sp.) from Japan, infected by *Leucochloridium paradoxum*. Sources: card: Gatherer; photograph: reproduced (cropped) from Nakao et al. 2019.

a.k.a. The Great Snail or God-Snail. He found enlightenment with the snails (who doesn't, right?) and roamed the world spreading the slimy Word and gathering followers (Johnson, 2024), such as the Thought Shucker and Lightshell Duo. Wick is seen with several snails in his card's art, part of which are similar to some of our plane's land snails but with a few oddballs that have rather unusual shell shapes. That is perhaps an indication that the snails of the multiverse managed to occupy more of the morphospace available to beings with coiled shells (Raup & Michelson, 1965; Raup, 1966).

It turns out, however, that the Great Snail was actually being controlled by a worm-like parasite. That goes to show that mortals should not put too much trust in a god, as already remarked by our plane's mythologies. In any event, the worm in question is probably similar to the *Leucochloridium* flatworms from Eurasia that infect exclusively members of the snail family Succineidae, known as amber snails (Ataev et al., 2016; Nakao et al., 2019). The parasitic flatworm manipulates the snail's behaviour, making it crawl towards places where it is more conspicuous to predators, namely birds, which are the definitive host of the parasite. Clearly, this Bloomburrow parasite can also infect other types of snails besides amber snails, as seen by the tell-tale bulging and striped tentacles of the Snail creature token (Fig. 1).

And speaking of parasites, the Skullcap Snail, from Ixalan, is infested by fungi, like something out of The Last of Us. Even so, we do not have good data on whether this is a parasitic, commensalistic, or mutualistic relationship between the fungus and the snail. In any event, the Skullcap Snail looks more like a slug that rented a skull for a house rather than a proper snail.

The rat spellcaster featured in Mind Spiral is shown with an odd-looking snail shell. That shell is exactly like a fossilised internal mould of a shell – that is, during the fossilisation process, the actual shell sometimes dissolves away, leaving only the mineralised sediment that had filled it up (you can find some examples in Salvador et al., 2018). Finally, let's just pretend that the chimeric caterpillar-dog-with-ant-like-antennae-and-gastropod-shell known as the Dogsnail Engine doesn't exist, alright?

Slugs

While the cards above contain all the terrestrial snails we could find around the multiverse, there are plenty of slugs in MTG, contrary to our plane, where snails are much more diverse than slugs. While snails and slugs are perceived as slow creatures, they can be quite active – just ask anyone trying to grow strawberries in their backyard. MTG is thus not free from cultural perceptions, with an Enchantment named Sluggishness. However, only the English language card is offensive; it has more appropriate names in other languages, such as Trägheit in German.

Let us start with the basics. The Slug creature token is overall reminiscent of the members of the Arionidae family found in our home plane. Still, all the teeth positioned around its mouth are completely alien. Actual gastropods have a structure called a 'radula' in their mouth, which is like a tongue with dozens of rows of tiny teeth that they use to scrape off their food. Thus, they ingest small morsels of food at a time and are not able to consume an entire skull or creature, as shown in the token's art. Some marine predatory gastropods, like the cone snails, however, have a radula adapted to hunting fast-moving prey and can ingest entire prey, including fish (Duda et al., 2001).

A similar weird mouth-and-teeth combination can be seen in the Catacomb Slug (from Ravnica), which has way too many tentacles on its head and looks like a cross between a sea hare (a type of marine slug belonging to the family Aplysiidae) and a sea cucumber (part of the echinoderm phylum). Terrestrial slugs (as well as the vast majority of land snails) have only two pairs of tentacles: the topmost pair are eyestalks, with the eyes positioned on their tip; the bottom pair is responsible for the chemical and tactile senses (Chase, 2001).

A good example of the two tentacle pairs is the oldie-but-goodie Giant Slug, from a time when the multiverse had not yet suffered from power creep, and the Rocket-Powered Turbo Slug, arguably one of the greatest cards in MTG. Gluttonous Slug also has two pairs of tentacles, but the second pair is positioned in-between the first one, not to mention it also bears tiny eyes. Weirdly enough, Gluttonous Slug has some leg-like appendages, which give it a rather caterpillar-ish look. The Thermopod, from Dominaria, also look like a cross with a

Figure 2. Spitting Slug and a banana slug (*Ariolimax californicus*) from California. Sources: card: Gatherer; photograph: iNaturalist (Neal Kelso, 2025), CC BY 4.0.

caterpillar because of its three pairs of leg-like appendages and the very arthropod-like mandible. Also, the Molder Slug from Mirrodin has an insect-like or crustacean-like armour plating on its rear end. Still, its armour also bears some passing resemblance to the multiple calcareous plates of chitons, members of the class Polyplacophora and also molluscs.

Slugs typically have their breathing pore (called 'pneumostome') on the right side of their bodies, which brings air to their lung. The Spitting Slug from Dominaria, however, has the pneumostome on its left side (Fig. 2). This mirrored anatomy (Schilthuizen & Haase, 2010) indicates that the illustrated slug is a sinistral, or left-handed, specimen – maybe the whole species is made up of sinistral animals! As implied by its name, this slug spits a substance which looks like mucus, which is something no gastropod can do (rather, they produce and secrete mucus through their skin).

Last but not least, we arrive at Toxrill, the Corrosive, the legendary slug horror from Innistrad. Overall, if it were a Pokémon, one could say it evolves from the Morkrut Necropod (also from Innistrad) when it reaches a high enough level. They share a similar body plan, reminiscent of a deflated sea hare that has been taken out of the sea (Fig. 3), have way too many tentacles and a toothed mouth. But, well, we suppose that's what makes it a slug horror. Curiously, the baby slugs shown around Toxrill have only three pairs of tentacles, implying that extra pairs appear during development. Like all slugs and snails, Toxrill can continuously produce mucus, which is reflected in game terms as slime counters.

SEA SNAILS & SEA SLUGS

Terrestrial gastropods make up about one-third of all gastropod species on our home plane. Except for a few hundred freshwater species, it is in the marine environment that the group shows its highest diversity (Rosenberg, 2014). This remarkable marine diversity is reflected in a wide range of forms, ecological strategies, and evolutionary adaptations. In contrast, marine fauna is not that well explored in MTG, particularly considering it is largely restricted to one out of the five mana colours.

There is one sea snail in MTG: Gary, the

Figure 3. Morkrut Necropod and a sea hare (*Aplysia vaccaria*) from Radès Sea. Sources: card: Gatherer; photograph: Wikimedia Commons (Smailtn, 2024), CC0 1.0.

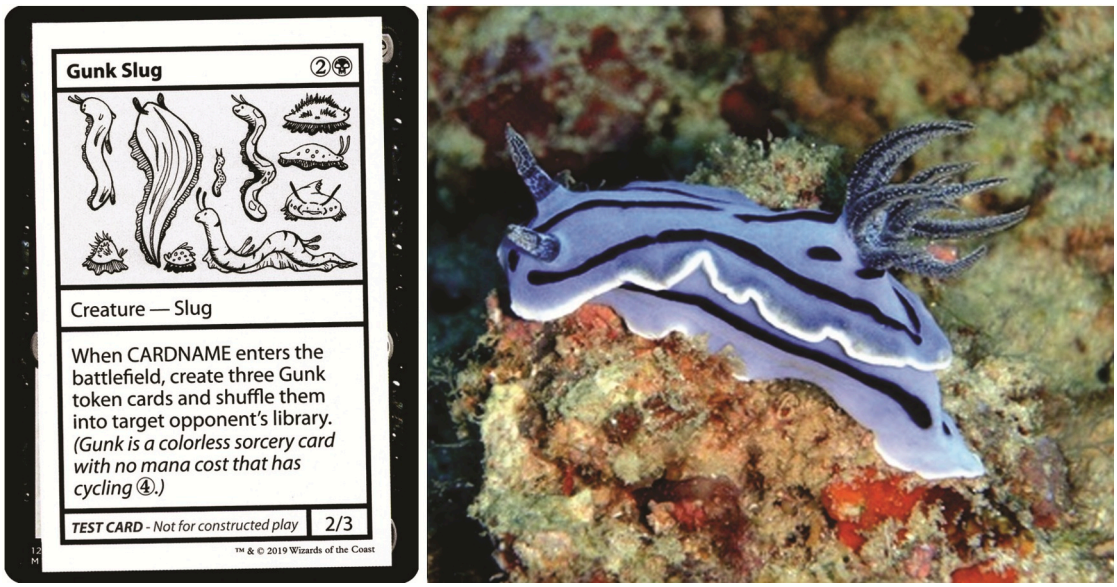

Figure 4. Gunk Slug and a sea slug (*Chromodoris willani*) from Malaysia. Sources: card: Gatherer; photograph: iNaturalist (Krampf, 2009), CC BY 4.0.

Snail (from *SpongeBob SquarePants*). However, Gary is just a different incarnation of the card Toxrill, the Corrosive, which is a terrestrial slug horror.

Sea slugs have not been particularly lucky either, being present only in the comedy set Mystery Booster. The critters in the card Gunk Slug seem to have been inspired by nudibranchs, such as members of the Chromodorididae family (Fig. 4), which are typically colourful animals with stripes that mark their dorsal region – too bad the card is in black and white!

BIVALVES

On our plane, bivalves are the second most diverse group of molluscs by number of species; however, it seems they may not be as common or perhaps as well studied across the multiverse. There's evidence of bivalve use in commerce and culture. A Seashell Cameo on a scallop makes for a source of mana in a pinch, and the flavour text from Nightwhorl Hermit and Shore Up indicates that mussels are known well enough to be used as votives and have found their way into vernacular expressions.

Giant Oyster resembles the giant clams, Tridacnidae, of our world (Fig. 5) and also occasionally traps hapless animals within their shells as recorded in mythology, museums, medicine (Marina & Popa, 2020) and media (Martin-Pavitt, 2022).

However, the most evidence of bivalve life from the multiverse comes from one of the two molluscan humanoid creatures (see Cephalids, below), the enigmatic and seemingly haphazard clamfolk. Clamfolk are anthropoid creatures with scrawny arms and legs with a head that resembles, well, a clam. They are the sworn enemies of the anthropoid lobster-like Homarids (McDermott et al., 1998). Not much is known about them, but a well-known song indicates there is at least one clamfolk settlement and music culture:

> *The Clams down in Clamville*
> *All scootered and skittled*
> *"The three is no more"*
> *The Clam fiddler fiddled*
> – Flavour text from Clam-I-Am card.

Figure 5. Giant Oyster and small giant clam (*Tridacna maxima*). Sources: card: Gatherer; photograph: Wikimedia Commons (Dupont, 2009), CC BY-SA 2.0.

Clam Session and Clam-I-Am indicate that the clamfolk like good music. However, they do wage war and occasionally end up shelling neutral parties, for which they attempt to make good by issuing Clambassadors with reparations. There's just one clamfolk legend recorded in the histories of the multiverses, and that is Alexander Clamilton, the clamfolk advisor rebel fond of wordplay and duelling rivals.

CEPHALOPODS

Since the previous review of cephalopods of the multiverse (Carnall, 2018), there has been an explosion of newly discovered cephalopods across the multiverse and one major taxonomic change. In 2018 it was just about possible to construct a decent 'tribal' octopus deck with a splash of other cephalopod creatures and spells for flavour (in MTG parlance, tribal decks are decks that benefit from running creatures of the same type and in legacy formats can be bolstered by artifacts like Herald's Horn, Vanquisher's Banner and Metallic Mimic). Now it is more than possible to create cephalopod-themed decks for formats like Commander, which restricts the number of copies of cards which can be used and have larger deck sizes.

From the monster-dominated plane of Ikoria comes the Sea-Dasher Octopus with the ability to mutate and merge with other creatures and share their abilities. The wonderfully named bioluminescent Octoprophet is a strictly better Giant Octopus with the same power, toughness and casting cost but with scrying power. From the waters of the Ravnica plane, we have the Mesmerizing Benthid, which creates paralysing illusions upon being summoned. Also from Ravnica, it seems the biomancers of the Simic Combine have been particularly inspired by octopus adaptations in their creations of shark-octopus-lizard Unruly Krasis, or, if you prefer your hybrids with more claws, the shark-octopus-crab Sharktocrab has you covered. Rounding off the hybrid/mutant/fusions are disguise artist octopus-fish Bubble Smuggler and robot-glove-octopus device Acquisition Octopus.

There are a number of new cephalopod creatures of such ability and renown that they are known as legends (legendary creatures in MTG have specific rules). From the plane of Muraganda, one of the three planes that is host to the plane-spanning, death-defying Ghirapur Grand Prix, is the legendary Caelorna, Coral Tyrant, an island-sized octopus that eats leylines for breakfast. Proving that octopuses on some planes are also

known for their smarts is the elemental Octavia, Living Thesis, the product of one of Strixhaven University's finest minds. The latest legend to be discovered is one that spans not only planes but franchises: Ultros, Obnoxious Octopus appears in over twenty games in the Final Fantasy series of video games, as well as Dragon Quest and Kingdom Hearts, and now joins the MTG multiverse thanks to a popular crossover set.

There's also been an update to the classification, from an arcane taxonomy point of view anyway, so update your codices, spell books and living tomes accordingly. Cephalids, MTG's humanoid cephalopod race, are now, thanks to a rules change, octopus creatures, which now means they won't be washed away by Whelming Wave and can be summoned up by Kenessos, Priest of Thassa. Cephalids are generally depicted as cruel, conniving and crafty, as indicated by card names, art and flavour text such as Callous Oppressor, Cephalid Aristocrat, Cephalid Looter, Cephalid Snitch and Cephalid Vandal. Cephalids play an important role in MTG's ongoing plane-spanning mythology. Aboshan, Cephalid Emperor once ruled the cephalid Mer Empire of the plane Dominaria's oceans but fell foul of the temptations of legendary MacGuffin, the Mirari, as told in the MTG novel Odyssey (Moore, 2001). Most recently, after a twenty-year absence, cephalids are back in MTG, putting their cunning and conspiring to good use on the mean streets of New Capenna on the plane Capenna. In a city where demon-led crime families vie for dominance, cephalids have found employ as goons for hire (Backstreet Bruiser), spies (Cephalid Facetaker) and information dealers (Psychic Pickpocket), among others.

Rounding off the cephalopod mollusc new discoveries across the planes, and it's not just octopuses which have seen some love from the designers of MTG. There's one new nautilus, the conchokleptic Hermitic Nautilus, which wears the shell of the devoured previous owner (that looks vaguely familiar to another MTG cephalopod). There's tantalising evidence of a fossil record of nautiloids from the plane of Theros, Pull from the Deep, depicts a rather fortuitously preserved fossil (or possible carving) of a nautiloid shell in section, per-

Figure 6. Pull from the Deep and sectioned chambered nautilus shell (*Nautilus pompilius*). Sources: card: Gatherer; photograph: specimen OUMNH-ZC-2022-11, courtesy Oxford University Museum of Natural History, reproduced with permission.

fectly showing the central siphuncle and nautiloid septa (Fig. 6). There are just two new squid: Skyclave Squid, the multiverse's first cuttlefish, perhaps; and the rather dapper and dastardly Squidnapper from Mystery Booster, one of MTG's occasional comedy sets.

Several other spells and creatures create, summon and otherwise combo with octopuses. Take care at the Astroquarium lest an octopus escape. Octomancers are frog druids who, well, mancy octopuses. You'll need to study hard for transformation lessons at Strixhaven to polymorph an octopus or frog (or should that be crab?) with Mercurial Transformation. Origami fans might want to practice for Octo Opus the next time the circus is in town. Summon: Leviathan will wash away everything but octopuses, krakens, merfolk, serpents and leviathans and if you spend some time levelling up with rod and tackle and you'll be fishing up octopuses in no time with a bit of Fisher's Talent. Lastly, various legends from the multiverse will bolster your suckered and tentacled troops: Kenessos, Priest of Thassa can help you get more octopuses onto the battlefield; planeswalker Kiora has two new aspects Kiora, the Rising Tide and Kiora, Sovereign of the Deep; and Krothos, Lord of the Deep can double your cephalopod forces with every attack.

CONCLUSION

We hope we have covered all the main molluscs from MTG, but feel free to let us know about further instances of mollusc-related stuff and "cameos". Echoing the ending remarks of Carnall (2018), we see some biological similarities in the molluscs of the multiverse, together with biologically questionable, implausible or outright impossible stuff – all in the name of making a fun game. There are still plenty of molluscs in our home plane to draw inspiration from, particularly the fossil ones, so we look forward to seeing more of them in MTG in the future.

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Mark Carnall is the collections manager of non-entomological invertebrates and human remains at the Oxford University Museum of Natural History with an inordinate fondness for cephalopods. Mark has spent years trying to build the perfect strictly cephalopod tribal deck and asks that you please wait until turn five because blue creatures are expensive okay but after that you're in trouble.

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When cyberpunk leaks into the timeline: megacorps, memes, and Rheinmetall as a real-world case study

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Pop culture increasingly provides the metaphors—and sometimes the scripts—that shape public conversations about geopolitics, technology, and corporate power. This article foregrounds the geek angle by first showing how ideas from science fiction and gaming (especially the cyberpunk genre) seep into everyday discourse; then it introduces the genre's signature trope of the all-powerful megacorporation. Against this backdrop, it presents German motor and arms manufacturer Rheinmetall's unusual announcement to deploy its own air-defence assets to protect a manufacturing plant in Ukraine as a real-world case study of "cyberpunk leaking into the timeline." Using grounded theory and qualitative content analysis of large social-media discussions, this study finds predominantly positive audience sentiment and frequent, sophisticated comparisons to cyberpunk universes (e.g., *Shadowrun* and *Cyberpunk*).

GEEK METAPHORS IN COMMON SPEECH

Comic books, films, and video games have long supplied shorthand for complex ideas. 'Superman', 'the Dark Side', or even 'zombie apocalypse' now function as everyday metaphors to discuss ethics, corruption, resilience, or societal breakdown (Tatsumi, 2006). Memes accelerate this transfer: a vivid fictional frame makes abstract or technical issues legible and emotionally engaging. These references are not mere jokes; they shape how people think and argue. When a debate invokes 'Skynet', 'red pills', or 'Weyland-Yutani', it pulls in narrative gravity from entire fictional canons—characters, moral alignments, and world-rules arrive pre-packaged (Singer, 2002). So, what some dismiss as "just pop culture" can structure public reasoning about serious topics, including war and corporate power.

CYBERPUNK MEGACORPS

At the heart of most cyberpunk stories is the megacorporation: a private actor so large that it blurs traditional lines between state and market. These firms maintain private security forces, project power across borders, and sometimes operate as if above the law. In fiction, megacorps are often coded as antagonists, being efficient, amoral, and ubiquitous. Famous game settings (originally tabletop, now also videogames) such as *Shadowrun* (originally by FASA, 1989) and *Cyberpunk* (originally by R. Talsorian Games, 1988) depict corporate enclaves with their own rules, corpo-

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Figure 1. *Shadowrun* artwork showing a runner over the Sprawl. Image from: wallpapers.com (by sevda._.damla), used here for scholarly commentary (fair use).

rate military assets, and forms of "extraterritoriality" (Brozek, 2013; Pondsmith, 2020). German-language sourcebooks helped cement these tropes for local audiences, with Saeder-Krupp and MET2000 becoming touchstones for corporate militarisation (FanPro, 1992; Pegasus Spiele, 2011).

This genre-specific grammar matters because readers bring it with them when encountering real-world events. When news breaks that a defence company plans to protect its overseas assets with its own air-defence systems, many immediately reach for the cyberpunk playbook (Roxl, 2023).

CASE STUDY

In July 2023, following public threats by Russian officials toward a planned production facility in Ukraine, Rheinmetall's CEO signalled the intent to deploy company-owned air-defence to protect the site (Roshchina, 2023). Regardless of legal nuance or ultimate implementation, that message—i.e., a corporation publicly proposing to defend its foreign factory with its own military equipment—landed online like a plot beat from *Shadowrun* or *Cyberpunk*. The episode became a memetic touchstone: social-media users debated corporate sovereignty, invoked megacorp lore, and compared Rheinmetall to fictional counterparts (Chaudhuri & Israel, 1991; Pondsmith, 2020; Roxl, 2023).

METHODOLOGY

Given the scarcity of prior research on pop culture framing in defence-industry discourse, a **grounded-theory** approach was adopted (Strauss & Corbin, 1994; Tolhurst, 2012). Source threads were located via platform search (Twitter/X, Facebook, Reddit, 9gag, Instagram, TikTok) and reverse-image/keyword queries (in German and English). Individual posts were coded iteratively for sentiment, themes, and explicit cultural references. Engagement metrics (likes/upvotes vs. dislikes/downvotes) were tallied to complement qualitative codes.

Table 1. Classification of social media posts analysed in this study. *Reference to other fiction games, movies, etc.: *Alien*'s Weyland-Yutani Corporation, *Command & Conquer*, *Starsector*'s Tri-Tachyon Corporation, *Syndicate, Warhammer 40000*.

Categorization of social media posts	Share of posts
Rheinmetall-specific themes	
Spying on Russia allegations	1.22%
Dystopian framings	6.53%
Negatively rated/downvoted	6.94%
"PR stunt" interpretations	7.76%
PMC advantages discussed	8.16%
Fictional & historical comparisons	
Cyberpunk universe (general)	7.34%
Arasaka	2.86%
Militech	1.22%
East India Companies (VOC/EIC)	1.64%
Metal Gear Solid	1.22%
Shadowrun universe (general)	4.89%
Saeder-Krupp	3.26%
MET2000	1.63%
Terminator's Cyberdyne Systems	4.08%
Other fiction references*	3.69%

RESULTS

Across a corpus of 245 threads (total 19,804 posts; Table 1), audience sentiment was notably positive toward Rheinmetall's stance. The ratio of likes to dislikes on initial posts reporting the announcement was ≈13.8:1, and approving comments substantially outnumbered critical ones (≈6.7:1). Many threads explicitly mapped the event onto cyberpunk worlds (Table 1), referencing *Shadowrun* (including Saeder-Krupp and MET2000) and *Cyberpunk* (Arasaka, Militech) (FanPro, 1992; Pegasus Spiele, 2011; Brozek, 2013; Pondsmith, 2020). Historical analogies to the Dutch and British East India Companies also appeared, typically in more critical contexts (Chaudhuri & Israel, 1991).

DISCUSSION

Looking at the results, the first question one should ask is "Why did the geek lens skew positive?". Three interacting dynamics help explain the upbeat reception. Firstly, **moral compression via genre**: cyberpunk habituates audiences to corporate militarisation as a narrative given; in that grammar, a firm moving to protect its assets feels "on brand" and, thus, not shocking (Brozek, 2013; Pondsmith, 2020). Secondly, **geopolitical priors**: post-2022 negative public attitudes toward Russia in the West likely shaped baseline sympathies (Darczewska et al., 2015; Beardsworth, 2022). Third, **platform dynamics and memetics**: threads remixing the story with recognisable IPs are more legible and shareable; referencing Saeder-Krupp or Arasaka supplies instant context and in-group signalling (Roxl, 2023).

Figure 2. *Cyberpunk 2077* Arasaka corporate security. Screenshot from the game, used here for scholarly commentary (fair use).

A historical counter-frame, i.e., comparisons to the VOC/EIC, correlated with more critical stances (Chaudhuri & Israel, 1991). The coexistence of celebratory cyberpunk mappings and cautionary historical analogies suggests that pop culture frames can both normalize as well as problematize corporate power, depending on which canon a community mobilises.

There are some implications for media literacy and digital citizenship to be extracted here. Pop culture seems to be an in-

put into public reasoning about war and related corporate power, media literacy must explicitly teach how fictional frames can bias interpretation: **frame-spotting**, **lore vs. law**, and **evidence hygiene** (Krugman, 2022). For instance, classroom modules can juxtapose genre tropes (e.g., megacorps being above the law) with actual legal constraints on companies and PMCs (private military companies) in particular (Singer, 2002), while highlighting engagement incentives that privilege memetic clarity over nuance.

The present dataset integrates different platforms and languages, with uneven moderation norms and bot activity. Sentiment proxies (likes/upvotes) are platform-specific and can be stacked. Future work should combine API-based sampling with network analyses to detect coordination, and extend coding to image macros to capture visual frames (e.g., screenshots pairing headlines with *Cyberpunk 2077* imagery) (Statista, 2022).

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When trash stops being a treasure: pollution and its effects in *Another Crab's Treasure*

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Marine ecosystems play a vital role in maintaining the planet's stability. They contribute to temperature regulation, carbon dioxide absorption, storm and flood mitigation, and serve as habitats for an immense variety of species (Barbier, 2017). These ecosystems also provide essential services that directly benefit humanity. The exploitation of marine natural resources supports numerous economic sectors, including fishing, maritime transportation, biotechnology, and tourism (Barbier, 2017). In its 2015 report "Reviving the Ocean Economy: The Case for Action", the WWF estimated the ocean's total value at $24 trillion, although this wealth is rapidly declining (Hoegh-Guldberg et al., 2015). Overfishing, climate change, and pollution remain the primary threats, undermining not only the ocean's economic potential but also its environmental integrity (UNCTAD, 2023).

Ocean pollution, in particular, involves the release, discharge, or disposal of contaminants into the environment, including chemical compounds, trash, and other debris (NOAA, 2023). These pollutants disrupt marine ecosystems by contributing to the formation of garbage patches, toxic algal blooms, coral bleaching, and the bioaccumulation of heavy metals and microplastics (Marcharla et al., 2024; Aziz et al., 2023; Lebreton et al., 2018).

Marine faunas are especially vulnerable to the detrimental effects of these pollutants, exhibiting health problems via debris ingestion, impairing reproduction and development, and altering behavior (Thushari et al., 2020; Oehlmann et al., 2009). Such environmental threats have been depicted in various forms of media, serving as both artistic inspiration and tools for raising awareness.

Another Crab's Treasure is an action-platformer video game developed by Aggro Crab that follows the story of Kril, a hermit crab on a journey to recover his confiscated shell. Along the way, Kril encounters numerous locations afflicted by pollution, including coral reef cities buried in trash, poisonous sludge lakes, sandy sea floors littered with microplastics, bleached coral areas, and algae forests damaged by eutrophication. Furthermore, a blight known as the Gunk has spread throughout the ocean due to the accumulation of trash, rendering afflicted fauna irreversibly violent and erratic. As a hermit crab, Kril can use trash to replace his shell, defend himself against Gunk-infected enemies, aid in traversal, and even serve as clothing.

Despite the clear inspiration and representation of human impact in the game, little is explained about the biological processes affecting these organisms and their environments. In this work, we examine the biological mechanisms underlying the ef-

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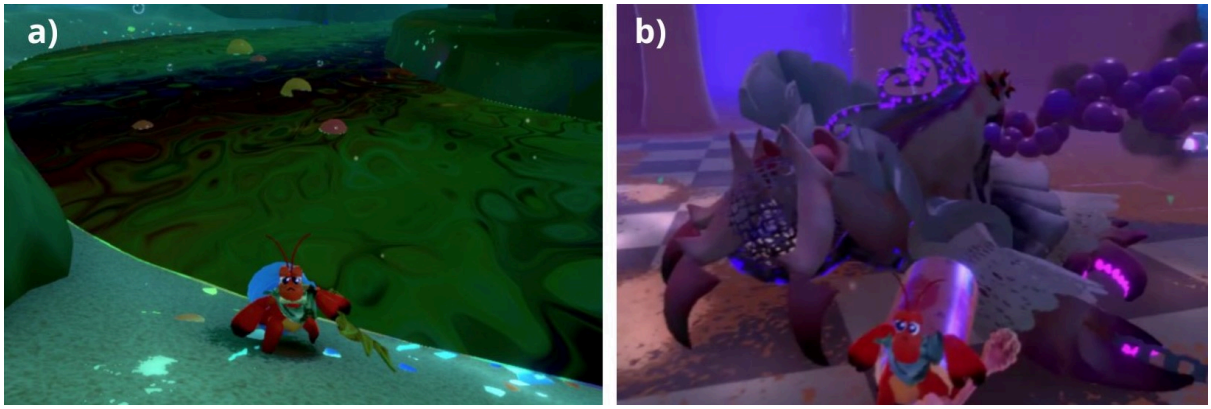

Figure 1. Environment and fauna afflicted by the Gunk. a) River of "Gunk" running through the Expired Grove's seabed. b) Magista, Tyrant of Slacktide, a crab, spewing "Gunk" during her boss battle. Kril is shown for scale. Game screenshots were captured on a PC.

fects of marine debris and overall pollution, as portrayed in the game, and place these fictional depictions in the context of real-world oceanic conditions.

Another Crab's Treasure showcases a diverse array of marine life, including fish, mollusks, worms, and arthropods such as shrimps, isopods, lobsters, and, of course, crabs. However, this fauna is shown struggling against persistent pollution. In the following sections, we will contextualize how different contaminants present affect both the ecosystem and its inhabitants.

THE GUNK

The Gunk is a purplish, iridescent substance that spreads across the seafloor, corrupting not only the marine environment but also the very conscience of its inhabitants (Fig. 1). For the player, contact with Gunk pools inflicts a poison-like status effect, gradually depleting health points (HP). For non-playable characters (NPCs), however, prolonged exposure results in drastic behavioral changes. Once afflicted, these characters fall into nihilism and hostility, attacking Kril on sight.

The Gunk shares several similarities with real-world contamination sources such as leachates from landfills, agricultural runoff entering the sea, and oil spills.

On the one hand, leachate forms when water percolates through solid waste, dissolving and transporting hazardous substances (Shaari et al., 2021). Once in the ocean, it introduces heavy metals, organic chemicals, and pathogens, creating toxic conditions for marine organisms (Shaari et al., 2021). Runoff, on the other hand, refers to surface water flow that carries contaminants into rivers, lakes, or coastal systems (Müller et al., 2020).

One of the principal consequences of both leachates and runoff is eutrophication, the excessive enrichment of aquatic systems with nutrients, particularly nitrogen and phosphorus. Landfill leachate wastewater is typically characterized by high values of chemical oxygen demand (COD), acidity, ammonia, heavy metals, and organic materials (Shaari et al., 2021). Such chemical imbalances promote harmful algal blooms (HABs) that degrade water quality and threaten the survival of marine fauna (Akinnawo, 2023). Indeed, HABs secrete bioactive extracellular compounds with paralytic effects on shellfish and other ichthyotoxic effects on fish (Rolton et al., 2022). This phenomenon is reflected in the Expired Grove, a region overrun by algal blooms to the extent that algae even grow on the shells of crabs and on the skin of fish. Figure 2 shows the Diseased Lichenthrope, a fish similar to the frogfish with a watering can on its head and algae growing on its skin.

Figure 2. Algae overgrowth on fish in the Expired Grove. a) The Diseased Lichenthrope resembles b) a frogfish with algae growing on its skin and a watering can placed on its head. Kril is shown for scale. Game screenshots were captured on a PC. The frogfish image was obtained from Wikimedia Commons (Stephen Childs - Flickr, CC BY-SA 2.0).

Similarly, oil spills involve the release of hydrocarbon-derived compounds into aquatic systems (Zhang et al., 2019). Common sources of oil contamination include shipwrecks, fuel leaks, offshore platforms, and drilling rigs (Zhang et al., 2019). Oil pollution primarily affects the marine environment in two ways: oiling and toxicity (NOAA, 2024). Oiling physically coats aquatic organisms with oil, often leading to suffocation and death. Toxicity, on the other hand, arises from the release of harmful compounds such as mono- and polycyclic aromatic hydrocarbons, with effects ranging from cellular damage to shifts in population and community dynamics (NOAA, 2024; National Research Council, 2003). Indeed, oil can enter the food chain via plankton and cause impaired development, deformities, and death in fish, bivalves, and crustaceans (Vignier et al., 2015; Mitra et al., 2012; Kasymov et al., 1987). The

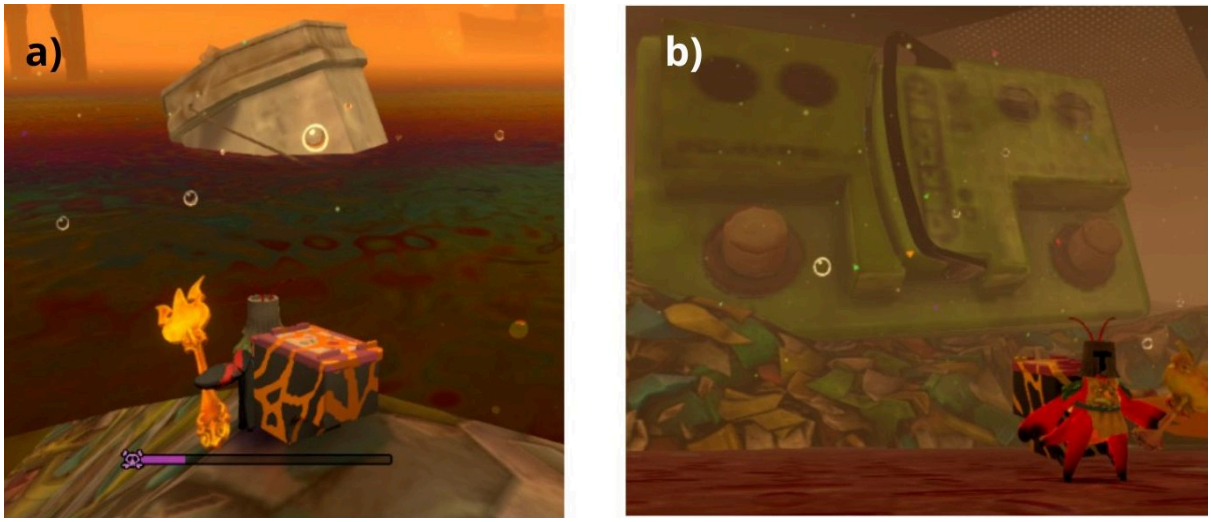

Figure 3. Hydrocarbon and chemical contamination in Flotsam Vale. a) Pool of "Gunk" on the seabed, derived from shipwreck debris and oil spills. b) Car batteries acting as a source of cadmium contamination. Kril is shown for scale. Game screenshots were captured on a PC.

impact of hydrocarbon pollution is evident in the Flotsam Vale area, where debris from a shipwreck, including shipping containers and propane tanks, is observed. This contamination gives the water a brownish appearance and leads to the formation of viscous pools of Gunk on the seabed (Fig. 3a).

Flotsam Vale also illustrates another form of chemical contamination: heavy metal pollution from discarded car batteries (Fig. 3b). Batteries are classified as hazardous materials because they contain ecotoxicological components, such as cadmium, lead, lithium, nickel, and other emerging contaminants, including metal and carbon nanomaterials, as well as ionic liquids (Melchor-Martínez et al., 2021). These compounds induce toxicity manifested through bioaccumulation in tissues, embryonic malformations, organ damage, elevated oxidative stress, and interference with DNA synthesis, ultimately contributing to carcinogenic processes (Melchor-Martínez et al., 2021).

Together, these contaminants create inhospitable conditions across the microenvironments of *Another Crab's Treasure*, symbolized by the Gunk itself. Yet the ocean floor is poisoned not only by invisible chemicals, but also physically smothered by discarded trash.

Figure 4. Presence of trash in different oceanic regions. a) Microplastics and glass debris in the neritic zone of The Sands Between. b) Piles of trash burying the coral reef city of New Carcinia. c) Polystyrene packing peanuts and glow sticks in the abyssal region of The Unfathom. d) Buoyant pieces of trash in the floating garbage patch. Kril is shown for scale. Game screenshots were captured on a PC.

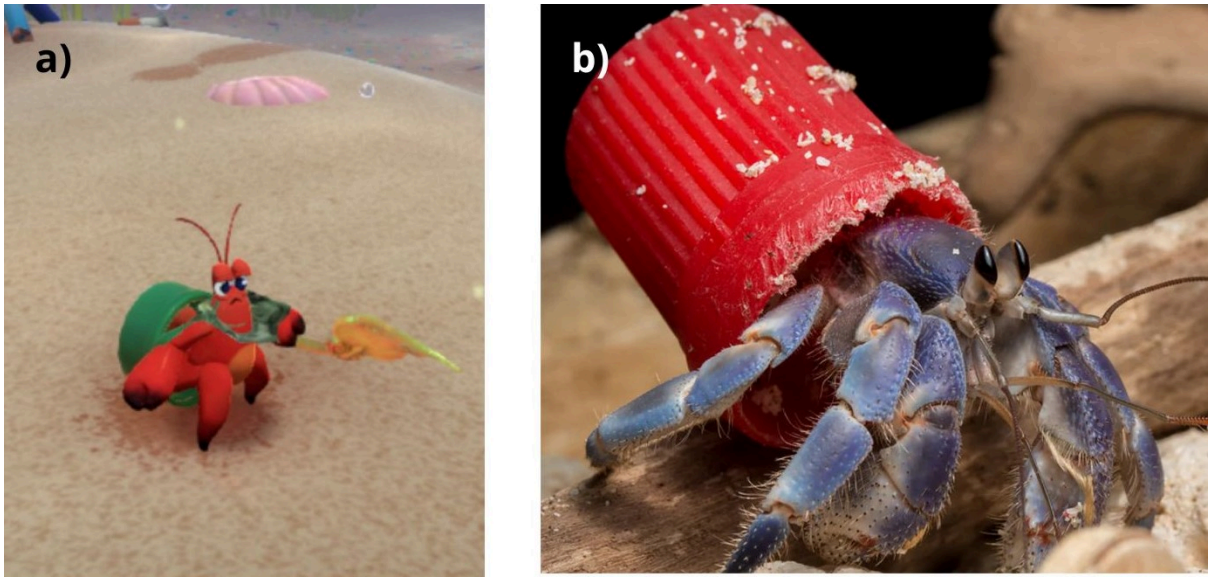

Figure 5. Another Crab's Treasure and real-world hermit crab adaptation to debris. a) Kril and b) a *Coenobita purpureus* hermit crab carrying a plastic cap as "trash shells". Game screenshots were captured on a PC. *Coenobita purpureus* photo by Shawn Miller (2015), retrieved from Burgess (2016).

THE GARBAGE PATCH

Every area in *Another Crab's Treasure* shows some degree of trash pollution. The seafloor is often covered in multicolored plastic particles, similar to those seen in The Sands Between, and even coral reef cities, such as New Carcinia, are found buried in debris (Fig. 4a,b). Pollution extends even into the abyssal depths of The Unfathom, where trash can still be observed (Fig. 4c).

Unlike chemical contamination, which has multiple sources, trash pollution in *Another Crab's Treasure* can be traced to a more specific origin: garbage patches (Fig. 4d). Garbage patches, also known as garbage islands, are large accumulations of debris formed by oceanic gyres, circular currents that trap and concentrate floating waste and organic material (Leal Filho et al., 2021). The Great Pacific Garbage Patch, for example, is the largest in the world, covering an estimated 1.6 million km² and containing ~80,000 metric tons of plastic waste, including fishing gear, bottles, and other small rigid objects (Lebreton et al., 2018).

However, garbage patches are not restricted to the open ocean; they can also form in coastal areas. These coastal garbage patches (CGPs) develop at oceanic fronts, regions where two water masses converge, and typically accumulate buoyant plastics such as films (Hajbane et al., 2021). Since Another Crab's Treasure takes place in tidepools and coral reef systems, the garbage patch depicted in the game can be inferred as a CGP. In this context, the trash that rains down onto the seabed and reefs can be traced directly to its accumulation above.

The presence of this debris has multiple ecological effects, both in the game and real-life ecosystems. First and foremost, the trash is scattered throughout the environment, covering ecosystems such as coral reefs and algae forests, and forcing the fauna to adapt. One way the fauna adapts is by using the trash as shelter, makeshift clothing, or protection (e.g., Fig. 5).

In real ecosystems, marine debris provides new artificial habitats for pelagic and coastal species (Haram et al., 2021). However, this same debris can also damage sedentary organisms through breakage and abrasion (Aguilar et al., 2022). Colonization of human-made litter not only affects benthic organisms but also disrupts other ecosystems. For instance, the colonization of buoyant debris creates a "raft effect" that transports fauna and threatens foreign ecosystems (De-la-Torre et al., 2023).

One of the most recognizable examples of trash being used as shelter comes from our hermit crab protagonist, Kril (Fig. 5a). Due to their evolutionary history, hermit crabs depend on empty gastropod shells for survival, as their soft, asymmetrical, coiled abdomens are adapted to fit inside them. These shells provide not only protection and shelter but also influence the crustacean's development (da Silva et al., 2020). Hermit crabs, however, have had to adapt to the presence of litter, exchanging their shells for trash (Fig. 5b). In Kril's case, these "trash shells" not only grant him protection but also special abilities he can use against enemies. Nonetheless, it has been suggested that real-life hermit crabs carrying "trash shells" would experience reduced reproductive success, higher metabolic costs, and an impaired anti-predatory effectiveness (Jagiello et al., 2024).

Although trash provides certain advantages for Kril, it remains a pervasive and insidious component of ocean pollution, with detrimental effects on marine environments that will persist for years to come.

MICROPLASTICS

Regarding trash pollution, one of its most prominent components is microplastics. These consist of plastic particles less than 5 mm in size, originating from the fragmentation or degradation of larger plastic waste (Marcharla et al., 2024). Such fragments have become ubiquitous hazardous materials, accumulating across virtually every ecosystem.

Another Crab's Treasure, however, peculiarly depicts microplastics: they function as a form of currency used to purchase items or costumes. Fittingly (though unfortunately), microplastics are obtained through the sale of plastic trash, such as hair claws or staple removers, as well as by defeating enemies. This latter gameplay mechanic implies that marine fauna carries microplastics on their bodies (Fig. 6). Indeed, ingestion of microplastics leads to their bioaccumulation in the tissues of the marine fauna, causing toxic effects on the host (Yang et al., 2021). These effects can be further exacerbated when microplastics interact with other chemical pollutants (Yang et al., 2021). Altogether, this combination of chemical and plastic pollutants could serve as a biological explanation for the heightened aggression of the fauna encountered in *Another Crab's Treasure*.

Figure 6. Defeated enemies bear microplastics within them. A sardine enemy releasing microplastics (black arrows) after being defeated by Kril's fork attack. Game screenshots were captured on a PC.

CONCLUSION

Behind the action and adventure of Another Crab's Treasure lies an ecological warning about the damage that contamination inflicts on marine ecosystems. The representation of trash and the indifference of the game's inhabitants toward it serve as a metaphor for our own lack of awareness of the catastrophic consequences our waste may bring. Scientific evidence already demonstrates the harm trash causes to marine fauna, and whilst video games can help

translate that knowledge into narratives that raise public awareness, awareness alone is not enough. If we truly want (and urgently need) to prevent these outcomes, further action must be taken. Trash should never be anyone's treasure.

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About the author

MSc. Abraham U. Morales-Primo is a Mexican biologist and science communicator specializing in the role of NETs in leishmaniasis. A proud geek, he explores the biological mechanisms of video game-related phenomena (and sometimes real-world ones). When he's not theorizing about carcinization, he's dreaming up new ways to blend science with video game culture; all in the company of his wife and their beloved puppy.

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Can conservation really be effective through video games? A case study on *Jack Barau* and some perspectives

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Almost half of the world's population plays video games (Buijisman, 2024). Whether the experience is intensive or sporadic, gaming has become commonplace, diverse, and complex. While many games, such as *Mario Kart*, *Fortnite* or *Rocket League*, are primarily designed to entertain players, the advent of independent gaming, combined with virtual and touch interfaces that are increasingly present in our lives, has led to the emergence of so-called 'serious' video games.

A 'serious' game is an experience that uses the codes of video games to convey a message (Annetta, 2010; Verdier, 2024b). They can be used in several cases, such as social learning, or to express serious topics, such as violence against women (Annetta 2010; Verdier, 2024b; Veríssimo, 2024). But this "serious" part of video games can be mixed with a practice whose primary objective is entertainment or discovery (Annetta 2010; Verdier, 2024b; Veríssimo, 2024). For example, many games with an environmental theme subtly teach ecology. The 2024 French video game *Kamaeru: A Frog Refuge*, behind its cuteness, teaches players about the importance of wetland management (Verdier, 2023a; Couture, 2024), while the more ambitious 2023's *Under the Waves* teaches the importance of marine ecosystems (Verdier, 2023a; Surfrider Foundation, 2024).

In recent years, video games have also been used for conservation purposes (Veríssimo, 2024). The game *Kakapo Run* aims to raise awareness about the future of the kākāpō (*Strigops habroptilus*), a critically endangered New Zealand parrot, by borrowing from another successful mobile video game, *Temple Run*, a pioneer of the new generation of "Endless Runner" genre (Chong, 2015) The game, which has been downloaded more than 100,000 times, is just one example of the many efforts being made to interest the general public in these issues.

In this study, we will look at another game based on another bird, Barau's petrel (*Pterodroma baraui*). Thierry Brochart and Rodolphe Bax, the developers of Pixel Sunset Studio, and Julie Tourmetz, Capacity Manager at the SEOR (Société d'études ornithologiques de La Réunion) Wildlife Conservation Centre, agreed to talk to me about the creation of *Jack Barau*, a video game that aims to raise public awareness about the future of this bird (SEOR, 2016). Camille Paget, who was Communication Officer of the SEOR at the time and a particularly important person on the 'Life+ Pétrels' project, could not be contacted for writing this paper.

After that, we will see that creating a video game about conservation remains

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complicated as it involves rules and constraints, but also that the success of the operation, although real, is difficult to measure given the actions taken before the game was released. In any case, video games remain a powerful tool for raising awareness and, when used effectively, can teach the general public about the importance of conserving species and the environments in which they live.

MAKING OF THE GAME

Barau's Petrel

Barau's petrel (*Pterodroma baraui*) is an endangered seabird measuring approximately 40 cm in length, 1 m in wingspan, and it belongs to the Procellariidae family. Only around 15,000 to 20,000 pairs of this bird remain; it is classified as 'Vulnerable' by the IUCN (Carboneras et al., 2020a; Life+ Pétrels, 2025). It spends half its time cruising the waters of the Indian Ocean, while the other half is devoted to breeding, which takes place only on the island of Réunion. This species is known to be philopatric, and the pair incubates, cares for, and feeds a single chick per year. If the clutch fails, for assorted reasons including predation by rats and cats, it is not replaced (Carboneras et al., 2020a; Life+ Pétrels, 2025).

Figure 1. A Barau's petrel. Photo by Julie Toumetz, used with permission.

The young birds that leave the nest are also subject to serious dangers. In addition to cats and other predators, young petrels are also victims of heavy light pollution, which disorients them during their first flights and causes them to land in the middle of cities, where they have great difficulty taking off again. These birds probably mistake the lights for food or the night sky, as their eyes are not yet fully developed (Carboneras et al., 2020a; BL Évolution, 2022; Guide-Reunion, 2025; Life+ Pétrels, 2025).

Figure 2. In these boxes, numerous Barau's petrels briefly wait their releasing to the wild. Photo by Julie Toumetz, used with permission.

Every year, the SEOR collects between 1,000 and 1,500 young Barau's petrels. The rescue success rate averages 85% of birds saved and released. This represents approximately 1/4 to 1/3 of all rescue operations carried out by the association over the course of a year. The most critical period is between 19 April and the end of the month when every effort is made to prevent Barau's petrels from stranding. Among its efforts, the island is trying to reduce the population of invasive alien species by poisoning rats and capturing cats (Carboneras et al., 2020a; Life+ Pétrels, 2025). These actions are not always well received by the inhabitants.

Since 2009, the island of Réunion, through the CCEE (Conseil de la culture, de l'éducation et de l'environnement), SEOR

and Réunion National Park, has also implemented a measure to turn off the lights in towns and cities. Initially synchronised with the event that takes place in mainland France and Québec in October (where it is named 'Le Jour de la Nuit', i.e., The Day of the Night; https://jourdelanuit.fr/), the SEOR decided to reschedule this date to coincide with the critical flight period for young Barau's petrels. Sixteen years later, the hour of extinction has turned into a month, corresponding to the flight period for young petrels (Carboneras et al., 2020a; BL Évolution, 2022; Guide-Reunion, 2025).

Figure 3. A young Barau's petrel, rescued from probably trapped under the lights. Photo by Julie Toumetz, used with permission.

The event called 'Nuits sans lumières' (Nights without lights), in Réunion, is not mandatory. "While some parts of the island are playing along, others are leaving their lights on, believing that they are not responsible for the birds stranding themselves, or that it is not a priority for them. The latter must reconcile the welfare of birds with public demands, particularly in terms of safety", explains Julie Tourmetz during our meeting. This process is also found in mainland France, where many towns and cities are taking a middle ground in order to reassure the population. For example, the intensity of lighting is reduced (Chavance, 2022).

In line with the conservation measures for Barau's petrel mentioned above, SEOR, the University of Réunion and the National Park have put together a dossier to access a Life+ programme, which provides European funding for various themes, such as the environment. In this case, the programme focused on the conservation of Réunion's endemic petrels, the Barau's petrel and the even rarer Mascarene petrel (*Pseudobulweria aterrima*) (Life+ Pétrels, 2025). Slightly smaller than the Barau's petrel, this bird is considered as 'Critically Endangered' by the IUCN (Carboneras et al., 2020b). Launched in 2014, the programme aimed to promote conservation, communication and awareness-raising activities about the two species of birds (Life+ Pétrels, 2025).

Figure 4. Two Mascarene petrels on the hands of two members of the SEOR. Photo by Julie Toumetz, used with permission.

Kickstarting the game

Among these discussions, a proposal for a Game Jam on the theme of the petrel was put forward. A Game Jam is a competition (video or board games) in which participants must create a game within a limited time frame on a given theme, at a local, national or even international level (e.g., https://globalgamejam.org/). At the end of the allotted time, a jury meets to test the games and select one or more winners based on the quality of the production, its originality, or its fidelity to the given theme.

Created in 2014 by Thierry Brochart, the 'Game Jam des Volcans' (Volcano Game Jam) is supported by the Bouftang collective, a regional video game association in Réunion. It is organised jointly with the national park and explores predominantly "serious" topics such as volcanology and the water cycle. "SEOR, through the director of the Cité du Volcan, Patrice Huet, has expressed its interest in the exercise," synthetized me Thierry in our conversation. While there may still be some reluctance to use video games in such concrete initiatives, there was no resistance to the novelty of the concept. "We were really interested to see what it could bring us [...] because it was an unusual medium for us. The idea of making a video game, especially through a competition, was intriguing. And that is why we decided to see this adventure through to the end," Julie Tourmetz summarised.

The jury was made up of members of SEOR, as well as game developers such as Éric Chahi, the renowned French creator of internationally acclaimed titles such as 1994's *Another World* and 1998's *Heart of Darkness*.

In 2016, the theme of protecting petrels brought together around fifty developers, including Thierry Brochart and Rodolphe Bax, the creators of *Jack Barau*. After attending a masterclass by members of SEOR on protecting petrels, the developers had 48 hours to design a game based on protecting the Barau's petrel. "What the game needed was for people to understand what the threats were and why we are trying to conserve the bird," summarises Julie. Developers were given a lot of freedom in how they interpreted the subject.

The game design of *Jack Barau*

Eight to nine projects were presented, and the one that won the jury's favour was *Jack Barau*, created by Thierry Brochart and Rodolphe Bax. It is a 2D platform game in which a Barau's petrel named Jack must guide young petrels to the end of each level, all in a cartoon-like atmosphere. Players must dodge the yellow lights to avoid losing individuals until they reach the end of the different level, keeping in mind that the more petrels they have behind them, the

Figure 5. Key art of *Jack Barau*. By Rodolphe Bax, used with permission.

Figure 6. The aim of the game is to bring young petrels to the end of the level by avoiding yellow lights and enemies. Screen capture from the game.

more complex it will be to navigate the level.

While the game's inspirations are unconscious, Thierry decided to adopt a design philosophy well known in the video game industry: "design by subtraction." Popularized by Fumito Ueda, a Japanese game designer famous for games such as *Ico* and *Shadow of the Colossus*, the concept consists of removing anything that could be superfluous in the process of development (Mecheri, 2017; Costa, 2022). "We didn't want anything complicated to get our message across. We thought it would work better if we set a simple framework for our rules and stuck to it," Thierry points out. As so, Thierry and Rodolphe worked hard to simplify the game and its mechanics, such as Jack's movement, which allows him to fly indefinitely and makes him invulnerable to yellow lights. This is one last point that could undermine the message but is coherent with reality, as only young birds get trapped by the lights, not adults.

The other rule that Thierry, Rodolphe, and by extension SEOR set for themselves was to make the game as easy to play as possible, since it was intended for all audiences. The cartoon style introduced by Rodolphe was a first step, since it's generally synonymous with accessibility. But this also had to be reflected in the game's playability. "We were really keen to offer a game that was very accessible from the outset, playable by a child using only a joystick. I didn't want us to include tons of tutorials explaining that if you press this button, you can fly," adds Rodolphe.

The simplicity also comes through in the use of certain codes specific to video games. While the aim was to show the danger of the city's yellow lights, the developers added another light on Jack's head – this one blue – to make it logic to players that the young birds they rescue must follow Jack. To complete the idea, audible and visual signal (a small blue halo) were added when Jack comes into contact with a young Barau's petrel. The distinction between colours and various signals makes it possible to differentiate between danger and safety. Thierry would have liked to bypass

the system, which meant finding another one to compensate. All these more playful choices surprised Thierry and Rodolphe to have been selected.

After the Game Jam, Thierry and Rodolphe were able to fine tune their basic project before developing *Jack Barau* for mobile devices with financial help delivered by the Life+ program. SEOR and the developers then worked closely together to complete the project, which was to be presented in schools and colleges, as the game's target audience had been refined. They then set out to develop two aspects that could not be realised during the Game Jam. The first was the presence of predators threatening the survival of young petrels: cats and rats. It was therefore necessary to show their dangerousness, but also that they had to be eliminated to not hinder the birds' survival. "It was a whole process that allowed us to better explain this to the public, who might be shocked by these actions. We're talking about cat and rat control, about living animals, even introduced and exotic species, which may offend some people's sensibilities," says Julie. The cartoon style made it easy to introduce and explain these conservation measures, particularly the use of wolf traps that must be triggered at the right moment in the game by the player. However, the violence of the title was toned down in the definitive version to comply with Nintendo Switch standards and audiences, much more family-friendly.

The other aspect that SEOR wanted to develop was the relationship between the Barau's petrel and the Mascarene petrel. The initial goal was therefore to create a first adventure with the Barau's petrel, then a second one, using the same game mechanics, where you control a Mascarene petrel called Black Bourbon, considered as the antagonist of the game. As a fun fact, the first colony of Mascarene petrel of Réunion was discovered during the creation of the game (Parc national de la Réunion, 2015). But unlike the Barau's petrel, the message could not be conveyed with such a small population. It was also much easier for the public to identify with the Barau's petrel, as it is easier to observe and is regularly cared for. The idea for this second quest was therefore abandoned. Nevertheless, Black Bourbon remains in the final game as a character in its own right, recounting its parallel adventure through a system of collectible bottles in the game. Each time a bottle is picked up, a slightly remixed cry from the Mascarene petrel can be heard.

SEOR tested the game regularly to provide feedback and make corrections where necessary. "SEOR really trusted us 100%, even though we didn't take many risks, as the message was crystal clear," says Rodolphe. The developers then iterated on each level, testing it repeatedly to achieve the best balance, ensuring it was neither too hard nor too easy. They were able to do this by calling on various people for playtesting sessions, with volunteers testing the game and then giving their feedback, positive and negative. Even though the game was primarily intended for young people, it was very important to have it played by as diverse an audience as possible. It was thanks to these playtests that Thierry and Rodolphe realised that even though they had developed the project on mobile, which remains the most accessible platform, the game could pose problems for some people, however young they were, who did not necessarily have the equipment to play for example. Outside of schools, *Jack Barau* was also presented at various public and private events.

CHARACTER DESIGN

Young petrels

Rodolphe and Thierry placed enormous importance on the game's character design, i.e., the representation and drawing of the characters in the game. For the petrels to be rescued, the two developers wanted to emphasise the simplicity of their design. Rodolphe therefore designed small white balls of feathers, very different from their real-life counterparts, to reinforce the em-

pathy we might feel for them (and to make the game easier to understand).

Jack Barau

The character of Jack Barau was designed to be likeable, clearly inspired by the pirate played by Johnny Depp in the movie series Pirates of the Caribbean. The idea for the pun came right at the start of the Jam, as the episode Dead Man Tells no Tales was set to come out in 2017; from there, Rodolphe created a preliminary design. Once again, Rodolphe set about giving Jack more personality than realism. "If the aim was to make Jack a bird that really resembled the Barau's petrel, it's a bit of a failure. Petrels are much slimmer, and in the end, Jack looks more like a Dodo," explains Thierry to me. With his chubby appearance, thick belt, hat, bandana, little tuft of hair and even his lucky coin, Jack is more like Johnny Depp's character than a petrel. His traits reinforce his identity as a confident and proud character (even when he is wrong). "What we're taught when designing characters is that the design must relate to the character's personality," continues Thierry. But one barely noticeable detail makes all the difference, and that is the small ring Jack wears on one leg. It is a subtle way of reminding the player that the bird has passed through the hands of other people. "It's a bit like a cross between the spirit of the player who wants to save the petrels and a slightly crazy captain who has the same intentions," sums up Rodolphe, in a clever way to break the fourth wall.

Figure 7. Art of one of the young petrels you must rescue through the game. Notice how its design is pretty simplified. By Rodolphe Bax, used with permission.

The enemies

With Jack's character in mind, the world of parody piracy seemed inevitable to the two partners. The first to be impacted were the cats and rats, enemies of the petrels, who are depicted as British soldiers. The need for rigid characters quickly allowed them to categorise their designs, even if these go further than the Disney's film series. Initially intended to be pirates themselves, Rodolphe and Thierry found it more interesting to refer these enemies to the past of Réunion, whose domination was shared between the French and the English. The final reference for the design of these characters was... rugby, and in particular a highly anticipated match between France and England, known as the Crunch. It's also a reference to Rodolphe's practice of this sport. Considered as the antagonist during a long part of the game, Black Bourbon has an opposite design to Jack, with a darker colour palette, but conserving the same aspect of the hero, as Black Bourbon is also a petrel.

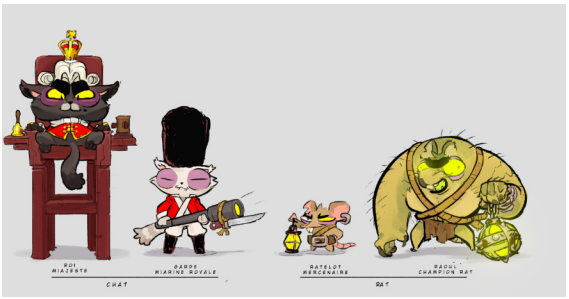

Figure 8. Concept art of the game's enemies. Some of them didn't make it to the final game. By Rodolphe Bax, used with permission.

Jack's crew

The final version of the game, released on Steam and Nintendo Switch in 2025, also features a whole new crew that follows Jack on his adventure. Rodolphe decided to give free roam to his imagination, while staying true to the theme of endemic species from Réunion and the surrounding area. Jack's right-hand man, the "Mister Smee" of the

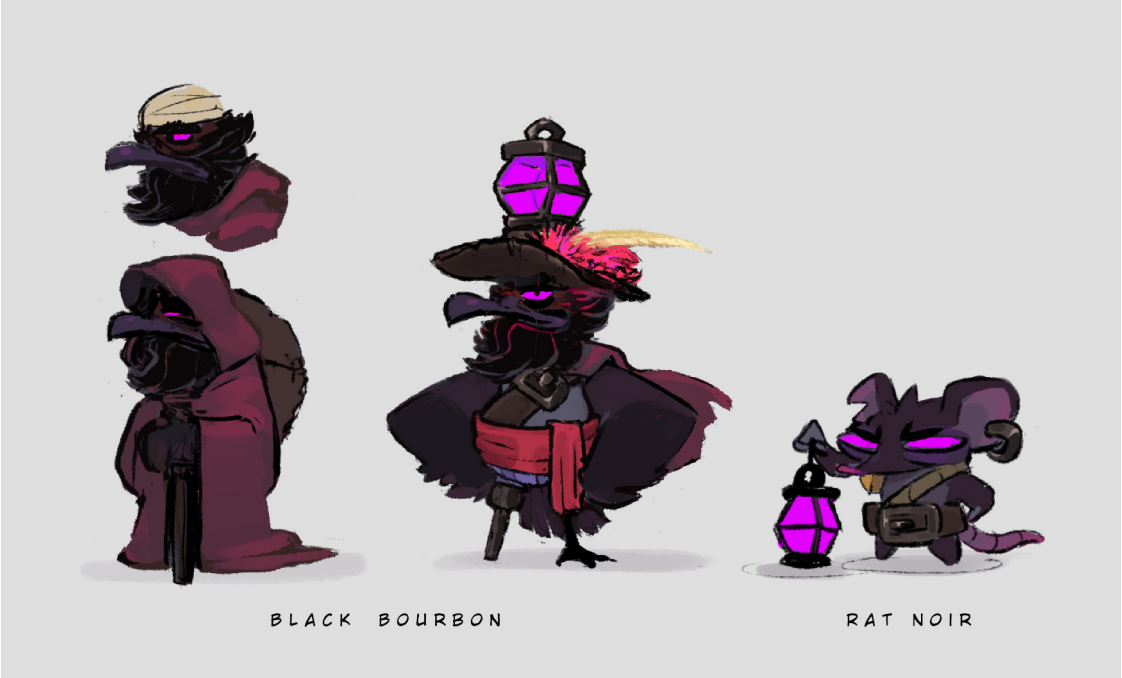

Figure 9. Concept art of Black Bourbon. Notice how close its design is to Jack's. By Rodolphe Bax, used with permission.

crew (a reference to Disney's Peter Pan's Captain hook's first mate), was therefore chosen to be a Manapany day gecko (*Phelsuma inexpectata*), endemic to Réunion. They are accompanied by a pair of Réunion cuckooshrikes (*Lalage newtoni*), which caused Rodolphe quite a few design problems. "At first, I was inspired by Google Images for their design, but that was a very bad idea. SEOR told me that it wasn't right and guided me in the right direction, which allowed me to refine the design. It's always better to have experts who know the field (laughs)."

The last member of the crew, the group's muscle, is a Mauritian flying fox (*Pteropus niger*). This is a nod from Rodolphe to his parents' origins, his father being Mauritian and his mother from Réunion, as this bat is

Figure 10. Concept art of Jack and his crew. By Rodolphe Bax, used with permission.

found on both islands (Carceres, 2010). All the animals, the vast majority of which are endangered, have also undergone a pirate makeover to fit in with the game's universe.

The scenery

To model it, Rodolphe opted for clarity, even at the risk of disrupting the game. "On Réunion Island, we have some truly incredible views and colours depending on the locations we wanted to include in the game. Except that we realised that changing the scenery changed the lighting atmosphere, and therefore the clarity," explains Rodolphe. As graphics are also a very costly resource in game development, Rodolphe and Thierry settled for simplistic scenery consisting of generally wooden constructions, beaches and streets seen in cross section. "There was no point in enhancing the scenery. My only regret is that at the end of the game, I would have liked to have had a little sunrise to end the adventure," concludes Rodolphe.

DISCUSSION

Aftermath of *Jack Barau*

As we have seen, creating a game based on the conservation of an animal species requires a huge investment and a great deal of thought. Developers must synergise realism and playfulness, with the ultimate goal of striking a balance between learning and fun. This tension between the two realities is a key foundation in many video games that want to teach things, whether they focus on the environment or history, or decided to make that learning subsidiary (Verdier, 2023c). Developers must also consider the simplicity of their game in order to convey their message clearly.

Finished in 2017, the primary version of *Jack Barau* has been enjoyed by all middle school students in Réunion. Thierry Brochart explained to me that the game was download more than 3,000 times. But the impact is probably greater than that, as Camille Payet (the previous communication officer at the SEOR) used the game on tablets for pedagogic meetings with the 83 high schools of the island, and that without counting the numerous discussions between parents and children about the game. If the game resounding success seems to be agreed upon by the three protagonists involved in the game, with students and the general public getting caught up in the game of conserving the Barau's petrel, it's pretty complicated to quantify clearly how many people have been really impacted by the game. The actions of SEOR since its creation in 1997 have undoubtedly influenced the general public's behaviour towards the bird. While the main target audience, namely young children, may indeed be more impressionable, it's possible that some of the 3,000+ people who downloaded *Jack Barau* were already aware of the importance of conservation efforts through other events like the annual 'Nuits sans lumières'. The use of the *Jack Barau* video game may in fact be just one of many tools for animal conservation, and this is how Thierry, Rodolphe, and Julie see it at the moment.

Controversy and benefits of conservation games

As mentioned earlier, serious games are used by many people to address serious topics that form the basis of the game (Annetta 2010; Verdier, 2024b). It is therefore inevitably interesting to know the impact that serious games could have on players. Numerous studies have demonstrated the positive results induced by gaming, particularly in terms of learning, with STEM subjects (science, technology, engineering and mathematics) being the most popular (Annetta 2010; Boyle et al., 2015; Verdier, 2024b). However, video games, like other media, have sparked controversy around what is known as 'Nature Deficit Disorder' (NDD) (Fletcher, 2017).

Theorised by Richard Rouv, this syn-

drome is characterised by a distancing from nature that has a negative impact on health (Rouv, 2010; Fletcher, 2017). As a result, the new learning methods made possible by new media have been somewhat criticised, for fear of reinforcing this disconnection and reducing the willingness to engage in conversation. Some studies have indeed concluded that there is a gap between the perception of reality and reality itself, while proponents of the use of these new media have argued that it is impossible to ignore one of the world's leading forms of entertainment, which can have benefits (Boyle et al., 2015; Fletcher, 2017; Dunn et al., 2021; Thomas-Walters & Veríssimo, 2022).

In this regard, more studies are attempting to counter critics by analysing the use of video games to raise awareness for species conservation. The augmented reality phenomenon *Pokémon GO* opened up new horizons in the late 2010s. Drawing on a rich mythology (namely the great diversity of Pokémon), and thanks to a mirror effect, the game encouraged players to take a greater interest in the animals of the world, even if nuanced (Dorward et al., 2016; Fletcher, 2017). In 2021, a study was conducted on the game *Red Dead Redemption II* to see if people can retain elements of the fauna seen on the game (Crowley et al., 2021). The vast majority of people recognized more species after playing and finishing the game than the others (Crowley et al., 2021). Thus, even if the game is not primarily focused on conservation of species, its stunning appeal to a kind of realism about nature and animals, notably birds, was praised by many people (Lund, 2019; Verdier, 2024a).

Figure 11. A blue jay (*Cyanocitta cristata*) in *Red Dead Redemption II* (Rockstar Games). Screen capture from the game.

In 2024, 200 randomly selected participants were invited to download and play the game *Kakapo Run* for seven days, before being tested on their knowledge of the bird in another study (Veríssimo et al., 2024). The results of the study showed that players were more inclined to understand the threats to the kākāpō, encouraged conservation efforts, and even had an effect on how they managed their pets. However, this study pointed out numerous limits to the use of video games, such as insufficient infrastructure, digital division of high and low income people in the same country or low reach of the game's target (only 2% of the 100,000+ people that downloaded *Kakapo Run* are from New Zealand, as it became a minor hit in India) (Veríssimo et al., 2024).

The multiple (and complicated) paths to make a conservation video game succeed

The recent global release of *Jack Barau* on Steam and Nintendo Switch on May 2025, after the primary version for educational purpose was made, might actually show other limits of video games. Although the final version of *Jack Barau* has 13 levels compared to 3 in the initial version presented to the public, and numerous adjustments, it cannot compete with other gaming experiences, even if its message is valuable. The game is pretty short, really repetitive and pretty expensive compared to others in a saturated market, something that developers are aware of (Corey, 2025).

Between playfulness and playful messaging, the former always seems to take precedence over the latter, preventing institutions or developers involved in this type of project from neglecting this aspect, lest their game fail to sell (Sandbrook et al., 2014). While the public is inclined to download a product such as *Kakapo Run* for free, it is fairly certain that this game would not have been as successful had it been paid. The audience that could afford to buy this type of product would probably be

those who are invested in either video games or conservation. All in all, the primary target audience (the general public) would not be reached. This is somewhat in line with the second part of the conclusion by Veríssimo et al. (2024), who noted that even though the tested people were more aware of conservation efforts, they were not more inclined to financially support this type of program (see also Sandbrook et al., 2014; Thomas-Walters & Veríssimo, 2022).

Still, there are games that have successfully mixed joyful and ecological message and could, in the future, serve as inspiration for the creation of more titles about environmental conservation as part of "naturalist video games" (Verdier, 2025a). *Alba: A Wildlife Adventure*, developed by Ustwo Games in 2020, successfully combines ecological messages with constant renewal. In it, the player controls the character Alba, who travels around an island to restore it and take photos of the local wildlife (mainly birds). The high degree of control given to the player, the variety of actions available, and the meticulous artistic direction have enabled the title to sell over a million copies. The developers also launched a campaign to plant trees for every game sold, which ended once a million copies had been sold (Ecologi, 2025). *Alba* is now considered a flagship environmental video game due to its universe and accessibility for younger players (Verdier, 2025a).

If *Alba* is just one good example of what can be done in the field of conservation, we must not overlook the realities of video game development, particularly economical ones. Making a game takes time and, above all, can be very expensive (Schreier, 2025). It is easy to imagine that development of *Alba* could have costed several hundred thousand or even million euros, therefore stilling a low-budget video game. Some productions exceed half a billion dollars, or even a billion like a certain *Grand Theft Auto VI* scheduled for release in 2026 (Schreier, 2025). This financial reality is incompatible with conservation efforts, which already requires colossal investments to be carried out, without necessarily guaranteeing the sustainability of these efforts due to political instability or global warming, for example. Furthermore, it is

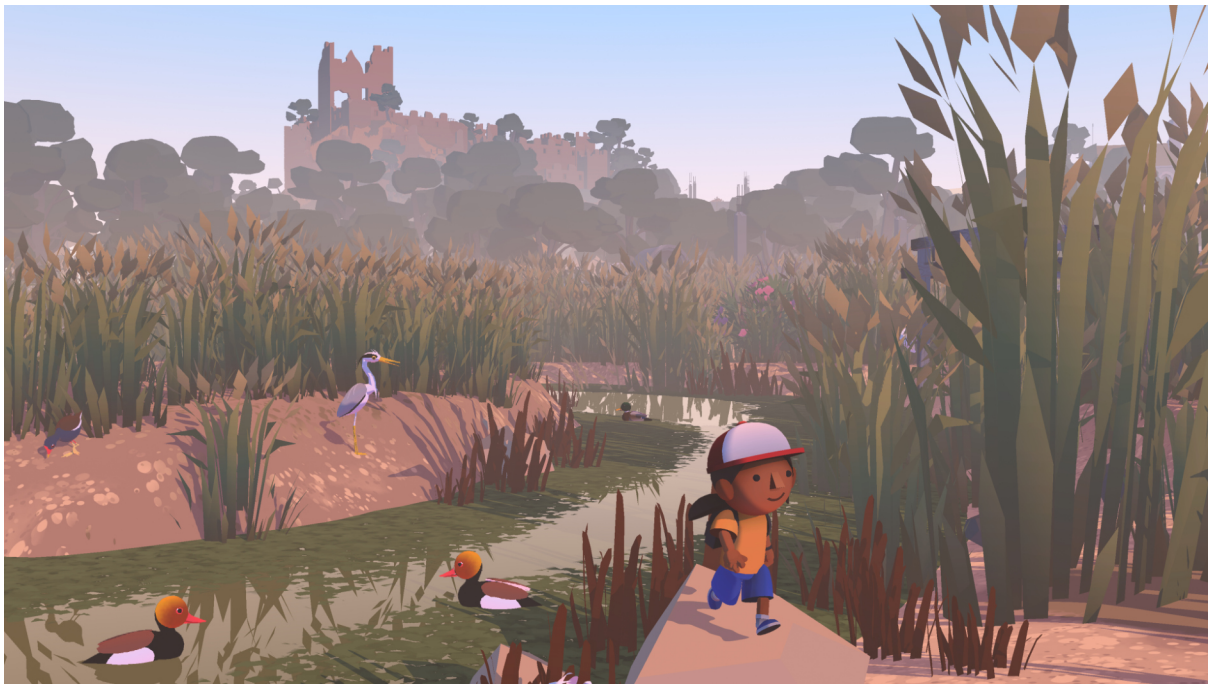

Figure 12. *Alba: A Wildlife Adventure* (Ustwo Games) lets you explore a wonderful Mediterranean island, full of animals. Screen capture from the game.

impossible to know whether video games will generate a return on the investment, and the operation may rightly be considered a financial risk due to market volatility. For all these reasons, it is normal for environmental associations and actors to turn more towards equally entertaining and educational media such as board games, which are less expensive, better known, and more profitable.

With a view to financing conservation efforts, the Philippines has proposed in 2024, a mobile game called *Animal Town*, developed by ThinkBIT Solutions in collaboration with the Biodiversity Finance Initiative (DENR-UNDP BIOFIN) of the United Nations Development Programme (UNDP), the Department of Environment and Natural Resources Biodiversity Management Bureau (DENR-BMB) and the Forest Foundation Philippines (FFP) (FFP, 2024; BIOFIN, 2025). The game is extremely interesting to analyse for several reasons. The first is that it was launched to raise funds for conservation. Although the game is free to play, it generates revenue through in-app purchases and advertising, with the profits allocated to supporting biodiversity projects (BIOFIN, 2024). The second is that *Animal Town* is a more complex game in terms of gameplay and narrative than other conservation games. It is a "City Builder" in which the player must manage a virtual city by completing various quests given by anthropomorphic animals. The more the player develops the city, the more inhabitants it will have. The game also incorporates a variety of information on biodiversity as a whole.

Unfortunately, despite the 30 million Filipino mobile gamers representing a market worth around 10 million dollars each year, the game is struggling to gain traction, having been downloaded only around 20,000 times and generating just around 300 dollars in revenue as of March 2025 (BIOFIN, 2025), once again confirming Verríssimo et al.'s (2024) conclusions. While *Animal Town*'s contribution may seem insignificant –especially compared to the 100 million dollars released by the Philippine Biodiversity Strategy and Action Plan (PBSAP) each year and the 530 million that would be needed to actually meet all biodiversity protection targets in the Philippines– again, each year the game opens the door to new solutions aimed at bridging this gap in a rapidly expanding market (BIOFIN, 2025). Around 75% of the country's 115 million inhabitants owned a telephone in 2024, a number that is expected to reach near 90% this year (Statista, 2024).

Figure 13. *Animal Town* (Forest Foundation Philippines). Screen capture from the game.

It is nevertheless interesting to note that in recent years, many developers have been campaigning to reconcile short development times, low investment costs, and hooked gameplay (Game Camp, 2025). As Julie reiterated in our interview, "it is certain that the creation of games will have to go through service providers, as institutions and other private actors do not have the knowledge, skills, or budget to create these games independently, or even to conceive them properly." The alliance of these developers with actors can lead these projects could constitute another bold avenue for action in the environmental field in the future. Less expensive but just as interesting for stakeholders, the possibility of partnering with an existing video game for one-shot operations could be another alternative.

In 2020, as part of the release of the documentary *Blue Planet II*, the BBC teamed up

with *Never Alone* developers E-Line Media, to create a game based on the documentary. (BBC Studios, 2020). Named *Beyond Blue*, the game's development was closely monitored by a team of specialists, including Dr Samantha 'Mandy' Joye from the University of Georgia (BBC Studios, 2020; Journal of Geek Studies, 2020). In 2023, the developers of *Under the Waves* at Parallel Studio partnered with the Surfrider Foundation in a cross-promotional effort to convey important environmental messages in a more story-driven adventure. These two examples illustrate the importance of involving partners who are knowledgeable about their subject matter in order to make it more tangible. However, this is not a necessity, and games such as *Endless Ocean* and *Songbird Symphony*, without necessarily focusing on conservation, have shown that the passion of certain developers can still spark interesting reflections on the animals and environment depicted (Verdier, 2023b, 2024c, 2025a).

Figure 14. *Abzû* (Giant Squid). Screen capture from the game.

Popular since many years, GAAS or "Game as a Service" are productions that are profitable for all the actors in a long run, with *Fortnite* being the best example, with a simple purpose (GSE Media 2018). To retain its players, the game is constantly renewing itself in terms of its gameplay mechanics, but also in the collaborations it can maintain through a system of "seasons". The game, which is free to play like *Animal Town* presented previously, relies on its collaborations to encourage purchases so that players can proudly display the character, weapon or whatever they have obtained, sometimes in an aggressive way called "dark patterns" (Niknejad et al., 2024). Without these dark patterns, GAAS could be an interesting way to imagine similar initiatives in the future to promote conservation, for example by remodelling part of the map to reflect the biome of the animal to be protected. Part of the money spent by players could then be donated to the program. Partnering with a GAAS offers all the benefits of an awareness campaign. Reflections on the game and its mechanics could provoke the same retention of information, or even the same empathy, as for *Kakapo Run* and *Jack Barau*, and the conservation actors would spend much less money than they would on developing a complete game. The game would benefit from a large range of people thanks to its free-to-play formula, and would, by varying its mechanics, prevent players from getting bored. It could also be gaining greater sympathy from players, since it is invested in a noble cause.

But there remains one very important limit in partnerships. The great majority of GAAS pushed by big publishers are TPS or FPS (third/first person shooters), genres that, by definition, emphasises the player's violence in order to win. There are some exceptions, such as *Rocket League* (a game consisting of cars playing football), but even so, a conservation organisation or other similar actor would find it difficult to get involved in such projects, as the game would be contrary to their values. Even cartoony violence in video games (and notably the use of guns) is still one of the friction point for detractors of video games, and serious studies have contradicted general statements about players' aggressive behaviours (Kühn et al., 2019; Przybylski & Weinstein, 2019).

Other limitations can be seen in creative thinking, for example, with regard to skins. While it is acceptable in a GAAS for players to have multiple costumes, it could be frowned upon to end up with an animal costume to wear, which could refer to poaching and everything surrounding it.

Establishing such partnerships requires a great deal of flexibility on the part of actors, which often results in lengthy negotiations and discussions (Verdier, 2025b).

Finally, it is likely that certain animals do not have the necessary appeal for players, due to their rarity or the clichés that still work against them. Conservation efforts involving sharks or spiders would therefore remain very difficult to implement, even when certain games such as *Abzû* uses an animal's dangerousness in the collective consciousness to surprise the player in its narrative, with the shark in the game going from enemy to ally, an extremely rare thing in the media (BrySkye, 2016; Mammola et al., 2020; Hoel et al., 2022).

In summary, there are many ways to integrate conservation into video games, and while the benefits are real, the implementation of each project faces numerous social, economic and gaming-related challenges. It is important for all stakeholders to identify the issues in order to make the most of the chosen format. Future studies should focus on clarifying the use of these methods and their potential benefits for conservation stakeholders, either directly (by helping to develop games) or indirectly (by relying on games that promote biodiversity in their experiences thanks to enthusiasts).

CONCLUSION

Jack Barau is part of a movement that seeks to use video games to convey a clear and simple message about animal conservation. With 3.5 billion gamers worldwide, it is unthinkable today that public and private actors would not use video games, a medium that has better resonance now compared to traditional channels. However, there are several realities that stand in the way. The complexity of developing a game requires choices by the developers that must be carefully thought out in order to make the game accessible, interesting, and useful to the general public for communicating its messages. The social and economic realities also remain obvious obstacles to creation, and success.

Nevertheless, it is interesting to see actors of the video game industry lift ecological messages across multiple trials. These games show that there is a real audience that is receptive to these messages and recognizes video games as a potentially major player in communication. The challenge now lies in the success of this communication, and the opportunity to convert this virtual support into real funds. With the narrowing of technological gaps and an increasing mastery of gaming systems, video games could prove to be a key player in conservation, provided that the actors involved understand and consider all their potential.

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About the author

Florian Verdier is a science communicator and lecturer in the field of ornithology. He is also an analyst in the field of video games. This dual expertise has led him to discuss issues relating to animal biology (mainly birds) and its representation in video games for several media outlets.

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Steampunk dinosaurs and Victorian-era palaeontology

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When watching, reading or playing works of fiction, we are the type of biologists who get annoyed with silly mistakes. Like when a movie has a bird sound that's not appropriate to the region or that belongs to a different bird species than shown; common cases include the screaming piha, the loon and the bald eagle vs red-tailed hawk, which have become more of common knowledge of late (Vox, 2021; Eberwein, 2025). We understand that sometimes choices are made in detriment to real-world biology, like Robin's robin in *Honkai: Star Rail* (Salvador, 2024), and that is absolutely fine. Still, it can be quite disappointing when mistakes could have been prevented with a five-second Google search, like the other Robin's robin in *Fate/Grand Order* (Salvador, 2024; Salvador & Tomotani, 2024)[1] or the many issues with the recent dinosaur films (e.g., Igielman, 2022).

On the other hand, we cannot help but beam with happiness when creators hit a biological nail right on its head. That was the case with a dinosaur depiction in an anime we recently watched, Chapter 2 of *Princess Principal: Crown Handler* (by Actas, 2021). Granted, it is a very minor appearance with no relevance to the plot whatsoever, but still, there is such an interesting story behind it that we just had to write about it.

DINOS & DRAGONS

Princess Principal is set in Albion, a fictional steampunk analogue of early 20th-century Britain. The original anime series aired in 2017 and now the *Crown Handler* series is being released as six films (we're currently in the 4th one). The story follows a group of five girls doing spy things; during *Crown Handler* Chapter 2, they go to the theatre during an investigation. And here, the small details included on this scene makes all the difference (Fig. 1).

In front of the theatre there are two lizard-like statues. Chise doesn't know what they are, so Ange explains to her that they are extinct animals called dinosaurs. Seems straightforward enough, but there are a couple of things to unpack here. First, while the British public at that time was familiar with dinosaurs (more on that later), that was not necessarily the case elsewhere, including Japan, where Chise comes from.[2] Secondly, while the statues might look

[1] Not to mention the fact that FGO writers did not know that South America and Central America are two different things, and that Mexico is located in neither of them.

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weird given our current understanding of dinosaurs, it is spot on for the period in which the anime takes place (more on that later as well). Of course, there are some nice "extra" touches, like the steam coming out of the statues' nostrils, which is at the same time very steampunky and in line with the dragon theme of the play at the theatre.

The dinosaur depicted in the anime is Iguanodon, and its weird lizard-like appearance with a horn on its nose was just the first iteration of one of the most revised and reinterpreted dinosaurs in the history of palaeontology.

Figure 1. The team arrives at the theatre and are greeted by two dinosaur statues. Images are screen captures of the film.

DISCOVERY AND NAMING

In the early 19th century, the British (and the European scientific community at large) were becoming acquainted with fossils of large reptilian animals, largely thanks to Mary Anning (Fig. 2), who was unearthing plesiosaurs and ichthyosaurs in Lyme Regis (Fallon, 2020; Salvador, 2021). Still, some fossils were very puzzling and didn't seem to fit well with other then known reptiles. Those included a handful of bones, teeth, and fragments that were later described as *Megalosaurus* (Buckland, 1824), *Iguanodon* (Mantell, 1825), and *Hylaeosaurus* (Mantell, 1833).

In 1842, the naturalist Richard Owen coined the name 'Dinosauria' for a new animal group that could house all those weird fossils, including carnivorous and herbivorous "reptilian" animals (Costantino, 2015).[3] That kick-started discussions and studies about such "new" animals, fuelled by more discoveries being made around the world. And *Iguanodon* has been in the centre of discussions ever since.

[2] While current paleontological advances started to become available in Japan during the Meiji era, alongside some stories like Julio Verne's gaining traction, the more "mainstream" dinosaur boom in Japan came in the 1980s with the amazing new discoveries that were happening in Fukui, now known as the Dinosaur Kingdom (Matsukawa et al., 2006; Fukui Station Dinosaur Area Portal Site, 2024). Technically, the first dinosaur discovered in Japan was *Nipponosaurus sachalinensis*, but it was found in Sakhalin (Nagao, 1936), which is now part of Russia.

[3] The name first appeared in 1841 in a talk to the British Association for the Advancement of Science. The proceedings of that meeting were published in the following year (Owen, 1842: 102).

Figure 2. Mary Anning and her fossil discoveries. Well, kinda. This is the artwork (by Riyo) for the Stage 3 ascension of Mary Anning in *Fate/Grand Order*, because we cannot have an article about British palaeontology and not talk about her. Source: Fate/Grand Order Wiki.

Figure 3. The original illustration of *Iguanodon's* teeth, with a comparative figure of an iguana's teeth. Source: Mantell (1825).

The first *Iguanodon* fossils came from Whitemans Green. They were rock-embedded teeth and were either found by Gideon Mantell and/or his wife Mary Ann (not Anning!) or acquired from the local quarry around 1820–1821 (Dean, 1999). At first, Mantell thought the teeth belonged to a large crocodile, but soon realized they belonged instead to a very large herbivorous reptile. That was a first, as no prehistoric reptilian herbivores were known so far (Osterloff, 2020). Among the known reptiles, the iguana had the most similar-looking teeth, although the fossils were many times larger. Thus, the new fossil species was named *Iguanodon* (that is, "iguana tooth") by Mantell in 1825 (Fig. 3).[4]

In the years that followed, Mantell kept looking for more fossils, but found only more teeth and isolated and fragmentary bones (Osterloff, 2020). Then, nearly a decade later, in 1834, mine workers found a more complete specimen of *Iguanodon* in Maidstone.[5] Mantell travelled to Maidstone to study the new specimen, which was used as the basis for the first attempt to reconstruct this extinct animal's skeletal structure –and also for the first artistic renderings of the species (Fig. 4). Still, the fossil was in a rather poor shape and led to some misinterpretations, the most infamous of which was the horn. *Iguanodon* was reconstructed as having a horn on its nose, like a rhino (remember the depiction in *Crown Handler*;

[4] Weirdly, Mantell did not provide the full binomial that is needed for a species scientific name (like *Homo sapiens*). That was later coined by Holl (1829): *Iguanodon anglicus*.

[5] This specimen is now considered to belong to a different species in a related genus, namely *Mantellisaurus atherfieldensis* (Norman, 2013).

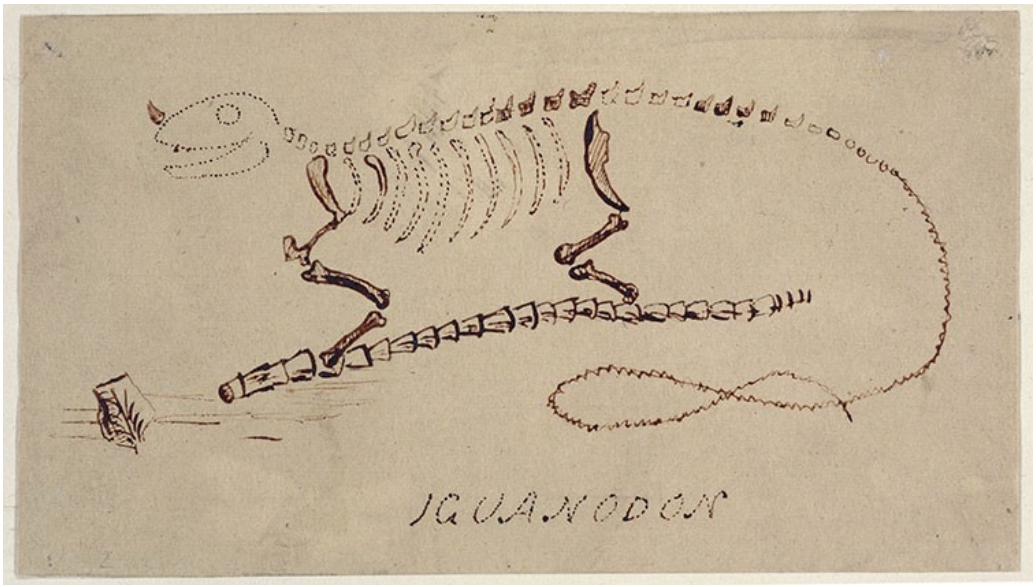

Figure 4. Mantell's reconstruction of *Iguanodon* would have looked like based on the Maidstone fossil and the anatomy of living reptiles. Source: Natural History Museum (public domain).

Fig. 1). Years later, better preserved fossils showed that the "horn" was actually a modified thumb, but that was not an easy thing to imagine back in the early days of dinosaur research. Speaking of which, in a sense it was Mantell who started scientific research on dinosaurs as he tried, along a series of published papers (e.g., Mantell, 1848, 1851a), to understand *Iguanodon* and imagine how it lived back in the Cretaceous Period.

THE CRYSTAL PALACE

By the late 1940s and early 1950s, Mantell was clashing against Owen regarding *Iguanodon*. Owen was a creationist and believed that the Biblical god had created dinosaurs to be elephant-like or rhino-like creatures.[6] Mantell, however, knew that couldn't be so, as *Iguanodon* had slender forelimbs and thus, should walk, move and live in a completely different manner (Mantell, 1851b; Dean, 1999). Mantell died in 1852, an event that resulted in Owen's interpretation of *Iguanodon* becoming accepted and established for the following decades, in no small part thanks to the Crystal Palace dinosaur sculptures.

Such sculptures were commissioned in 1852 to mark the Crystal Palace's move to its new location in London. They were made by Benjamin Waterhouse Hawkins, who counted with scientific advice of none other than Owen (McCarthy & Gilbert, 1994). When unveiled to the public in 1854, they were the world's first sculptures of extinct animals and should represent the latest scientific knowledge of Victorian palaeontology (Osterloff, 2023). They included species from 15 genera of extinct animals (only three of which are actual dinosaurs, by the way). Today, we know the sculptures reflect the many mistakes of early palaeontology, of which the most notable example is perhaps Owen's interpretation of *Iguanodon* (Fig. 5; the wrongly positioned horn/thumb was Mantell's fault, though). Although many people would

[6] Owen appears in *Assassin's Creed: Syndicate* (Ubisoft, 2015) as an antagonist in a quest line where the main characters work alongside Charles Darwin. You can read a bit more about him in Salvador (2019).

Figure 5. *Iguanodon* sculptures at the Crystal Palace. Left: before restoration (1995). Right: after restoration (2014). Sources: Wikimedia Commons, respectively (Casliber, 2006; public domain) and FunkMonk (2014; CC BY-SA 2.0).

make fun of such mistakes, that is part of how science advances and our present-day knowledge will no doubt look silly to researchers in the next century.

The sculptures are recognized as having historical importance and were restored in 2002, which attenuated the derpy look of the originals (Fig. 5). The dinosaur sculpture in *Crown Handler* also attenuated that derpiness by giving *Iguanodon* front teeth (Fig. 1), which made it (purposefully or not) look a bit more dragon-like.

IGUANODON 2.0

A better reconstruction of what *Iguanodon* would have looked like had to wait until the end of the 1870s, when nearly complete skeletons of over 30 individuals were discovered in a coal mine in Bernissart, Belgium (Norman, 1980, 2005). These belonged to a new species, *Iguanodon bernissartensis*. On top of the regular research on those new specimens, one skeleton was mounted for public display in Brussels by Louis Dollo (Fig. 6). With access to numerous fossils, Dollo could see that Owen's interpretation was incorrect (Dollo, 1883). Based on what was then known about the somewhat similar Hadrosaurus in North America, Dollo mounted the *Iguanodon* skeleton in a bipedal kangaroo-inspired posture and hypothesized that it was amphibious and used its tail to swim (Godefrolt, 2017).

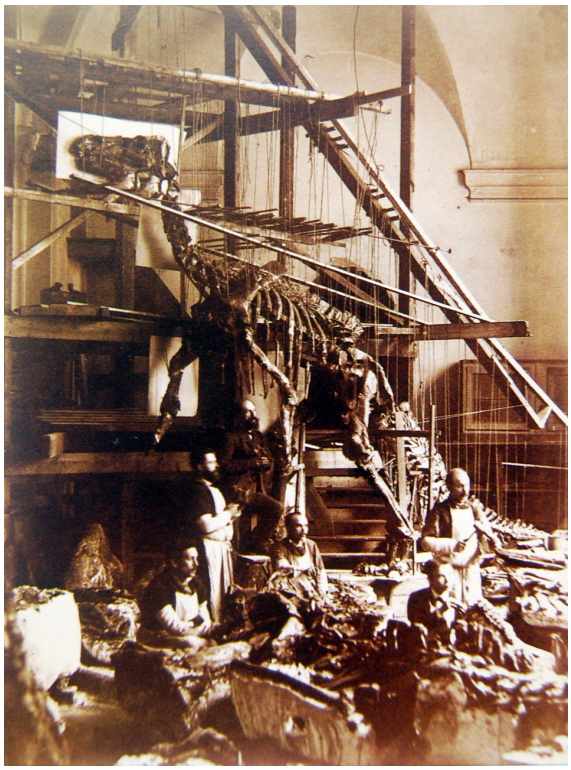

Figure 6. Skeleton of *Iguanodon bernissartensis* being mounted for display in the St. George Chapel in Brussels. Source: Wikimedia Commons (Aimé Rutot, 1882; public domain).

Importantly, Dollo was able to see that the "horn" was actually a modified thumb that looks like a spike (Fig. 7). To this day, palaeontologists still do not know what the hell is going on with this thumb. Some argue that it was used as a defensive weapon; others say it is a specialization for stripping leaves from branches, like the panda's "thumb". In any event, iguanodons' thumbs would have been even larger in life, as the bone could have been covered with keratin (Osterloff, 2020).

Figure 7. The hand of an *Iguanodon* specimen from the Natural History Museum (London, UK) showing the modified spike-like thumb. In all honesty, it does look like a horn or something similar. Source: Wikimedia Commons (Ballista, 2006; CC BY-SA 3.0).

After that, research on *Iguanodon* slowed down as interest in it waned, and wars, economic depression, and the rise of fascism changed the priorities in Europe away from dinosaurs. Then, as it is widely known, a "dinosaur renaissance" started around the 1960s, when new data and fresh research started to indicate that dinosaurs were not sluggish overgrown lizards but rather active warm-blooded animals (Bakker, 1986). Such reinterpretation started to show dinosaurs under a different light, as animals capable of complex behaviours like forming social structures and caring for their young (for instance, *Maiasaura* is the classic example of parental care; Horner & Makela, 1979). It took a while, but eventually, in the 1980s, the renaissance movement reached *Iguanodon*.

New research was done in skeletal anatomy, providing new ideas on topics like feeding mechanisms, posture and movement. Among the palaeontologists studying *Iguanodon*, David Norman was perhaps the most prolific and active (see, for instance, Norman, 1980, 1986). One major realization was that Dollo's kangaroo posture was impossible, because it required a flexible tail; the fossils clearly showed that the tail of iguanodons was straight and could not bend the way Dollo displayed. Thus, the new reconstructions have iguanodons as terrestrial animals walking with their body and tail held parallel to the

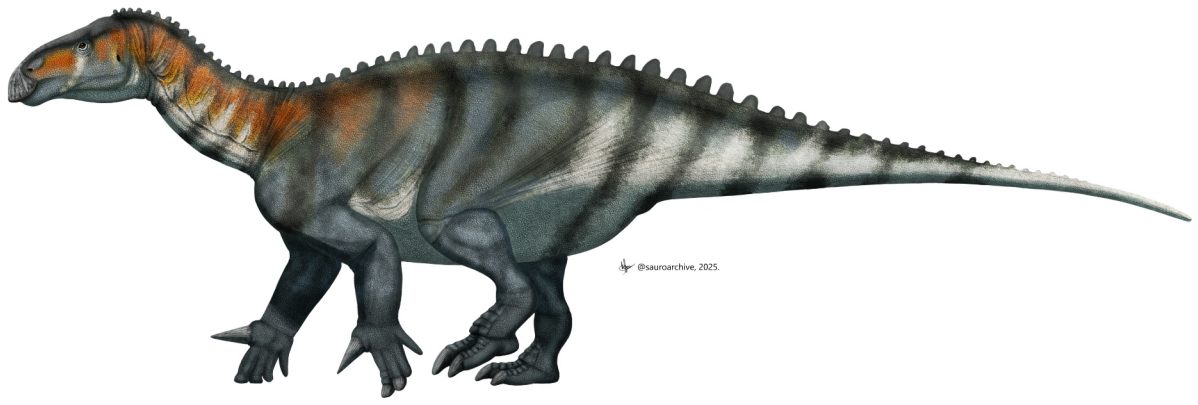

Figure 8. Modern reconstruction of *Iguanodon bernissartensis*. Source: Wikimedia Commons (Sauroarchive, 2025; CC BY 4.0).

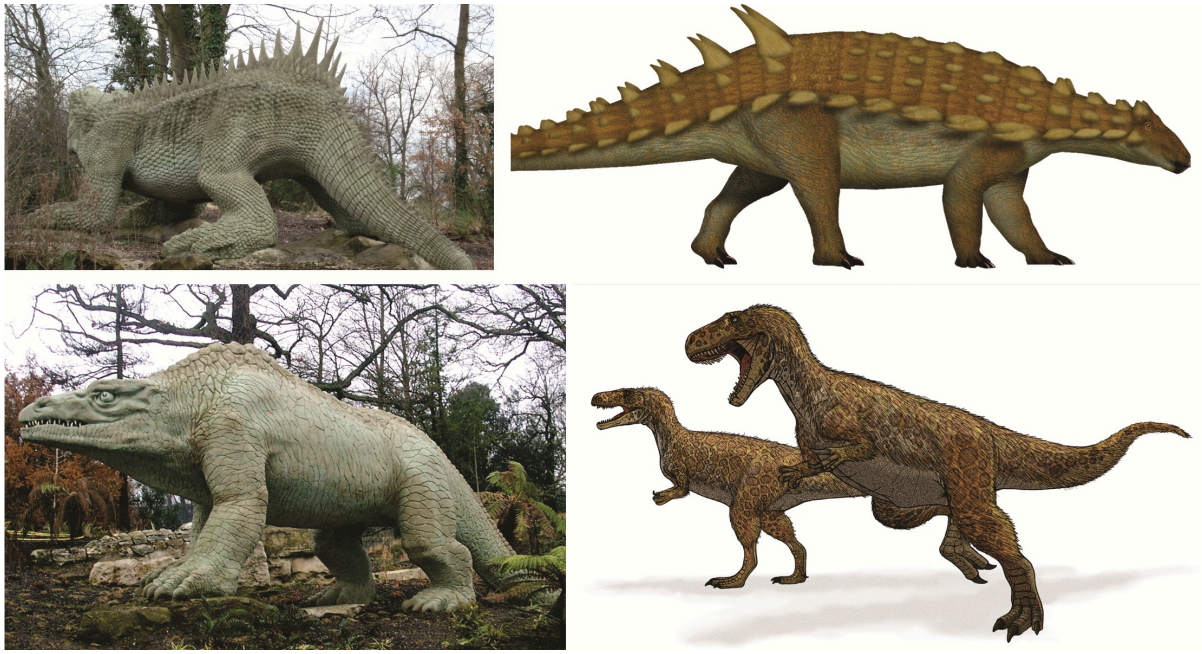

Figure 9. Crystal Palace dinosaur sculptures and modern interpretations of the animals. Top row: *Hylaeosaurus*. Bottom row: *Megalosaurus*. Sources: Wikimedia Commons (cropped), from top left respectively FunkMonk (2008; CC BY-SA 2.0), TotalDino (2023: CC BY-SA 4.0), CGP Grey (2005; CC BY 2.0), LadyofHats Mariana Ruiz (2006; public domain).

ground, and with arms offering further support to the body (Fig. 8). There were also discoveries about their behaviour, as rich fossiliferous deposits in Nehden, Germany, showed that iguanodons were gregarious animals (Norman, 1987).

Iguanodon was not the only one that went through reinterpretations over the decades. So, it is interesting to see how those other dinosaur reconstructions from the Crystal Palace compare to modern "post-renaissance" interpretations (Fig. 9).

FINAL THOUGHTS

Iguanodon, while not as well immediately recognizable to the public like T-rexes, stegosaurs and triceratopses, are still rather common in pop culture from Arthur Conan Doyle's *The Lost World* (1912) to Disney's *Dinosaur* (2000) and *Jurassic World Dominion* (Universal Pictures, 2022). They have long been present as collectibles too, starting perhaps with the cards in German chocolate bars during the 1900s–1910s (Fig. 10) and continuing to present-day gashapon miniatures (Fig. 11).

Box 1. A jumble of names

In the 200 years since its original description, the genus Iguanodon had many new species added to it. Some have remained in it, like *I. bernissartensis* and *I. galvensis* (described in 2015 from Spain; Verdu et al., 2015, 2018). Many have been transferred to other genera, like *I. atherfieldensis*, which became *Mantellisaurus atherfieldensis* (Paul, 2007) and includes the Maidstone specimen formerly thought to be *I. anglicus*. Such reassignments were due to anatomical features observed in the fossils and differences in the geological times in which they lived (e.g., Norman, 2010, 2013) – and due the penchant of vertebrate palaeontologists for oversplitting species and naming "new" species. Case in point, many putative new species described along the years have been synonymised with other previously known species (e.g., Norman, 2013).

Curiously, many fossils identified as the original *I. anglicus* were shown to belong to other species; *I. anglicus* itself is known only by teeth and it is considered a problematic species (a nomen dubium in the jargon). That led palaeontologists Charig & Chapman (1998) to select *I. bernissartensis*, represented by numerous complete skeletons, as the type species of the genus *Iguanodon* in detriment to *I. anglicus*, which was the first species described.

Figure 10. Painting by Heinrich Harder (c. 1916) of a group of iguanodons, part of a series of collector cards sold alongside chocolate bars. Source: Wikimedia Commons (public domain).

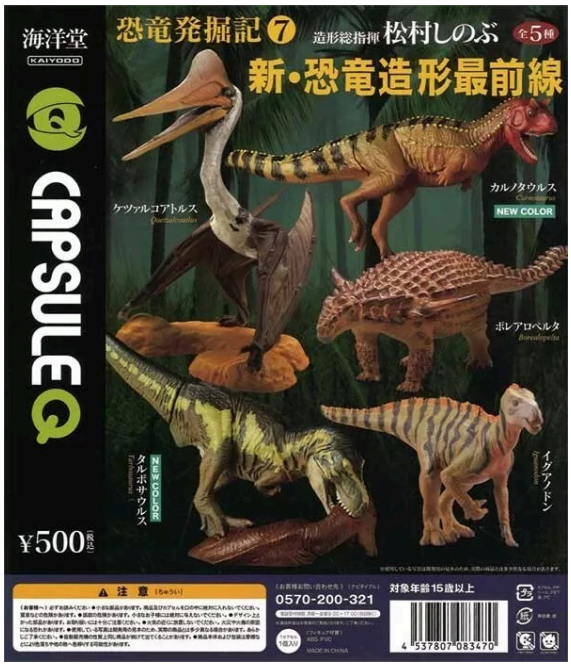

Figure 11. Advertisement of Kaiyodo's gashapon set from including an iguanodon (bottom right corner). Source: KAIYODO (2019).

Popular takes on iguanodons have largely followed the many changes in interpretation, from elephant-like to kangaroo-like, from terrestrial to amphibious, and finally to the modern reconstruction. While today's iguanodons are agile bipedal animals, we cannot help but think that there is a certain charm to the fat dragon-like reconstruction of the Crystal Palace and *Crown Handler*. Case in point, even the King of Monsters took inspiration from the old iguanodons (Tsutsui, 2004), so we are certainly not alone in thinking that.

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About the authors

Dr Rodrigo B. Salvador is a curator in the Finnish Museum of Natural History. While his past research was mostly in palaeontology, nowadays he is mostly studying the present-day fauna. He even had a brief stint studying dinosaurs but soon left that toxic research community behind. He loves steampunk and is always on the lookout for new titles to watch, play or read. By the way, could someone give these dinosaurs top hats and monocles, please? That should improve each and every palaeoart reconstructions.

Dr Barbara M. Tomotani is a researcher in the Arctic University of Norway who has actually not seen the anime. However, she is in this article not because she has done some research on extinct dinosaurs before and neither because she studies the living fluffball dinosaur known as *Parus major*; no, she is here because this year she spent hundreds of hours playing *Path of Titans* as a *Latenivenatrix*, which made her go through her many old dinosaur books.