

If Dante had known Phytoplankton. A comparison between literature and science through the didactics of metaphors.

Maria Rosaria Vadrucci¹, Floriana Vitale¹, Maria Teresa Duggento², Caterina Alberani², Aurora Calò², Giorgia Giancane², Beatrice Barbara Rizzelli², Syria Schipa², Roberto Visconti²

¹ ARPA Puglia – Agenzia Regionale per la Protezione Ambientale della Regione Puglia – Dipartimento di Lecce, Italy

² Liceo Classico Musicale “G. Palmieri”, Lecce, Italy

Abstract.

This project, conducted with Classical High School students, was developed under the "Alternating School and Work Experience" program (Italian Law n. 107/2015) between the "G. Palmieri" High School of Lecce and the Environmental Protection Agency of Puglia (ARPA), Department of Lecce, in Italy. In particular, this paper describes the “HABs’ world” allegorically, in terms of one of the most famous examples of Italian literature, the Divine Comedy. Harmful algal blooms, or HABs, occur when colonies of algae, simple photosynthetic organisms that live in the sea and freshwater, grow out of control while producing toxic or harmful effects on people, fish, shellfish, marine mammals, and birds. Since HABs can be defined as “bad”, based on their negative characteristics, some of these were compared to the sinful souls that Dante and Virgil encountered along their journey into Hell. It is argued that such integration of literary and scientific contexts in terms of ecological indicators helps students understand the relationship between the sustainability of human and environmental trajectories.

Key words: Phytoplankton, Harmful Algae Blooms (HABs), The Divine Comedy, Dante Alighieri, ecological indicators

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Corresponding Author: Maria Rosaria Vadrucci, Agenzia Regionale per la Protezione Ambientale della Regione Puglia – Dipartimento di Lecce, Italy.

E-mail: m.vadrucci@arpa.puglia.it

Perspective: Educational visions

Fields: Earth life support systems

Issues: Ecological indicators

Introduction

Phytoplankton, also known as microalgae, are the basis of several aquatic food webs. They are autotrophic organisms able to fix carbon dioxide and water for synthesizing organic matter and oxygen. Sometimes, however, their roles are more sinister. Occasionally, under the right conditions, the algae grow very fast or "bloom" and accumulate into dense, visible patches near the surface of the water. "Red Tide" is a common name for this phenomenon where certain phytoplankton species contain pigments so that the human eye perceives the water to be discolored. Blooms can appear greenish, brown, and even reddish orange, depending upon the type of organism, the type of water and the concentration of the organisms. A small number of species produce potent toxins that can be transferred through the food web where they affect and even kill the higher forms of life such as zooplankton, shellfish, fish, birds, marine mammals, and even humans that feed either directly or indirectly on them.

Other algae are nontoxic, but they use all the oxygen in the water as they decay, clog the gills of fish and invertebrates, or smother corals and submerged aquatic vegetation. Other microalgae discolor water, form huge, smelly piles on beaches or contaminate drinking water. Collectively, these events are called harmful algal blooms, or HABs. However, awareness of their existence in nature and of their dangerous consequences is not widespread outside the scientific world. The following project, conducted with Classical High School students, was developed under the "Alternating School and Work Experience" program (Italian Law n. 107/2015) between the "G. Palmieri" High School of Lecce and the Environmental Protection Agency of Puglia (ARPA), Department of Lecce, in Italy. It was developed as a learning project starting from the knowledge and skills already possessed by students, since they are included in their overall study plan, and using them to facilitate the understanding of the new scientific topics encountered. More specifically, the point of

departure was a well-known work of Italian literature, the *Divine Comedy* of Dante Alighieri, that was metaphorically linked to the scientific topic proposed to the students: HABs and their effects on human health.

Metaphors are persuasive in our languages and conceptual systems. Metaphors may structure the way we perceive situations, events and topics. Therefore, metaphors may influence our way of understanding them. Furthermore, if we are able to restructure the frame through which we perceive a problem by generating alternative metaphors, we may be able to discover new perspectives and new solutions to the problem (Marshall, 2009). This paper shows how the project describes the "HABs' world" allegorically. Since HABs can be defined as "bad", based on their negative characteristics, some of these have been assimilated to the sinful souls that Dante and Virgil encountered along their journey into Hell.

The project

The project is based on three study sheets that involve analysis and interpretation of characters or salient moments and events of the three *Cantiche* of the *Divine Comedy*. The purpose is to create links with the microscopic aquatic organisms found in the phytoplankton communities. Such organisms are known to the scientific community in particular for their important role as producers of energy and oxygen as well as for their unbelievable variety of forms, colors and functions.

Study sheet 1: *If Dante had known Phytoplankton, part I: Harmful Algal Blooms (HABs).*

The study sheet was developed based on reading and action research activities together with analysis and interpretation of events or characters of the first *Cantica* of *Divine Comedy* in order to identify particular allegorical links with the world of the HABs.

The students

The study sheet was worked on by a group of six 16-17 year-old students during the 2016-17 school year.

The topics

The study sheet was characterized by a high level of multidisciplinary interdisciplinary content that encompasses the following topics: Italian Literature, Biology, Geography, English, and History.

Time and resources

The study sheet was developed over a period of 75 hours, corresponding to the duration of the activities envisaged by the alternating school and work experience program. The activities were carried out in the water biology laboratories of the ARPA Puglia Department of Lecce. Two tutors of the Agency supported the students' activities in all the phases of the project.

Learning outcomes

The envisaged learning outcomes concerned the design, by the students, of a narrative process that reconstructed the nodal points of *Divine Comedy*, during the first stage of Dante's journey in the afterlife. Starting from analysis of the text in its rhetorical complexity (from the cosmological references, to the imagination of Dante expressed in 'figures'), the students constructed a map of events and characters so as to link them to comparable events and characteristics of HABs within the marine environment. Specific products of this intended meaningful learning process were the creation of a hypertext in Italian and the preparation of a manuscript for a scientific journal in English.

Prerequisites

In order to work through the study sheet, the students needed to possess knowledge about:

1. The historical period in which Dante lived, his biography and the framework of his works.
2. A critical-hermeneutic perspective on the *Divine Comedy* in terms of its geographical, thematic (the journey as a redemptive mission, the imaginary: supporting themes, the symbol characters and their meaning) and symbolic (the concept of 'allegory' of *profetia ex eventu*, of 'aerial body' structures).
3. The structure of plant cells.
4. The organization of living organisms.
5. Various forms of representative expression, from dramatization to

depiction and drawing by using Power Point presentation and other programs

Teaching methodology and resources

A range of different teaching methods were used: lecture sessions, working in tandem, cooperative learning, problem-solving and action research. The resources provided for the students were the text of the *Divine Comedy* with comments (Jacomuzzi et al., 2014), together with texts from various sources, textbooks and scientific articles on HABs included online resources. In addition, the students were free to make their own decisions both concerning the choice of reference sources and the modes of expression. Tutoring was provided for all the activities by two specialist technicians of the agency.

The activities

The preparation of the study sheet involved the following activities:

1. The tutor summarized the approach based on learning through developing competences, focusing above all on the 'experiential' aspect of the teaching/learning process and clarifying the concept of 'competence' as 'knowing how to act', that is, of knowledge built and used in order to resolve a problem). The tutor emphasized the central role of the student who becomes the 'learning subject' in terms of autonomy and responsibility.
2. The tutor illustrated the work experience program, and the importance of starting from the given knowledge already possessed by the students, that is subsequently enriched by building new and more specific knowledge. This included reference to the *mission* of Arpa Puglia in the field of protection and conservation of aquatic ecosystems. Tutors on specific toxic microalgae topics carried out a series of lectures and laboratory experiences, concerning the taxonomic position, the morphological characteristics, the geographical distribution, types of

toxins and their possible effects on human health. Finally, the role of Arpa Puglia in monitoring and controlling the diffusion of HABs in marine and freshwater ecosystems was also illustrated. Each input session was followed by laboratory experience during which students were able to observe some HABs, using the most appropriate observation techniques.

3. Through a cooperative learning approach, the tutors and students decided together the particular perspective to be assigned to each phase of the study, with contributions from the tutors concentrating on details concerning especially microalgae. By activating their given knowledge, the students identified various characters and events in the *Divine Comedy*, considered significant for the purposes of the project. The tutors advised them on how the choice among the events and the key characters selected could be connected to characteristics of HABs.
4. The students engaged in an interesting and intensely-participated discussion about the proposed combinations, demonstrating a notable ability to work together in tandem and adopt a problem solving approach. As a result, they were able to locate, within Hell, the selected HABs and characters of the *Divine Comedy* and to describe through a short text the reasons for their choices.
5. Images of microalgae and pictures on Inferno were then selected from various on-line bibliographic sources.

The learning experience

The idea of the ARPA Puglia tutors to work on linking Dante's Inferno and HABs arises from

the need to find an effective way to integrate learning projects and the student's school study plans in terms of knowledge and skills development. In this respect, working through the study sheet clearly enabled the students to:

- improve research skills aimed at investigating a topic through different sources;
- organize and sort the information acquired in a conceptual map of the world of HABs;
- formulate sustained analysis of episodes, characters and songs based on a motivated critical interpretation;
- produce written texts of different types and complexity.

At the end of the experience, the students considered both motivating and emotionally engaging the way in which reactivating their knowledge of Dante and the *Divine Comedy* in order to facilitate the understanding of a topic completely new to them, that of HABs and their effects on man and aquatic environment. In particular, they found it highly stimulating to be able to develop autonomously their own learning space, open to new input from various external sources, and produce a text they constructed as the basis of their own learning process.

Learning products

The students developed six themes on particular species of HABs (Hallegraeff *et al*, 2003) and associated them with the characters of *The Divine Comedy*. The products are described below. They were included in a hypertext of Dante's Inferno.

1. Dante in the gloomy wood (Canto I) & *Pseudo - Nitzschia spp.*

We started with the writer, Dante Aligheri, who began his allegorical trip in a wild dark forest, in a complete delirium, as described in the following lines:

<p><i>Nel mezzo del cammin di nostra vita mi ritrovai per una selva oscura ché la diritta via era smarrita. (1-3)</i></p> <p><i>io non so ben ridir com'í' v'intrai, tant'era pien di sonno a quel punto che la verace via abbandonai. (10-12)</i></p>	<p>When half way through the journey of our life I found that I was in a gloomy wood, because the path which led aright was lost. (1-3)</p> <p>I cannot well say how I entered it, so full of slumber was I at the moment when I forsook the pathway of the truth; (10-12)</p>
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The image presented of the Author is of a person lost in the gloomy wood. This can be

associated with the species *Pseudo - Nitzschia spp.* (Figure 1).

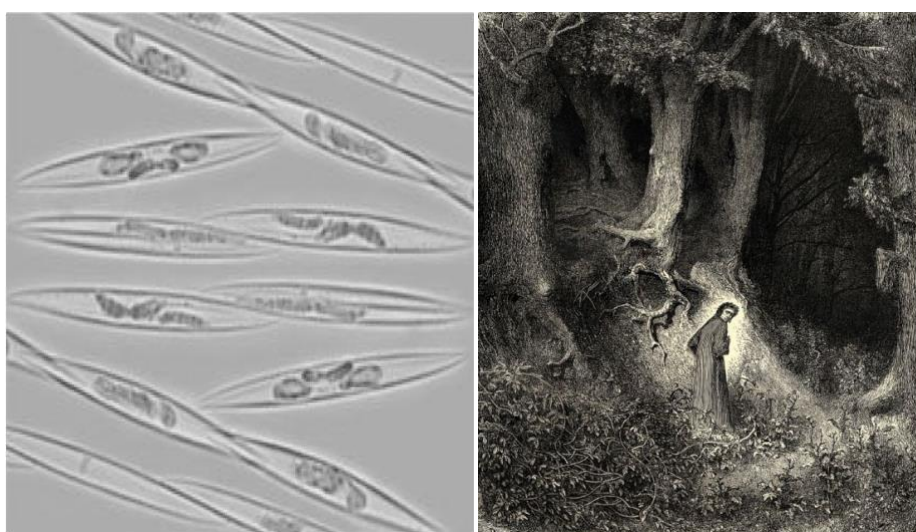


Figure 1- *Pseudo - Nitzschia spp.* and Dante in the gloomy wood

Pseudo-nitzschia species are bilaterally symmetrical diatoms. Their cell walls are made up of elongated silica frustules. Silica frustules contain a central raphe, which secretes mucilage that allows the cells to move by gliding. Cells are often found in overlapped, stepped colonies, and exhibit collective motility. *Pseudo-nitzschia* species can be found in coastal regions worldwide. Some *Pseudo-nitzschia* species are capable of producing the neurotoxin domoic acid (DA), which is responsible for the neurological disorder known as Amnesic Shellfish Poisoning (ASP). Harmful algal blooms (HABs) of *Pseudo-nitzschia* can cause diseases and death in many marine creatures, as well as the humans, who consume them. Shellfish become contaminated after feeding on

toxic *Pseudo-nitzschia* blooms and can act as a vector to transfer domoic acid to humans upon ingestion. Effects can be as minor as vomiting, cramps, and a headache, or as severe as permanent short-term memory loss, coma, and death.

These symptoms are similar to the state of being lost affecting the author of the *Cantica* from the beginning of his allegorical journey.

2. Paolo and Francesca (II circle - V poem - "Luxurious") and *Noctiluca scintillans*

Going on his trip, Dante found himself in a dark place, where a terrible storm raged constantly and dragged the damned, beating them from one side to the other of the circle. Dante understood they were the "luxurious", who flew forming a wide flock similar to the stornellis when they fly in the sky. Among

them there were two souls moved by the wind as in life they were moved by passions:

Paolo and Francesca. They are described in the following lines:

*La bufera infernal, che mai non resta,
mena li spirti con la sua rapina;
voltando e percotendo li molesta. (31-33)*

The infernal hurricane, which never stops, carries the spirits onward with its sweep, and, as it whirls and smites them, gives them pain.(31-33)

*Intesi ch'a così fatto tormento
enno dannati i peccator carnali,
che la ragion sommettono al
talento. (37-39)*

I understood that to this kind of pain are doomed those carnal sinners, who subject their reason to their sensual appetite.(37-39)

*Amor, ch'al cor gentil ratto s'apprende
prese costui de la bella persona
che mi fu tolta; e 'l modo ancor
m'offende. (100-102)*

Love, which soon seizes on a well-born heart, seized him for that fair body's sake, whereof I was deprived; and still the way offends me.(100-102)

*Amor, ch'a nullo amato amar perdona,
mi prese del costui piacer sì forte,
che, come vedi, ancor non m'abbandona.
(103-105)*

Love, which absolves from loving none that 's loved, seized me so strongly for his love of me, that, as thou see'st, it doth not leave me yet. (103-105)

In this case, the species *Noctiluca scintillans*, with its enchanting luminescence in the night and the red or pink trails colored in daylight,

well represents the souls in love of the two characters described by Dante (Figure 2).

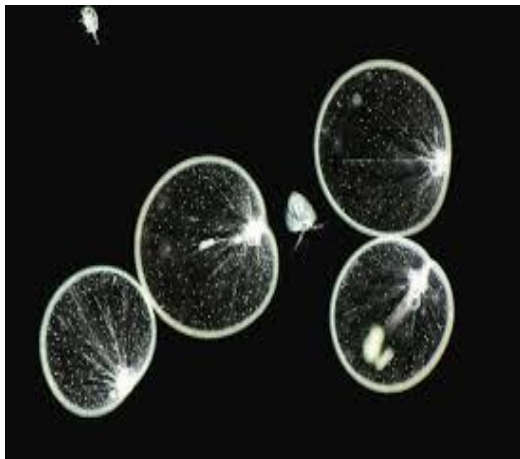


Figure 2 - *Noctiluca scintillans* and the souls in love

Noctiluca scintillans is a marine dinoflagellate. It is a large (about 1–2 mm in diameter), spherical, gelatinous single-celled organism enveloped in a thin pellicle. It is one of the most commonly occurring bioluminescent organisms in coastal regions of the world. *N. scintillans* does not appear to be toxic, but it accumulates and excretes high levels of ammonia into the surrounding area. The scintillating effect of *Noctiluca*'s bioluminescence, which is most conspicuous at night during a bloom (population increase), was historically a mysterious phenomenon, frequently contributing to what was called "burning of

the sea" or "sea sparkle" by sailors and coastal inhabitants. In daylight, instead, such blooms form a thick scum across the sea surface, visibly red or pink.

Noctiluca scintillans can therefore be linked to the indissoluble passion that Paolo and Francesca left behind them.

3. Cerbero (III circle - VI poem – "Greedy") & *Dinophysis/Prorocentrum lima*

Later, in the third circle, in which Dante included "the greedy", an eternal cold that fell constantly, mixed as dirty water and snow. It forms on the ground a disgusting mud, from which an unbearable stench arises. This image is described in the following lines:

*Io sono al terzo cerchio, de la piova
eterna, maladetta, fredda e greve;
regola e qualità mai non l'è nova. (7-9)*

In the third circle am I, that of rain eternal, cursed, cold and burdensome; its measure and quality are never new. (7-9)

*Cerbero, fiera crudele e diversa,
con tre gole caninamente latra
sopra la gente che quivi è sommersa.
(13-15)*

A wild beast, Cerberus, uncouth and cruel, is barking with three throats, as would a dog, over the people that are there submerged. (13-15)

The greedy are laid in the mud and Cerbero, a cruel and three-headed beast, barked above them with its three jaws. It had red eyes, dirty and black beard, a swollen abdomen and legs with claws. It scratched the souls to tatters and its barking echoed in their ears so that they wanted to be deaf. The damned shouted like dogs at the rain, often turning from side to side, in the vain attempt to protect themselves.

It is possible to compare Cerbero to the following three species. *Dinophysis acuta* and *Dinophysis acuminata* are armored, marine, planktonic dinoflagellates. These species are compressed laterally. Their cell size ranges between 40-94 µm in length. They are oceanic and neritic planktonic species of cold

or temperate waters. *Prorocentrum lima* is an armored, marine, benthic dinoflagellate with world-wide distribution. *P. lima* is a bi-valvate species often observed in valve view. Its cell size ranges between 32-50 µm in length and 20-28 µm in width (Figure 3).

They are toxic species associated with "**Diarrhetic Shellfish Poisoning**" (DSP) events. As the name suggests, this syndrome manifests itself as intense diarrhea and severe abdominal pains. Nausea and vomiting may sometimes occur too.

DSP and its symptoms usually set in within about half an hour of ingesting infected shellfish, and last for about one day.



Figure 3 - *Dinophysis acuta*, *Dinophysis acuminata*, *Prorocentrum lima* and Cerbero

The association with Cerbero refers to the state of malaise generated by the alga, comparable to what the damned suffer because of the fire.

4. Medusa (VI circle – IX poem – “Eretics and Epicures”) & *Alexandrium spp/Gymnodinium catenatum*

In the VI circle, where “Heretics and Epicures” were found, there was the figure of Medusa, one of the three Gorgons of Greek Mythology,

the most dangerous because she is able to petrify whoever looks at her.

Dante put her among the demons which guarded the city of Dis. She didn’t appear directly, but was evoked by the three Furies in order to petrify Dante. Virgilio, his companion, who obliged Dante to turn and to cover the eyes with his hands, took the threat very seriously.

Volgiti ’n dietro e tien lo viso chiuso; ché, se ’l Gorgón si mostra e tu ’l vedessi, nulla sarebbe di tornar mai suso». (55-57)

Turn back, and close thine eyes, for should the Gorgon reveal itself, and thou behold the face, there ’d be no more returning up above. (55-57)

Così disse ’l maestro; ed elli stessi mi volse, e non si tenne a le mie mani, che con le sue ancor non mi chiudessi. (58-60)

The Teacher thus: and turning me himself, on my hands he did not so far rely, as not to close mine eyes with his as well. (58-60)

The ability of Medusa to petrify people can be represented by the species *Alexandrium spp.* e *Gymnodinium catenatum*. *Alexandrium spp.* are armored, marine planktonic dinoflagellates. They have a rounded shape with a central sulcus. Their cells size ranges between 20-60 and 15-40 µm in width. *Alexandrium spp.* are widely distributed in cold temperate coastal waters. The *Gymnodinium* is an unarmored, marine

planktonic dinoflagellate species. This species is typically seen in chain formation with up to 64 cells. Their cells are small with a morphology varying between single cell and chain formation. Single cells are generally elongate-ovoid with slight dorso-ventral compression. Their cell size ranges between 34-65 and 27-43 µm in width. *G. catenatum* populations are found in warm, temperate coastal waters.

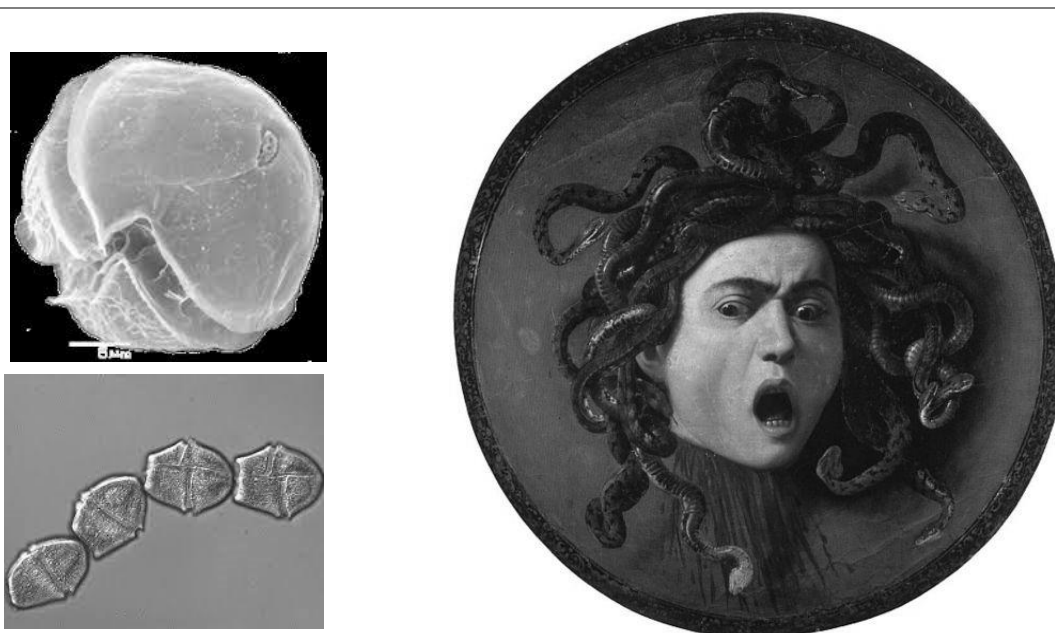


Figure 4 - *Alexandrium* spp, *Gymnodinium catenatum* and Medusa

These microalgae are planktonic red tide, toxin-producing species linked to Paralytic Shellfish Poisoning (PSP), events which occur throughout the world. PSP affects people who come into contact with the toxins by ingestion of affected shellfish. Symptoms can appear from 10 to 30 minutes after ingestion, and include nausea, vomiting, diarrhea, abdominal pain, tingling or burning lips, gums, tongue, face, neck, arms, legs, and toes. Shortness of breath, dry mouth, a choking feeling, confused or slurred speech, and loss of coordination are also possible. Because of

these symptoms, the microalgae were associated with Medusa (Figure 4).

5. Odysseus (VIII circle-XXVI poem – “Fraudulent advisers”) & Karenia

The “fraudulent advisers” in life acted with deception and fraud. Among these damned, in a little flame with two points, stood Odysseus, the Greek hero famous for his cunning and tricks.

Odysseus served his sentence sharing his little flame with Diomed, another Greek hero and his closest friend.

*E 'l duca che mi vide tanto atteso,
disse: «Dentro dai fuochi son li spirti;
catun si fascia di quel ch'elli è inceso». (46-48)*

*Rispose a me: «Là dentro si martira
Ulisse e Diomede, e così insieme
a la vendetta vanno come a l'ira; (55-57)*

And the Leader, who beheld me so attent, Exclaimed: “Within the fires the spirits are; Each swathes himself with that wherewith he burns (46-48)

He answered me: “Within there are tormented Ulysses and Diomed, and thus together They unto vengeance run as unto wrath. (55-57)

Odysseus was the inventor of the idea to construct a huge wooden horse as a treacherous gift to leave to the Trojans. The strongest Greek soldiers, hidden in the horse,

opened the city door of Troy and conquered it. Odysseus is associated with the highest points because of his overreaching, deceitful nature, described in the following lines:

<p><i>Considerate la vostra semenza: fatti non foste a viver come bruti, ma per seguir virtute e conoscenza</i> (118-120)</p>	<p>Consider ye the seed from which ye sprang; Ye were not made to live like unto brutes, But for pursuit of virtue and of knowledge (118-120)</p>
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It is possible to compare Odysseus and Diomedes to the following two species:

Karenia brevis and *Karenia papilionacea* (Figure 5).



Figure 5 - *Karenia papilionacea* and *Karenia brevis* vs Odysseus and Diomedes

Karenia brevis and *Karenia papilionacea* are unarmored, marine, planktonic dinoflagellate species. Their cells are small and dorso-ventrally flattened. *Karenia brevis* is smaller than *Karenia papilionacea*. In the first, their cells range in size from 20-40 μm in width and 10-15 μm in length. They are planktonic oceanic species, though populations have been documented in estuarine systems under bloom conditions. Either species produce brevetoxins responsible of Neurotoxic Shellfish Poisoning (NSP). NSP is a disease caused by the consumption of molluscan shellfish contaminated with toxin.

NSP causes a range of signs and symptoms, both neurological and gastrointestinal. Most individuals report multiple symptoms. Victims of NSP most frequently describe numbness and tingling in the lips, mouth and face, as well as numbness and tingling in the extremities. These paresthesias may be from minor to severe, and have been described as feeling like one's "nerves are on fire or ants

are crawling and biting all over" one's body. The reversal of hot and cold sensations has been reported as well, a symptom shared with ciguatera poisoning. Slurred speech, headache, pupil dilation, and overall fatigue are also commonly reported. Victims have been described as appearing disoriented.

The association with Ulysses and Diomedes is related to the fact that they carried out their actions through deception and therefore were deceivers of reality.

6. Lucifer (IX circle-XXXIV poem – "The benefactors' traitors") & *Gambierdiscus toxicus*

This last example links the HABs to the IX circle of the Hell, where the benefactors' traitors stood, such as Lucifer, the most wicked character of all the poem. He deceived people to whom he gave the happiness of mankind and lived in absolute silence.

He was an horrid creature, endowed with three faces on one head and three pairs of bat wings. He was submerged in ice from the

waist down and he broke the sinner with one of his three jaws.

Dante and Virgilio saw Lucifer as the beginning of every evil and the most dangerous creature in Hell.

The damned souls were covered by ice and shone through the ice like straws under glass. The petrified and mute damned are described in the following lines:

*Lo 'mperador del doloroso regno
da mezzo 'l petto uscìa fuor de la ghiaccia;
e più con un gigante io mi convegno, (28-30)*

The Emperor of the Realm of Woe stood forth, out of the ice from midway up his breast; and I compare more closely with a Giant, (28-30)

*Oh quanto parve a me gran meraviglia
quand'io vidi tre facce a la sua testa!
L'una dinanzi, e quella era vermiglia; (37-39)*

Oh, what a marvel it appeared to me, when I beheld three faces to his head! One was in front of us, and that was red; (37-39)

This terrible image can be well represented by the species *Gambierdiscus toxicus*.

As Lucifer represents the principle of every evil, *Gambierdiscus toxicus* is the most toxic microalgae know in the world (Figure 6).

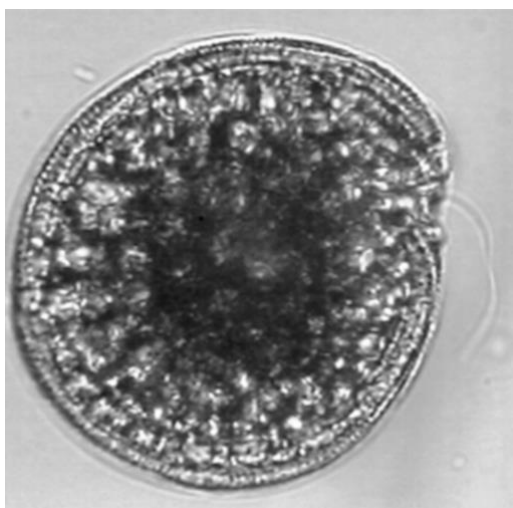


Fig. 6 - *Gambierdiscus toxicus* and Lucifero

Gambierdiscus toxicus is an armored, marine, benthic dinoflagellate species. Its cells are large, round to ellipsoid. The cell surface is smooth with numerous deep and dense pores. The cells range in size from 24-60 μm in length, 42-140 μm in diameter, and 45-150 μm in dorso-ventral depth. This species was identified from tropical reefs in the Pacific Ocean, the Indian Ocean, and the U.S. Virgin Islands. Populations have been found in tidal pools and lagoons, as well as in colored sand, in the Caribbean. *Gambierdiscus toxicus* produce *ciguatoxins*, a type of toxin

that causes the foodborne illness known as ciguatera. Ciguatera is the most common form of seafood poisoning caused by harmful algal blooms in the world and its incidences and range appear to be spreading. Best estimates indicate that more than 50,000 people are globally affected every year. Hallmark symptoms of ciguatera in humans include gastrointestinal, cardiovascular, and neurological effects. Gastrointestinal symptoms are usually followed by neurological symptoms such as headaches, muscle aches, paresthesia, numbness of extremities,

mouth and lips, reversal of hot and cold sensations, ataxia, vertigo and hallucinations. Severe cases of ciguatera can also result in cold allodynia, which is a burning sensation on contact with cold. Neurological symptoms can persist and ciguatera poisoning is occasionally misdiagnosed as multiple sclerosis. Cardiovascular symptoms include bradycardia, tachycardia, hypotension, hypertension, orthostatic tachycardia, exercise intolerance, and rhythm disorders. Death can occur, but is extremely rare. The symptoms can last from weeks to years, and in extreme cases as long as 20 years, often leading to long-term disability.

Conclusions

Although harmful algal blooms can be natural phenomena, the nature of the global problem has expanded in both extent and its public perception over the last decades. The presence of HABs in aquatic ecosystems are ecological indicators of an environmental degradation and consequent problems for sustainability. HABs have one unique feature in common—they cause harm, either due to toxins production or to the manner in which the cells' physical structure or accumulated biomass affect co-occurring organisms and alter food web dynamics (Anderson et al., 2002).

Many factors may contribute to HABs. Studies indicate that many algal species flourish when wind and water currents are favorable. In other cases, HABs may be linked to eutrophication phenomena. This occurs when nutrients (mainly phosphorus and nitrogen) deriving from anthropogenic sources, such as lawns and farmlands, flow downriver to the sea and build up at a rate that 'overfeeds' the algae that exist normally in the environment. People often get sick by eating shellfish containing toxins produced by these algae. Airborne HAB toxins may also cause breathing problems and, in some cases, trigger asthma attacks in susceptible individuals. HABs can also be costly in economic terms as well. At present, HABs cause about \$82 million in global economic losses to the seafood, restaurant, and tourism industries each year. HABs reduce tourism, close beaches and

shellfish beds, and decrease the catch from both recreational and commercial fisheries. While much is being done on the technical side to reduce nutrient pollution, as yet there is a recognition that the general public may not fully understand the basic association between nutrient pollution and algal bloom and how this impacts on sustainability. In this project our intention was to share technical information about research and monitoring efforts underway, and to explore approaches for enhancing communication and education efforts directed towards the general public and, in particular, groups of students (Bravo, 2015).

HABs have been studied for many years, but they are little known at the level of learning curricula. To promote understanding and awareness, our idea was to explain the phenomenon through building an imaginary pathway based on parallels between scientific investigation and texts and a literary work such as *The Divine Comedy*, through a detailed comparison between scientific and literary contents language. It can be argued that Dante constantly pointed out the unsustainability of human behaviors both in terms of their physical and ethical consequences. Such correspondences can help grasp the dimension and the extension of the issues and the problems faced.

The experience was positive for all those involved. For the tutors, it was very satisfying to be able to deal with complex topics while teaching students who had not previously built knowledge and skills in this specific technical-scientific field, by using a multi- and inter-disciplinary learner-centered approach. From their point of view, the students expressed their sense of the ease with which they managed to understand such scientific topics thanks to the correlation with the literature already known to them. Not only did this facilitate learning of new content, but also enable a vision that goes beyond the perspective of science and humanities as separate disciplines.

Overall we believe that such integration of literary and scientific contexts in terms of ecological indicators and their various related impacts helps students understand the

relationship between the sustainability of human and environmental trajectories.

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The pictures of Posters 1, 2, 3, 5 and 6 are taken from Paul Gustave Doré, Dante, *Divina Commedia - Inferno* (1861)

The picture of Poster 4 (Medusa) is taken from Caravaggio, Uffizi Gallery (1597)

The pictures of microalgae are taken from <https://oceanservice.noaa.gov>, www.inlandbays.org, www.researchgate.net.