1. Title

A Naturalist Who Became a Pioneer of Experimental Marine Oceanography in Portugal Assets for Science Education

Keywords: History of Science; History of Oceanography; Nature of Science; Biology Education; Science Education; Science Museums

2. Author(s) and Institution

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This case study results from a partnership between the Institute of Education of the University of Lisbon and The Aquarium Vasco da Gama.

3. Abstract

The case of D Carlos de Bragança, King of Portugal from 1889 to 1908 and a pioneer oceanographer, serves as an occasion to explore biological classification, specimen collecting and scientific illustration (biological drawing). The proposed activities help students to develop a deep understanding about the nature and methods of science and an awareness of the complex interactions among science and society.

The activities are focused on the work of King D. Carlos, who dedicated himself to the study of Portuguese coastal fauna, and were addressed to Secondary Biology students (levels 10 and 11). They include a pre-visit orientation task, two workshops performed in a science museum (Aquarium Vasco da Gama) and a follow-up learning task. In class, students have to analyse original historical excerpts of the king's work, to discuss and reflect about the nature of science. In the museum, students actively participate in a set of activities related to biological classification and specimen drawing.

The general proposition underlying this case study is that engaging students in an activity that involves a field trip to a science museum, extending it by adding a historical dimension, constitute a compelling context for learning about scientific practices and concerns over time. Additionally, it highlights the importance of the use of science museums as an excellent context to develop activities embedded by history of science, since many of them possess historical collections that represent unique resources, rarely available in schools.

4. Case Study description

The central theme of the activities is the work of D. Carlos de Bragança, king of Portugal (1889-1908), a pioneer oceanographer who dedicated himself to the study of Portuguese coastal fauna and leaved a legacy of scientific knowledge. The king dedicated himself to the study of the sea and tried to accumulate data in a systematic mode. During 12 years of oceanographic campaigns (1896 to 1907) along the Portuguese coast, D. Carlos collected a large zoological collection with great historical and scientific value. Besides their biological value, this collection is largely valued by D Carlos numerous personal observations about some aspects of the ecology of the species, their economical value and fishing methods used, as well by the drawings and water-colors he produced. In addition, the King also had an extraordinary role in scientific public divulgation. He organized a large number of national and international exhibitions, representative of the biological diversity of Portuguese coast.

The activities are designed to run both in class and in a local Aquarium, the Vasco da Gama Aquarium. In a pre-visit orientation class, students analyse two excerpts of the king's diary related to the 1897 oceanographic campaign, and respective laboratory reports, in order to discuss different forms of scientific reporting and to compare different methods of collection and preservation of biological specimens. In the Aquarium, students participate in two workshops about biological classification and specimen drawing. In the follow-up activity, students analyse excerpts of texts of a contemporary Portuguese oceanographer, Luíz Saldanha, about the king's scientific work and about the scientific historical context of the time, in order to discuss and reflect about the nature of science and scientific work.

5. Historical and philosophical background, including the nature of science

In the beginning of the twentieth century the study of the sea was giving its "first steps". For example, life at great depths was not accepted by the scientific community, even in the presence of numerous evidences, because of the work of Edward Forbes, in 1841 in Egean Sea. According to this researcher, life wasn't possible below 660m depth because of the absence of light and low temperature, characteristic of these depths ("azoic zone theory"). Scientists were so convinced about this wrong idea, that Barbosa du Bocage, another Portuguese dedicated to the study of the sea, in 1864, when describing a new species collected by local fishermen, didn´t refer that it was collected deeper than 660 m. Only 7 years later, in 1871, he disclosed that information, after a number of similar evidences similar came out all over the world. One of these evidences was obtained in Portugal, where local fishermen (from Setubal and Sesimbra) were used to catch sharks at 1200m depth.

D. Carlos de Bragança, King of Portugal from 1889 to 1908, dedicated himself to the study of the sea and tried to accumulate data systematically. During 12 years of oceanographic campaigns along the Portuguese coast, D. Carlos collected a large inventory of the Portuguese faunal coast. The King made numerous personal observations, concerning the geographical distribution, behavior, fishing methods and economical value of the described species. He also made drawings and water-colors illustrating rigorously specimens and natural phenomena. In addition, the King also had an extraordinary role in scientific public divulgation. He organized a large number of national and international exhibitions with the

zoological specimens and the oceanographic instruments used for collection (e.g. 1897, Science Museum of Lisbon; 1898, Aquarium Vasco da Gama; 1902 and 1903-1904, Science Museum of Oporto; 1904, Geographical Society of Lisbon; 1906, Science Museum of Milan, Italy). Some collected specimens were also sent to Natural History Museums of Paris and London.

D Carlos' legacy was remarkable for scientific knowledge and methodological innovation, setting together a naturalistic point of view through scientific illustration, and an experimental approach with a range of collecting procedures whose data he systematically registered. The logs filled with beautiful water-colours, field notes, data and calculations, the zoological collection, and the instruments from oceanographic campaigns he leaded are part of the permanent exhibition of the Vasco da Gama Aquarium located near Lisbon.

The Vasco da Gama Aquarium is a scientific and pedagogical institution, which opened its doors to the public in 1898, during the 4th centenary celebrations of the discovery of the sea-route to India by the renowned navigator Vasco da Gama. 100 years later, the Aquarium still plays a fundamental role in the divulgation of Aquatic Biology in Portugal.

6. Target group, curricular relevance and educational benefits

The activities are addressed to secondary students of Biology, with an age between 15 and 18 years (10th and 11th grades), and are related to the curriculum themes of biological diversity, systematics and the nature of scientific investigation.

General learning objectives are:

Substantive and procedural knowledge

- *To develop a better understanding of the diversity of Portuguese coastal fauna*
- *To understand the importance of the observation and data report in Biology*
- *To understand the role of scientific illustration in the study of life*
- *To understand the importance of taxonomy and systematic by the use of dichotomic keys*
- *To know the work of the King D Carlos*
- *To contact directly with original documents and features*

Epistemological knowledge

- To develop a deeper understanding of the nature of science
- To understand the relations between science and society
- To understand how the scientists work

- To understand the transitory nature of the scientific knowledge

Communication

- To use scientific language
- To analyze and interpret different sources of information in different media
- To present and discuss different ideas
- To use technology for information search and presentation

Reasoning

- To solve problems
- To interpret data
- To carry out inference
- To evidence relationships

Attitudes

- Curiosity
- Perseverance
- Aesthetic sense
- Creativity
- Value evidence
- Critical reflection
- Capacity of observation
- Scientific accuracy
- Respect for the others opinion
- Collaboration

The project's evaluation procedures (observation, questionnaire, interview, analysis of students' activity sheets) evidenced that students seemed motivated and involved since they all kept participating throughout the activities. Students considered the project popular and relevant for science learning. All of them stated that it was important not only for knowledge acquisition but also to the understanding of the nature of science. In addition, they also expressed that they felt highly motivated by the activities, recognizing the necessity to implement more often this kind of activities in science classes. The majority of them considered that the historical approach was important for the comprehension of the nature of science. Finally, students admitted that the activities contributed to change their vision about how scientific knowledge develops, namely that it is always changing and undergoes several influences, and about how science is made.

7. Activities, methods and media for learning

<u>Pre-visit orientation class</u>
Students analyse two excerpts of the king's diary related to the 1897 oceanographic campaign and respective laboratory reports in order to:

- discuss different forms of scientific reporting either in the laboratory or in the field;

- deal with methods of collection, preparation and preservation of biological specimens, and compare the methods used in past with present ones;
- reflect about the psychological qualities of scientists.

Aquarium Workshop 1: Biological classification
Students are introduced to the king's work, collection and scientific methods. Furthermore, they compare actual biological classification methods with those developed by the king, and classify a group of marine organisms, present in life exhibition of the Aquarium, with a dichotomous key.

Aquarium Workshop 2: Biological drawing
Students are introduced to biological illustration and drawing techniques, based on observation. Furthermore, they observe and draw some marine organisms, present in life exhibition of the Aquarium.

Both workshops have a theoretical session and a practical session.

Follow-up activity Students analyse excerpts of texts of a contemporary Portuguese oceanographer, Luíz Saldanha, about the king's scientific work. They are asked to reflect about how scientific knowledge is constructed and about the importance of scientific publication.

The main strategies used in these activities are collaborative work, discussion, interpretation of historical documents, internet research, analysis and contrast of different ideas (biological classification systems) and methods for collecting data, use of dichotomous keys, observation and description of living beings, scientific drawing.

8. Difficulties in teaching and learning

The main difficulty is related with the analysis of the historical documents because of the old fashioned writing style characteristic of the Portuguese language used in the end of the XIX century.

9. Pedagogical competencies

Concerning school activities teachers are asked to:

- Supervise students' collaborative work which involves document analysis (in the activity sheets), discussion, and information search on Internet;
- Update both their knowledge about history of science (in particular related to the topic in study), and experience about how to integrate history of science in science teaching;
- Dialogue with the museum staff in order to promote an adequate integration of in school and in museum activities.

10. Documentation research evidence of studies

Several methods of data collection were applied in order to assess the effectiveness and applicability of the activities under study. All the sessions in which the activities were implemented were video and audio recorded. In addition, a record of students' behavior was registered by one of the researchers in the context of participant observation. All documents produced by the students were collected and subjected to content analysis.

When activities concluded students answered to a questionnaire in order to present their perception towards the activities. This questionnaire was inspired in one developed by the European Project PARSEL - Popularity and Relevance of Science Education for Scientific Literacy (www.parsel.eu) and included 20 questions. A Likert scale of five terms was used to register the intensity of response. The terms ranged between 1, total agreement and, 5, total disagreement. The questions were organized in five dimensions: general perspective about science teaching and the importance of teaching history of science; feelings towards the activities; perception about the relevance of biological sketching/drawing activities, the importance of the history of science, and the promotion of affective and cognitive competences. The questionnaires' responses were submitted to a statistical descriptive analysis. At the end of the activities one student (n=5) of each group (chosen by the group) was interviewed with the purpose to obtain in-depth profiles of students' views about the following dimensions: popularity and relevance of this type of work for learning science, relevance of the scientific subject, relevance of the historical approach and their impact in students' ideas about the nature of science. These interviews were video and audio-recorded. Records were transcribed for content analysis in which coding categories emerged from searching the different meanings in students' answers, which were subsequently organized into different categories. The creation of these categories was influenced by the objectives and the theoretical scaffolding of the study.

11. Further professional development of users

Websites

http://aquariovgama.marinha.pt/PT/Pages/homepage.aspx

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12. Written literature resources

1. Scenario of the school activities with the worksheet:

- pre-visit
- post-visit

2. Workshops at the Aquarium (Brief description of the workshop activities to be developed in the Aquarium)

3. Students' questionnaires

Post visit orientation
Follow-up learning activity (in the classroom)

Analyze the following texts.

Text1:

"In Portugal, the interest in the organisms was not already a dead letter and in the principles of the nineteenth century several works are already published by Royal Academy of Sciences of Lisbon, written by Constantino Botelho de Lacerda Lobo and an anonymous, where the fish and the state of fisheries of Algarve and the rest of the country were presenting. In one of these works (1815) the great depths to which some sharks live are indicated, as the gilled shark, fished at 450 fathoms deep. These data are important for understanding the progress of knowledge about the fauna of the deep sea. In the second half of the last century, the great naturalist José Vicente Barbosa du Bocage (1823-1907), founder of zoology in Portugal, focuses on a sponge new to science, giving the name *Hyalonema lusitanica*, and that is brought by the fishermen of deep sharks of Setubal. These, together with those of Sesimbra and Algarve, has long had developed a longline fishery - long lines with hooks - that allow them to reach depths of 1200m. Attached to the hooks had other animals such as sponges and sea fans. Bocage, that also publishes on cartilaginous fish, in collaboration with Felix de Brito Capello (1828-1879), described in 1864, a new species, the deep shark *Centroscymnus coelolepis.*

The evidence of life in the deep ocean, although had been obtained by many scientists since the beginning of last century (and our Lacerda Lobo was a pioneer in this area), were challenged by the scientific community based on the work of Edward Forbes at Egean Sea, in 1841. This researcher, following the dragging he made, has postulated the principle of scarcity or absence of life below 300 fathoms deep. Indeed, the lack of light, cold and pressure were certainly factors that prevented the existence of life. The principle were known as the "theory of Forbes' azoic zone," and impressed so much the minds of the time, that even after the discovery of more compelling evidence of the existence of life at greater depths, many scientists have treated the subject with utmost caution. This is why Barbosa du Bocage, when in 1864 described the *Hyalonema lusitanica*, by prudence didn't mention the depth of collection. Only in 1871 he did it, after reflecting on the overwhelming evidence accumulated since then, which included the dragging of Percevel Wright off the coast of Arrábida in 1868. He justified himself by saying that although there was unanimity in the testimony of the fishermen, he thought they exaggerate and that the animal should live a depth less than that laid by Forbes as the limit of marine animal life.

Forbes's theory was in fact so rooted that it was truly a scientific stubbornness. Interestingly, the fishermen of Setúbal captured sharks at 1200m deep, while scientists doubted the existence of life below about 550m deep. In this regard, D Carlos wrote in his work on the sharks of Portugal (1904): "We all know that in an epoch in which they discussed the lack of animal life, especially for the complex animals, beyond a certain depth, our longline fishermen normally fished sharks of great depths, and brought accidentally, hooked to their apparatus, large sponges (*Hyalonema, Askonema*). To them

we owe the discovery of a number of new species, some of whom still known only in our seas. "

(Taken from Luiz Saldanha, 1996. *Sea explorations* In: D Carlos de Bragança - The Passion of the Sea, edited by Parque Expo 98, SA, pp. 32 and 33)

1. What is the scientific dilemma discussed in the text? *Does life exist only up to 300 fathoms (660m) deep?*

2. Comment the following statement:

"Sometimes the knowledge prevalent in the scientific community influence its evolution along time". *Students should refer to the following: - Sometimes the existing knowledge, because they are too embedded, make it impossible to understand new discoveries and their integration into scientific knowledge accepted by their community;*

- In the text is discussed an example in which although there are already plenty of evidence of the existence of life beyond the boundary drawn by Forbes (e.g. sharks catch at 450 fathoms deep), the "theory of Forbes' azoic zone" continued to be accepted as valid scientific knowledge.

3. Comment on the importance of the accumulation of facts that are not explained by the dominant scientific theory for the evolution of knowledge. *In answering this question students should emphasize the importance of the appearance of facts not explained by theories accepted by the scientific community as a driver for the need to review the existing scientific knowledge so that it can explain the new evidence.*

4. Based on the situation described in the text, discuss the possible contribution of common citizen (non-researcher) for the evolution of scientific knowledge. *Sometimes the common citizen in the course of their day-to-day routine, observe certain aspects of the natural world that are not known by the scientific community. In some cases this knowledge can contribute to the evolution of scientific knowledge. In the example given in the text, the fishermen have long been known of the existence of life beyond the boundary drawn by Forbes.*

5. How do you assess the importance given by the scientific community to the knowledge built by common citizen compared to that generated by the researchers. *The knowledge built by common people is in most cases devalued or ignored by the scientific community. This may be due to several aspects, such as the acquisition of this knowledge does not follow the accepted procedures for the construction of scientific knowledge (methodologies of data collection, accuracy in observation, interpretation of observations, theoretical foundations, etc.); there are no communication between the scientific community and the society; etc.*

Text2.

"The sharks obtained on the shores of Portugal during the campaigns of 1896-1893, are published in 1904 and they represent an excellent work on the shark Portuguese fauna. The work is drawn along the lines that D Carlos has always promoted, because they are seen as the best that could contribute to the knowledge of the biology of the species, of which there were a remarkable ignorance. If, for example, they reasonably knew the

species of the Portuguese oceans, they didn´t know almost nothing about their geographical and bathymetric distribution. The publication of critical books, where, in addition to quoting the species, figured their habitat, breeding seasons and migration, as well as the methods of capture, was to D Carlos, one of the major objectives to be achieved not only for their scientific value but also because of the utility that may have to support the fisheries research.

D Carlos bases his work on sharks in a masterly way. After an introduction, in which he describes various methods of fishing and in particular the longline, that provided the best examples of his collections, introduced the systematic study of the species, with their synonymy and references to the various authors that have already referred to them. He also give its common names in Portuguese and French, the list of specimens captured in its oceanographic campaigns, indicating the size, sex and the presence of fetuses, date and depth of capture, stomach contents, color, and the presence of internal and external parasites. He also states what part of the animal we could use for economic purposes.

He compares also some species with each other and make critical remarks about the status of conservation of some of them. Finally, he presents tables with the bathymetric distribution of the thirty-two species studied and keys for their identification.

In his work, he also outlines an ecological classification of the various sharks, distinguishing between the coastal sedentary, coastal pelagic and abyssal, although recognizing that the distinction between these categories can sometimes be difficult. The abyssal presented, for example, a dilatation of the pupil that highlighted the green-metal of the retina, giving an appearance of phosphorescence to the eye, that was not real even in total darkness.

The merit of his work is also the clarification of several issues that were less clear concerning the abundance of some species, such as *Centroscymnus coelolepis*, hitherto considered rare. It also refer the presence in the Portuguese waters of the species *Chlamydoselache anguineus*, known only in the seas of Japan, Norway and Madeira until then, and says: "It was a real surprise to me, recognize in a fish that fishermen from Cezimbra brought to me, an exemplar very well preserved, of this species".

One of the crowns of glory have been a description of a new species, which he called *Odontastis nasutus*, a shark with a long face, that had been reported six years ago, in the seas of Japan, by David Starr Jordan, under the name of *Mitsukurina owstoni*. The slowness or difficulty in obtaining scientific publications, which then would be very difficult, are probably responsible for the fact, but it does not minimize in any way the work of D Carlos. Moreover, it is Girard that claims that D Carlos was extremely cautious when he doesn't knew the specimens captured, not falling into the temptation of immediate describing new species. He prefer to accumulate data, study and then decide."
(Taken from Luiz Saldanha, 1996. *Sea Explorations* In: D Carlos de Bragança - The Passion of the Sea, edited by Parque Expo 98, SA, pp. 76 and 78)

6. Compare the methodology used by King D Carlos in their publications with the records of the oceanographic campaigns (remember pre-visit activity). *In the records of the*

oceanographic campaigns the King merely recorded the data collected at each station. Only later, in the publication of the data, exists an integration and interpretation of all information collected to enable the classification of the captured organisms (sharks). Moreover, these data are presented in a more general context of scientific knowledge known about the species under study.

7. Investigate about the importance of studying the stomach contents to enhance the knowledge of the species.
The analysis of stomach contents can be used for discovery of new species and is an excellent indicator on a number of aspects of the ecology of the species, in particular, its habitat, feeding mode, depth of living, migrations done, etc.. Students can recall here the concept of gastrolits and coprolites.

You can search the following sites:
http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0034-71081998000400011
http://periodicos.unitau.br/ojs-2.2/index.php/biociencias/article/view/148

8. In the Aquarium Vasco da Gama, you classified a group of biological organisms. Compare the criteria you used there with those used by King D Carlos in the classification of sharks. *In work carried out in the aquarium, the classification of organisms were based solely on morphological features (biological classification), while the King's was based on aspects of the ecology of the species (ecological classification).*

Based on the two texts:

9. Investigate the importance of scientific publication for the validation of scientific knowledge. *With this question it is expected that students understand that for knowledge to be scientifically validated it must be published in a scientific journal. This process is crucial because it allows the validation of new knowledge for the rest of the scientific community and its dissemination.*

10. As you noticed, many scientists are concerned to examine closely the evidence to the point where they are irrefutable before it is published. As you have already studied, Charles Darwin was also afraid to report their findings because they would undermine the current knowledge. Discuss the weight that society, in its various dimensions (religious, economic, etc.), may have on the construction of scientific knowledge.
In answering this question students should refer that the construction of science is closely related to the society in which it operates, that is, scientists are an integral part of their society, suffering direct and indirect influences of the same (e.g. economic pressures; ethical issues; religious issues, etc.).

11. Represent through a drawing the following fish specimen. Back to use the fish in the pre-visit activity. Students must be careful to do the draw according to what they have learned in the workshop of the Aquarium Vasco da Gama (accuracy of observation and of recording).

Note: one fathom equals 2.2m

Pre-visit orientation activity (in the classroom)

These activities are focused on the work of D. Carlos de Bragança, king of Portugal (1889-1908), a pioneer oceanographer who dedicated himself to the study of Portuguese coastal fauna and leaved a legacy of scientific knowledge. During 12 years of oceanographic campaigns (1896 to 1907) along the Portuguese coast, D. Carlos collected a large zoological collection with great historical and scientific value.

Before start reading the following excerpts related to one of the oceanographic campaigns led by King D Carlos, imagine for a moment if you were a King…

1. What reasons might you have to go out on a research expedition yourself? (Would you go?! Why or why not?)
2. What records would you keep? Why?
3. Considering the specimens collected along the campaign, how might you preserve them for a long-term reference and study? (Think about modern techniques for preserving food, like sun-drying, pickling, canning, freezing…what advantages or disadvantages do those methods have for preserving biological specimens?)
4. What would you expect the experience to be like?

Read carefully the following excerpts taken from the "Nautical Diary of the Yatch Amelia - Oceanographic Campaign held in 1897" (see in Annex I the original documents of King D Carlos) (documents written in Portuguese language from the nineteen century).

On May 7, 1897
We suspended at 7h20am - clear sky, little wind from NE.
At 8h20am we put in the sea 12 fish-sets at 238m deep (Cabo de Cezimbra 24 NE - Espichel 24 NO).
While the fish-sets were fishing, pelagic fisheries were made with good results: three Mantellas; Beroes; other Ctenophorus; Physophorus; macrurus shellfish, and crustacean larvae brachyurus; at 10h45am we wanted to harpoon a Rolim (Orthagoricus mola), the harpoon hit him, but let him go, and disappeared.
At 11am the fish-sets were collected = they brought three species of sharks and merlucius. One of the sharks carried parasitic crustaceans of the genus Pandarus =

At 12h20pm we launched the drag at 137m deep (Espichel 23 NO - Castle Cezimbra 40 NE) = up to the 1h45pm (Espichel 32 NO - Castle Cezimbra 18 NE). Brought Comatulas a.a, Turritella, and a few crustaceans = at 2h45pm it was launched again at 73m deep, near the coast off Cezimbra.
up to the 3h45pm = little result.
Girard and I boarded at 4h10pm in the whaleboat to do some littoral dragging near the Penedo beach, gave no result. Before returning on board we made some pelagic fisheries,

with very good results.
At 6h20pm we stopped again in the bay of Cezimbra. We got more fish between 800m and 1200m. The following fish: Rat Fish (Malacus levis); Emperor (Beryx decadactylus); Hall (Beryx?), Hake (Phycis); Cantharilhos (Sebastes), and several sharks

May 27, 1897
We dropped from Cezimbra at 8am. Cloudy weather. Wind NW regular. At 9am we dropped out the drag (Cape d'Ares 68 NW - Palmella 32 NE) at 75m deep. It was raised at 9h35am - virtually no results - dead shells) Avicula; Cardita; Venus; Calyhtraea, and a Pandora alive = the drag was dropped at 10h10am 38m (Ponta da Escada 72 NW. Palmella 11 NE) put it in at 10h45am (Ponta da Escada 69 NW - Palmella 5º NE) bringing: 2 Pleuronectes, and some shelfish = the net fish came all cut and got damaged = was changed and at 11h and released again (Convento da Arrábida 38 NO - Malha da costa 40 NE) at 62m deep
Was suspended at 11h30 for picking up the bottom bringing:
Fish: Callyonimus (a.a); Lepadogaster (af);
Tunicates: Ascidians (a.a);
Crustaceans: Galathea (a.a); Amphipoda
Shellfish: Inachus (a.a) Artemis (a.a) Venus (a.a) Astarte (a.a)
Echinoderm: Ophiurideos (a.a) Echina.
Bryozooary: (a)
Augmented some cause the sea we demanded to the Setubal port and we anchor in Troia at 1h30pm. In order to fix the equipment. At 3h I went in the whaleboat to do some drags in 30m in front of Troia - Spongiary: Crustaceans (Henorpyrechus). At 5am we gave three chinchorros which yielded the following species: Sea Bream, Sculpins, Breams, Sole, Plaice (Arnoglossus mycrochirus); Gobius; Redheads, Raccoons, Uge; Tremelgo; Hypocampus; Wrasses (Crenilabrus); King Fish (Atherina), Mackerel and Petinga; Trathurus = traps anchored in the Cezimbra bay at 18m we obtained 2 Wrasses, 5 Breams, 6 Sea Bream, 1 Mackerel, 1 Pic; 1 Salema.

- **1.** What kind of information is recorded in the Diary? *Students can refer to some of the following information: weather, geographical location, bathymetry, methods of collection, species collected.*
- **2.** How would you classify the work of King D Carlos according to existing jobs? Justify. *It is assumed that the students identify the king as a scientist dedicated to the study of oceanography. The justification should be based on data from the text.*
- **3.** What characteristics do you consider important to develop this type of work? Based your answer on examples of the texts. *In answering this question it is expected that students relate some aspects underlying scientific activity, such as persistence, accuracy, etc.*
- **4.** List the collection methods used by King D Carlos. Analyze whether these methods are still used today in research. *Based on the analysis of the text, students must identify the following fish equipment: pots, dredges, chinchorro, trawl fishing harpoon. Based on the research students may refer that these methods are still used today, but are complemented by less destructive methods such as scuba diving.*

You can search the following sites: http://www.horta.uac.pt/port/pesquisa/marine_ecology_1.html

Analyze the records of King D Carlos from the oceanographic campaign of 1897 (in Annex II), in which are summarized the results of the collections made in each workstation, after laboratory analysis of specimens.

- **5.** Compare concerning their nature these records with those described in the Diary of the yacht Amelia. *Students should highlight the differences between the field report and the laboratory report, referring that the second one should present more rigor, the information should be more systematized, etc.*
- **6.** Analyze the order as the species are presented in the record. Analyze the randomness of this classification. *Students should come to the conclusion that the species are grouped by the taxonomic group: Filo.*

You can search the following site or in your text-book: http://en.wikipedia.org/wiki/Filo

Read the following text:

"The first two yachts did not have laboratories and the preliminary study, preparation and preservation of specimens was a problem difficult to solve. It was however natural that at board there was a barn which store alcohol, formaldehyde, bottles and other material essential to the preservation of the specimen collected. (...) Because of these difficulties and since the places that he usually explore - Costa da Guia, the mouth of the Tagus river, Sesimbra sea - were near Cascais, D Carlos created a laboratory with aquaria in the Citadel of this town, to where the specimens were transferred, since it reached land. Between the collection and the aquarium, animals were transported in buckets full of water, for trying to keep them alive for two or three hours. With the means at its disposal, D Carlos says he has obtained outstanding results in the preparation and preservation of marine invertebrates and gives us hints about the processes used, which were in fact the best of his time. The use of glycerin, for example, allowed to keep the color of the specimens, which is important in its study and exhibition. In Amelia III, more spacious, D Carlos transformed a smoking room in a laboratory. (...) The furniture was supplemented by a table for writing and a large closet with books, dissection tools, chemicals needed to anesthesia, fixation and preservation of biological material, tow and cotton, as well as bottles of various sizes. Attached to the walls, suspended from the ceiling or on shelves, were the instruments used most often, such as bottles of water for water collection, thermometers, hydrometers and others. The installation was not perfect but allowed to work. In addition, the laboratory was able to be transformed in a dark-room, not only for photographic work but also to study the luminescence of fish and marine invertebrates. (...) The large fish, which could not be kept with alcohol or formaldehyde, had to be assembled dry and so they were sent to the Royal

Museum of Natural History, created by D Carlos in ther palace. " (taken from "Submarine Explorations" Luiz Saldanha In: D Carlos de Bragança - The Passion of the Sea, 1996).

Figure 1. Photograph of a microscophic preparation of plancton - crustacean (one of the first made in Portugal)

- **7.** Discuss the importance of carrying out laboratory work after the fieldwork. *With this question is intended that the students indicate the importance of conducting further work after the field work, including laboratory work, since because of the circumstances in which it is done, allow higher accuracy in the organization and interpretation of the data collected in the field. Furthermore, because of special equipment allow making observations that cannot be performed outside the laboratory.*
- **8.** Compare the methods used by King Carlos D with the current ones in preparation and preservation of the biological material. *Through the search, students must conclude that the procedures used by the King are very similar to those used today. However, there are some new techniques, such as cryogenics.*

You can search the following sites:

http://www.austmus.gov.au/fishes/faq/fixation.htm
http://www.airproducts.com/medical/pt/aplicaciones/criobiologia.html
http://www.dbi.uem.br/trabalhopratico.pdf

Observe the following watercolors of King Carlos (figures 2 to 5):

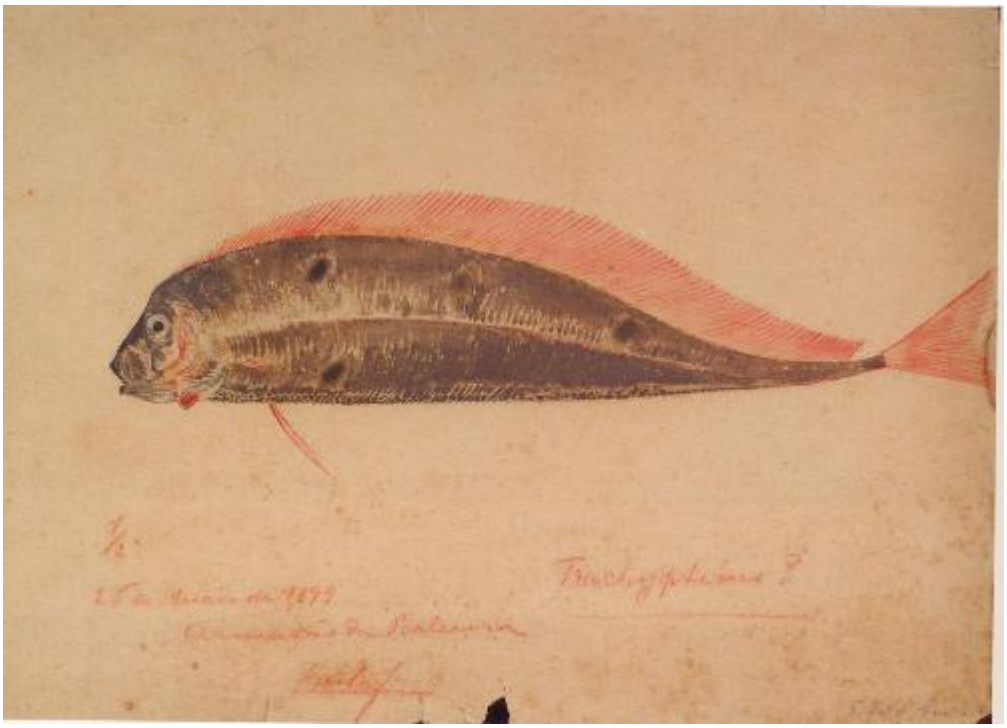


Figure 2. Watercolor and notes of King D Carlos about a fish specimen (1889) (*Trachipterus arcticus)*.

9. *Compare the two watercolors with the biological drawings of each species and argue which do you consider as an appropriate biological register. With this question it is intended that students understand they are dealing with two different forms of draw. For the first watercolor, there is a concern for accuracy, claiming to be a faithful representation of the specimen drawn. For the second watercolor, this is an artistic representation, which is not intended to be a representation close to reality. With this in mind, they should point the first representation as the watercolor that is most appropriate as a biological register.*

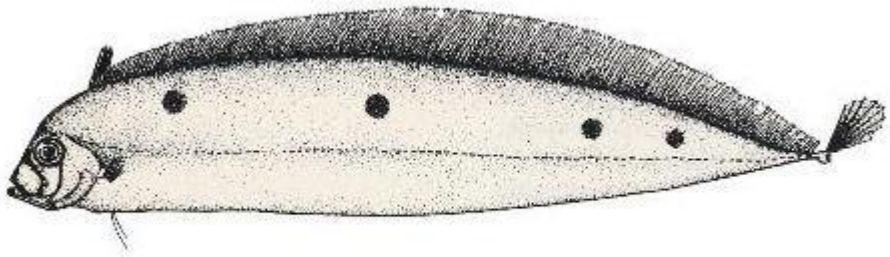


Figure 3. *Trachipterus arcticus*

(from: Check-list of the fishes of the eastern tropical atlantic, 1990, J.C. Quéro, J.C. Hureau, C. Karrer, A. Post e L. Saldanha (eds), UNESCO).

Note: to obtain more information about this species search the site: http://www.fishbase.org/Summary/SpeciesSummary.php?id=3265&lang=english

Figure 4. Watercolor and notes of King D Carlos about a fish specimen (1904) (*Alepocephalus bairdii).*

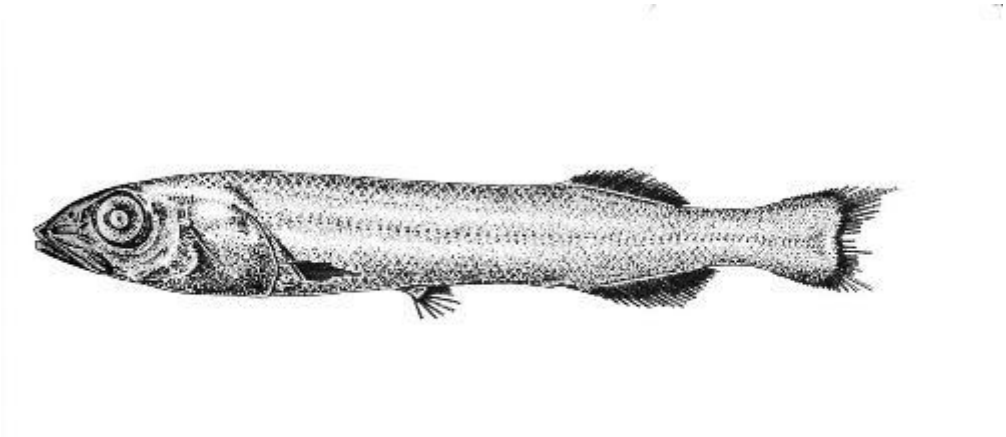


Figure 5. *Alepocephalus bairdii*

(from: Check-list of the fishes of the eastern tropical atlantic, 1990, J.C. Quéro, J.C. Hureau, C. Karrer, A. Post e L. Saldanha (eds), UNESCO).

Note: to obtain more information about this species search the site: http://www.fishbase.org/Summary/SpeciesSummary.php?id=230&lang=english

- **10.** Discuss the need to use the biological drawing method for the development of the scientific work. *With this question it is intended that students mention some of the following: understand the need to make accurate drawings of the specimens in order to know the species even when we do not have access to actual specimens; the biological drawing contributes to a greater understanding of the biological structures.*
- **11.** Represent through a drawing the fish specimen provided by your teacher. *To this activity is necessary to bring to the class a specimen of a fish. (note: it is necessary to freeze the specimen to be re-used in post-aquarium activity).*

Notes

Species

To obtain more information about some of the species collected by King D Carlos search the following sites:

Fish

- *Beryx decadactylus*: http://www.fishbase.org/Summary/SpeciesSummary.php?id=1319&lang=english
- *Phycis blennoides*: http://www.fishbase.org/Summary/SpeciesSummary.php?id=1340
- *Spondyliosoma cantharus*: http://www.fishbase.org/Summary/SpeciesSummary.php?id=1356&lang=english
- *Lepidotrigla cavillone*: http://www.fishbase.org/Summary/SpeciesSummary.php?id=1722&lang=english
- *Sarpa salpa*: http://www.fishbase.org/Summary/SpeciesSummary.php?id=204&lang=english
- *Sarda sarda*: http://www.fishbase.org/Summary/speciesSummary.php?ID=115&genusname=Sarda&speciesname=sarda

Crustaceans http://pt.wikipedia.org/wiki/Crust%C3%A1ceo http://www.geocities.com/maquaticos/crustaceos.htm

Shelfish http://pt.wikipedia.org/wiki/Moluscos http://curlygirl.no.sapo.pt/moluscos.htm

Equinoderms: http://pt.wikipedia.org/wiki/Equinoderme http://www.naturlink.pt/canais/Artigo.asp?iArtigo=15634&iLingua=1

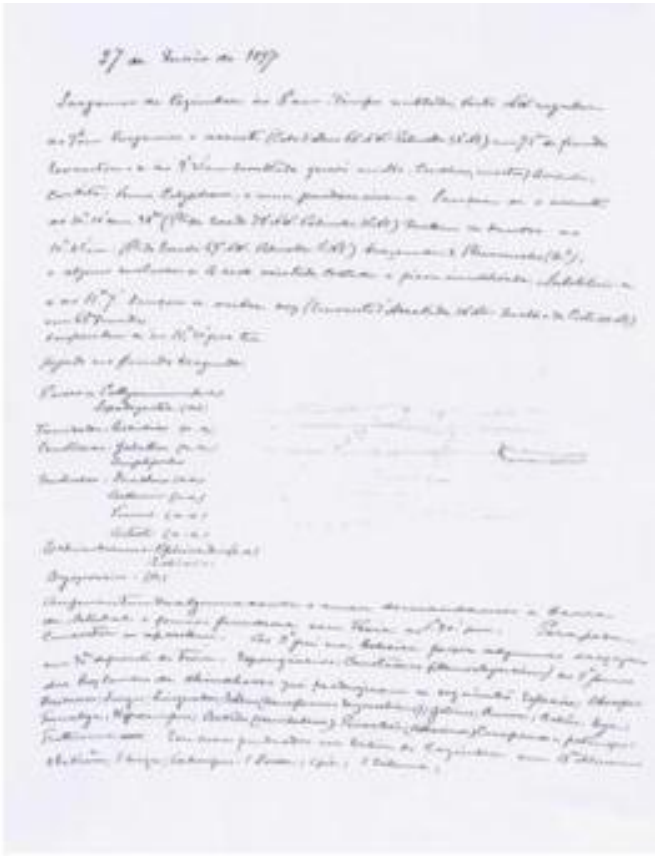
Fishing Gear

(From: C. Nédélec, 1986, Definition and classification of categories of fishing gear, National Institute for Fisheries Research).

- Pots**:** Traps round about 40cm in diameter and with only one entry. Made of wire. Suitable for capturing shellfish and crustacean.
- Drags**:** gears revolving fund, usually to catch shellfish (eg mussels, oysters, scallops, clams). The catches are held in a kind of bag or sieve which allows the output of water, sand and silt.
- Chinchorro**:** Art of trawling generally used for fishing eel, plaice, sole, sea bass and crabs. The network is launched in a circle.

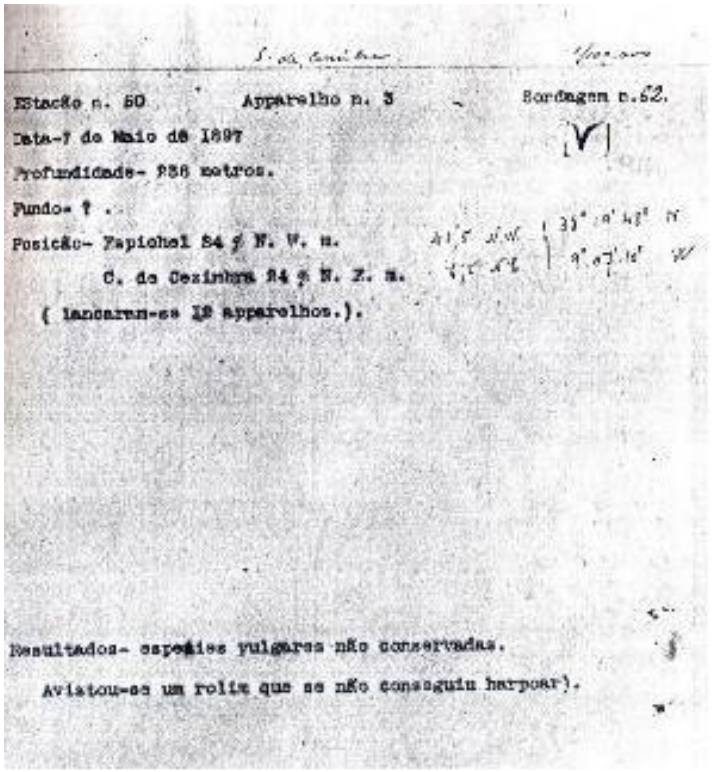
Annex I.

"Nautical Diary of the Yatch Amelia - Oceanographic Campaign held in 1897"

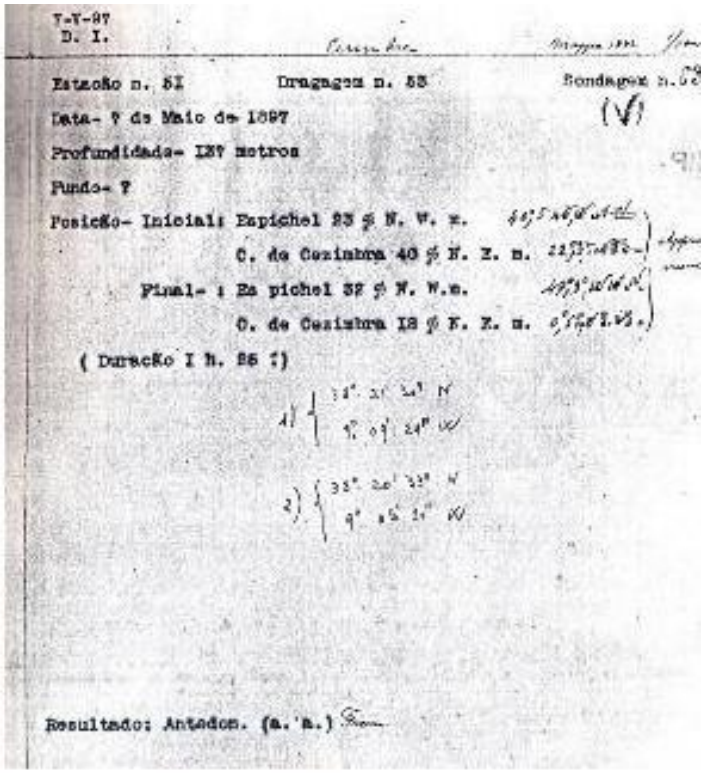


Annex II.

Reports of the Oceanographic campaign of 1897



Estação n. 50 Apparelho n. 3 Sondagem n. 52.
Data- 7 de Maio de 1897
Profundidades- 936 metros.
Fundo- ? .
Posição- Papichel 84 ° N. W. m.
C. de Cezimbra 84 ° N. E. m.
(lançaram-se 12 apparelhos.).
Resultados- espécies vulgares não conservadas.
Aviatou-se um roliz que se não conseguiu harpoar).



Estação n. 51 Dragagem n. 53 Sondagem n. 53
Data- 9 de Maio de 1897
Profundidades- 137 metros
Fundo- ?
Posição- Inicial: Papichel 83 ° N. W. m.
C. de Cezimbra 40 ° N. E. m.
Final- : Papichel 32 ° N. W. m.
C. de Cezimbra 18 ° N. E. m.
(Duração 1 h. 25 ')
Resultados: Antedon. (a. h.)

Students' Questionnaire

Please mark with an "X" the option with which you most agree:
1-Totally agree, 2-Agree partially, 3-Neither agree nor disagree, 4-Disagree partially; 5-Strongly Disagree

	Statements	1	2	3	4	5
1	Learning science is interesting when it involves a discussion of a historic issue related with science					
2	Learning science is interesting when we can see how scientists work.					
3	Having to think a lot makes science more interesting.					
4	I think that my participation in this type of activities is important for my learning.					
5	Participation in more activities like this one would make science learning more interesting for me.					
6	The drawings that I had to do in these activities helped me to learn more about the organisms.					
7	With these activities became more aware of the characteristics of living organisms.					
8	With these activities I learned how to better observe living organisms.\					
9	With these activities I learned to describe an organism.					
10	The use of the drawing task make the activities more interesting.					
11	With these activities I understood how to use the classification criteria.\					
12	The historic issue of these activities helped me to understand the way we make science					
13	This type of activities helped me to understand the way knowledge is built.					
14	These activities helped me to understand the influence of society on the evolution of the scientific knowledge.					
15	Introducing the activity using an historic context made the activity interesting.					
16	I believe the discussions in this module were relevant for improving my reasoning skills.					
17	These activities made me think a lot.					
18	These activities encouraged me to share ideas with my friends.					
19	These activities encouraged me to ask questions.					
20	This activity provided me with opportunities to participate in group work.					