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HMS *Challenger* and SMS *Gazelle* – their 19th century voyages compared

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Abstract. This paper analyses the pioneering global voyages of HMS *Challenger* and SMS *Gazelle* in the 1870s – a time of rapid scientific advances and technological innovation. The voyage of *Challenger* has become well known as marking the start of the global-scale science of oceanography. The voyage of the *Gazelle* is much less well known despite the two voyages ending in the same year, 1876, and having similar geographical and scientific scope.

Rather than focussing on the scientific achievements, the paper concentrates on how the expeditions were planned and executed, the lives and characters of the personnel involved, and the underlying motivation behind the voyages. The paper presents the author's translations of key elements of the *Gazelle* reports as a means of introducing the *Gazelle* expedition to an English-speaking readership.

1 Introduction

In spring 1876, two naval vessels anchored in the River Plate in Montevideo, Uruguay, as they returned towards their home ports at the end of their multi-year circumnavigations (Fig. 1). The descriptions of their time in that port recorded in the official narratives differed markedly. The narrative of SMS[1] *Gazelle* (in port, 16–19 February) (Hydrographisches Amt der Admiralität, 1889a) comments that they found HMS[2] *Challenger* (in port 15–25 February) there and reached an agreement that the two vessels would follow different tracks towards Europe – *Gazelle* eastwards on 35° S and then northwards on 25° W and *Challenger* eastwards on 38° S and then northwards on 15° W. Surprisingly the official *Challenger* narrative (Tizard et al., 1885b) makes no mention of the encounter with *Gazelle*. It is, however, mentioned in the personal letters of Assistant Steward Joe Matkin (Rehbock, 1992) and on p. 194/5 of the travelogue of James Wild, the *Challenger*'s official artist (Wild, 1878). The *Challenger* narrative does, however, comment on the cost of beef and sheep meat in Montevideo.

This suggests that the two expeditions took rather different approaches to reporting. What were the other differences and the similarities, and how did the two expeditions relate to one another?

2 The historical, scientific, and technological context

The 1860s and 1870s were decades of invention, expansion, and change. At sea, steam and sail co-existed, (Harley, 2010), with many ships now powered with both sails and steam-driven screw propulsion using coal-fired boilers. Sails freed them on long voyages from total dependence on widely spaced coaling stations, while steam gave them greater manoeuvrability in light winds and in confined waters.

Politically, in Europe the decade started with the Franco-Prussian war, declared in July 1870. Prussian forces besieged Paris, and the navy of the North German States was blockaded in its home ports by the French fleet. Those navies were in the midst of the transition from sail to steam. In part, the blockade failed because of a shortage of coal supplies for the French. By February 1871, victory was declared by the newly founded Federal German state.

[1] Seiner Majestät Schiff (His Majesty's Ship).
[2] Her Majesty's Ship.

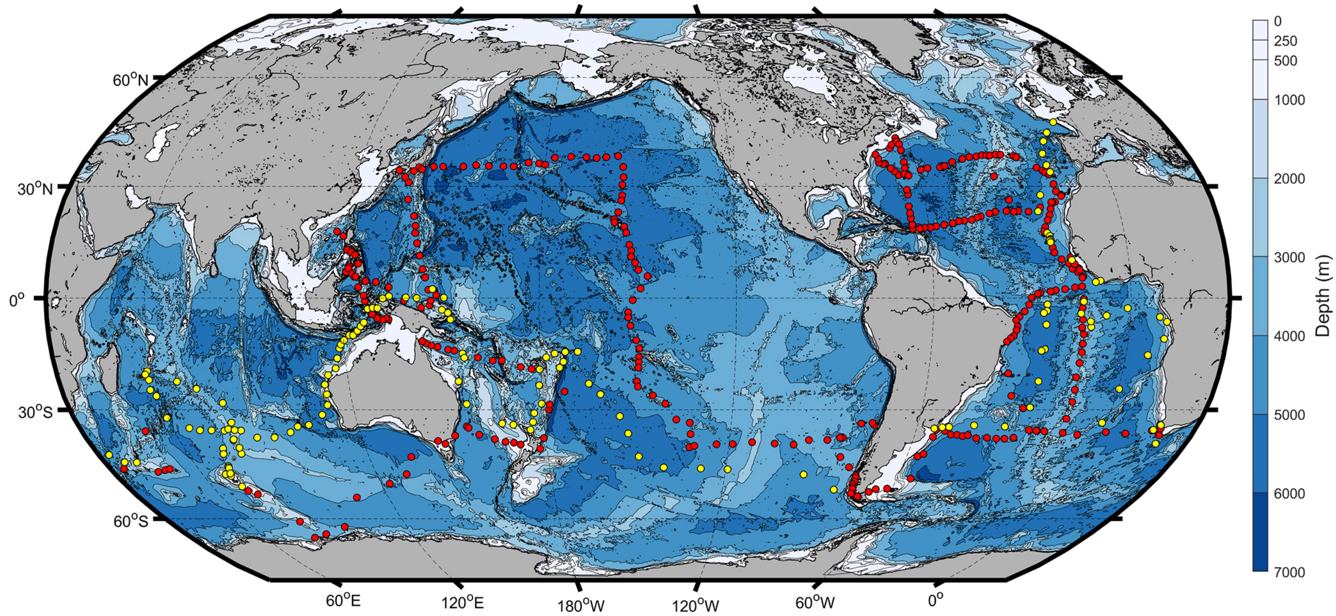

Figure 1. *Challenger* (red) and *Gazelle* (yellow) station positions overlaid on the now known (ETOP05) ocean bathymetry.

In Britain, 1870 saw the 50-year-old Queen Victoria start the 33rd year of her reign over Great Britain and Ireland and over an empire, with a population approaching 300 million spanning the globe. Communication across that empire was still largely by sea using fast mail ships. The building of the Suez Canal, a project led by the French but largely ignored by Britain, shortened passage times between Britain and India (Bell, 1965; see also https://wavellroom.com/2021/07/16/britain-suez-canal-strategy-1854-1882/, last access: 12 April 2022). Its opening in 1865 was a major event and presented an opportunity for a meeting of the world's maritime powers.

In June 1870, a new era dawned as the final connection was made in a telegraph cable linking Britain to India (By the mid-1860s, transatlantic telegraph messages could be transmitted at eight words per minute.) Laying and maintaining submarine cables brought about a growth in what we now call marine technology. Brunel's ship, the *Great Eastern*, had had an uneconomical life as a transatlantic passenger ship from 1859 to 1863 but in 1865 was converted for cable laying, a task she continued to carry out until she was laid up in 1874. Ships with suitable steam powered winches were needed to deploy the submarine cables and to recover them if they failed. Critically, knowledge was needed of ocean depths, not just close to land but along the entire cable routes, and of the nature of the seabed.

Many years of seafaring had resulted in the accumulation of a great deal of knowledge about the oceans' waves and currents. These were systematically analysed and summarized in Maury's *Physical Geography of the Sea* (Maury, 1855), an initiative perhaps in part stimulated by Benjamin Franklin's study of the Gulf Stream and Timothy Folger's map (Richardson, 1980) published in 1778 and by James Rennell's posthumously published study of ocean currents (Rennell, 1832).

Safe access to ports depended on knowledge of the state of the tides, and during the 19th century the number of places with systematic tidal observations, mostly in Europe and North America, grew. The understanding of tidal theory increased to the point where a tidal prediction machine could be built by Sir William Thomson in 1872 (Cartwright, 1999).

However, below the surface, the oceans remained unexplored and unknown save for the discoveries made on a small number of pioneering voyages, notably the research of Carpenter, Jeffreys, and Wyville Thomson on HMS *Lightning* and HMS *Porcupine* in 1869 and summarized by Wyville Thomson (1873).

The large-scale understanding of terrestrial geological features was at that time encapsulated in the various works of Charles Lyell between 1830 and 1868, notably his *Principles of Geology* (Lyell, 1830–1868). The development of the understanding of the terrestrial and coastal flora and fauna had been published in Darwin's *Origin of Species* (Darwin, 1859).

Photography was also becoming commonplace, and though, in the context of science, it allowed for the accurate recording of places and objects, it required cumbersome plate cameras and long exposure times and was not well suited to record activities.

This then sets the scene for two round-the-world voyages of ocean exploration conducted in the 1870s. One, that of HMS *Challenger*, is well known and resulted in an enormous volume of reports and publications, together with biological and seabed samples that continue to be analysed. The other, by the German naval vessel SMS *Gazelle*, is much less known.

3 Preparations and rationale for the voyages

Present-day expeditions with global scope require detailed and extensive planning and the commitment of substantial resources. The same was true in the 1870s. Both of these voyages were carried out using naval vessels, indicating national levels of commitment.

3.1 The naval and organizational context

Before the 1870s, there had been very few global-scale expeditions, and certainly a very small number had a significant scientific component. Most had been aboard British vessels – James Cook, HMS *Endeavour*, 1776–1781; George Vancouver, HMS *Discovery* and HMS *Chatham* 1792–1795; Matthew Flinders, HMS *Investigator* 1801–1803; and Robert Fitzroy, HMS *Beagle*, 1831–1836. Some carried civilian scientists, notably Joseph Banks with Cook and Charles Darwin with Fitzroy.

Less well known are the two voyages led by Jules Dumont-d'Urville aboard the French ship *l'Astrolabe* (1826–1829 and 1837–1840). Both had a Pacific and Australasian focus, but the second sought to reach the south magnetic pole (Dumont-d'Urville, 1842–1846). The 1857–1859 circumnavigation by SMS *Novara* (Scherzer, 1864) on behalf of the Austro-Hungarian Navy is also little known, but it carried seven scientists, and its investigations were guided by Alexander von Humboldt, who exhorted them inter alia to measure sea temperatures and ocean currents, using drift bottles, and to create benchmarks against which sea level change could be measured.

The *Challenger* and *Gazelle* belonged to very different navies. The Royal Navy was long-established and in the 1870s was arguably the sole global sea power, a position encapsulated in the phrase "Britannia Rules the Waves" originating in the 1760s[3]. The Royal Navy also had a long history of its ships carrying out global-scale voyages of exploration. So, the Navy's role in, and support for, the *Challenger* voyage is unsurprising.

The rationale behind the *Challenger* expedition is summarized in the introduction to Wyville Thomson's 1878 report on *The Atlantic* (Wyville Thomson, 1878), largely written while *Challenger* was still at sea. The report is dedicated to the Right Honourable G. J. Goschen, M.P., "the First Lord of the Admiralty under whose administration the *Challenger* expedition was organised", a clear recognition of the scientists' indebtedness to the Admiralty.

After describing many of the factors already touched on in Sect. 2 of this paper, Wyville Thomson states the following:

> and finally Dr. Carpenter addressed a letter to the First Lord of the Admiralty, urging the dispatch of a circumnavigating expedition thoroughly equipped, and with a competent scientific staff, to traverse the great ocean basins and prepare sections showing their physical and biological conditions, along certain lines. Dr Carpenter's letter was referred in due course to the Hydrographer to the Navy, who at once threw himself cordially into the project and prepared a report, which resulted in the Lords of the Admiralty agreeing to the dispatch of such an expedition if the Royal Society recommended it, and provided them with a feasible scheme. A committee was appointed by the Royal Society, and the comprehensive scheme was set up.

This was to be an unusual arrangement with a fully equipped naval survey vessel carrying out her normal duties as detailed in the sailing instructions issued to her commanding officer and yet carrying a team of distinguished, civilian scientists each with their own interests and more loosely defined objectives and with a recognized scientific leader. These potential tensions are alluded to by Wyville Thomson in the preface (p. xii) to Wyville Thomson (1878), but, clearly, they did not pose a problem.

> The somewhat critical experiment of associating a party of civilians, holding to a certain extent an independent position, with the naval staff of a man-of-war, has for once been successful. Captain Nares and Captain Thomson both fully recognized that the expedition was intended for scientific purposes, and I do not think that in one single case the operations of the combined scientific staff were hampered in the least by avoidable service routine. All the naval officers, without exception, assisted the civilian staff in every way in their power, and in the most friendly spirit. If I wished anything done I had only to consider who was the man, naval or civilian, who was likely to do it best; and the consequence has been that, with the entire sanction of Captain Nares and Captain Thomson, the parties sent to camp out or detailed for any special service have always been mixed, to the great advantage, I believe, of all concerned.

The Imperial German Navy (Kaiserliche Marine), by contrast, had only come into existence after the foundation of the German Reich in 1871. It grew out of the Prussian Navy and was headed by General Albrecht von Stosch (1818–1896) (Hollyday, 2017) (von Stosch did not became an admiral until 1875!).

The personal memoirs of Admiral Alfred von Tirpitz (von Tirpitz, 1919) provide some context in terms of von Stosch's leadership, of the new navy's primary objectives, and of the wider political climate.

[3]Now best known for its use in Sir Henry Wood's musical composition, Fantasia on British Sea Songs.

> Stosch (sic) started from the idea of developing Germany's maritime interests, of strengthening and protecting "Germandom" and German labour in the world.
>
> Stosch's increasing endeavour to further Germany's maritime interests in all directions was pursued under great difficulties from the beginning of his period of office. Foreign service at this time almost overstrained the resources of the navy. Every commander, however, could reckon upon Stosch's consistent support in his activities abroad, even in the often independent and difficult decisions which foreign service required as a result of the scarcity of cable connections. But this was not done without some friction with the Imperial Chancellor.

Von Tirpitz remarks that the continuing Prussian influences in Germany's government favoured the army over the new navy, which was seen as being tainted with links to commerce and trade.

> As far back as the seventies Stosch was convinced that we must acquire colonies and that we could not continue in existence without some means of expansion. He considered that the prosperity of the young empire would only be ephemeral if we did not counterbalance the decided disadvantage of our position and history overseas before it was too late.
>
> He attached great value to the posting of cruisers to foreign stations, and rightly too in his time.

There is however a clear hint that von Stosch supported the new navy being technologically and scientifically advanced.

> In the naval academy which Stosch founded at Kiel he inspired the right idea of teaching fewer special subjects and promoting general education and independent study. A great deal of mathematics was taught, besides philosophy, natural and nautical science (regarding which we sent many observations to the museums during our voyages), and astronomy, which in any case can be reckoned among the special sciences.

Von Tirpitz also remarks on the high esteem in which the British (English) Royal Navy was held, both in terms of military experience and technical prowess, as the following quotation makes clear.

> We grew up on the British Navy like a creeping plant. We preferred to get our supplies from England. If an engine ran smoothly and without a hitch, if a rope or a chain did not break, then it was certain not to be a homemade article but a product of English workshops – a rope with the famous red strand of the British Navy. In those ships which we had built ourselves things broke with uncomfortable readiness.

Remarkably there is a reference to *Gazelle* in the von Tirpitz memoirs, but it does not relate to her round-the-world voyage.

> It was seldom that the paths of the Prussian Navy crossed those of Prussian politics. When it did happen, it was generally in the way related to us by those who took part in the voyage of the *Gazelle* to Japan in 1864. A German ship had gone ashore in the neighbourhood of Yokohama and had been looted. The commander of the *Gazelle*, Captain von Bothmer, went thither with a landing party to protect it.

3.2 Scientific guidance and operational orders

The *Challenger* voyage came about as a continuation and expansion of the pioneering work aboard HMS *Lightning* and HMS *Porcupine* and was planned within the technological and political context of the 1870s. It was given strong scientific guidance delivered primarily through the Royal Society and to a lesser extent by deliberations within the British Association for the Advancement of Science. These coalesced into a report by the Royal Society's Circumnavigation Committee. The Committee was made up of officers and council members of the Royal Society and included Carpenter, Wyville Thomson, Gwyn Jeffreys (an expert on molluscs who had collected samples on HMS *Porcupine)*, Capt. Richards (the Admiralty's Hydrographer), the biologist Thomas Huxley (who came to be known as Darwin's bulldog for his advocacy of the theory of evolution), Sir William Thomson (renowned for his work on tides and his innovative work on submarine telegraphy and who had been involved in discussions within the British Association), and the botanist Joseph Dalton Hooker.

The Committee's report, finalized in August 1872, recommended where *Challenger* should go and provided details of the observations that should be made and the manner in which they should be carried out. Interestingly, the report was published by the US Navy (Navy Department, 1872) and so became widely available. The report was also published in *Nature* in the following January (Anonymous, 1873).

Here it is perhaps appropriate to mention just a few striking features of the guidance – first, balance; a single page is devoted to defining the route to be taken and four pages to physical observations under the headings of "Temperature (subsurface and surface)", "Movements of the ocean", "Tidal observations", "Bench-marks", "Specific gravity", and "Transparency of the water". Only half a page relates to chemical observations, five and a half pages to botany, and half a page to zoology. The concluding remarks also encourage the collection of ethnological information in remote communities.

The positioning of the depth sounding and sampling stations is prescribed only generally.

> In crossing the great ocean basins observations should be made at stations, the positions of which are carefully determined, chosen so far as possible at equal distances, the length of the intervals being of course dependent on circumstances.
>
> The simple determination of the depths of the ocean at tolerably regular distances throughout the entire voyage is an object of such primary importance that it should be carried out whenever possible, even when circumstances may not admit of dredging or of anything beyond sounding.

The following is also advised:

> Each station should have a special number associated with it in the regular journal of the day's proceedings, and that number should be noted prominently on everything connected with that station.

Interestingly, while it is recommended that the collection of subsurface temperatures should be carried out with thermometers and with "Mr Siemen's instrument" (see Sect. 6.3), it is implied that the collection of serial information using thermometers would be time-consuming and that compromises in sampling strategy might have to be made.

The guidance of the Circumnavigation Committee was primarily directed towards the scientific party, but, as with all naval voyages, the *Challenger*'s commanding officer was issued with sailing orders indicating where the vessel was to go and what tasks it should undertake and setting the rules under which the vessel should operate. *Challenger*'s sailing orders were issued to the captain and to Professor Wyville Thomson both by the Navy Hydrographer, George Henry Richards, and by Robert Hall, Naval Secretary of the Admiralty. These instructions appear on pages 34 to 40 of Tizard et al. (1885a) and contain the following instruction to Nares.

> The main object of the voyage is to investigate the physical conditions of the deep sea throughout the three great ocean basins, that is, to ascertain the depth, temperature, circulation &c., to examine the physical and chemical characteristics of their deposits and to determine the distribution of organic life, throughout the areas traversed, at the surface, at intermediate depths, and especially at the deep ocean bottoms.
>
> As secondary but by no means unimportant objects are the hydrographical examination of all the unknown or partially explored regions which you may visit, a diligent search for all dangers which may be in or near your track, with a view to expunging them from the charts or definitely determining their positions, a careful series of magnetical and meteorological data, and the observation and record generally of all those oceanic and atmospheric or phenomena, which, when faithfully recorded, afford the means of compiling practical information of the greatest importance to seamen. Your own experience as the commander of a surveying ship, and the general rules which have been issued from time to time by the hydrographical department for the guidance of Admiralty Surveyors – copies of which are supplied to you – obviate the necessity of entering into any detailed instructions on this head, and I will only observe that on all the coasts along which you may pass, and at all the ports which you may visit, I shall hope to receive from you such surveys and such complete hydrographical information as circumstances and the time at your disposal may enable you to accomplish.
>
> If anyone of the various objects of the expedition is more important than another, it may be said to be the accurate determination of the depth of the ocean, for on this must depend many other problems of deep scientific interest.

The route that was to be followed will be discussed later in this paper. However, the part of the sailing orders describing it was prefaced with the following.

> The general route which it is proposed the ship should follow is shown on a chart of the world which you are provided with, and although it is possible that it may be found necessary to deviate in some degree from the course there laid down and that you may not be able to adhere strictly to the dates assigned in these instructions, yet they are to be observed as far as circumstances will admit, and there must be no departure from the general programme without the special sanction of their Lordships.

The *Challenger* voyage was a major event in the history of the Royal Navy's Hydrographic Service and in the career of Richards (knighted in 1877 and promoted to the rank of Admiral in 1885), as is remarked in Dawson (1885).

> At the close of 1872, the chief event of Sir George Richards' official career as hydrographer took place, in the sailing of the *Challenger* on a scientific voyage of three years' duration. There is no doubt but that he was the prime mover in that undertaking from start to finish, not only in a scientific sense, owing to his position as one of the

> Council of the Royal Society, but especially as regards the more practical and less pleasant portion of his official duty, in successfully overcoming any monetary objection raised against its advancement.
>
> In a few remarks made in public, prior to the *Challenger*'s departure, the hydrographer remarked "that an expedition such as this, which had been the hope and dream of his life, was now on the eve of realization".

The only source of information on the *Gazelle* expedition that describes the voyage's overall purpose can be found in the first volume of the published report (Hydrographisches Amt der Admiraltät, 1889a), and it is clear that *Gazelle*'s sailing orders were drawn up with due consideration of the orders give to *Challenger*.

However, the opening lines of the preface[4] state the following:

> In 1874, SMS *Gazelle* was sent on a two-year voyage, firstly to carry the German expedition destined for the observation of the transit of Venus in December 1874 to the Kerguelen Islands and to take part in these observations and secondly to promote oceanography and to conduct physical and oceanographic research in the maritime sciences.

The importance of the transit of Venus in defining the early part of the *Gazelle* expedition is a major difference between the two voyages. *Gazelle* was tasked with transporting a team of six astronomers, led by Carl Börgen, and their equipment to the observation site at Betsy Cove on the Island of Kerguelen in the South Indian Ocean (approx. 49° S, 69° E). Following the completion of the observations[5], the astronomers and their equipment were to be taken to Mauritius from whence they would return to Europe on a commercial vessel, and *Gazelle* would continue her circumnavigation. The details of the astronomical observations in Kerguelen are described in Duerbeck (2004). A more personal account attributed to one of them, Ladislaus Weinek, is given in Davoust (1999). No further description of that astronomical work is given here.

The overall scientific rationale for the *Gazelle's* oceanographic and geophysical observations is similar to that given for the *Challenger* voyage and indeed refers to her voyage which had set off 18 months before *Gazelle*. The rationale for the *Gazelle*'s work is also set in the context of Maury's promotion of the collection of systematic observations as follows:

> Only at the beginning of the fifties did a new area of systematic exploration of the seas begin on a strictly scientific basis. MAURY, the director of the National Observatory in Washington, deserves the credit for giving the first impetus to this and for having applied a systematic approach. After collecting oceanic and meteorological observations made by American seafarers between 1840 and 1850, he designed schemes to achieve a uniform observation system, which was given to the American ships to record their observations which were then returned to the central office after the voyage and analysed. Furthermore, following his suggestion, the government of the United States requested other seafaring nations to develop and participate in oceanic and maritime-meteorological research. They were invited to a conference in Brussels in August 1853, at which the first agreements on this were made.
>
> MAURY's efforts were particularly encouraged by the need for cable-laying overseas, which arises from the trade and transport conditions of the new era and which in turn requires precise knowledge of the depths of the sea, the nature of the seabed and other physical properties of the ocean.

Three sets of sailing orders (dated 3 June and 13 November 1874 and 23 June 1875) were issued by the head of the Imperial German Navy, Admiral Albrecht von Stosch.

It is clear from these orders that the German Admiralty was monitoring *Challenger*'s progress as there are references to it in the first sailing orders

> After leaving Kiel, after the coal has been replenished in Plymouth if necessary, you should choose the course so that it starts from the latitude of the Azores almost halfway between the course of the English ship "*Challenger*" and the European–African coast then to pass Madeira and the Canary Islands in the west and, if necessary, to call at the Cape Verde Islands to refill coal.
>
> The most recent work by HMS "*Challenger*" in the North and South Atlantic Ocean gives clues for deciding the importance of the positions with regard to these observations. There is a copy of the report on this work up to the Cape of Good Hope on board SMS "*Gazelle*", from which the main sounding positions can be taken, and since comparison observations relating to the earlier American work are also included in this report, it offers the clues for the decision of the expediency of the observation for certain stretches.

[4] Quotations in English from the *Gazelle* reports are the author's own translations. The author's translation of the introduction to the *Gazelle* narrative is appended as the Supplement to this paper. It is what is referred to as "freie Übersetzung" (free translation), i.e. not literally word for word but conveying the meaning.

[5] A parallel set of observations was made by German astronomers at Tschifu (now Yantai in Shandong Province of PRC). At the time of the transit, *Challenger* was undergoing a long stay and refit in Hong Kong.

The third instructions state the following:

> Consideration should also be given to the soundings along the line on which HMS "*Challenger*" has recently been active in the western part of the Pacific Ocean and will continue to do so in the northern and western parts in the near future, as well as on the routes and areas already worked by the "*Gazelle*".

There follow detailed instructions relate to *Gazelle* making observations to complement those made by *Challenger* in the Pacific around the Kermadec Islands, Tonga, and Fiji.

The overall rationale for the voyage and the constraints within which Gazelle operated are summarized in an early paragraph:

> By the highest cabinet order of March 10th this year, S.M.S. *Gazelle* is commissioned for scientific purposes, and the corvette has been given special equipment for this purpose. In order to gain space, the guns have been reduced to eight and the crew has been reduced. Nevertheless, S.M.S. *Gazelle* must retain the character of a warship, and I expect that, Your Excellency, the conventions of managing the ship will always be maintained, even under the given circumstances.

Shortly thereafter there is a reference to a visit by *Gazelle* to the River Congo and to Loanda (Luanda, Angola).

> You will find the German expedition to explore Central Africa on the Loanda coast. The appearance of the "*Gazelle*" there will increase the reputation of the expedition among the population and can be of advantage for their work. A further purpose should by no means be connected with the visit to this coast, and your Excellency must avoid any demonstration which could give the inhabitants the impression that you are pursuing political aims.

This must refer to the Loango expedition (1873–1876) (Güssfeldt et al., 1888). The report of that expedition refers to observations by SMS *Gazelle* being used to confirm the expeditions' magnetic observations. This wording of sailing instructions hints, perhaps, that the voyage may also have had an underlying "show the flag" purpose on behalf of the newly founded German state and its navy but that they were trying not to give that impression.

4 The ships

Both *Challenger* and *Gazelle* were mid-sized warships, each with both sails and steam propulsion. Sails were used primarily on passage, and steam propulsion (Sennett and Oram, 1899) was available for holding position when making observations. Both ships had already spent considerable time far from their home countries. *Challenger* had been flagship of the Australia station from 1866 to 1870, and *Gazelle* had been sent to Japan in 1864 on a somewhat political mission to protect a German ship that had been wrecked near Yokohama (von Tirpitz, 1919). Their visual similarity (Fig. 2) is striking, though *Challenger* appears to have a higher freeboard than *Gazelle*.

Challenger was a Pearl class corvette [6] – a class described by Winfield (2014) as follows:

> These "open battery" corvettes mounted all their guns on an exposed weather deck but as in 18th century frigates there was a complete unarmed deck below. ... This provided plenty of berthing space and led to the description of the ships as troop frigates because they could transport soldiers when required.

Thus, it seems *Challenger* was ideally suited for modification for her new role.

Gazelle was an *Arcona* class frigate described at the beginning of Chapter II of Hydrographisches Amt der Admiralität (1889a) as follows:

> S.M.S. "*Gazelle*", although not one of the very latest ships of the Imperial Navy, was one of the best and most suitable vehicles for the purposes of the expedition in terms of space and size, in terms of facilities and sea characteristics. Built entirely from wood, it belonged to the class of "covered corvettes", now called cruiser frigates, and as such offered a spacious, airy and light deck below the upper deck, the battery, which was intended for the placement of the guns. Being protected from sun and rain it was suitable for scientific work and for setting up work and living rooms.

Both ships required modification to prepare them for their multi-year voyages and for the changes from their normal naval duties. As noted, their standard pre-expedition armaments were reduced, more substantially in the case of *Challenger*, perhaps reflecting the exhortation in *Gazelle*'s first sailing orders that she "must retain the character of a warship".

The complements of both ships were reduced but the *Gazelle*'s from a much higher original figure, suggesting *Gazelle* would have been much more crowded.

4.1 The commanding officers

The captains of both ships (Fig. 3) were experienced naval officers. George Nares, the sixth child of a naval officer, was

[6] A frigate was defined as a ship with a single gun deck immediately below the main deck. A corvette was of similar size, but the guns were mounted on the main deck.

Figure 2. Left: HMS *Challenger* in St Thomas, West Indies, March 1873 (archives of the Natural History Museum, London). Right: SMS *Gazelle* (archives of Marineschule Mürwik, Germany).

Table 1. The principal characteristics of HMS *Challenger* and SMS *Gazelle*.

	HMS *Challenger*	SMS *Gazelle*
Vessel type	Pearl class corvette[a] Second of class	*Arcona* class covered frigate[b] Second of class
Date Launched/commissioned	Chatham, 13 February 1858/6 May 1861	Danzig (Gdansk), 19 December 1859/ Kiel, 15 May 1862
Length (LOA)/beam/draught (m)	68.7/12.3/5.7	72.0/13.0/6.5
Displacement	2137 t	2391 t
Rig	Full rig, 3 mast 1500 m^2	Full rig, 3 mast, 2200 m^2
Propulsion[c]	Two cylinder trunk engine 1450 HP 2 blade screw	Single expansion steam engine 1320 HP 2 blade screw
Range/speed under steam	??? @ 10.7 kts (19.8 $km\,h^{-1}$)	1150 nm @ 11 kts (20.4 $km\,h^{-1}$)
Complement as commissioned Expedition initial complement	290 233 (175 naval personnel, 50 boys[d], 6 scientists, 1 lab assistant, 1 domestic servant)[e]	390 338 (officers, crew and 1 scientist)
Armament as commissioned Expedition armament	2 × 8 in. (20 cm), 1 × 68 lb (31 kg) (10 in., 25 cm) 2 × 68 lb (31 kg)	28 × 68 pounder (31 kg) 8 × 68 pounder (31 kg)

[a] Winfield (2014). [b] https://second.wiki/wiki/arcona-klasse (last access: 6 June 2022). [c] Sennett and Oram (1899). [d] The Royal Navy accepted boy sailors with a minimum age of 15. See Smith (2021). [e] Rice (2001).

41 years of age when *Challenger* sailed. He already had experience of expedition work, having sailed as second mate aboard HMS *Resolute* on the 1852–1854 Arctic search for the missing Franklin expedition. Prior to his appointment to *Challenger*, he had served for 5 years as a surveyor on the east coast of Australia and later in the Mediterranean. He was promoted to the rank of Captain in 1869, and his appointment to the command of HMS *Challenger* followed his involvement in oceanography in the Gulf of Suez and in the Strait of Gibraltar (Carpenter, 1870)[7].

He, together with Lieutenant Pelham Aldrich, left *Challenger* when she reached Hong Kong in December 1874 so that he could take up his appointment to command the British

[7]Nares' 9-year-old son, William Grant Nares, embarked on the voyage. *Challenger* carried a schoolmaster, Adam Ebbels, to help with the crew's education, but he died at sea and was buried in Bermuda. His replacement joined in Simonstown. William returned to the UK from South Africa.

Arctic expedition (1875/1876) aboard HMS *Discovery* and HMS *Alert*. Pelham Aldrich was replaced in Hong Kong by Lieutenant Carpenter.

Nares' successor aboard *Challenger* was 44-year-old Captain Frank Tourle Thomson, who had not had the expeditionary experience of Nares but who, nonetheless, went on to co-author many of the *Challenger* narrative reports. He became commander of the Royal Yacht *Victoria and Albert* from May 1877 until October 1884, the year in which he died aged 54.

The captain of SMS *Gazelle*, Georg von Schleinitz (https://adb.anu.edu.au/biography/schleinitz-georg-gustav-freiherr-von-4542, last access: 6 June 2022; https://second.wiki/wiki/georg_von_schleinitz, last access: 12 April 2022), had joined the Prussian Navy in 1845 at the age of 11. He had experience of working far from Europe as a flag lieutenant on the Prussian expedition to China, Japan, and Siam between 1860 and 1862. In 1864, he was first officer on the covered corvette *Arcona*, sister ship of the *Gazelle*.

In 1869, von Schleinitz became a corvette captain on *Arcona*, and in summer 1874 he took command of *Gazelle*.

The fact that both Nares and von Schleinitz were naval surveyors led to them both being at the ceremony to open the Suez Canal on 17 November 1869, von Schleinitz as Commander of the *Arcona* and Nares as commander of the HMS *Newport*, a vessel that was involved in hydrographic surveying in the Mediterranean.

At the opening, Nares, contrived to make HMS *Newport* the first ship to transit the canal from north to south, ahead of the intended first vessel, the French Imperial yacht *l'Aigle*, carrying Empress Eugénie. Though officially reprimanded for this breach of protocol, Nares undoubtedly gained some kudos from this manoeuvre, and it seems unlikely that von Schleinitz would have been unaware of the incident.

4.2 Ships' officers

The following are short biographies of some of *Challenger*'s officers.

Second in command to Nares and Thomson was Commander John Fiot Lee Pearse Maclear. He was 34 years old and was the second son of Sir Thomas Maclear, who in 1833 had been appointed Her Majesty's Astronomer at the Cape of Good Hope. John Maclear joined the navy as a 13-year-old cadet, with much of his naval career being spent in foreign waters. After his return from *Challenger* in 1878, John Maclear married Julia, a daughter of the eminent astronomer Sir John Herschel.

Lieutenant Pelham Aldrich was 28 when he joined *Challenger*. He had joined the Royal Navy as a 15-year-old cadet in 1859 and served aboard ships in the Pacific and Mediterranean before his service in *Challenger*. He left the vessel in Hong Kong to accompany Nares on the British Arctic expedition on which he led the sled party to Ellesmere Island. His naval career ended with his appointment with the rank of Rear Admiral and later Vice Admiral as the Superintendent of Portsmouth Dockyard (1899–1903). He died in 1930 aged 86.

Lieutenant Arthur C. B. Bromley was born 16 September 1847 and entered the Navy as a cadet in 1860. He was 25 when he joined *Challenger*. His career ended (rank of Vice Admiral) in 1905 with him as Superintendent of the dockyard in Malta. He died on 25 October 1909[8].

Lieutenant George R. Bethell was a Yorkshireman, born in 1849, and was 23 when he joined *Challenger*. Compared with his fellow officers, his naval career was short. In 1885, with the rank of Commander he stood for parliament and was elected for the Yorkshire constituency of Holderness, a position he held until 1900 when he lost the seat over his views on the government's policy on South Africa. He died in 1919.

Arguably the ship's officer who had the greatest influence on the scientific work of *Challenger* was Thomas Tizard. He had entered the Royal Navy by competitive examination in 1854 (aged 15) and 6 years later started his career as a surveyor in the Mediterranean and was aboard HMS *Newport* with Nares at the opening of the Suez Canal in 1869. He was navigator and chief surveyor aboard *Challenger* and was responsible for the current measurements – he had earlier experience of researching currents in the Strait of Gibraltar. The obituary in the Geographical Journal (A.M.F., 1924) makes these comments:

> His duties involved the closest associations with the leader of the expedition and of the scientific staff in decisions bearing on the carrying out of the objectives of the expedition. From the outset he closely identified himself with every undertaking with which the expedition was concerned. As time went on, the influence he exerted was increasingly apparent.

When Nares left *Challenger* in 1875, it was clear that Tizard, who was identified by Wyville Thomson as the "chief of the naval scientific staff" (Wyville Thomson, 1878), had become indispensable to the continuity and presumably the success of the voyage's work.

After the *Challenger* voyage, the Admiralty seconded him to work with John Murray on the compilation and publication of the narrative and of the oceanographical and hydrographical results. In 1891 he was elected a fellow of the Royal Society.

Gazelle's officers are listed as follows in Volume 1 of the narrative – their ranks are those while aboard *Gazelle*, though many were later promoted.

Captain zur See[9],

[8] Times archive 27 October 1909.

[9] The term "zur See" was used in the Imperial German Navy to distinguish the ranks from the equivalent ones in the Army.

Figure 3. The commanders of the round-the-world voyages: left – Kapitän zur See von Schleinitz (photo dated 1890) (http://www.tripota.uni-trier.de/single_picture.php?signatur=385_1275, last access: 9 April 2022), middle – George Nares (1872–1874) (archives of the National Portrait Gallery, London), and right – Francis Tourle Thomson (1874–1876) (courtesy of Mary Evans Picture Library).

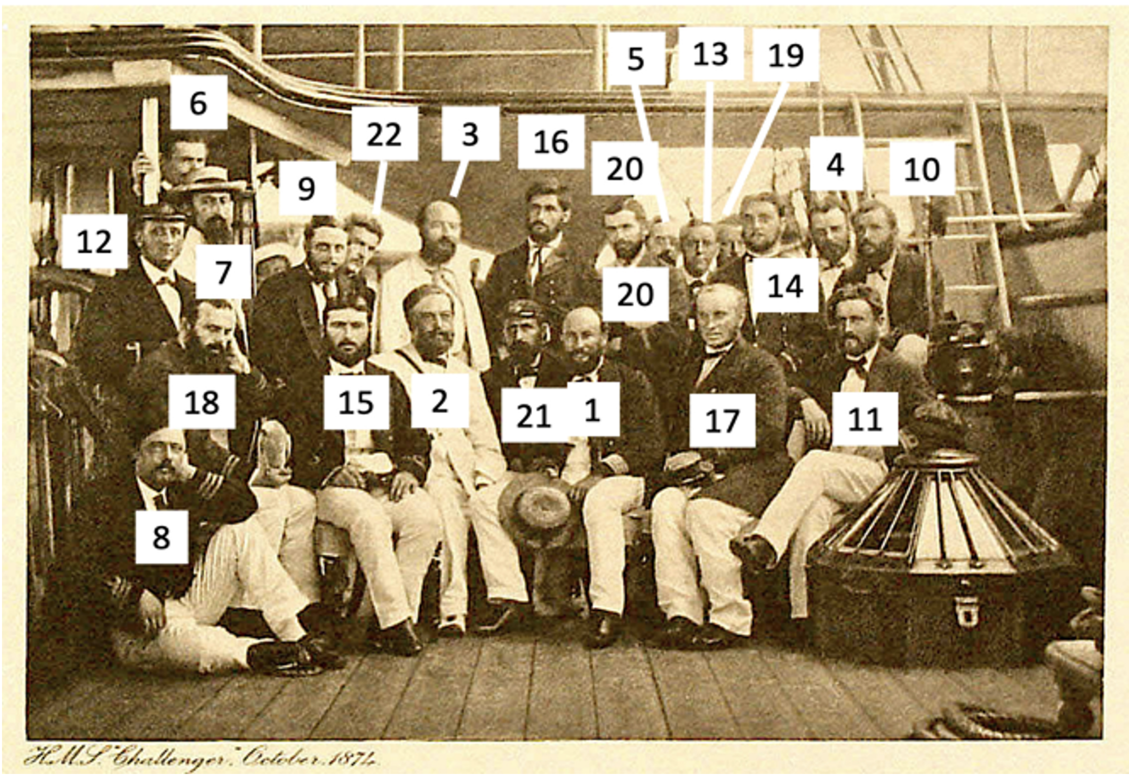

Figure 4. A group photograph of the *Challenger*'s officers and scientists (courtesy of the archives of the Natural History Museum). Though they were unidentified in the *Challenger* reports they were identified by Rice (1986) as follows: (1) Nares, (2) Wyville Thomson, (3) Wild, (4) Murray, (5) Moseley, (6) Willemoes-Suhm, (7) Buchanan, (8) Cdr. Maclear, (9) Lt. Aldrich. (10) Lt. Bromley. (11) Lt. Bethel, (12) Sub-Lt. Balfour, (13) Sub-Lt. Channer, (14) Sub-Lt. Harston, (15) Nav. Sub-Lt. Havergal, (16) Nav. Sub-Lt. Swire, (17) Staff Surgeon Crosbie, (18) Surgeon Maclean, (19) Paymaster Richards, (20) Ass. Paymaster Hynes, (21) Engineer Spry, (22) Ass. Engineer Howlett. Absent from this photograph were Chief Engineer James Ferguson, Engineer Allen, Sub Lt. Sloggett, Asst. Engineer Abbott.

Baron von Schleinitz as Commandant,

Lieutenant Captain Dietert as First Officer,

Lieutenant Captain Jeschke as Navigational Officer,

Lieutenant Captain, Bendemann,

Lieutenant zur See, Strauch,

Lieutenant zur See, Rittmeyer,

Sub-lieutenant zur See, von Ahlefeld,

Sub-lieutenant zur See, Wachenhusen,

Sub-lieutenant zur See, Credner,

Sub-lieutenant zur See, Breusing,

Sub-lieutenant zur See, von Seelhorst,

Sub-Lieutenant zur See, Zeye,

Navy medical officer, Dr. Naumann,

Marine assistant doctor, Dr. Huesker,

Navy underpaid master, Lindenberg.

Their responsibilities for the scientific work were also listed in the narrative of the voyage, and the following are some biographical details.

Lieutenant Captain Conrad Dietert (5 October 1844–15 September 1906) was the First Officer under von Schleinitz but does not appear to have had any scientific responsibilities.

Lieutenant (Rudolf?) Rittmeyer and Sub Lt. Conrad von Seelhorst (5 April 1853–6 July 1930; https://de.wikipedia.org/wiki/Conrad_von_Seelhorst, last access: 6 June 2022) were responsible for the meteorological observations and for astronomy. Though it is not specified in the reports, we might speculate that the astronomical work could have involved support of the astronomers who observed the transit of Venus as well as including any other astronomical phenomena observed during the voyage (aurora australis, meteor showers) (Sperberg, 2021). The sailing orders also state the following:

> In addition to frequent observations of lunar distances, investigations are also to be carried out on the possibility of successfully using star sights and the eclipses of Jupiter's moon, etc. for the purpose of deriving the geographical longitude, and this is to be reported on later.

Von Seelhorst was invalided out of the Navy in 1878 with a serious lung condition but went on to have an academic career in agriculture in Göttingen.

Captain Lieutenant Jeschke, Lieutenant zur See Breusing and Lieutenant zur See Zeye were responsible for navigation as it related to surveying, sounding (but not including deep-sea sounding), documenting coastlines, and sailing instructions, as well as the astronomical and magnetic observations.

Lieutenant Captain Felix von Bendemann (8 August 1848–31 October 1915; https://wp-de.wikideck.com/Felix_von_Bendemann, last access: 6 June 2022) and Lieutenant Wachenhusen were responsible for the oceanographic measurements, such as deep-sea soundings, temperature, and specific gravity measurements, determining the chemical composition of seawater and observations of currents and tides. Bendemann had been one of the first graduates of the new naval academy in Kiel.

Lieutenant Franz Strauch (11 April 1846–12 August 1928; https://second.wiki/wiki/franz_strauch, last access: 6 June 2022) was primarily responsible for the ethnological work. He had joined the Prussian Navy as a cadet in 1864. His interests in ethnology continued after the *Gazelle* voyage, and he became a link between the (Imperial) Navy and the Ethnology Museum in Berlin. The relationship between the Navy and ethnology is revealed in Zimmermann (2001).

> The Navy's collecting duties developed from an occasional activity for officers during their leisure time to an integral part of its operations. In 1874 Bastian persuaded the Navy to order the surveying ship SMS *Gazelle* bound for the South Pacific, to acquire "everything collectible" from ports of call. A lieutenant Franz Strauch assigned to the *Gazelle* did much ethnographic collecting for the museum and developed a lifelong interest in anthropology. He eventually rose to the rank of Rear-Admiral and acted as a key intermediary between the Navy and the Museum of Ethnology.

Zimmermann comments that the close relationship between the Navy and the Museum continued into the 20th century.

Lieutenant Hunold von Ahelefeld (5 March 1851–5 September 1919; https://second.wiki/wiki/hunold_von_ahlefeld, last access: 6 June 2022) was responsible for gravity measurements (Pendel Beobachtungen) and for topography. He had joined the Prussian Navy as a cadet in 1867, and after his service on *Gazelle* he became involved with naval shipyards before retiring in 1907. In his work he was assisted by Lieutenant Credner.

The ship carried two medical officers, Dr. Neumann and Dr. Huesker. Neumann assisted with the botany, while Huesker did the geological and anthropological research.

4.3 The scientists who joined the voyages

Much has already been written about the *Challenger*'s six scientists (Aitken and Foulc, 2019), and so they will be described only briefly here.

Charles Wyville Thomson was leader of the scientific party and was 42 when *Challenger* sailed. He was a Scot, born in Linlithgow, a few miles east of Edinburgh 5 March 1830. He was christened Wyville Thomas Charles Thomson (he appears as Wyville Charles Thomson in the 1881 census records) but apparently changed his name to Charles Wyville Thomson in 1876 when he was knighted. This is the name by which he is now known and which appears in the all the *Challenger* reports.

According to anonymous (1876), he left school in 1845 and spent the next 3 years studying medicine at Edinburgh University, following in the footsteps of his father, a surgeon with the East India Company. His intense studies affected his health, and, as an easier option, in 1850 he began lecturing in botany at the University of Aberdeen, which conferred on him a Doctor of Laws (LL.D.) degree. He married Jane Dawson in 1854, and their son Frank was born in 1860. Until he assumed responsibility for the scientific work of HMS *Challenger* in 1872, he had broadened his scientific interests into chemistry, mineralogy, palaeontology, and zoology, holding academic positions in Cork, Belfast, and Edinburgh. His interests also grew in wider educational matters, in the arts, and in local politics and law.

Perhaps the spark that led to the *Challenger* voyage lay in a discussion between Wyville Thomson and Carpenter in 1868 when Wyville Thomson suggested that the deep-sea floor would be a rich hunting ground for naturalists. He urged Carpenter to use his influence to mount an expedition, and this he did in a letter to the President of the Royal Society, as documented in Wyville Thomson, 1873.

John Young Buchanan was the expedition's chemist and also took responsibility for the physical measurements (water temperature and specific gravity) except those such as meteorological measurements, which were the responsibility of the ship's officers. He was also an accomplished mineralogist. Born on 20 February 1844, he was the second son of a well-to-do Glasgow family and was 28 at the start of the voyage. In 1863, he graduated with an arts degree from Glasgow University before studying chemistry in Germany at Marburg and Bonn and then Leipzig before moving to Paris. He returned to Scotland around 1870 as assistant to the Professor of Chemistry at the University of Edinburgh, Alexander Crum Brown. So, he came to the *Challenger* expedition as someone who was already widely travelled and with eclectic interests.

Henry Nottidge Moseley was born in Wandsworth in South London on 14 November 1844 and so was 28 when he joined *Challenger*. The most complete description of his life is to be found in a memoir by the zoologist Gilbert Bourne (Bourne, 1892) as an introduction to Moseley's narrative of the *Challenger* voyage (Moseley, 1892). His father, also Henry, as well as being a clergyman, was an eminent mathematician and a fellow of the Royal Society. Henry Moseley was educated at Harrow School and then at Exeter College, Oxford (1864–1868), graduating with a first-class degree in natural sciences, though the initial intention had been for him to study mathematics or classics. The move to science was prompted by his interest in natural history as a hobby that started when he was at school and continued in Oxford. After graduation, he was awarded a travelling fellowship that took him in 1868 to work in Vienna. He then enrolled as a medical student in London but returned to the continent in 1871 to work in Leipzig. On his return to London in autumn that year, he was invited to join the British Government's Eclipse expedition to Ceylon (Sri Lanka) (total solar eclipse, 12 December), on which he acted as a naturalist and took part in the astronomical observations[10]. So, by the time he was selected to join *Challenger*, he was already well travelled and had wide scientific interests and experience. His scientific character is perhaps revealed by this comment by Tizard.

> Whenever they arrived at a new place Moseley would ask his colleagues what they intended to work at so that he might undertake what they did not care for. His anxiety was that the whole ground should be covered, and he was willing to leave all the more apparently interesting work to others, reserving for himself what they rejected. It came about that he did more work than anybody else on the expedition, though his friend von Willemoes-Suhm might have run close had he survived.

These were the three British-born members of the scientific party. All were from relatively affluent backgrounds.

John Murray was born on 3 March 1841 in Cobourg, now in Ontario, Canada. He was the second son of an accountant who had emigrated to Canada in 1834. After school and college in Cobourg, he returned to Scotland aged 17 to continue his education, enrolling to read medicine at Edinburgh University in 1864. Much of Murray's character is revealed in the obituary notice by George Agassiz, the eldest son of the famous oceanographer Alexander Agassiz (Agassiz, 1917), who comments on Murray's character.

> Impatient of dogmatic authority, he was somewhat scornful of inherited tradition and treated his prescribed studies with a cheerful lack of consideration. For even in those days, he desired to find out things for himself and delve for knowledge independently.

He gained his scientific knowledge through contact with the "small group of scientific men who made Edinburgh famous", a circle that expanded to include the writer Robert Louis Stevenson. Armed with that broad and inquisitive nature, but without a degree, in 1868 he embarked as surgeon on the Scottish whaling ship *Jan Mayen* on a 7-month voyage to the Arctic. On his return, he completed his studies in geology at Edinburgh University.

[10]Coincidentally, J. F. L. P Maclear was also a member of the 1871 Eclipse expedition, perhaps an additional influence on Moseley's selection for the *Challenger* voyage. (Anonymous, 1872).

In 1872 he was recruited by Wyville Thomson to collect and prepare the scientific equipment for the *Challenger* voyage.

Rudolf von Willemoes-Suhm at age 25 was the youngest of the scientific party, born in Glückstadt, Schleswig Holstein, then part of Prussia, on 11 September 1847. His expertise had been gained entirely at German universities.

In 1872 he joined the Danish *Phoenix* expedition studying vertebrates and polychaetes around the Faroe Islands. On its return journey, the ship called at Edinburgh on 10 October 1872, and on the 11th Willemoes-Suhm was invited to dinner by Wyville Thomson and his wife. Clearly impressed, Wyville Thomson said that if Thomas Huxley could persuade the Admiralty, then Willemoes-Suhm could join the *Challenger* expedition. Willemoes-Suhm took the train to London and met Huxley. By the 20 October he received the confirmatory telegram and on the 19 November was aboard *Challenger* in Sheerness (von Willemoes-Suhm, 1877). This serendipitous and rapid engagement suggests that Willemoes-Suhm was a very impressive young man.

The oldest member of the scientific party was Jean Jacques Wild, who was a Swiss national born in Zurich in 1828 and who later anglicized his name to John James Wild. There is much less known about the pre-*Challenger* life of Wild than about the other civilian members of the party. It is thought that Wyville Thomson may have encountered Wild in Belfast.

Gazelle carried only one specialist civilian scientist apart from the astronomers who were, in effect, passengers from Kiel to Kerguelen and Mauritius, and so virtually all the scientific work of the voyage was carried out by serving naval officers under the leadership of von Schleinitz.

That single scientist was the 29-year-old zoologist Théophil Studer (27 November 1845–12 February 1922; https://en.wikipedia.org/wiki/Th%C3%A9ophile_Rudolphe_Studer, last access: 6 June 2022), a Swiss ornithologist and the curator of the zoological collections and later professor at the Natural History Museum in Berne. He took part in the scientific and zoological work during the entire trip, though he had not joined the vessel with this intention. He had meant to take part in operations as a member of the transit of Venus expedition studying the fauna and flora of Kerguelen. However, from the beginning of the journey he showed such great expertise in zoological research that it was thought essential that he remain on board. This was approved by “a higher authority” (presumably the German Admiralty) and the University of Bern, and he remained on board until the end of the voyage.

He went on to publish reports on Ophiuroidea and on the isopods and other crustaceans collected between the west coast of Africa and the Cape of Good Hope.

The ship’s doctor, Friedrich Carl Naumann (https://plants.jstor.org/stable/10.5555/al.ap.person.bm000046495, last access: 6 June 2022) (born 1841), had trained in medicine and natural sciences at the universities of Berlin and Heidelberg before joining the (Prussian) Navy as a fleet surgeon. Before joining the *Gazelle* he had been on the 1869–1871 voyage of the SMS *Medusa* (https://en.wikipedia.org/wiki/SMS_Medusa_(1864), last access: 6 June 2022), *Gazelle*’s sister ship, to South America and into the Pacific where he made botanical collections mainly in Japan and Hong Kong. He was responsible for the botanical collections from *Gazelle*. The ship’s assistant doctor Carl Huesker, about whom little is known, helped with the zoological, botanical, geological, and anthropological research.

Though *Challenger* carried a party of expert scientists, since she was a survey vessel, the officers were very much involved in making the scientific observations, and indeed Thomson was involved in the preparation and publication of the narrative reports of the expedition.

We have already examined Nares’ role; in addition, Aldrich, Bromley, Bethell, and Carpenter had responsibility for sounding, seabed sampling, and temperature measurements. The other officers who would have been concerned with the scientific work were Maclear, who had responsibility for the magnetic observations which included intercalibrations with shore stations in South Africa and Hong Kong, and Bromley, who took a particular interest in meteorology and maintained a personal log. Tizard did a particular study of the meteorology of Japan quite independent of the *Challenger*’s objectives (Tizard, 1876).

Challenger’s scientific activities were thus a true joint enterprise between officers and civilian scientists.

5 The voyages, routes, and ports

Though both vessels circumnavigated the earth, their tracks, as shown in Fig. 1, were markedly different. The routes and port calls were dictated both by scientific objectives and in the case of *Gazelle* by information received in preliminary reports from *Challenger*. A major logistical consideration for both ships was that regular calls at suitable ports were needed to replenish coal supplies and provisions. There were also timing constraints, most noticeable for *Gazelle* set by the time of the transit of Venus (November 1874) and for both vessels to avoid high southern latitudes in winter.

5.1 Scientific considerations

We can compare the routes in terms of their ability to achieve the following broad objectives:

- revealing the deep-sea bathymetry and distribution of seabed types in support of cable routing;
- sampling a wide variety of ocean circulation regimes;
- sampling deep water and shelf sea biology;
- studying the ethnology, flora, fauna, and geology of rarely visited islands.

The first of these could only be addressed in the most general of sense since there is no way that a few hundred soundings can define global-scale bathymetry. In terms of potential cable routes, only *Challenger*'s routes across the North and South Atlantic and North Pacific could be said to approach studying potential routes. The Pacific crossing, however, fails to cover the approach to the North American continent. Despite these shortcomings, both ships' collection of seabed samples greatly improved knowledge of the types of deep-sea sediments and their geographical and depth distributions, information relevant to the selection of cable routes.

Most of *Challenger*'s North Atlantic stations were occupied during what was regarded as a training and trials phase. But in terms of exploration of the earth's major current systems, they added several crossings of the Gulf Stream and North Atlantic Current. *Challenger* also crossed the East Australian Current, the Kuroshio, and the Brazil Current. *Gazelle* made very few observations in western boundary regions.

Both vessels covered a wide range of latitudes, though neither entered the northern hemisphere subpolar regions. *Challenger* crossed the major structures of the Antarctic Circumpolar Current and occupied its southernmost station on 14 February 1874 at 65°42′ S, 79°49′ E (1 1/2 miles (2.4 km) from the edge of the pack ice). *Gazelle*, by contrast, ventured no further than about 52° S.

It should be remembered that neither vessel occupied stations close enough together to reveal the sharp frontal structures that we now know to characterize these major current systems. Remarkably, however, the *Gazelle* measured surface temperature and salinity (actually specific gravity) every 2 h throughout the voyage. These observations are, surprisingly, tabulated in the meteorology report (Hydrographisches Amt der Admiraltät, 1890) (Appendix B), but no positions are recorded corresponding with these measurements, and they have never been analysed.

The Pacific sectors of the two voyages were markedly different. *Challenger* spent a significant time in the western Pacific between Australia and Japan crossing the Equator three times. *Gazelle* entered the Pacific north of Australia and spend over 100 d surveying around New Guinea and the Bismarck Archipelago. The motivation for this was almost certainly with a view to assessing the commercial/colonial potential of the area (Overlack, 1973; Ohff, 2008, 2015). After visiting Brisbane and Auckland and making a northward excursion to Fiji, Tonga and Samoa, *Gazelle* headed across the South Pacific to the Strait of Magellan. *Challenger* by contrast headed east from Japan on approx. 35° N and then southwards via the what the *Challenger* reports refer to as the Sandwich Islands, the name given to the islands by Captain Cook but which was gradually being replaced by the name Hawaii, particularly after the signing of the Reciprocity Agreement with the USA in January 1875, 6 months before *Challenger* arrived.

After their passages through the Strait of Magellan, both vessels called at Montevideo, as was mentioned in the Introduction, and then returned to Europe by different routes – *Challenger* taking 88 d to reach Portsmouth and *Gazelle* 55 d to Plymouth.

Both ships appear to have deviated substantially from the route that was originally intended. For *Challenger* this occurred in the North Pacific. Rather than crossing from Japan to Vancouver Island and studying the California Current on her way to Cape Horn, *Challenger* headed to the Sandwich Islands (Hawaii) and thence to Valparaiso via Tahiti and Juan Fernandez. There are tantalizing comments in Joe Matkin's letters that relate to this sector of the voyage. On p. 25 of *At Sea with the Scientifics* he remarks

> We are to have warm clothing sent out to the Cape of Good Hope in a year's time, and it will be issued before going down amongst the ice, or rather lent, for it will be taken away as soon as we reach the latitude of Melbourne and again issued at Petrapolowski (Petrapavlovsk) before going through the Bering Straits. We are also to have extra pay in the cold weather.

On p. 122 he comments again about the voyage in the North Pacific:

> on to Yodo (Osaka) Japan after which the Kuril Islands and Petrapolopsky (Petrapavlovsk) the cold capital of Kamchatka, thence Aleutian islands, Bering Straits and down to Vancouver about May 1875 after which we begin again.

One wonders whether this change of plan was brought about by the replacement of Nares, who had experience of high latitudes, in Hong Kong.

For *Gazelle* the departure from the plan concerned the high southern latitudes. There are clear indications in *Gazelle*'s sailing orders that observations were planned far to the south. The first set makes this statement:

> The bank or ridge in the ocean, which according to the latest investigations of the "*Challenger*" apparently connects the Kerguelen and MacDonald[11] Islands, should be examined more closely, particularly temperature conditions and currents.
>
> If ice is suspected, or if S.M.S. "*Gazelle*" is near icebergs, frequent and precise determinations of salinity and temperature must be made.

Indeed, the sailing instructions suggest that it was intended that the vessel might approach the Antarctic continent.

[11] MacDonald Island lies at 53° S.

> The course is to be taken in such a way that SMS "*Gazelle*" does not occupy similar positions to those of the "*Challenger*", namely in the pack ice near the presumed Termination Land[12] but rather in the vicinity of Enderby[13] or Kemp's Land can advance. Under all circumstances, however, the S.M.S. "*Gazelle*" command must ensure that the ship does not get caught in pack ice or even get trapped in it, even if only for a while.

In the second set, received in Cape Town, these references to the Southern Ocean are replaced:

> leaving the port of Mauritius around the middle of March 1875, you have to endeavour to reach the parallel of latitude of 30° by the shortest route in order, following the same, to cross the Indian Ocean to the east

Both vessels left a geographical legacy in the naming of features (https://www.ngdc.noaa.gov/gazetteer/, last access: 6 June 2022); *Challenger* most notably for the Challenger Deep in the Marianas Trench and *Gazelle* particularly around New Guinea with the naming of the Gazelle peninsular and the von Schleinitz range of mountains in New Ireland and the later-named Gazelle Fracture Zone in the South Indian Ocean.

5.2 Logistics and statistics

Though the two vessels circumnavigated the world and made similar observations, the voyages differed in many respects, most notably in their durations. *Challenger* took 1250 d from 21 December 1872 to 24 May 1876 and *Gazelle* 678 d from 21 June 1874 to 28 May 1876. The distances sailed were markedly different too, *Challenger* 68 590 nm and *Gazelle* approximately 36 000 nm. Though the two ships are noted for sailing around the globe, they spent a great deal of time in port (to replenish supplies, including coal, to send and receive mail to send samples and equipment home, and to undergo repairs). *Challenger* spent 522 d in port or exploring islands and land masses. The figure for *Gazelle* was 297 d. Since a central element of both voyages was to explore rarely visited regions, many of the port calls were in places that could provide little support for the ships or respite for the officers and crew (Table A1 in Appendix A).

It is noteworthy that while *Challenger* spent a month or more in Simonstown (South Africa), in Sydney (Australia), in Hong Kong, and in Yokohama, the *Gazelle* only had extended stays around Kerguelen in the inhospitable sub-Antarctic and exploring New Guinea and its surrounding islands. These differences are graphically summarized in Fig. 5, and their implications will be explored more fully in Sect. 7.

[12]Part of Wilkes Land in East Antarctica.

[13]Coasts at around 67°30′ S.

5.3 Station routine

The time at sea on both ships was marked by the occupation of stations, and each must have fallen into a well-practised sequence of operations. This routine can be deduced from the summary narrative of *Challenger* (Wyville Thomson, 1878), and it is reasonable to assume that *Gazelle* would have operated similarly. Almost all station work was carried out during daylight hours, with the preparations usually starting between 06:00 and 08:00. Stations in deep water typically took between 10 and 12 h. First came the firing of the boilers, so that the steam propulsion could be used to keep the vessel head to wind on station and the donkey engine to be used to haul in the lines. With sailed furled, the first observation was to take a depth sounding and recover a sample to reveal the nature of the seabed. This was followed by water sampling and temperature measurements using bucket sampling at the surface and slip bottles and thermometers at depth. Current drift was measured, biological net samples taken, and finally dredging for biological and geological samples. This presumably was left to last so that the scientists would have time to sort and preserve the samples and the crew clear the deck while on passage towards the next station.

The very different water sampling and temperature measurement strategies on *Challenger* and *Gazelle* are demonstrated in the figure of water sample distributions in the supplementary information provided in Gould and Cunningham (2021). *Gazelle* sampled only three horizons (surface, 100 fm[14], and near the seabed). *Challenger* sampled six horizons between the surface and 1000 fm, but this regime started only after station 90 at the end of July 1873, resulting in the North Atlantic being comparatively poorly sampled.

6 The balance between conservatism and innovation

The planning of these two multi-year voyages took place in a time of rapid scientific and technological advances, and it might have seemed natural for the most recent technological devices to be employed. Yet, a balance had to be struck between using methods and instrumentation that were well tried, robust and so could be easily maintained without access to specialist skills and those that were innovative and which might give new insights. For both expeditions, the emphasis seems to have been on reliability. This was perhaps especially true of *Gazelle*, which carried only one scientist.

6.1 Rope vs. wire

The most obvious generic technology that could have been used was multistrand wire rope rather than traditional hemp sounding and dredging lines. Multistrand wire rope had been increasingly used in bridge building and mining since the

[14]1 fathom (fm) = 6 ft = 1.8288 m.

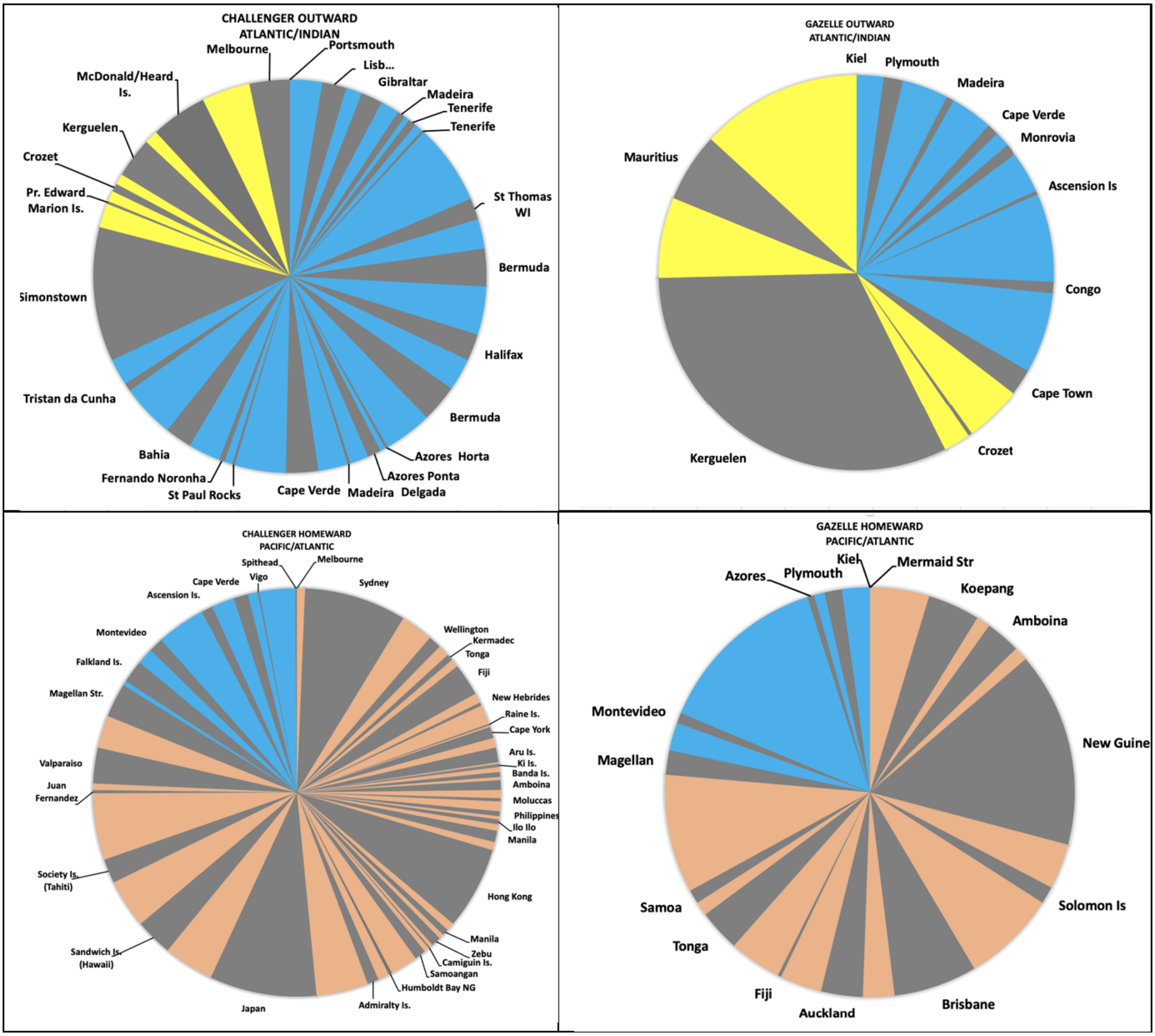

Figure 5. Time spent in ports and periods of extensive surveys (grey colouring, sequence reads clockwise) compared with time at sea (coloured sectors, Atlantic (blue), Indian and Southern (yellow), Pacific (brown)). Format follows that used by Aitken and Foulc (2019). Dates in port are in Table A1.

mid-19th century and was also being used in submarine telegraph cables. However, use at sea for the deployment and recovery of equipment where it would have to be repeatedly wound on and off winches and would be subject to corrosion would have been a high risk, and therefore *Challenger* and *Gazelle* both opted to retain hemp line. *Challenger* started the voyage with 20 000 fm of No. 1 sounding line and took on board a further 20 000 fm. A total of 26 000 fm was used; 64 000 fm of No. 2 sounding line was embarked and 34 000 fm expended.

The *Gazelle* report makes these remarks:

The sounding lines delivered by the English shipyard had a length of 10 000 English fathoms and were made from Italian hemp, three-strand, cable lay, 27 yarns. Their circumference was 1 in. (25.4 mm), the breaking load dry 792, wet 702 kg. These lines were used exclusively during the entire voyage to the deep-sea explorations, without ever breaking. In three cases the line brought 125 kg of sounding weights back to the surface from depths of more than 4500 m when the sounding device had not worked when it hit the bottom. The lines came on board in lengths of 1000 fathoms spooled on small drums and were split in lengths of 125 fathoms with double short splices (cut splice). On board a drum for 4000 fathoms was made, and the line held on this ready for use. Initially it was intended to mark the line in metres in order to indicate the depths in the measure prescribed in the Imperial Navy; however, this was abandoned and the English fathom measure, according to which the depths are given in most of the existing nautical charts, was retained. The line was marked accordingly from 25 to 25(?)[15] fathoms. As marks for 100 fathoms each, strips of canvas that protruded from the line and showed a consecutive number applied with oil paint were found to be suitable for the purpose. The 25 and 75 fathom marks were marked with blue and the 50 fathom marks with red, with flag cloth tucked into the rope stands.

Ritchie (2000) comments that the *Challenger* used tried and trusted observation methods with soundings made using rope and the so-called timed methods[16].

6.2 Photography

The *Challenger* expedition was the first to carry an official photographer. In fact, there were three photographers at various times, Caleb Newbold, Frederick Hodgeson, and Jesse Lay. The expedition's photographs were originally catalogued by John Horsburgh (1885). There is a more recent catalogue of the over 800 photographs (Brunton, 1994). The original plates and prints are now widely scattered, and Brunton lists 10 persons or institutions as owners. The majority of these photographs are landscapes, a significant number would be classified as ethnological, and some are of groups of scientists, officers, crew, or visitors. None show the interior of the vessel, nor the conduct of its seagoing science activities. This might well be due, in the former case, to the long exposure times needed which would have required the subjects to pose or to the inadequate lighting below decks and inappropriate camera lenses. An extensive discussion of the use of photography aboard *Challenger* is given by Jones (2019).

Photographs were also taken on the *Gazelle* expedition, but the report recounts a sad outcome.

> (Privy Councilor HARTMANN) not only took on in the most courteous manner, the processing of the S.M.S. *Gazelle*'s collected anthropological material, which work is set down in a special appendix. He also succeeded, in processing various photographic recordings of an anthropological and ethnological nature made on the trip. This was despite them being damaged due to the adverse climatic and weather conditions of the tropics and at sea where they had suffered so much from the long storage that they no longer appeared viable for reproduction. The imperfect plates supplemented the areas mentioned with the help of his excellent knowledge – to produce drawings which made it possible to reproduce them in this work.

There are many photographs of the astronomical work on Kerguelen (Duerbeck, 2004), and so it seems likely that those plates were shipped back to Germany from Mauritius and so avoided the damage reported above.

6.3 Oceanographic equipment

The equipment used to make oceanographic observations on the two vessels (water sampling bottles, deep-sea thermometers, dredges, sounding weights) was virtually identical and represented the state of the art in instrumentation at the time as used and refined by Wyville Thomson and Carpenter. Indeed, *Gazelle* called in Plymouth on her outward voyage to collect much of her scientific equipment.

> S.M.S. *Gazelle* was equipped with the two sounding devices most commonly used for deep-sea sounding, the BAILLIE sounder and the HYDRA sounder, three of the former type and one of the latter. However, the HYDRA sounder was only used once, and since it did not work properly, all further measurements at great depths were carried out with the Baillie apparatus. The sounding equipment as well as the deep thermometer was all obtained from England, as there was no experience with this in Germany. With the kind co-operation of the Hydrographic Office in London, all the sounding devices were provided by the Royal Shipyard Chatham and delivered to the "Gazelle" when she was in Plymouth.

The rigging and means of deployment of the equipment were also virtually identical to those used on *Challenger* as is demonstrated in Fig. 6, which shows the elastic accumulator used as a shock absorber.

Perhaps the most innovative technique used on either vessel was an attempt on *Gazelle* to measure the height and period of waves by making measurements of the ship's rise and fall using a very sensitive aneroid barometer. This activity is described briefly in Vol. 2 of Hydrographisches Amt der Admiralität (1888) but, unsurprisingly, was not successful. (A 1 m vertical displacement of the ship would have resulted in a pressure change of only 11 Pa (0.11 mbar). This is comparable with the pressure variations that would be caused by

[15] Presumably this indicates an illegible or erroneous manuscript entry. The second value should perhaps be 75.

[16] The time taken for each 25 fm. length of line to run out in free-fall with the sounder weight taking it towards the seabed. When the rate of descent suddenly slowed, it indicated that the sounder had hit the bottom. When hauled in until an increase in tension was felt, the depth could be recorded.

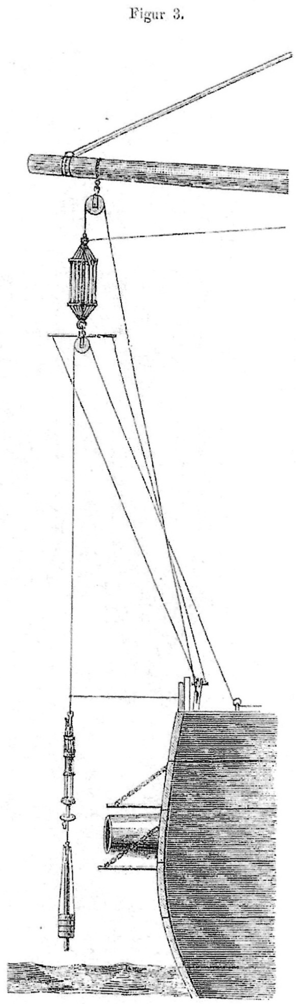

Figure 6. Reproduction of Fig. 3 (p. 16) of the *Gazelle* narrative showing the deployment of a Baillie sounder.

turbulent wind flow around the ship, and these would have been hard to separate from changes caused by waves.) The problem of recording sea waves from a ship was not solved until the development of the shipborne wave recorder by Tucker (1952), who refers to the failed attempt by *Gazelle*.

In some ways the deep-sea thermometers used on both voyages were experimental in that their performance and ability to faithfully record the temperature profiles, particularly when the vertical variations were not monotonic, was not fully understood. *Challenger* embarked 35 "protected" thermometers to which a further 69 were added at intermediate ports and 48 "expended" – presumably lost or broken. The vast majority were the double-bulb version of Six's thermometer known as the Miller-Casella thermometer which recorded maximum and minimum temperatures. The true reversing thermometer was being developed by Negretti and Zambra at the time of the *Challenger* voyage, and several were sent to the ship for comparison with the Miller-Casellas.

> Several thermometers for use in the apparatus were forwarded from time to time. A greater number were found broken when they reached the ship, owing either to imperfect packing or negligence in the transport, but a sufficient number arrived in safety to admit of their having a fair trial.

Gazelle had 22 Miller-Casella thermometers and one Negretti-Zambra, presumably, sourced as were *Challenger*'s, from Chatham and loaded in Plymouth. The subsequent controversies about the interpretation of the temperature measurements are summarized in Deacon (1971).

By the 1870s the rapid spread of the submarine telegraph cable network had stimulated interest in using electrical apparatus in the ocean. The leading innovator in this field was the Anglo-German William (Carl Wilhelm) Siemens (1823–1883, born in Germany but who moved to London in 1843; Thurston, 1884). He developed the bathometer: effectively the forerunner of the conductivity–temperature–depth (CTD) probes that started to replace the reversing thermometers in the 1960s. The bathometer measured temperature using a sensor in one arm of a Wheatstone bridge, and one of the instruments was used on *Challenger* and its comparison with thermometers reported. The bathometer was used more extensively by Alexander Agassiz aboard the USS *Blake* in 1881 and reported by Siemens (1882). The *Challenger* instrument's performance was reported (Narrative, Vol. 1 Part 1) as follows:

> Several more or less successful observations were made with this instrument during the cruise, which agreed fairly well with those made by the protected thermometers. No permanent place was fitted for the galvanometer or apparatus, and in consequence continuous and careful observations were not made. When accurate temperature observations are required from intermediate depths, this instrument is especially valuable, and it will in all probability be extensively used in future deep-sea investigations.

This prescient observation might well be seen as the start point for modern-day electronic ocean science. *Challenger* also carried two other experimental devices. One, designed by Siemens, measured the depth to which light penetrated by exposing light-sensitive paper for a fixed length of time. The second, Buchanan's piezometer, sought to separate the effects of pressure and temperature (Rice, 2001). Neither of these devices was used routinely.

Finally, there was one technology which arrived just too late to be employed aboard *Challenger* and *Gazelle*. This was the sounding machine developed by Sir William Thomson (later Lord Kelvin). A prototype was provided to the British Admiralty for use on the *Challenger* expedition but was declined as not being sufficiently reliable for use on such a long voyage. However, a version of the Kelvin machine modified by the Berlin instrument maker Carl Bamberg was being used aboard USS *Tuscarora* in the North Pacific in 1874 (Theberge, 2014), and the fact that these 483 soundings had been made was a factor in the change of *Challenger*'s route across the North Pacific. Spry (1876) makes this statement:

> Last year (1874) the United States government dispatched the steam vessel *Tuscarora* on a deep-sea sounding cruise between San Francisco, the Sandwich Islands and the coast of Japan, with instructions on their return route to complete a line of soundings from Yokohama extending in a great circle to the north, passing along the islands of the Aleutian group and so towards Puget Sound with a view to finding a practical cable route across. The course therefore selected by us was one intermediate between these two (through the parallel of 35° N latitude) until reaching 155° W longitude.

The fact that *Tuscarora* made more soundings in a few months than *Challenger* made in almost 4 years shows the advantages of a Kelvin-type sounding machine. Arguably had the *Challenger* and *Gazelle* voyages been a few years later, both might have used sounding machines and thus saved considerable station time.

6.4 Divergence of scientific foci

Though the core scientific observations of *Challenger* and *Gazelle* were similar, in other respects there were distinct differences, which might be accounted for largely by *Challenger* carrying a team of scientists while *Gazelle* carried naval officers and surveyors. Thus, the major focus of *Challenger* was marine biology and chemistry driven by the scientists on board. *Gazelle* made similar measurements of seawater properties and collected biological and geological samples for later analysis but also made extensive geophysical (gravity and geomagnetic) measurements better aligned to the interests and experience of the naval surveyors she carried. It is interesting to note that the *Gazelle*'s magnetic equipment was carefully calibrated in Berlin before the voyage and that the sailing orders include encouragement to compare them with shore-based observatories at the Cape of Good Hope and Mauritius and with the site established on Kerguelen. Such an intercalibration is now well recognized as good scientific practice.

7 Health and safety

Nineteenth-century ships were not safe places. Ships' companies on vessels such as *Challenger* and *Gazelle* had to deal with both the hazards of working aloft to set and furl the sails and managing the steam engines, both those for propulsion and the donkey engines used to provide mechanical assistance on deck. The crews included a significant number of young cadets (boys) in their mid-teens with little experience. Warships were traditionally crowded, and though they carried doctors (surgeons), medical care and the understanding of disease was rudimentary by present-day standards. The food, without refrigeration, was similarly basic and monotonous. The two voyages discussed here covered a wide range of climatic conditions, ranging from the tropics to the Southern Ocean, and spent long periods far from land.

However, with the advent of steam engines came freshwater evaporated from seawater, thus freeing vessels from the vagaries and hazards of water supplied from shore. Though the water may have been safer, it was not popular with *Challenger*'s crew as Matkin comments (Rehbock, 1992, p. 32):

> A good many of the men complaining of the water which is condensed from the sea at night & drank(sic) the next day & is scarcely cool. I felt ill myself the other day but have improved by qualifying the water with a little Rum or Lime juice.

The *Challenger* health record is covered in Appendix IV to the narrative (Tizard et al., 1885b) by Fleet Surgeon George Maclean, R.N. The opening lines convey the fact that ill health was not regarded as an issue.

> The medical history of the *Challenger* expedition is, fortunately perhaps, of little interest, considering the rapid variations of climate experienced, the large proportion of time spent at sea, and the trying nature of the seamen's work. The health of the ship's company during the commission of nearly 4 years must be regarded as exceptionally good and will probably compare favourably with that of any ordinary cruiser on any of the foreign stations.

Scurvy was entirely absent, and this was attributed to the diet, the issuing of lime juice[17] (Smith, 2018) and, according to Maclean, the fact that "the duration of the passages was limited and was capable of being calculated with strict accuracy, owing to the use of steam". This statement is at odds with the comment by Buchanan (1919) on page 36:

> Her screw propeller could be hoisted up out of the water. This was a great convenience because all the passage was made under sail. The whole amount of coal which she could carry was very little more than that required for manoeuvring the ship at the sounding and dredging stations.

[17] Ironically, the British Antarctic expedition (1875–1876), which Nares led, suffered badly from scurvy. They chose not to carry lime juice because of its weight and the fuel needed to thaw it (https://api.parliament.uk/historic-hansard/commons/1877/jun/18/navy-report-of-the-arctic-committee; last access: 6 June 2022).

The summary of the losses and illnesses states that there were on average 240 men on board and seven deaths, two due to natural causes, three by violence (two by drowning and a single fatality to a seaman when a dredging rope broke), and two by poisoning. A total of 11 were invalided, and 15 were sent to hospital. The only other losses of the ship's company were due to desertions "for which the attractions of the Australian ports visited were chiefly responsible."

The diseases encountered were enteric fever (typhoid, 2 cases), yellow fever (1 case), malaria (28 cases, all comparatively mild), erysipelas (the single fatal case of this bacteriological skin disease that claimed the life of Willemoes-Suhm), syphilis (10 cases), and phthisis (pulmonary tuberculosis, 6 cases). Three men suffered from heart disease and five from bronchitis. Two had pneumonia, and there were many cases of catarrh.

The health of the participants in the *Gazelle* voyage has been summarized by Hartmann (1995), but there are other glimpses of medical issues.

Chapter 14 of the *Gazelle* narrative starts sombrely and continues to recount the vessel's stay in Brisbane, beginning 26 September 1875.

> Unfortunately, the *Gazelle*'s stay in Brisbane was significantly longer than intended due to an epidemic of illness among the crew.
>
> Under the influence of the hot climate and the long period eating only ship's rations[18] coupled with the exertions of constantly sailing the ship, chopping down and collecting wood the ship's company were repeatedly sick with tropical and typhoid fevers, dysentery and scurvy. Infections occurred, and in the short period from the beginning of July[19] to the end of September, unfortunately we mourned the death of five people.
>
> Later the number of sick people increased to 50 or so, with up to 22 fever patients. Typhoid gradually assumed an epidemic character leading the Health Authority in Brisbane to quarantine the ship as soon as it arrived. As a result, the supply of the ship with coal, water and provisions became even more cumbersome and time-consuming. Additionally, since coal was not available in Brisbane, it had to be brought in from a distant pit.
>
> On October 7, the ship went to the quarantine station at Peel Island, where all those suffering from fever, insofar as they were not yet convalescent, went to the island's barracks. The whole ship, the hammocks, woollen blankets, and the sailors' belongings, etc., was repeatedly cleaned, disinfected and fumigated, and all communication with the infirmary stopped.
>
> Through this and through the administration of a strong diet consisting exclusively of fresh provisions and strengthening drinks, it was possible to stop the spread of the epidemic, so that the ship could already be freed from the quarantine on October 12th. However, in order to be able to reembark the sick, among whom unfortunately two deaths occurred, without danger, the stay had to be extended until October 20th. During this time regular traffic was maintained between the ship and Brisbane, and the officers and crew were treated with courtesy by both the German and English population.

The report of a visit to the ship on 16 October, in a local newspaper[20], sheds further light on the situation. The ship was at anchor near the quarantine station on Peel Island, and the report makes these comments:

> We understand that, owing to the continued illness of some of the seamen of the *Gazelle*, now landed on Peel Island, it is probable that the vessel may remain in our waters for some days to come.

The report from the Peel Island quarantine station, dated 1 January 1876, mentions *Gazelle*.

> *Gazelle* (German warship). Maybe around 10 deaths, with graves made up and headboards with suitable inscriptions placed at each one, unlike many of the later graves from English ships.

The newspaper report also describes the crew's living quarters as follows:

> Near the engines are the furnaces and boilers, which are ranged on either side of the vessel, with a narrow passage between, and close to these is the condensing apparatus. This deck is the home of the sailors, the space forward of the engines being occupied in the centre of the vessel by racks for the men's "kits", which were stowed away in canvas bags. On either side were to be seen the utensils used by the men in taking their meals, and overhead were the hooks to which their hammocks are swung, and the portable tables, kept there when not in use.

The paper by Hartmann (1995) gives an overall perspective on the voyage but sheds light on some of the issues raised above. In particular the reference to "chopping down

[18] Since leaving Mauritius on 15 March, the vessel had been in significant ports for only 23 out of 195 d, 13 in Koepang (now Kupang in West Timor) and 10 in Amboina (now Ambon in Indonesia's Kupang State). Both were then Dutch colonies.

[19] She was then surveying north of New Guinea.

[20] *The Queenslander*, Saturday 23 October 1875.

and collecting wood" during the period spent surveying New Guinea. This tropical area had light winds, and the *Gazelle* had by then exhausted its coal supplies. Thus, the crew, who were already in poor condition, had to collect timber and bring it on board to fuel the furnaces for the ship's steam engine and to do this in high temperatures and humid conditions. The area was mosquito-infested, and, although at that time these were not recognized as the vectors for malaria, many of the crew were affected.

Hartmann also sheds light on many aspects of the health of *Gazelle*'s crew. In the "roaring forties" a sailor fell from the rigging and was killed, and there were, among the crew, "a large number of so-called mechanical injuries, which today we call bone fractures, ligament ruptures and dislocations"[21].

During the period spent around New Guinea, on average, 7 % of the crew were "sick on the bunk". On some days more than 50 people were not able to work.

In part this was due to the prevalence of malaria despite the officers and crew receiving daily prophylactic quinine (3×0.5 g) since before their first approach to the African coast. Quinine was however unpopular, and an officer is quoted (Richter, 1910) as saying the following:

> Like the crew for a long time, we now have to swallow a lot of quinine, by which everyone is affected a little, some being affected very badly; I feel ill from it. The quinine makes the night watches very hard to manage, as one can barely keep awake in the calm weather.

Hartmann also sheds light on the prevalence of scurvy, a disease that had at that time been eliminated from the Royal Navy. The diet of the *Gazelle*'s sailors was poor.

> The meals on board consisted mainly of hard bread, the ship's biscuit, legumes like pearl barley and beans, once a week dried potatoes and salted meat, the so-called preserved meat, which was also issued once a week. This provision, which was stowed inside the ship, was called sea provisions. Fresh meat could only be served seven times during the 6 months of travel or shortly after visiting a port.

However, their diet was similar to that on *Challenger*. While around Kerguelen, the diet was supplemented with Kerguelen cabbage which James Cook 100 years earlier had recognized as an antiscorbutic. Most significantly, the Imperial German Navy gave its crews citric acid rather than lemon or lime juice since it was cheaper and easier to store but contained no vitamin C.

Even in the relatively benign climate of the Pacific, there were hazards. A diamond back snake was brought on board and bit Dr. Huesker, who "believed he was dying as a result. Thank God the fear was in vain".

Thus, the two vessels fared very differently with regard to health, due, in large part, to the extremely long and arduous periods spent by *Gazelle* around Kerguelen (over 100 d with average temperature of 7 °C) and around New Guinea (almost 2 months with high humidity and temperature around 30 °C[22]) and the poor diet and flawed prophylaxis.

8 The reports

For both voyages, the process of analysis, interpretation, and reporting was a long one. For *Challenger* it lasted from 1885 until 1895. The *Gazelle* reporting covered only 2 years, but the first was not published until 13 years after the voyage's completion. Each was hindered by the deaths and illness of key personnel.

Rudolf Willemoes-Suhm died at sea. He had suffered from eruption of boils for much of *Challenger*'s voyage and died on 13 September 1875, a few days after the vessel left Hawaii. The cause of death was given as erysipelas, a bacterial infection, which now would be treated with antibiotics. A memorial plaque was erected in Itzehoe, Schleswig Holstein, by his *Challenger* colleagues. It was later moved to Bad Segeberg (Kortum, 1996), perhaps by von Willemoes-Suhm's mother, with whom he had corresponded throughout the voyage (von Willemoes-Suhm, 1877).

On his return from the expedition, Wyville Thomson had been elected a fellow of the Royal Society and received the Society's Royal Medal. Its citation was "For his successful direction of the scientific investigations carried on by HMS *Challenger*". (Since the medal's inception in 1826, very few awards did not mention a particular area of science; https://royalsociety.org/grants-schemes-awards/awards/royal-medal/, last access: 6 June 2022.)

Further insights into Wyville Thompson's life as a scientist and to his character are in the obituary notice (Balfour, 1883) read to the Botanical Society of Edinburgh (p. 278 of https://www.google.co.uk/books/edition/Transactions_and_Proceedings_of_the_Bota/vpBMAAAAMAAJ?q=&gbpv=1#f=false, last access: 6 June 2022) on 13 April 1882. Following his return, it was noted that the voyage "had not brought about increased vigour", and indeed the planning of the analysis of the results of the expedition and the preparation of the reports must have been a considerable burden on him in addition to the lecturing about the voyage that he was called on to do. Balfour, a personal friend, records that in June 1879 he suffered a paralytic attack (perhaps a stroke) and a second one at the beginning of 1882. He died on 10 March of that year aged 52 and is buried at St. Michael's Church, Linlithgow.

[21] Quotations are from the author's translation of Hartmann's paper.

[22] Temperatures estimated from the meteorological records in Vol. 5 of the *Gazelle* report.

Buchanan's recollections of the *Challenger* expedition are recorded in the chapter "A Retrospect of Oceanography" in his book *Accounts Rendered of Works Done and Things Seen* (Buchanan, 1919).

Deacon (1971) proves an insightful summary of the political, personal, financial, and scientific issues surrounding the disposition of the collected samples and the process of publication of the *Challenger* reports. Wyville Thomson had stipulated before the voyage that the samples should become government property, and he secured funding for 5 years to cover the cost and expenses of the staff concerned with storing the samples and writing the reports. This was opposed by the British Museum, who, eventually, secured the terrestrial items, while the marine material was retained in Edinburgh where a *Challenger* office had been established at 32 Queen Street. This office would serve as the focus for the publication process, even though the *Challenger* scientists eventually returned to their former academic positions. The Challenger offices saw a steady stream of international scientists involved in the preparation of the reports. However, the publication process was slow, and when the initial funding was coming to an end, the government (Treasury) gave no hope of the grant's renewal. The stress this caused to Wyville Thomson may well have contributed to his illness and sudden death. Eventually the Treasury relented and allocated a further 5 years of funding, and John Murray became director of the *Challenger* office. The publication process, the analysis of the results, and samples from *Challenger* stimulated much scientific discussion and debate.

At the end of the publication process in 1895, John Murray designed and paid for the production of a *Challenger* medal (an online index of the medals can be found at http://www.19thcenturyscience.org/HMSC/Chall-Medal/ChallengerMedal.html, last access: 14 April 2022) to be issued to people who had been involved in the expedition and in the publication process. A total of 120 medals were struck and issued between 1895 and 1897. Murray was knighted in 1898. The medals were awarded to the ship's officers, scientists, and crew, to scientists involved in the publication, and to politicians and others who had helped make the expedition possible.

The *Challenger* reports (Fig. 7) finally ran to a total of 50 volumes (online at https://www.biodiversitylibrary.org/bibliography/6513, last access: 6 June 2022) and were compiled by a large, international group. For the present-day researcher, navigating through their many pages to find specific pieces of information presents a considerable challenge.

The publication of the reports of the *Gazelle* voyage (Hydrographisches Amt der Admiraltät, 1888, 1889a, b, c, 1890) followed a very different but no less difficult path. Since *Gazelle* was a survey vessel, von Schleinitz submitted regular short reports via mail steamer (particularly relating to surveys of harbours and coasts), and these were published in *Annalen der Hydrographie und Maritmen Meteorologie*, the journal of the German Hydrographic Office and Coastguard.

Figure 7. An almost complete set of *Challenger* reports (National Oceanographic Library, Southampton) and the *Gazelle* reports to the same scale. (Walter Zenk, GEOMAR Helmholtz-Zentrum für Ozeanforschung, Kiel).

However, the introduction to Vol. 1 of the *Gazelle* reports shows that their publication had not been planned.

> it was not at the time the intention to summarize and publish the results of the research in a special report; only later, a few years after the expedition, when the rich and valuable material collected on the voyage was assessed, did the need became clear to process it further and to compile it into a unified work.

There is a clear recognition that this delay seriously hindered the process of report preparation not least in that the material and information collected by *Gazelle* had become scattered. However, in 1880 a memorandum was submitted to the Reichstag, and funds were allocated and, partly through the auspices of the Academy of Sciences, a concerted effort to prepare the reports began.

> The preparatory work for the publication was carried out up to the beginning of 1886 under the personal direction of the former commander of S.M.S. "*Gazelle*", Kontre-Admiral Freiherrn von Schleinitz. When he was taken from this activity by his appointment as governor of Kaiser Wilhelmsland and the Bismarck Archipelago[23], the head of the Admiralty commissioned the Hydrographic Office with the publication of the work and under the same the Admiralty Council Captain Lieutenant D. ROTTOK with the publication work. This task was not an easy one, firstly because of illnesses of individual employees and also because various work had either not yet started or been completed, so the collection of the material intended for publication was made extremely difficult and impossible. In addition, the funds allocated for the work set rather narrow limits on the scope of the same. This resulted in a considerable reduction of some already completed parts and a few significant restrictions on others, and in some cases it was necessary to exclude individual sections from publication.

Though he had not previously been involved in the *Gazelle* voyage, Rottok was clearly a key person in the publication process which resulted in five volumes: Vol. 1 – The narrative, Vol. 2 – Physics and Chemistry, Vol. 3 – Zoology and Geology, Vol. 4 – Botany, and Vol. 5 – Meteorology. (See Appendix B for the full contents list.) It had been intended that the meteorology would be included in Vol. 2.

> To classify the results of meteorological observations in this part, as was originally planned, had to be given up on account of their great extent. It is intended, however, that the extensive material, which has been completed under the direction of the director of the Naval Observatory, if the means at hand allow it, to be subsequently published in a special fifth part.[24]

The difficulty in preparing the reports is illustrated by the following quotation.

> It caused great embarrassment when Dr. GOTTSCHE, who had studied the very extensive and valuable collection of liverworts, suddenly fell ill and could not finish his work. Eventually, Privat docent DR SCHIFFNER found himself ready in Prague to finish the work. The painstaking processing of the Diatomaceae, to which Director JANISCH had devoted himself tirelessly for years, came to a very regrettable end after a number of interesting and valuable tables of the Diatomaceae he had identified had come to a halt due to ongoing illness. It has not been completed, and in order not to postpone the publication of the work any longer, has unfortunately been omitted from the publication.

What is perhaps revealing is the heavy emphasis in the *Gazelle* narrative (Vol. 1) on anthropology. Approximately half the illustrations and large parts of the text in that volume are devoted to the subject.

The international nature of the preparation of the *Challenger* material and the international connections of the *Challenger* scientists have already been mentioned, and this international dimension continued with the reporting which involved scientists from 10 nations. These contributors are listed in Appendix C.

By contrast, the *Gazelle* scientists and naval officers involved in writing the reports were, with the exception of Dr. Studer who was Swiss, all German. From a modern-day perspective, it also seems remarkable that no French scientists were involved in the preparation, execution, and reporting of either of the voyages, but this may be explained by the diminished state of French science following the conclusion of the Franco-Prussian war (Crosland, 1976; Dolan, 2020).

9 Postscript and conclusions

So, how were the voyages regarded as they came to their conclusions? The end of Vol. 2 of the *Challenger* narrative contains the following assessment.

> finally the crew was paid off at Chatham on the 6th of June 1876. Sir C. Wyville Thomson says: – "Writing now after the commission has come to a close, I think I am justified in saying that the object of the expedition had been fully and faithfully carried out. The instructions of the Lord commissioners of the Admiralty, founded upon the recommendation of a committee of the Royal Society, were followed so far as circumstances would permit. We always kept in view that to explore the conditions of the deep sea was the primary object of a mission, and throughout the voyage we took every possible opportunity of making a deep-sea observation. We dredged from time to time in shallow water in the most remote regions, and we have in this way acquired many undescribed animal forms; and collections of land animals and plants were likewise made on every available occasion; but I rather discouraged such work, which in our case could only

[23] In 1884 the northeast part of New Guinea and nearby island groups became a German protectorate, Kaiser-Wilhelmsland. Von Schleinitz was appointed its first governor (Landeshauptmann), returning to Germany in 1888 (https://adb.anu.edu.au/biography/schleinitz-georg-gustav-freiherr-von-4542; last access: 15 April 2022).

[24] This was written in 1889, but part 5 was not published until 1890.

> be done imperfectly, if it seemed likely to divert our attention from our special object".

Joe Matkin (Rehbock, 1992) wrote his last letter from Chatham Dockyard on 11 June where *Challenger*'s crew were paid off and the ship was to be decommissioned. It was to be the end of his naval service. His letter provides a view from "below deck".

> several of those who were entitled took their discharges from the Navy – myself among the number – finding sea life nought but vanity, and vexation of spirit, especially the latter – my opinion of it coinciding with that of Dr Samuel Johnson's AD 1776 – with which quotation I will conclude my long series of letters from HMS *Challenger*:
>
> A ship is worse than a jail. There is, in a jail, better air, better company, better convenience of every kind: & a ship has the additional disadvantage of being in danger. When men come to like a sea-life they are not fit to live on land.
>
> Men go to sea, before they know the unhappiness of the way of life; & when they have come to know it, they cannot escape from it, because it is then too late to choose another profession, as indeed is generally the case with men when they have once engaged in any particular way of life. Hoping to see you tomorrow, Believe me, Sincerely your Joe Matkin.

Rehbok comments that Matkin's letters hint at strained relationships between the crew and the officers and scientists and at the particular challenges the crew faced due to long periods spent in inhospitable climates.

The conclusion of the *Gazelle* narrative includes no summary, no assessment of achievements, nor any comment on the end of the voyage. It merely ends with the following words:

> On the 28th in the morning at 6 1/2 o'clock the Bülk lighthouse came into sight as the first outpost of the home port. At 8 o'clock we passed it, and an hour later the lighthouse of Friedrichsort was passed, and we entered the port of Kiel, where the "Gazelle" tied up at the buoy at 9 3/4 o'clock. After the inspection of the ship by the Chief of the Admiralty, which took place on the following days, disarmament proceeded, and on May 12 at 2 p.m. with the usual ceremony and with a toast to His Majesty the Emperor, the "Gazelle" was decommissioned.

Perhaps a more insightful, but unofficial, view of the *Gazelle* voyage is in the diary of *Gazelle*'s purser quoted by Hartmann (1995).

> Gott lob, diese schwere und mühevolle Reise liegt nun hinter uns.
>
> Thank God, this difficult and arduous journey is now behind us[25].

On their return, both vessels were nearly 20 years old but were reaching the end of their useful lives. *Challenger* had a refit in 1878 to convert her to a training ship but was not used for that purpose and was put in reserve until 1883. She then became a hulk on the river Medway and was scrapped in 1921. *Gazelle* continued in naval service until 1884, later becoming a barrack ship in Wilhelmshaven and being broken up in 1906 (Gröner, 1990). All that remains of the ships is *Challenger*'s figurehead, standing guard at the entrance to the National Oceanography Centre in Southampton.

10 Legacy

From a 21st century perspective, the data and preserved samples from these 19th century global voyages provide an important baseline against which the modern ocean, affected by anthropogenic climate change, may be compared (e.g. Roemmich et al., 2012; Gould and Cunningham, 2021) and help us to address such issues as ocean heat storage, acidification and its effect on marine organisms, and the acceleration of the global hydrological cycle. After the *Challenger* material had been studied and reported, most of the marine material was deposited at the Natural History Museum in London, where it still resides and is available for study (e.g. Fox et al., 2020). So, their value has lasted 150 years.

It cannot be denied that the *Gazelle* voyage became almost invisible in the shadow of *Challenger*. The roots of that invisibility can probably be traced to the fact that, although the quality and scope of the observations were similar, the undoubted traumatic nature of the *Gazelle* voyage was perhaps a factor in the delayed publication of the report. Momentum was lost. An additional factor may be found in the underlying motivations for the *Gazelle* voyage, which are hinted at in the first volume of the report and can be summarized and roughly ranked as follows:

- improving the technical capabilities of the newly formed Imperial German Navy
- "showing the flag" for that Navy
- transporting the "Transit of Venus" astronomers
- anthropological and colonial exploration
- adding to our knowledge of the deep oceans and shelf seas.

Perhaps none of these was seen a giving a strong motivation for celebrating the voyage's achievements. One might even

[25] Bruno Buchwald: *Die Forschungsreise S.M.S. "Gazelle" 1874 bis 1876. Tagebuchnotizen des Oberbotteliers Rudolph Buchwald.* Hamburg, Berlin 1999, S. 11. Held by Marineschule Mürwik, Germany.

speculate that had it not been for the transit of Venus and the colonial aspirations, there would have no good reason for a circumnavigation by *Gazelle*.

We have already commented on the fact that the *Challenger* reports were compiled by an international team (Appendix C), and this may have contributed to *Challenger*'s visibility. Kortum (1996) also speculates that had von Willemoes-Suhm survived, he might have played a critical role in building scientific bridges between Britain and Germany based on the *Challenger* and *Gazelle* voyages. This might have increased the visibility of the *Gazelle* voyage.

The lasting scientific legacy of both voyages is the information contained in their published reports and in unpublished logbooks, notes, and diaries, together with the preserved samples that were collected. The reports are readily available in print and online, but other material is widely scattered, and, in the case of *Gazelle*, little seems to have survived the intervening 150 years. Fortunately, after the *Challenger* samples had been studied and reported on, most of the marine material was deposited at the Natural History Museum (NHM) in London where it still resides and is available for study. Because the voyages took place early in the industrial age, the recorded observations made from both ships provide an important baseline against which the modern ocean, affected by anthropogenic climate change, may be compared. Such studies have included temperature change (Roemmich et al., 2012; Wenegrat et al., 2022) and salinity change as an indicator of changes in the global hydrological cycle (Gould and Cunningham, 2021). The *Challenger* samples have been used to show the impacts of recent ocean acidification on planktonic foraminifera (Fox et al., 2020). Samples collected in the 1870s also provide a rich resource for taxonomists, though it is a cause for concern that access by researchers to the enormous *Challenger* collection may be at put at risk by changing priorities at the NHM (Naggs, 2022).

Anniversaries provide catalysts for celebrations and reassessments. A period of 100 years after *Challenger* sailed, Eric Linklater's book, *The Voyage of the Challenger* (Linklater, 1972), brought the voyage back to the attention of the general public. A *Challenger* centenary medal was struck, and, at a celebratory dinner, Madeira wine that had been carried around the North Atlantic aboard *Challenger* was drunk (Rutherford, 1972; Mayson, 2015). We now approach the 150th anniversaries of these voyages, and, while there will be many retrospective assessments, a fitting tribute to all those involved in the two expeditions would be the further use of their measurements and samples to better understand the oceans' role in earth's climate.

Appendix A

Table A1. Port calls and survey areas.

Atlantic outbound					
Challenger			*Gazelle*		
Port	Dates	Days	Port	Dates	Days
Portsmouth sailed	21 Dec 1872		Kiel Sailed	21 Jun 1874	
Lisbon	3–12 Jan 1873	9	Plymouth	28 Jun–3 Jul 1874	5
Gibraltar	18–26 Jan 1873	8	Madeira	15–16 Jul 1874	1
Madeira	2–5 Feb 1873	3	Cape Verde	27–30 Jul 1874	3
Tenerife	7–10 Feb 1873 13–14 Feb 1873	3 1	Monrovia	4–7 Aug 1874	3
St Thomas W.I.	16–24 Mar 1873	8	Ascension Is	18–19 Aug 1874	1
Bermuda	4–21 Apr 1873	14	Congo	2–5 Sep 1874	3
Halifax	9–19 May 1873	10	Cape Town, South Africa	26 Sep–3 Oct 1874	7
Bermuda	31 May–13 Jun 1873	13			
Azores, Horta	1–2 Jul 1873	1			
Azores, Ponta Delgada	4–9 Jul 1873	5			
Madeira	16–17 Jul 1873	1			
Cape Verde	28 Jul–9 Aug 1873	12			
St Paul Rocks	28–29 Aug 1873	1			
Fernando de Noronha	1–3 Sep 1873	2			
Bahia	15–25 Sep 1873	10			
Tristan da Cunha	15–18 Oct 1873	3			
Simonstown, South Africa	28 Oct–17 Dec 1873	50			
Indian and Southern Ocean					
Port	Dates	Days	Port	Dates	Days
Leave Simonstown	17 Dec 1873		Leave Cape Town	3 Oct 1874	
Prince Edward/ Marion Is	26–27 Dec 1873	1	Crozet	18/19 Oct 1874	1
Crozet	31 Dec 1873– 3 Jan 1874	3	Kerguelen	26 Oct 1874 5 Feb 1875	103
Kerguelen	7 Jan–1 Feb 1874	15	Mauritius	26 Feb–15 Mar 1875	18
McDonald Is and Heard Is	6–27 Feb 1874	21	Mermaid Strait, Australia	27 Apr 1875	1
Melbourne	17 Mar–1 Apr 1874	15			

Table A1. Continued.

Pacific					
Port	Dates	Days	Port	Dates	Days
Leave Melbourne	1 Apr 1874		Leave Mermaid Strait	27 Apr 1875	
Sydney	6 Apr–8 Jun 1874	63	Koepang	14–26 May 1875	13
Wellington	28 Jun–6 Jul 1874	8	Atapopa	27–28 May 1875	2
Kermadec	13–17Jul 1874	4	Amboina	2–11 Jun 1875	10
Tonga	19–22 Jul 1874	3	New Guinea Bismarck Archipelago	15 Jun–11 Aug 1875	56
Fiji	24 Jul–11 Aug 1874	18	Solomon Is	24–29 Aug 1875	5
New Hebrides	17–19 Aug 1874	2	Brisbane, Aus	26 Sep–20 Oct 1875	24
Raine Is	31 Aug 1874	1	Auckland, NZ	29 Oct 11 Nov 1875	13
Cape York	1–8 Sep 1874	7	Fiji	23 Nov 1875	
Aru Is	14–23 Sep 1874	9	Tonga	8–20 Dec 1875	12
Ki Is	24–26 Sep 1874	12	Samoa	24–28 Dec 1875	4
Banda Is	29 Sep–2 Oct 1874	3	Magellan Strait	1 Feb 1876	
Amboina	4–10 Oct 1874	6			
Ternate Moluccas	15–17 Oct 1874	2			
Samboangan Philippines	23–26 Oct 1874	3			
Ilo Ilo	28–31 Oct 1874	3			
Manila	4–11 Nov 1874	7			
Hong Kong	16 Nov 1874–6 Jan 1875	51			
Manila	11–15 Jan 1875	4			
Zebu	18–24 Jan 1875	6			
Camiguin Is	26 Jan 1875	1			
Samboangan	29 Jan–5 Feb 1875	7			
Humboldt Bay NG	22–24 Feb 1875	2			
Admiralty Is	3–10 Mar 1875	7			
Japan	11 Apr–16 Jun 1875	66			
Sandwich Is, Hawaii	27 Jul–19 Aug 1875	23			
Society Is, Tahiti	18 Sep–3 Oct 1875	15			
Juan Fernandez	13–15 Nov 1875	2			
Valparaiso	19 Nov–11 Dec 1875	22			
Magellan Strait	31 Dec 1875–20 Jan 1876	21			

Table A1. Continued.

Atlantic homeward					
Port	Dates	Days	Port	Dates	Days
Leave Magellan Str	20 Jan 1876		Leave Magellan Str	1 Feb 1876	
Falkland Is	23 Jan–Feb 6	14	Punta Arenas	6–8 Feb 1876	2
Montevideo	16–25 Feb	9	Montevideo	16–19 Feb 1876	3
Ascension Is	27 Mar–3 Apr	7	Azores	10–12 Apr 1876	2
Cape Verde	17–26 Apr	9	Plymouth	15–20 Apr 1876	5
Vigo	2 May	1	Kiel	28 Apr 1876	
Spithead	24 May	1			

Appendix B: Translation of the contents list of *Gazelle* reports

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Chapter 5	The tide observations at Kerguelen, Betsy Cove. Edited by Professor Dr. BORGEN	117–127
Chapter 6	Wave observations carried out on board S.M.S. "Gazelle". Edited by Capt. Lieutenant a. D. ROTTOK	128–134
Chapter 7	The Magnetic Observations. SMS "Gazelle". Edited by Professor Dr. BÖRGEN	135–195
Chapter 8	Geomagnetic and tidal observations on the Auckland Islands (Terror Cove, Port Ross). Processed by Professor Dr. BÖRGEN	196–216
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2. Algae processed by Prof. Dr. E. ASKENASZY. With 12 figures.
3. Mushrooms and lichens
   A. Mushrooms processed by Baron FELIX v. THÜMEN
   B. Lichens processed by Prof. Dr. A. MÜLLER in Geneva
4. Liverworts (Hepaticae) based on the preparatory work carried out by Dr. A.C.M. GOTTSCHE edited by Dr. V. SCHIFFNER. With 8 figures.
5. Mosses processed by Dr. KARL MÜLLER in Halle.
6. Ferns (Filicinae) and clubmoss-like plants (Lycopodinae) processed by Dr. M KUHN with 3 figures.
7. Siphonogams (Phanerogamen) processed by Prof. Dr. A ENGLER with 15 figures.

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Appendix C: International contributors to the *Challenger* expedition reports (nationalities are those of the institutions in which the contributors worked at the time)

The reports are available online at https://www.biodiversitylibrary.org/bibliography/6513 (last access: 19 September 2022).

Contributions are to the zoology reports unless otherwise stated.

Austria	Ludwig von Graff
Belgium	Paul Pelseneer, Rev Alphonse Francois Renard (sediments)
Denmark	Rudolph Bergh
Germany	Albert Günther (British-born Germany), Ernst Haeckel, Richard Hertwig, Franz Eilhard Schulze, Emil Selenka, Theophil Studer, Otto von Linstow, Albert von Kölliker (born Switzerland)
Ireland	Daniel John Cunningham, Alfred Cort Haddon, William Johnson Sollas
Italy	Francesco Castracane degli Antelminelli (botany Diatomaceae)
the Netherlands	Paulius Peronius Cato Hoek, Ambrosius Arnold Willem Hubrecht
Norway	Georg Ossian Sars
Russia	Nikolai Nikolaevich Poléjaeff
Sweden	Hjalmar Théel
USA	Alexander Agassiz, W.K. Brooks, Theodore Lyman III

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