A deeper history of the 'world's largest dead zone' in the Gulf of Oman

SCOTT T. ERICH
City University of New York (CUNY) Graduate Center

Abstract

This article attempts to trace a deeper history of a 'dead zone'—the term for areas of the ocean with lower than normal amounts of dissolved oxygen—in the Gulf of Oman. Due to the paucity of oceanographic data before the late twentieth century, this article reviews a range of British imperial travelogues and fisheries records with an eye to knowledge gleaned from contemporary scientific knowledge of the phenomenon. Although imperial sources do not discuss the issue directly (the science of dead zones was not articulated until the mid-twentieth century), they serve as sources of valuable indirect data pointing to the presence of accompanying phenomena of low-oxygen waters—large-scale blooms of the bioluminescent plankton *Noctiluca scintillans* and fluctuations in fish stocks—long before the 'discovery' of 'the world's largest dead zone' in 2018. This approach yields a deeper view of the sea's changes through time instead of accepting the sensationalist immediacy of contemporary journalistic accounts, and impels us to take seriously the wisdom of local fishers as a counterweight to scientific knowledge. In doing so, it hopes to advance a scholarly conversation about mixed methods in environmental history and Indian Ocean studies, and about the paradoxes and contradictions of life in the 'Anthropocene'.

Keywords: Gulf of Oman, oceans, dead zones, indirect data, environmental social science

> The ocean is suffocating. Of course all fish, marine plants and other animals need oxygen, so they can't survive there.[1]
>
> As for the report's claim that 'marine life in the Arabian Sea has become impossible,' this is an exaggeration and an obvious fallacy.[2]

1 Tom Embury-Dennis, '"Dead Zone" Larger than Scotland Found by Underwater Robots in Arabian Sea', *Independent*, 27 April 2018, www.independent.co.uk/climate-change/news/dead-zone-arabian-sea-gulf-oman-underwater-robots-ocean-pollution-discovery-a8325676.html, accessed 27 May 2021.

2 Muḥammad Sulaymān, 'Khubra' wa masūwalūn yū'kidūn salāmah al-hayyāh al baḥriyyah fī baḥr 'ūmān wa taqrīr "āl-Independent" mubāligh fīh', Al-Shabībah (Muscat), 2 May 2018, shabiba.com/article/96053, accessed 27 May 2021.

Introduction: Elusive truths about an emergent 'dead zone'

In the spring of 2018, an article published in the scientific journal *Geophysical Research Letters* (*GRL*) raised alarms about a looming environmental crisis.[3] Using underwater drones, a team of scientists from the United Kingdom and Oman confirmed that hypoxic—or low oxygen—conditions encompass a large swathe of the Gulf of Oman,[4] which could have serious implications for regional fisheries. News outlets across the world took note of the *GRL* article, dubbing the Gulf of Oman the 'world's largest dead zone'[5] and indicating that the situation would only worsen due to warming ocean temperatures and the currents of the Indian Ocean. The possibility that a stretch of water roughly the size of Florida or Scotland—as some of the articles claimed[6]—might be devoid of oxygen (and therefore fish) sparked panicked conversations online about fisheries, climate and livelihoods in the north-west Indian Ocean.

The paper in *GRL,* however, gave no such warning. The phrase 'dead zone' appears nowhere in the piece, with the authors preferring instead to use the more specific term 'oxygen minimum zone'. And while the paper indeed says that the north-west Arabian Sea is the site of the 'thickest and most intense [oxygen minimum zones] worldwide',[7] forecasting that the Gulf of Oman will undergo deoxygenation at a rate faster than the Arabian Sea to its east, it stops short of making outright claims as to the size or scale of a current 'dead zone' in the Gulf of Oman. Instead, it calls for 'further investigation' of the Gulf of Oman because of its deoxygenation *potential*, and because the Gulf is a body of water about which little climatological data have been historically available.

Rather than wading through the paper's scientific findings, international news outlets such as *Business Insider*, the *CBC*, *Haaretz* and the *Independent* ran attention-grabbing stories based on a press release[8] issued by the university of one of the co-authors, which was intended to stir interest in otherwise technically dense research. With headlines that read 'Gulf of Oman Now World's Largest Oxygen-Depleted "Dead Zone"',[9] '"The Ocean is Suffocating:" Dead Zone Bigger than Scotland Identified

3 Bastien Y. Queste et al., 'Physical Controls on Oxygen Distribution and Denitrification Potential in the North West Arabian Sea', *Geophysical Research Letters* 45, no. 9 (2018), 4143–52, doi.org/10.1029/2017GL076666.

4 For clarity, I use the International Maritime Organization's standards on naming bodies of water here and elsewhere: the Gulf of Oman for what is sometimes called the Sea of Oman or Oman Sea, and Persian Gulf for what is sometimes called the Arabian Gulf.

5 'Gulf of Oman Now World's Largest Oxygen-Depleted "Dead Zone"', *CBC News*, 2 May 2018, www.cbc.ca/news/science/gulf-of-oman-marine-dead-zone-1.4645018, accessed 27 May 2021.

6 It should be noted that Florida is roughly twice the size of Scotland.

7 Queste et al., 'Physical Controls', 4143.

8 'Growing "Dead Zone" Confirmed by Underwater Robots', *University of East Anglia Press Release Archives* (27 April 2018), www.uea.ac.uk/about/news/press-release-archives/-/asset_publisher/XDAZWr64QAqJ/content/growing-dead-zone-confirmed-by-underwater-robots, accessed 27 May 2021.

9 'Gulf of Oman Now World's Largest Oxygen-Depleted "Dead Zone"'.

in Gulf of Oman',[10] and '"Dead Zone" Larger than Scotland Found by Underwater Robots in Arabian Sea',[11] the articles based on the press release implied that without oxygen, neither ocean flora nor fauna can survive, and that a sizeable low oxygen zone might therefore bring about regional or even global ecosystem collapse.

The Omani Government issued a response in the Arabic-language newspaper *Al-Shabībah*, calling the *Independent* piece 'exaggerated' (*bil-mubāligh*), 'inaccurate' (*ghayr ad-daqīq*) and 'unscientific' (*ghayr al-'almiyah*).[12] In an effort to prove the 'fertility' (*khusūbah*) of the Gulf of Oman, officials cited statistics from Oman's Ministry of Agriculture and Fisheries Wealth, which showed that a record-breaking 300,000 tons of fish were caught in 2017. The officials further stated that dead zones are a 'natural phenomenon' (*dhāhirat tabī'īah*) which occur all over the world.[13] And as a final rebuttal of the *GRL* article, a member of Oman's Food and Water Security Committee indicated that a dead zone of this size was unlikely, because Oman did not produce large quantities of agricultural and industrial run-off—usually singled out as the sole culprit for the proliferation of dead zones—because it is 'still in the early stages of establishing industrial projects'.[14]

Believing that the contrasts between the *GRL* paper, news articles and Omani response are themselves meaningful and point to a more complex environmental reality, this article seeks to outline the nature, scope and possible history of hypoxic water in the Gulf of Oman through a discussion of how scientists, media outlets, government authorities, fishers and colonial officials have observed and understood this phenomenon. Moreover, it examines historical and archival sources that trace the depletion of oxygen in the gulf to a time long before our environmentally conscious and climate anxiety-filled present.

This article therefore aims to parse what type of dead zone exists in the Gulf of Oman, first through a brief translation of the scientific concept, and subsequently through a discussion of some of its observable manifestations in the region: red tides and fish kills. Historical instances of these and associated phenomena, which I term 'morbid symptoms'[15] of dead zones, are then interpreted as indirect data that suggest the possibility of already deoxygenated water since the nineteenth century. My intention

10 Ruth Schuster, '"The Ocean Is Suffocating": Dead Zone Bigger than Scotland Identified in Gulf of Oman', *Haaretz* (29 April 2018), www.haaretz.com/science-and-health/MAGAZINE-the-ocean-is-suffocating-dead-zone-bigger-than-scotland-identified-1.6035247, accessed 27 May 2021.

11 Embury-Dennis, '"Dead Zone" Larger than Scotland'.

12 Sulaymān, 'Khubra' wa masūwalūn yū'kidūn'.

13 Ibid.

14 Ibid.

15 This phrase recalls Antonio Gramsci's '*fenomeni morbosi*', from one of the most quoted lines of the *Prison Notebooks*: 'The crisis consists precisely in the fact that the old is dying and the new cannot be born; in this interregnum a great variety of morbid symptoms appear' (Antonio Gramsci, *Selections from the Prison Notebooks of Antonio Gramsci*, transl. Quintin Hoare and Geoffrey Nowell Smith (New York: International Publishers, 1971), 276). We might consider the current era of climate change, often discussed in terms of 'ends' and 'deaths' (as in the end of polar ice, the death of coral reefs, the ongoing extinction of megafauna, etc.), instead as a long interregnum: a period of transition on a planetary scale, where new ecologies are struggling to be born in the ruins of the old.

is not to *prove* that a dead zone existed prior to the era of scientific measurements—an impossible task—but to demonstrate, through a methodological intervention, how indirect data about related phenomena might be a useful workaround to understanding the environmental conditions of the past.

Ethnographic snippets from the digital worlds of regional fishers inform my interpretation of contemporary dead zones, and are situated alongside and against scientific discourses. These are then constellated with indirect data from the past, using contemporary scientific understandings of the ocean to read back through texts written before such science was elaborated. This mixed methodology, of pairing historical and indirect data about the environment with contemporary accounts from scientists and laypeople, widens the angle of view beyond the soberly scientific *GRL* piece, the sensationalist headlines in the international press and the swift denials by the Omani authorities.

'Dead zones' and deoxygenation

Dead zones—or bodies of water that contain dangerously low amounts of dissolved oxygen—are both a naturally occurring phenomenon and a recent anthropogenic problem.[16] They are a natural phenomenon because they arise in part due to the consumption of nutrients and oxygen by micro-organisms—where there are more nutrients to consume, the more oxygen is used by those very micro-organisms. They are also an anthropogenic (or human-caused) problem because nutrient levels in certain bodies of water, such as the Gulf of Mexico, the Baltic Sea and the Gulf of Oman, have skyrocketed in the last several decades, while their oxygen levels have plummeted beyond hypoxic (less than normal amounts of oxygen) to *anoxic* (no oxygen).[17] The number and size of dead zones has increased dramatically since about 1950,[18] a moment in time that aligns with the 'Great Acceleration' of the 'Anthropocene'.[19] The evidence globally is overwhelming: human activity has intensified the problem of oxygen depletion, as effluents from industrialised agriculture, infrastructure and transportation have found its way into the earth's waterways and oceans—a process emblematic of the type of 'human–climate–environment nexus' that Fiona Williamson discusses elsewhere in this issue.

Dead zones have no single cause. They are an ouroboros of anthropogenic and natural causes and effects, including (but not limited to) run-off from sewage and/or agricultural fertiliser, which contains the nutrients nitrogen and phosphorous;

16 I am indebted to work David Kirchman, whose recent book *Dead Zones: The Loss of Oxygen from Rivers, Lakes, Seas, and the Ocean* (New York: Oxford University Press, 2020) has informed the following discussion.
17 Kirchman, *Dead Zones*, viii–ix.
18 Ibid., 65.
19 Will Steffen et al., 'The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?', *Ambio* 38, no. 8 (December 2007).

the dramatic increase in paved surfaces, which worsens the problem of run-off; diminished salinity due to increased rainfall and run-off; increased stratification of the water column due to altered salinity; higher ocean temperatures, which make oxygen less dissolvable; and the proliferation of nutrient-loving organisms in warmer waters.[20] This last phenomenon, closely associated with dead zones, is often referred to as blooms of so-called toxic algae, sometimes called 'red tides'. These are often identified as a cause of dead zones, but are instead trapped in a cause-and-effect loop with them, constituting both an effect of dead zones and a contributor to further ones. This process, called eutrophication, is when the introduction into waterways of nutrients, such as nitrogen and phosphorous, robs them of oxygen because they both oxidise and are consumed by algae or plankton, which thrive on these nutrients and consume oxygen simply by living, and which then also die and consume oxygen as they themselves decay and oxidise (not unlike a cut apple that turns brown as it oxidises and decays).[21]

When a dead zone occurs in the open ocean rather than a bay, lake or river it is referred to as an 'oxygen minimum zone', or OMZ.[22] This is the terminology the authors of the *GRL* paper used rather than the headline-grabbing 'dead zone'. Moreover, OMZs often have oxygen concentrations significantly below those of dead zones.[23] While the same basic biogeochemical process is responsible for OMZs, the situation is further exacerbated in the open ocean because of upwellings from nutrient-rich deep water.[24] Here, again, decaying nutrients are the enemy of well-oxygenated water.

Morbid symptoms of the 'world's largest dead zone'

The size and scope of the dead zone in the Gulf of Oman is difficult to discern without scientific instruments, and almost impossible to 'map' in the conventional sense due to the capricious nature of oceanic space, depth, seasons and currents. Its morbid symptoms, however, have been visible to fishers and residents for decades. The same month as the *GRL* paper was published, an Omani fisher shared a video on Twitter, viewed several thousand times, showing heaps of dead fish strewn across the shore as people inspected the carcasses and prodded them with their feet. The user posed a question—'what are the reasons for a die-off of this size … when did this happen and where exactly was this video taken?'—and used a hashtag popular among Omani

20 Kirchman, *Dead Zones,* 31, 58, 145.
21 Ibid., 65.
22 Ibid., 141.
23 Ibid.
24 Ibid.

fishers to elicit responses from them.[25] Fish kills such as this have been common along the shores of Oman for decades, and news reports of unusable Omani and Emirati beaches covered in rotting fish are frequent. Local media usually blames the problem on fishers dumping by-catch, but the quantity of fish and range of species involved in fish kills suggest that something in the water is to blame.

A related morbid symptom is the so-called red-tide, often singled out for the rise in fish kills. Red tides commonly occur in the bays, coves and inlets of the Gulf of Oman and around the world, and they cast a red-brown pall on the water. Sometimes described as 'toxic algae', the red tides in Oman are not usually the result of algae per se, but instead of an algae-like phytoplankton called *Noctiluca scintillans*.[26] This plankton is a dinoflagellate that en masse can take on either a reddish or greenish tint, and is known for its ability to phosphoresce. When it proliferates, it sometimes thickens the water to such an extent that fishers have recorded videos of themselves running their hands through what looks like a viscous green soup. However, at night, this same phenomenon delights beachgoers with a bioluminescent spectacle, sparkling blue and green when agitated by wave motion. When quantities large enough to cause such a spectacle occur, the dinoflagellates eventually die and decay as a part of their natural life cycle, robbing oxygen from the water. This is detrimental to both fish and humans, which is why they are sometimes known as 'harmful algal blooms' ('algal', in this case again being somewhat of a misnomer, because they are phytoplankton and not algae).

While these morbid symptoms are prevalent throughout the Gulf of Oman littoral, I argue that it is not helpful to think of the dead zone as equivalent to the size of Florida or Scotland—as the media pieces that followed the *GRL* piece claimed—as this imposes a terrestrial (and therefore flat) view of space on the ocean. Instead, we should consider the ocean as a volumetric space,[27] with hypoxic spaces occurring primarily at the very depths (or benthic zone) of the sea (which is somewhat normal and natural). Thus, dead zones and OMZs, such as the one in the Gulf of Oman, are more like enormous bubbles expanding and contracting somewhere between the very depths of the sea and the water's surface. Such bubbles occasionally rise close to the surface, but might be better imagined as being suspended in mid-ocean, just below the surface of the water, whose oxygen content is continually replenished by exposure to wind and air. Scientific instruments, such as the underwater drones used by the authors of the *GRL* piece, have detected traces of such a bubble throughout

25 See tamingthesea.commons.gc.cuny.edu/files/2022/06/1.png, accessed 3 November 2022. In an effort to archive the ephemeral nature of social media, and out of an ethical duty to protect the identity of digital interlocutors, I have preserved and anonymised social media posts at the website tamingthesea.commons.cuny.edu. The publicly visible metadata for each post (i.e. the date the post was published) remains, but identifying details, including username, display name and profile picture have been obscured.

26 Khalid Al-Hashmi, 'Insight: Green Tide in the Sea of Oman', *Anglo-Omani Society* (24 June 2020), www.ao-soc.org/news/aos/insight-green-tide-in-the-sea-of-oman, accessed 27 May 2021.

27 Franck Billé, 'Introduction', in *Voluminous States: Sovereignty, Materiality, and the Territorial Imagination*, ed. Franck Billé (Durham, NC: Duke University Press, 2020), 10.

the Gulf of Oman—hence claims about the size of dead zones—but seasonal changes in temperature, currents and eddies, and varying levels of harmful plankton make the dead zone 'bubble' an amorphous phenomenon which is constantly changing in size and varying in location.

Traces of environments past: Indirect data and hypoxia

Notably, although human-caused eutrophication as a worldwide phenomenon was only recognised in the 1980s, and global instances of dead zones rose sharply just a few decades before that, deoxygenated zones as a *natural process* have existed for millennia.[28] With this in mind, in order to attempt to trace a possible history of the dead zone in the Gulf of Oman before the immediate present, I reviewed historical and archival materials from the nineteenth and twentieth centuries for traces of these morbid symptoms—red tides and fish kills. Both symptoms would have been obvious to even a casual, unscientific observer, and specialists would have certainly taken note. While there is no definitive, direct evidence of either of these phenomena by name, indirect evidence of associated events, such as water discoloration, bioluminescence, oyster die-offs and abundant fish catches appear somewhat frequently and in sometimes unexpected places.

The following sections describe how the associated phenomena, noted in the archives, might indicate a dead zone in formation in the early twentieth century. Direct instrumental data about oxygen levels, which would certify the existence of a dead zone, do not exist in scientific writings before the mid-twentieth century. Therefore, this study relies on the richness of proxy, or indirect, data[29] as evidence from *before* the time of complex bathymetric measurements and underwater scientific drones. Indirect data, when combined with other methodologies from the humanities and social sciences, can be valuable, and in some cases the only way to reconstruct historical data about the ocean.[30]

28 A. J. Gooday et al., 'Historical Records of Coastal Eutrophication-Induced Hypoxia', *Biogeosciences* 6 (2009): 1707–45, doi.org/10.5194/bg-6-1707-2009.

29 Greg Bankoff, 'Climate and the Environmental Historian' (presentation to Appraising Risk Partnership: 1st Summer School Workshop; Climate of the Indian Ocean World: Past and Present, University of Sussex, 26 May 2021).

30 David J. Starkey et al., eds, *Oceans Past: Management Insights from the History of Marine Animal Populations* (London: Earthscan, 2008). See also W. Jeffrey Bolster, *The Mortal Sea: Fishing the Atlantic in the Age of Sail* (Cambridge, MA: Belknap Press of Harvard University Press, 2012); A. J. Gooday et al., 'Historical Records'.

Red tides and sparkling seas

There is relatively little mention of red tides, algae or algal blooms in the British colonial records relating to Omani and Trucial Coast fisheries in the nineteenth and twentieth centuries, except in navigational treatises that refer to water discoloration due to hazards on the sea floor.[31] Red tides were witnessed by Charles Darwin when aboard the *Beagle* off the coast of Peru,[32] and at the turn of the twentieth century by the famed pearl farmer Mikimoto Kōkichi when *akashio* ('red tide')[33] destroyed his pearl oyster beds. However, the concept of 'red tide' was first popularised in the Anglophone world in 1948 by Rachel Carson and Paul Galtsoff when investigating the 'large streaks of reddish brown water' and massive fish die-offs near Florida for the US Fish and Wildlife Service.[34]

Unlike the wild pearl fishery of Arabia, Mikimoto's cultured pearl enterprise did not rely on indebted or enslaved labour, and provided a much more consistent supply of large, pristine specimens for Western markets. Mikimoto is therefore often blamed for the collapse of the natural pearl market of the Persian Gulf in the first half of the twentieth century.[35] However, a British Government-sponsored scientific investigation carried out in 1911 by James Hornell (1865–1949), marine assistant to the Government of Madras,[36] found that predatory fish, parasites and local populations were primarily responsible for overfishing formerly plentiful pearl banks in the Persian Gulf. He noted that the pearl fishery 'is suffering from direct and increassingly [sic] serious consequence of unrestrained over-fishing due to the lack of any restrictions and regulations', although he made no reference to the fact that the thirst for pearls in the industrialising (and 'bourgeoisifying') West was at an all-time high.[37] Market demand notwithstanding, it is also possible that ecological factors that

31 See, for example, the *Persian Gulf Pilot* published annually by the British Admiralty in c.1870–1930.

32 Kjell Ericson, 'Making Space for Red Tide: Discolored Water and the Early Twentieth Century Bayscape of Japanese Pearl Cultivation', *Journal of the History of Biology* 50 (2017): 393–423, doi.org/10.1007/s10739-016-9443-x.

33 Ibid. It should be noted here that fishers' knowledge is critical in the development of the scientific concept; Mikimoto borrowed the term from local fishers, as did Carson and Galtsoff.

34 Ibid.; Paul S. Galtsoff, *Red Tide: Progress Report on the Investigations of the Cause of the Mortality of Fish Along the West Coast of Florida Conducted by the United States Fish and Wildlife Service and Cooperating Organizations* (Special Scientific Report, 46) (Washington, DC: United States Fish and Wildlife Service, 1948).

35 See Matthew S. Hopper, *Slaves of One Master: Globalization and Slavery in Arabia in the Age of Empire* (New Haven, CT: Yale University Press, 2015), doi.org/10.12987/yale/9780300192018.001.0001.

36 'Persian Gulf: Pearl Fisheries. Investigation into the Alleged Depletion of Pearl Banks. Germans and the Industry. Concessions, etc.', File 2830/1914 Pt. 2 India Office Records and Private Papers, British Library, London, via the Qatar Digital Library, www.qdl.qa/en/archive/81055/vdc_100000000419.0x000160, accessed 28 September 2017. See also National Library of Australia, 'Guide to the Papers of James Hornell (as filmed by the AJCP)', nla.gov.au/nla.obj-761658752/findingaid, accessed 27 September 2022.

37 'Persian Gulf: Pearl Fisheries'. File 2830/1914 Pt. 2, L/PS/10/457. British Library: India Office Records and Private Papers. The fisheries specialist also doubted Arab captains' insistence that the return of oyster shells would be beneficial to the banks. Perhaps not incidentally, returning shells is now the primary method of oyster habitat restoration across the world.

resemble a dead zone—known in modern times to cause die-offs of oysters, fish and other marine life—may have also contributed to the depletion of pearl banks around this time.

To this end, the notes of Samuel Barrett Miles (1838–1914), a British diplomat who served in the Gulf from 1869 to 1886, suggest that mass quantities of dinoflagellates may have already been blooming in the Persian Gulf and Gulf of Oman at that time. In his observations of the fisheries of Oman, he notes that 'during the summer months, the surface of the sea for many miles off shore is covered with floating fish spawn in immense patches of rusty red or yellowish colour and which gives off a disagreeable odour'.[38] Importantly, Miles was not a biologist—and to an untrained eye, a red tide might have been easy mistaken for a particularly large fish or coral spawn. Spawning fish, like a red tide, occurs during seasonal elevations in water temperature, and is often accompanied by a rotten smell. The following passage from the same text probably indicates that Miles may have been observing plankton blooms in addition to fish spawns:

> The luminosity or phosphorescence of the sea observable in these parts is a remarkable sight … It is caused by some forms of protozoa and presents a magnificent spectacle. The crest of each wave as it breaks on the rocks sparkles brilliantly and appears like a sheet of molten silver producing a most marvellous and fascinating sight. In passing near the rocks by night in a boat, the phenomena may be seen to great perfection, the brightness of the phosphorescence lighting up the surrounding objects, each splash of the oars giving a fresh burst of radiance[.][39]

In a similar vein, the 1904 work by the British traveller Edgar Collins Boehm (1869–1928), *The Persian Gulf and South Sea Isles*, offers the following observation of the Persian Gulf littoral: 'There is, at night, to be seen sometimes a lot of phosphorescence in the water, and waves of blue flame leap and play about and the night seems light as day.'[40] Describing his favourite memory of travelling in the Gulf, near the Strait of Hormuz, he writes:

> every wave that we threw aside became lit up with a glittering blue and gold light, and for miles behind the boat's wash was like a lake of fire. In the Gulf of Siam I once saw the water lit up in this way, but never before have I seen this curious blue sheen, as if some giant electric light were throwing up its rays from beneath the surface.[41]

38 Samuel Barrett Miles, *The Countries and Tribes of the Persian Gulf*, vol. 2 (London: Routledge, 2005), 407, doi.org/10.4324/9781003073581.

39 Miles, *Countries and Tribes*, 411–12.

40 Edgar Collins Boehm, *The Persian Gulf and South Sea Isles* (London: Horace Cox, 1904), 102–3.

41 Boehm, *Persian Gulf,* 103. It should be noted that the Gulf of Thailand (formerly the Gulf of Siam) is also home to contemporary dead zones.

A quarter of a century later, when the royal court of Omani Sultan Taimur bin Faisal (r. 1913–32) was travelling north along the Batinah coast of Oman, his adviser, the English diplomat and explorer Bertram Thomas (1892–1950), recounted swimming at Bu Baqarah one evening: 'The water was beautifully warm in the tropical starry night, and so brilliant with phosphorescence that one came out with bathing suit bespangled.'[42] The Bedouin who accompanied the group refrained from swimming, maintaining that bathing in such water 'causes a month's fever'.[43] Today's medical knowledge confirms what the Bedouin seemed to already know: human contact with dinoflagellates, which themselves can feed on toxic bacteria, can cause a range of illnesses.[44] Some years later, on a journey from Zanzibar to the Gulf, the master sailor and prolific author Alan Villiers (1903–82) likewise observed the sea sparkle at the mouth of the Gulf of Oman, as he rounded Ras al Hadd, writing that at night 'we wandered on through a queerly phosphorescent sea with breaking crests of the black swells looking as though they were floodlit in green below'.[45]

If these descriptions are taken at face value—as proxy data for lack of instrumental data—they open the possibility that massive dinoflagellate blooms were already somewhat regular, large and widespread occurrences in the lower Persian Gulf and Gulf of Oman in the years leading up to and following the oyster die-offs of 1911. These blooms would have had deleterious effects on pearl oysters, and probably caused the die-offs in Mikimoto's pearl beds around the same period.

Fish kills and teeming fish

Fish kills, the other visually obvious morbid symptom of dead zones, are also conspicuously absent from the British colonial fisheries records and travelogues. Omani fisheries scholars have noted that the earliest *recorded* mass fish kill event in Oman (itself specifically associated with red tide) was in 1976.[46] Colonial records before this, rather than mentioning instances of fish kills, emphasise the exact opposite. They indicate the fertility of Gulf waters and the abundance of fish therein, to the degree that comments about teeming fish are somewhat of a leitmotif.[47]

A prime example of this motif are the comments of the Scottish Orientalist James Baillie Fraser (1783–1856) about fish off the coast of Oman in 1821:

42 Bertram Thomas, *Alarms and Excursions in Arabia* (London: George Allen & Unwin, 1931), 197.
43 Ibid.
44 Centers for Disease Control and Prevention, 'Illnesses and Symptoms: Marine (Saltwater) Algal Blooms' (19 April 2021), www.cdc.gov/habs/illness-symptoms-marine.html, accessed 27 May 2021.
45 Alan Villiers, *Sons of Sindbad* (New York: Charles Scribner's Sons, 1970), 280.
46 Hamed Mohammed Al Gheilani et al., 'Fish Kill Incidents and Harmful Algal Blooms in Omani Waters', *Agricultural and Marine Sciences* 16 (2011), 24, doi.org/10.24200/jams.vol16iss0pp23-33.
47 For a history of this leitmotif extending back to the early modern period, see Alastair Hamilton, *An Arabian Utopia: The Western Discovery of Oman* (Oxford: Oxford University Press, 2010).

> I know of no place equal to Muscat for the abundance and excellence, perhaps too for the variety, of its fish. The water around the ship was continually alive with them. Those particularly of the herring and pilchard kinds swarmed, thick as gnats in a summer's evening, seeking, as it were, protection in the shadow of the vessel from the larger fish, that constantly pursued them for food; the sere fish [sic], the king fish, and cavally [sic], with many other sorts … were continually darting in every direction among the shoals, which scattered and fled on all sides, till the water was all in foam[.][48]

By the 1880s, the British colonial authorities noted with excitement that 'Muscat is an extraordinarily prolific place for fish',[49] and dozens of India Office files speak to the ongoing imperial concern with Oman's waters and how to govern the extraction of valuable marine life from them. For example, Miles noted that the 'coast of Oman is remarkable for the wealth, variety, and strangeness of its marine fauna', that in Muscat harbour 'the surface of the water is often disturbed by small fish jumping up, making the water appear as if in a state of ebullition' and that fish 'are so abundant that the whole coast of Oman is a continuous series of fishing stations'.[50] The *Gazetteer* compiled by the British diplomat John Gordon Lorimer (1870–1914), one of the most often cited sources about the gulf, notes the exhaustive colonial reports on the region's fish and devotes an appendix to fish taxonomy.[51] The British India Office and Foreign Office records are likewise replete with files that detail schemes for how to extract the most wealth from south-eastern Arabia's fertile waters. By 1948, Sultan Said bin Taimur (r. 1932–70) commissioned a report by the British zoologist Colin Bertram (1911–2001), who remarked that the fisheries of Arabia 'reach their peak in the Gulf of Oman', and that 'it would be difficult to find anywhere in the world a fishery comparable both in primitiveness and productivity'.[52]

Such references to Oman's plentiful supplies of fish seem contrary to the idea that a dead zone was already in formation in the region at the turn of the twentieth century. But if we remember the earlier discussion of the dead zone as a 'bubble', there is a possibility that these two seemingly contradictory features—abundant fish *and* a dead zone—are not incongruous. Fish are, by their very nature, a moving target. With few exceptions they are mobile, itinerant, resilient and adaptable—tuna migrate thousands of miles across entire oceans, while other species, such as sardines and mackerel, limit their runs to hundreds of miles along coasts. Thus, the marine bioscientist David Kirchman has noted how dead zones and OMZs are somewhat

48 James B. Fraser, *Narrative of a Journey into Khorasān in the Years 1821 and 1822, Including Some Account of the Countries to the North-East of Persia; with Remarks upon the National Character, Government, and Resources of That Kingdom* (London: Longman, Hurst, Rees, Orme, Brown, and Green, 1825).

49 I. MacIvor, 'Notes on Sea-Fishing in the Persian Gulf by Lieutenant I. MacIvor, Assistant Political Resident, Persian Gulf', in *Report on the Administration of the Gulf Political Residency and Muscat Political Agency for the Year 1880–1881* (Calcutta: Foreign Department Press, 1881), 54–77.

50 Miles, *Countries and Tribes,* 401, 407, 409–10.

51 J. G. Lorimer, *Gazetteer of the Persian Gulf, 'Omān, and Central Arabia*, vol. I: *Historical*, part II (Calcutta: Superintendent Government Printing, 1915), 2308–18.

52 G. C. L. Bertram, *Report on the Fisheries of the Sultanate of Muscat and Oman* (Muscat: Sultanate of Muscat, 1948).

paradoxically 'associated with rich fisheries'.[53] As dead zones and OMZs emerge, fish are pushed to the margins of low-oxygen areas in search of more habitable waters. Higher oxygen levels can be found at the surface, but this is also where they are much more easily caught.

Bastien Queste, the lead author of the *GRL* article, also noted this phenomenon, stating that the dead zone 'moves up and down … causing fish to be squeezed in a thin layer at the surface'.[54] The takeaway here is that if we envision a dead zone as a 'bubble' suspended in the ocean, to the margins of which fish are pushed in order to survive, dead zones can actually be a boon to some fisheries—certainly so for Oman and the United Arab Emirates, which to this day comprise artisanal industries that use skiffs, hand lines and small nets to fish coastal and surface waters. Again, we should consider the possibility that the unique abundance of Oman's fisheries noted in the historical record points to a nascent dead zone that was pushing fish away from deoxygenated waters directly into fishers' nets.

Conclusion: A deeper history

Within minutes of a Twitter post about the massive fish kill on an Omani beach, a prominent Omani fisher and social media influencer brushed it off as a 'natural phenomenon' (*dhāhirat tabī'īah*) sometimes caused by the 'red tide' (*al-mud al-āhmar*).[55] There is a tension here between recognition of the very real threats that this 'natural phenomenon' poses (namely, a large-scale die-off) and the reality of consistently good catches that fishers have witnessed in the last several years. As recently as 2021, a member of Oman's elected governing body and its Food and Water Security Committee, in sharing a picture from ArabiaWeather.com[56] purporting to show the size and extent of the dead zone, stated:

> It isn't true that the map which is circulating shows the size of the dead zone in the [Gulf] of Oman, as it includes the coasts of Sharqiyah, Muscat, and the Batinah, and indicates that these areas are dead and there is no life in them! This contradicts reality, which is that the coasts of these three governorates are the best places for landing fish in the region.[57]

This post was shared widely among fishers in Oman—the individuals whose livelihood depends on the health of Omani waters—who seem to understand it as a scientific problem but not an immediate threat. On the one hand, scientists have confirmed

53 Kirchman, *Dead Zones*, 144. The Gulf of Mexico and north-western coasts of South America are such cases.
54 'Growing "Dead Zone" Confirmed by Underwater Robots'.
55 tamingthesea.commons.gc.cuny.edu/files/2022/06/2.png, accessed 27 May 2021.
56 Sunan Khalaf, 'Al kashf 'an ākbar biq'ah mītah fi al-'ālam fi khalij 'Ūman, Taqs al- 'Arab' (Arabia Weather), 13 August 2018, www.arabiaweather.com/ar/content/ن-ام-ع-جي-لخ-في-مل-اع-ال-ي-في-مت-ي-م-ة-ع-ق-ب-ر-ب-ك-أ-ن-ع-ف-ش-ك-ال, accessed 27 May 2021.
57 See tamingthesea.commons.gc.cuny.edu/files/2022/07/Arabia-Weather-May-8-2021-post.png, accessed 27 May 2021.

that the north-west Arabian Sea and the Gulf of Oman are home to a burgeoning dead zone, and fishers tacitly acknowledge its existence as a natural phenomenon, albeit one that has yet to cause any serious problems beyond the occasional nuisance. On the other hand, the northern and eastern coasts of Oman are indeed the most productive fisheries in the region, and the tonnage of catch sizes in recent years has only increased.

Rather than viewing these online sentiments as avoidance of a looming problem, the pragmatic online ruminations of Omani fishers might better be viewed as a kind of synthesis between the apparently opposing viewpoints of the scientists and government officials laid out at the beginning of this article. Omani fishers, perhaps more than any other stakeholders, have a vested interest in preserving the health of fish stocks in the Gulf of Oman. After all, when fish are understood as a finite rather than inexhaustible resource,[58] the fishing industry is cursed with the same fate as all extractive industries: annual increases in production deplete a key regional protein source and jeopardise long-term job prospects for fishing communities.

Fishers' recognition of the reality and persistence of red tides and fish kills, paired with their experience of abundant catches, mediates the cold rationality of strictly scientific information and the sensational alarmism of popular media. This seemingly contradictory posture of fishers in relation to dead zones reflects a possible reality of the situation—that despite occasional massive fish kills washing ashore, fish escaping the deoxygenated waters of the Gulf of Oman and Arabian Sea might be fleeing directly into their nets—and while a problem exists somewhere in these waters, it is by no means a 'dead zone' in the literal sense: devoid of oxygen and therefore fish. The sheer abundance of fish in the Gulf of Oman, noted by colonial observers and contemporary officials alike, thus belies this larger problem that is still on the horizon, one not yet felt in the fishers' nets.

Scientists, journalists, government authorities and fishers alike should all be concerned by the future implications of dead zones. My attempt at contextualising the discourse that arose from the publication of the 2018 article in *GRL* should not be read as an effort to cast the media coverage as climate alarmism, the responses by government officials as climate denial or the ambivalence of fishers as passive. Instead, each group seems to be acting according to the interests of their profession: the media is trying to get 'clicks' by widely publicising a new ecological disaster in the making; Omani officials are assuaging the fears of their people by assuring them that there are still fish to be caught, sold and eaten; and fishers have one eye on the looming catastrophe of dead zones and another on their, at least for the moment, full nets.

58 Boris Worm, 'Averting a Global Fisheries Disaster', *Proceedings of the National Academy of Science* 113, no. 18 (2016): 4895–7; Bolster, *The Mortal Sea*.

Seriously considering and analysing a broader array of voices beyond the *GRL* piece is an attempt to construct a wider view of the problem of a dead zone in the Gulf of Oman, rather than partial glimpses mediated through a single group. Moreover, an eye to history 'below the waves'[59] shows us that this problem may not have simply materialised in 2018 when the article was published in *GRL*, but might instead have a deeper history. As we have seen, hypoxic conditions might have been quietly haunting the waters off southern Arabia for the better part of a century, worsening with the rapid development of the Arabian Peninsula's metropolises in the past 50 years and culminating in the near-crisis levels of today.

Natural forces, such as the monsoon paired with further despoliation of the ocean and anthropogenic warming of the planet, present a problem: not that fish will immediately disappear, or that the ocean will suddenly be 'dead'; instead, these shifts have the potential to cause 'cracks in the base of the food chain',[60] which may be imperceptible to us now, or appear as momentary aberrations to fishers today in the same way that 'mysterious' die-offs and bioluminescence were anomalies outside the understanding of the historical figures mentioned in this article. As the world continues to see declining fish stocks, and as various staple species become threatened or regionally depleted, the fishers who rely on healthy stocks will most certainly be the first to notice, and it is to them whom we should look; as Marx quipped in *Capital*, volume I, 'no one has discovered the art of catching fish in waters that contain none'.[61]

59 Tamara Fernando, 'Seeing Like the Sea: A Multispecies History of the Ceylon Pearl Fishery 1800–1925', *Past & Present* 254 (2022): 160, doi.org/10.1093/pastj/gtab002.

60 Kirchman, *Dead Zones*, 127.

61 Karl Marx, *Capital*, vol. I: *A Critique of Political Economy*, transl. Ben Fowkes (New York: Penguin, 1976), 287n7.

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