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Hydrographical Observations during a Red Tide with Fish Mortalities at Masirah Island, Oman

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البيانات الهيدروغرافية أثناء المد الأحمر ونفوق الأسماك في جزيرة مصيرة، سلطنة عمان

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الخلاصة: يمكن أن يكون لازدهار الطحالب الضارة تأثير مهم في توزيع وحياة الأسماك واللافقاريات في المياه الساحلية، وبالتالي في الاقتصاد المحلي أينما كان الصيد من الأنشطة المهمة. في أكتوبر من عام ٢٠٠٥م، اصطبغت المياه في شرق جزيرة مصيرة باللون البني/ البرتقالي بسبب الازدهار الكبير للطحالب مما أدى إلى نفوق الكثيرمن الأسماك. وبيّنت صور الأقمار الصناعية وجود تيارات بحرية صاعدة (انبثاقات) باردة قبيل حدوث ظاهرة الازدهار ونفوق الأسماك، ثم أعقبها ارتفاع تدريجي في درجة حرارة المياه متزامنا مع بداية حدوث الظاهرة. قراءات الأعماق للأكسجين الذائب، ودرجات الحرارة، والملوحة، ومعدل الحموضة التي أخذت يوم ١٩اكتوبر (أثناء حدوث الظاهرة) بينت بجلاء وجود انحدار حراري على عمق حوالي ١٥مترا، بينما قلت كمية الأكسجين الذائب كثيرا حيث بلغت ٠,٨٢مل/لتر على عمق ٢٥مترا، وارتفعت هذه الكمية قليلا إلى ١,٣مل/لتر يوم ٢٢أكتوبر (بعد حدوث الظاهرة).وكانت هناك اسماك قاعية هامة اقتصاديا ضمن الأسماك النافقة. لم يكتشف وجود تلوث بكتيري في عينات الأسماك كما لم يتم تسجيل أي تسمم بين المستهلكين. وأظهر تحليل عينات العوالق البحرية وجود ازدهار لثنائيات الأسواط البحرية إضافة إلى ازدهار الطحالب الخضراء-الزرقاء.

ABSTRACT: Harmful Algal Blooms (HABs) can have a significant impact on the distribution and survival of coastal fishes and invertebrates, and consequently they can affect local economies where fishing is an important activity. In October 2005, extensive algal blooms with brownish/orange discoloured water and fish mortalities were observed east of Masirah Island. Satellite images revealed cooler upwelled surface water along a broad front just prior to the event, followed by a gradual warming period coinciding with the mortalities. Depth profiles of dissolved oxygen (DO), temperature, salinity and pH taken on 19th October (during the fish mortality event) showed a pronounced thermocline at ~15 m depth and minimum DO of 0.82 ml/L at 25 m depth, and a slight improvement in DO to 1.3 ml/L was measured on 22nd October (after the event). Demersal fishes of several families were prominent among mortalities. No bacterial infestation was found in fish samples and no human poisoning was reported. Planktological data showed that marine dinoflagellates *Noctiluca scintillans* and *Prorocentrum micans* and toxic blooms of cyanobacterium *Trichodesmium erythraeum* were present.

Keywords: Red tide, upwelling, fish mortalities, Arabian Sea, Oman.

Introduction

Official documentation of red tide events along the coast of Oman began in 1978, and fish, mollusk and crustacean mortalities associated with these events have often been reported in the region (Claereboudt *et al*. 2001). The causes of mortalities are not always clear – these may be the result of harmful algal blooms (HABs) dominated by toxic dinoflagellates (e.g. *Peridinium, Dinophysis, Prorocentrum* spp.) which may poison fish or other organisms when they release their toxins, or alternatively the result of oxygen depletion in confined areas during the bacterial oxidation of collapsed blooms. Claereboudt *et al*. (2001) suggested that mortalities during a red tide (mainly the non-toxic diatom *Coscinodiscus* spp.) in the Gulf of Oman in 2000 were driven by oxygen

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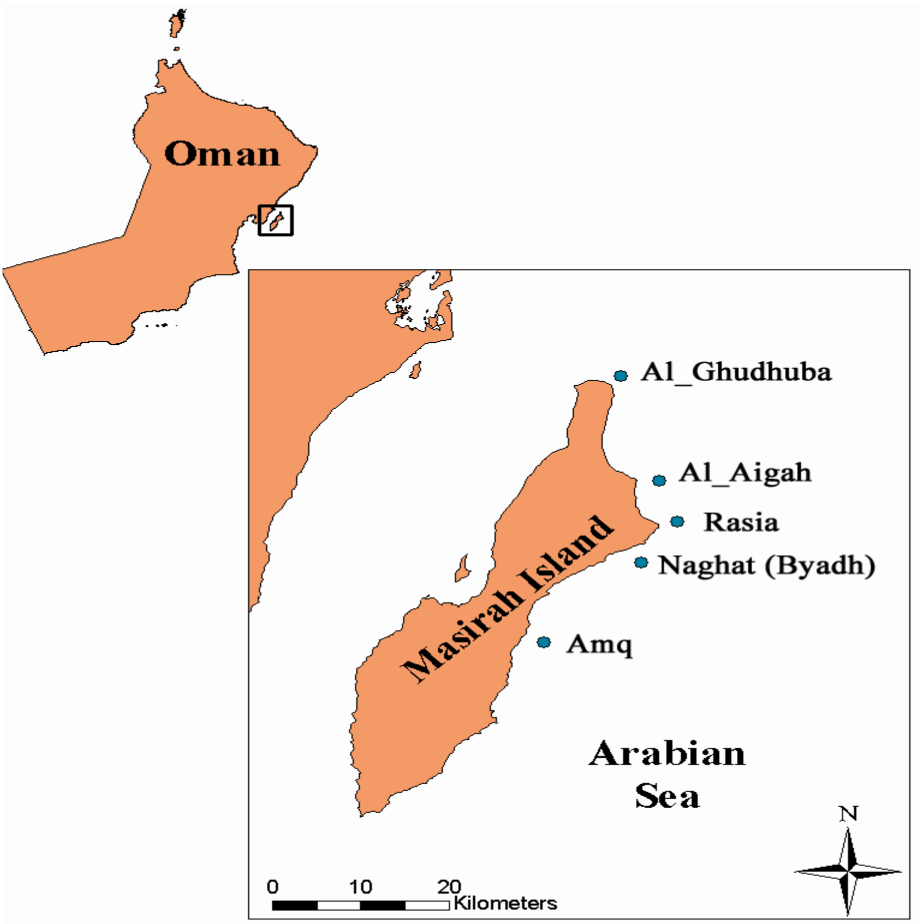


Figure 1. Study sites in Masirah Island, Arabian sea.

depletion below the thermocline and not by toxicity. Other red tide events in Oman have been attributed to *Noctiluca* blooms (Thangaraja *et al.,* 2000), which are known to affect the water quality by depleting the oxygen in seawater or by contributing to higher levels of ammonia (Okaichi and Nishio, 1976).

Massive fish and invertebrate kills were reported along the coast of Masirah Island around 13th October 2005 and mortalities continued up to at least the 19th of the month. During this period fishers noted that some fish species were lethargic, and could be caught easier than usual. Seawater in the immediate area was discoloured, brown and orange, suggesting a large phytoplankton bloom. SST, water temperature, dissolved oxygen, pH and salinity were measured from the surface to 30 m depth during and after the event, and water samples analysed to identify the predominant algal groups. Affected fish were identified to family level. Based on these observations, we suggest a possible cause for the mortality event.

Methods

Phytoplankton samples were taken from five sites along the eastern coast of Masirah Island (a 45 km stretch) on October 18th and 19th (during the fish kill) and on October 22nd (thereafter). From north to south, the sites were Al Ghudhuba (20º42´N; 58º 55´22E) Al-Aijah (20º42´N; 58º55´22 E and 20º34´57 N; 58º57´43 E), Rasiyah (20º31´ 01 N; 58º59´29E and 20º31´24N; 59º00´29E), Naghat (20º27´41N; 58º58´03E) and Amq (20º22´22N; 58º54´58E) (Fig. 1). Phytoplankton samples were collected using a Bongo net (80 µm mesh size) and Niskin bottles, and were preserved with formaldehyde (4%, Velikova and Larsen, 1999), and studied under a microscope, without staining.

Samples were taken from all five sites on 18th and 19th October, and again at two badly affected sites at Al-Aijah (2nd position) and Rasiyah on 22nd October. Water quality parameters pH, temperature, salinity and dissolved oxygen (DO), were measured from the surface and at 5m depth intervals up to 30 m depth using Hydrolab (Data Sonde 4a). SST of the Gulf of Oman and Arabian Sea between Ras al Hadd and Salalah (including Masirah Island) was available for the 26th of September, and the 3rd, 12th and 13th of October from NOAA-14 AVHRR (Advance Very High Resolution Radiometer) imagery.

Dead fish were identified to family level whenever possible, and bacteriological examination of the frozen samples was done in a specialised laboratory (Bacteriology Section, Department of Laboratories, Ministry of Health). Samples were analyzed for the presence of *Colioformis, Esherichia coli*, *Salmonella, Shigella, Vibrios, Staphylococcus aureus, Cyanobacteria, Bacillus cereus, Clostridium* and *Listeria monocytogenes*.

Results and Discussion

Phytoplankton samples showed the presence of *Noctiluca scintillans*, (Fig. 2), *Prorocentrum micans* (Fig. 3) and *Trichodesmium erythraeum* (Fig. 4), whilst the dinoflagellate *P. micans* was the dominant species. Blooms of *P. micans* generally occur in zones receiving high solar energy and anthropogenic inputs, which are rich in nutrients and dissolved organic matter (Anderson *et al*., 2002; Subba Rao *et al*., 1995). In several parts of the world, fish kills have been attributed to low dissolved oxygen levels generated by high biomass blooms and not necessarily due to toxicity. For example, from 1980–1989, at least 50% of fish killed in the Gulf of Mexico and 69% in the South Atlantic, USA, were attributed to low dissolved oxygen (Lowe *et al*., 1991). Similarly, low DO levels have also been the most popular cause for the fish mortality in Oman. In most cases the dominant red tide causing species in the Gulf of Oman is *Noctiluca scintillans* (Thangaraja *et al.,* 2000). *Noctiluca scintillans* is also non-toxic but can reduce water quality by depleting oxygen and raising ammonia levels (Okaichi and Nishio, 1976).

The identification of the marine cyanobacterium *Trichodesmium erythraeum* was less straightforward than that of diatoms and dinoflagellates because of the lack of distinct and unique morphological characteristics. Nevertheless, our identification was based on the morphological description of Post *et al*. (2002), who described colonies with trichomes arranged in parallel bundles or rafts (tufts) floating on the surface in the Gulf of Aqaba. An extensive surface bloom of *T. erythraeum* was also previously observed in the central basin of the Arabian Sea during the Spring Intermonsoon of 1995 (Capone *et al.,* 2000), a period of calm winds similar to the conditions at Masirah Island in October 2005. *Trichodesmium erythraeum* is capable of utilizing ammonia and urea (Ohki *et al.,* 1991), and it does contain toxic, water-soluble material which is the progenitor of major toxins carried by some ciguateric fish. Release of these water-soluble toxins into ambient seawater may constitute a health hazard for humans (Endean *et al.,* 1993).

The satellite image from 26th September shows a broad front of cooler surface water (approx. 20°C) stretching alongshore from Ras al Hadd to Salalah, and enveloping Masirah Island (Fig. 5a). By 3rd October, upwelling have intensified to the south of Masirah Island (15–17°C), with warming surface waters towards the north of the island (Fig. 5b). A narrow band of cooler coastal waters (around 20–21°C) is apparent along the east coast of Masirah Island and northwards to Ras Al Hadd on the 12th of October (Fig. 5c), but by 13th October temperatures seem to have increased along the entire coastline (Fig. 5d). These images suggest that upwelling events occurred over a period of at least 2 weeks before fish kills were reported at Masirah Island, but the mortalities themselves, or at least the reports thereof, coincided with warmer surface temperatures. Unfortunately, no earlier images were available to show the SST conditions leading up to the 26th of September, nor were images available for the period of most reported mortalities after 13th October.

A pronounced thermocline at 15 m depth was apparent at Rasiyah on 19th October, and below this depth temperature declined from 26.2°C to 21.6°C at 25 m depth (Table 1, Fig. 6). DO likewise declined from 6.57 ml/L at 15 m depth to 0.82 ml/L at 25 m. Similar temperature and DO profiles (minimum DO of 1.3 ml/L at 20 m) occurred at Al-Aigah, although the

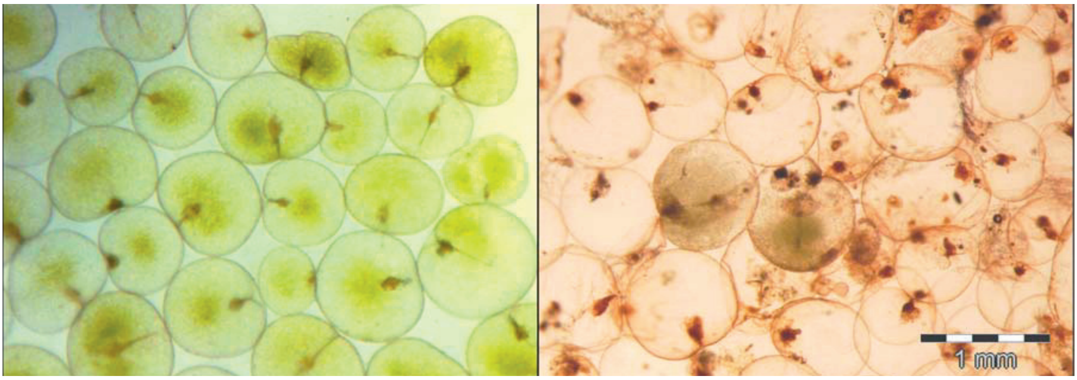


Figure 2. Phytoplankton (Noctiluca scintillans) when alive (green) and while decaying (red) found in the Masirah Island Red Tide.

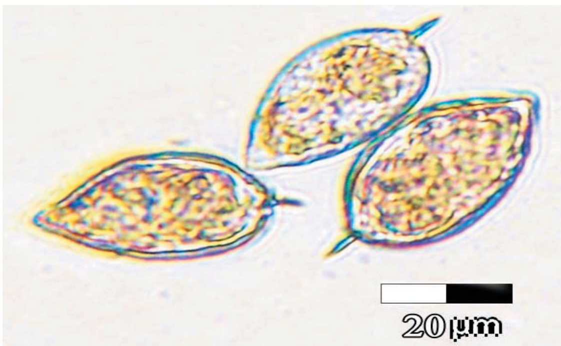


Figure 3. Phytoplankton (*Prorocentrum micans*) found in Masirah Island Red Tide.

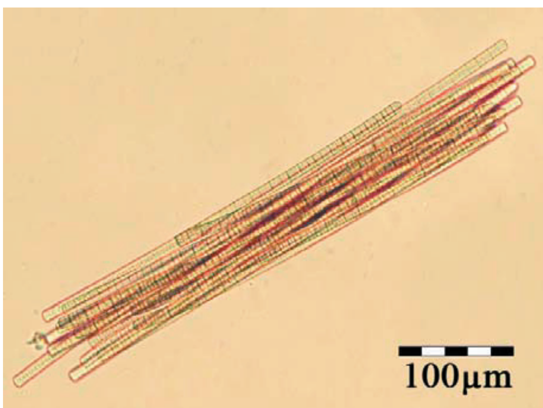
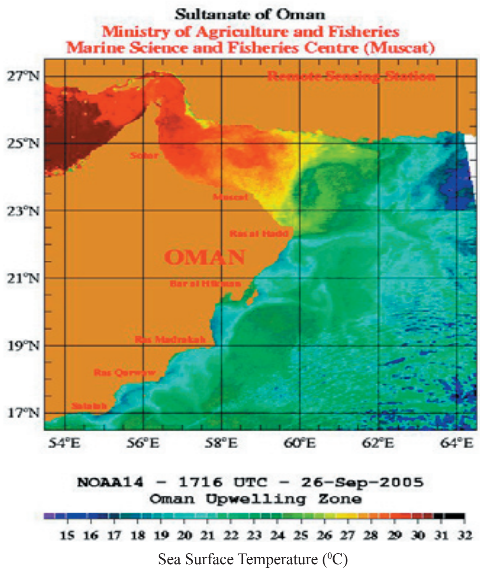
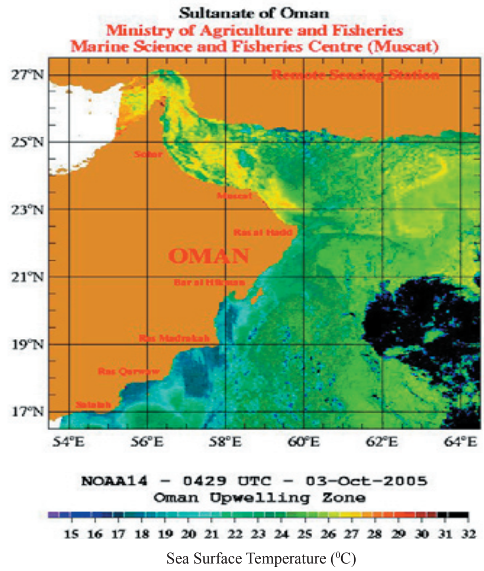


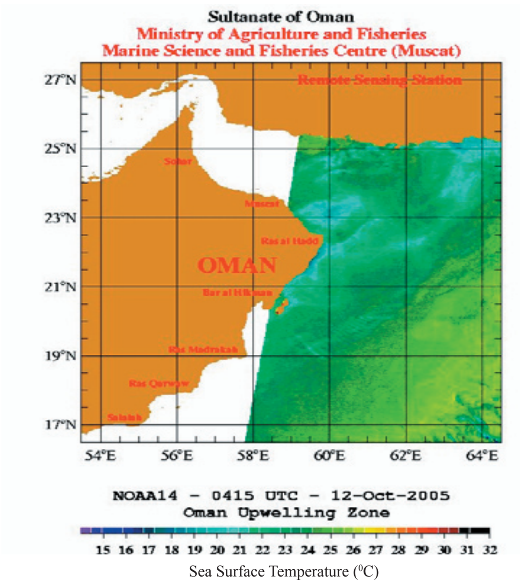
Figure 4. Phytoplankton (*Trichodesmium erythraeum*) found in Masirah Island Red Tide.



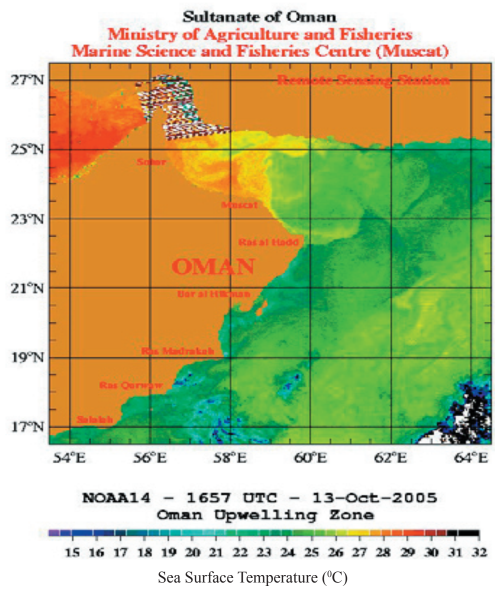
Sea surface temperature (26th September 2005)



Sea surface temperature (3rd October 2005)



Sea surface temperature (12 October 2005)



Sea surface temperature (13th October 2005)

Figure 5. Satellite images show the variation in temperature before, during and after the Red tide blooms in Arabian Sea (Oman upwelling zone).

Source of images: Remote Sensing Station at Ministry of Fisheries Wealth, (Satellite NOAA 14).

Table 1. Temperature (Temp), Dissolved Oxygen (DO), Salinity (Sal.) and pH during Red tide bloom.

Location	Date/ Time	Distance from shore	Latitude/ Longitude	Depth (m)	Ecological Parameters			
					Temp (°C)	DO (ml/l)	Sal. (‰)	pH
Al-Aigah	19/10/2005	2 km	20°34'13N	0	26.15	7.11	36.58	7.95
	7:10 am		58°59'11E	5	26.08	6.83	36.64	8.00
				15	24.02	3.44	36.70	7.78
				20	22.07	1.30	36.65	7.68
Rasia	19/10/2005	2 km	20°31'24N	0	26.44	6.40	36.64	8.04
	8:00 am		59°00'29E	5	26.29	6.42	36.66	8.09
				10	26.18	6.35	36.65	8.13
				15	26.15	6.57	36.65	8.16
				20	23.64	3.40	36.68	7.89
				25	21.61	0.82	36.60	7.66

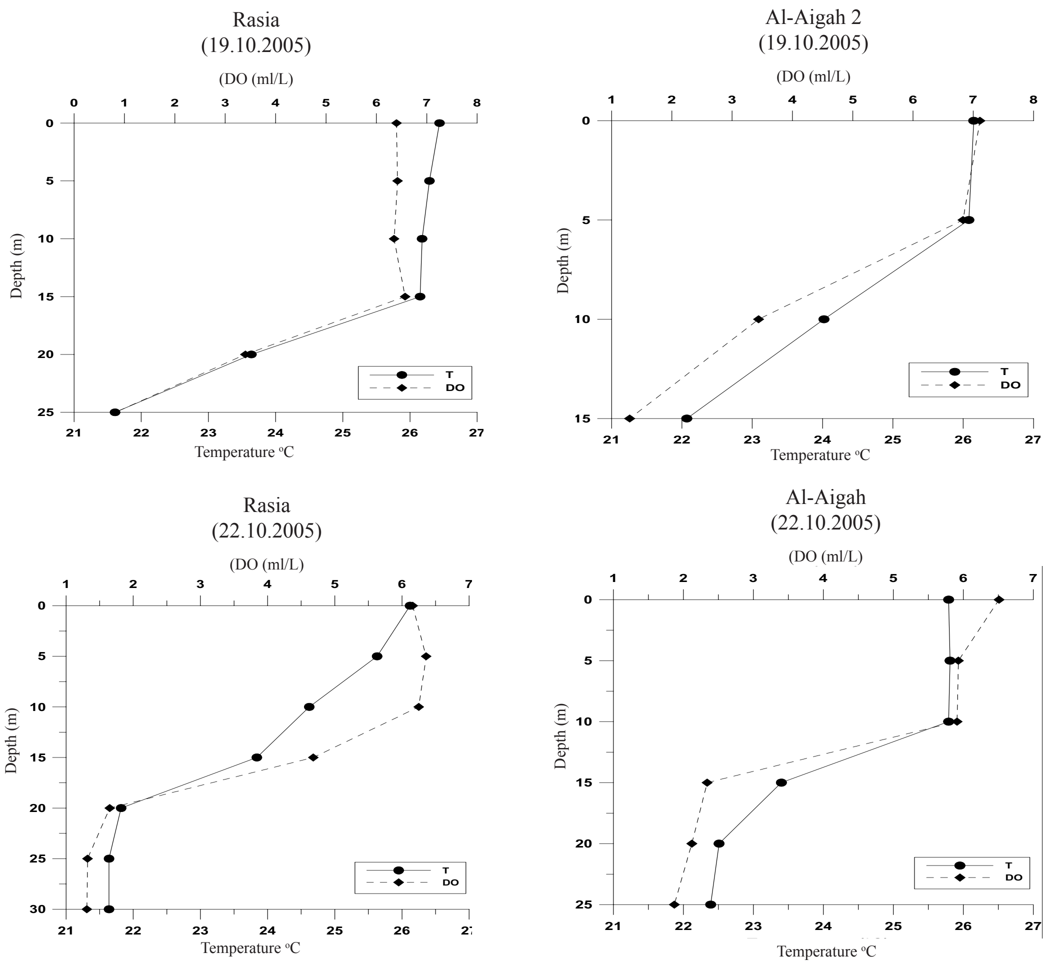


Figure 6. Show the relation between depth, Dissolved Oxygen (DO) and Temperature (T), during and after red tide in two stations.

Table 2. Temperature (Temp), Dissolved Oxygen (DO), Salinity (Sal.) and pH after Red tide Bloom in two stations after red tide blooms.

Location	Date/ Time	Distance from shore	Latitude/ Longitude	Depth (m)	Ecological Parameters			
					Temp (°C)	DO (ml/l)	Sal. (‰)	pH
Al-Aigah	22/10/05	2 km	20° 35’ 19 N	0	25.79	6.51	36.61	7.95
	7:10 am		58° 57’ 11 E	5	25.81	5.93	36.66	8.04
				10	25.79	5.91	36.67	8.07
				15	23.40	2.34	36.62	7.82
				20	22.51	2.12	36.58	7.80
				25	22.39	1.87	36.57	7.79
Rasia	22/10/05	2 km	20° 31’ 01 N	0	26.12	6.16	36.62	8.08
	8:00 am		58° 59’ 29 E	5	25.63	6.36	36.65	8.11
				10	24.62	6.25	36.60	8.12
				15	23.84	4.68	36.59	8.02
				20	21.82	1.65	36.58	7.79
				25	21.64	1.32	36.57	7.77
				30	21.64	1.31	36.59	7.78

thermocline appears to have been shallower at 5–10 m depth (Table 1, Fig. 6). A marginal increase in DO was seen at both sites on the 22nd of October – at Rasiyah the DO at 25 m depth had increased from 0.82 to 1.32 ml/L, and at Al-Aigah the increase at 20 m depth was from 1.3 to 2.12 ml/L (Table 2, Fig. 6). Salinity and pH profiles were similar on 19th and 22nd October, with salinity remaining between 36.57‰ and 36.70‰ irrespective of depth, and pH fluctuating between 7.66 and 8.16 (Fig. 7).

Dead and weakened fish and invertebrates were observed on or near the surface of the water and along the tide line on the shore. Fishers caught larger than usual quantities of jobfishes (Lutjanidae) and remarked that the fish seemed lethargic, easier to catch than usual, and were schooling. Large numbers of swimming crabs (Portunidae) were observed in surface layers. We identified Lutjanids, Sciaenids, Carangids, Lethrinids and Sparids among the dead fishes. Most of these families form part of the demersal assemblage in coastal waters (Al-Abdessallaam, 1995). Samples of dead fish analyzed for presence of bacteria showed that none of the samples were infected with *colioforms, E. coli, Salmonella, Shigella, Vibrios*, *Staphilococcus aureus, Cyanobacter, Bacillus cereus, Clostridium,* or *Listeria monocytogenes*. These fish were therefore safe for human consumption, and fisherman who continued to consume the fish during the red tide event did not report any adverse reaction.

Most demersal fish species require a DO of at least 2 ml/L (Al Gheilani, 2007) to survive, and the DO levels of <1.4 ml/L below 15 m depth at both sites are unlikely to sustain some species over an extended period. Therefore stress induced by low oxygen conditions below the thermocline may have been the cause of mortalities where fish could not move away. Fish that could move away may have been displaced from their habitat, but the effects of this on their condition can only be surmised. The low oxygen conditions were apparently the result of blooms and collapse of the dinoflagellates *P. micans* and *N. scintillans* and the cyanobacterium *T. erythraeum* following on a series of upwelling events with nutrient enrichment of surface waters. The breakdown of the thermocline during such upwelling, and the mixing that brings cooler nutrient-rich waters to the surface layers can be caused by wind forcing or lower air temperatures during fall or winter (Lindell and Post, 1995; Genin *et al.,* 1995). No cell counts of the three predominant phytoplankters were done, and it is therefore difficult to rule out poisoning of fish by toxins released by *T. erythraeum*. Nevertheless, most

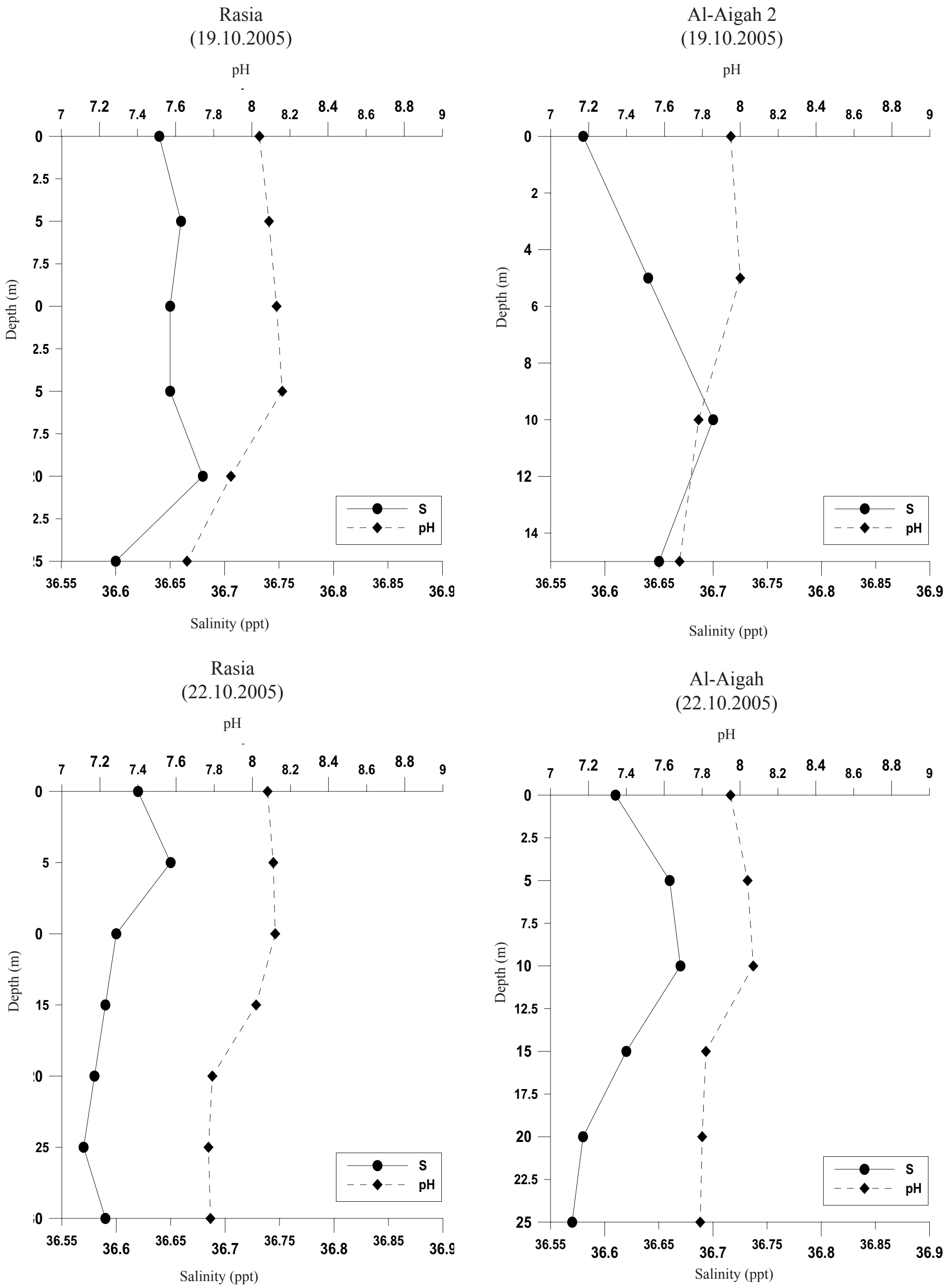


Figure 7. Show the relation between depth, pH and Salinity, during and after red tide in two stations.

evidence points to low oxygen conditions below the thermocline during the red tide event as an indirect cause of fish mortalities.

Acknowledgments

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References

Al-Abdessalaam, T.Z.S. 1995. Marine Species of the Sultanate of Oman: An Identification Guide. Marine Science and Fisheries Centre, Ministry of Fisheries and Agriculture, Muscat Printing Press (1st ed.), 412 pp.

Al-Gheilani, H.M. 2007. Physiological and Biochemical Effects of Hypoxia Exposure on Goldlined Seabream, *Rhabdosargus sarba*. Ph.D. thesis, Portsmouth University, UK.

Anderson, D.M., G.M. Gilbert and J.M. Burkholder. 2002. Harmful algal blooms and eutrophication: Nutrient sources, composition, and consequences. *Estuaries*, 25(4b):704-726.

Capone, D.G., A. Subramaniam, J.P. Montoya, M. Voss, C. Homborg, A.M. Johansen, Q. Wang, H. Li, and F. Post. 2000. The nitrate assimilation genes of the marine diazotrophic cyanobacterium '*Trichodesmium*' sp. strain WH9601. *Journal of Bacteriology*, 182:1764-1767.

Claereboudt, M., G. Hermosa, and E. McLean. 2001. Plausible cause of massive fish kills in the Gulf of Oman. In: *Proceedings of the First International Conference of Fisheries, Aquaculture and Environment in the NW Indian Ocean*, M. Claereboudt, S. Goddard, H. Al-Oufi, E. McIlwain (Editors), 123-132. Sultan Qaboos University, Muscat, Sultanate of Oman.

Endean, R., S.A. Monks, J.K. Griffith and L.E. Llewellyn, 1993. Apparent relationship between toxins elaborated by the cynaobacterium *Trichodesmium erythraeum* and those present in the flesh of the narrow-barred Spanish mackerel *Scomberomorus commersoni Journal of Toxicology*, 9:1155-1165.

Genin, A., B. Lazar and S. Brenner, 1995. Vertical mixing and coral death in the Red Sea following the eruption of Mount Pinatubo. *Journal of Nature*, 377:507-510.

Lindell, D. and A.F. Post. 1995. Ultraphytoplankton succession is triggered by deep water mixing in the Gulf of Aqaba (Eilat) Red Sea. Limnol. *Journal of Oceanography*, 40:1130-1141.

Lowe, J.A., D.R.G. Farrow, A.S. Pait, S.J. Arenstam, and E.J. Lavan. 1991. Fish kills in coastal waters 1980-1989. *National Oceanographic and Atmospheric Administration*, 69pp.

Okaichi, T. and S. Nishio. 1976. Identification of ammonia as the toxic principle of red tide of *Noctiluca miliaris*. *Bulletin of Plankton Society, Japan*, 23:75-80.

Ohki, K., J.P. Zehr, P.G. Fallowski, and Y.Fiujita. 1991. Regulation of nitrogen fixation by different nitrogen sources in the marine non-heterocystous cyanobacterium *Trichodesmium* sp. NBB1067. *Journal of Archeology and Microbiology*, 156: 335-337.

Post, A.E., Z. Dedej, R. Gottlieb, D.N. Thomas, M. El-Absawi, A. El-Naggar, M. El-Gharabawi, and U. Sommer. 2002. Spatial and temporal distribution of *Trichodesmium* spp. in the stratified Gulf of Aqaba, Red Sea. *Marine Ecological Progress Series*, 239:241-250.

Subba Rao, D.V., Y. Pan, and S.J. Smith. 1995. Allebopathy between *Rhizosolenia alata* (Brightwell) and the toxigenic *Pseudnitzchia pungens* f. multiseries. In: *Harmful Marine Algal Blooms*, P. Lassus, G. Arzul, E. Erard-Le Deen, P. Gentien and C. Marcaillon-Le-Baut, (Editors), 329-334. Paris, Lavoiser.

Thangraja, M., A. Al-Aisri, and H. Al-Shaqsi. 2000. Phytoplankton Blooms, Red Tide Phenomena and Recorded Impacts in Oman. *Marine Science and Fisheries Center Annual Report,* Ministry of Agriculture and Fisheries, Sultanate of Oman, 22pp.

Velikova, V. and J. Larsen. 1999. The *Prorocentrum cordatum/Prorocentrum minimum* taxonomic problem. *Grana* 38:108-112.