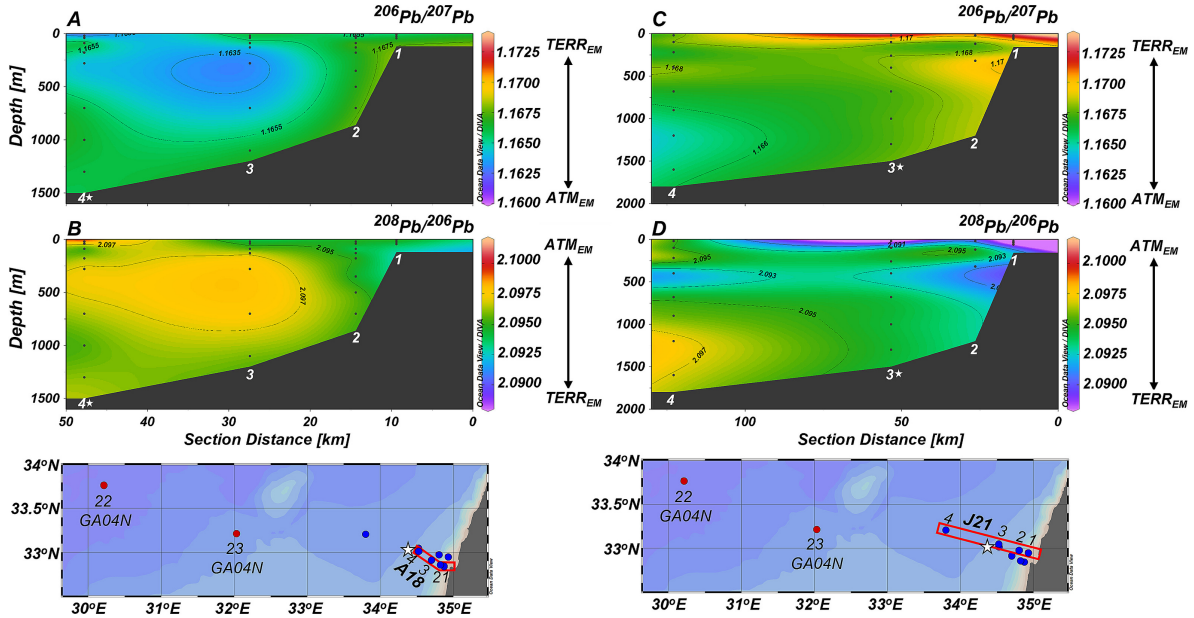
ANNUAL REPORT ON GEOTRACES ACTIVITIES IN ISRAEL

May 1st, 2024 to April 30th, 2025

New GEOTRACES or GEOTRACES relevant scientific results

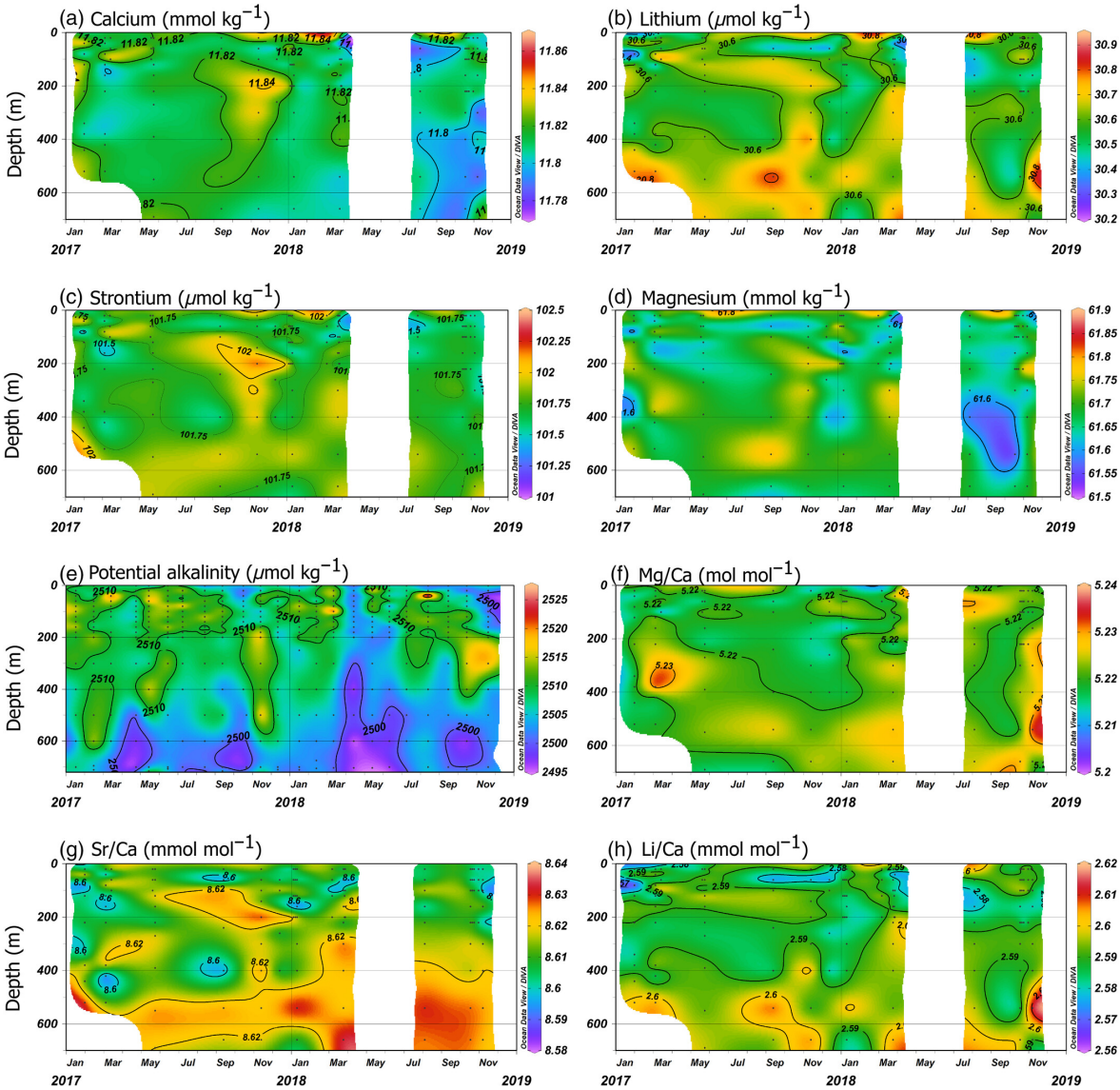
- Dynamics of dissolved trace metals, rare earth elements and Pb isotopes across the eastern margins of the Mediterranean Sea (Benaltabet et al., 2025): Continental margins support marine primary productivity by transferring nutrients and micro-nutrients (trace metals) from the coast to the oceans. Yet, the mechanisms governing the delivery of trace metals across the land-sea continuum, and how they vary temporally, are still poorly constrained. Here, we report high spatial resolution depth profiles of dissolved trace metals (Al, Mn, Fe, Co, Ni, Cu, Zn, Cd, and Pb), rare earth elements (REEs), nutrients (PO_4, TON, and $SiOH_4$) and Pb isotopes from two transect cruises in the oligotrophic eastern Mediterranean Sea. Varying anthropogenic inputs resulted in inter-cruise variations in Zn and Pb concentrations and Pb isotopes. In contrast, low temporal variability was registered for PO_4, $SiOH_4$, Cu, and Co. The isotopic composition of Pb in the eastern Mediterranean Sea ($^{206}Pb/^{207}Pb$ = 1.161–1.173 and $^{208}Pb/^{206}Pb$ = 2.085–2.101) is controlled by advected Atlantic surface water and anthropogenic inputs delivered via continental runoff (terrestrial) or atmospheric shuttles. The deep-water inventory of Pb is partially controlled by historical anthropogenic sources. An enrichment in Zn and Cd (81 and 17 %, respectively) and a 50 % depletion in Pb relative to open-waters was observed in Intermediate Levantine Waters, in tandem with terrestrial Pb isotopic signatures, light REE depletion (shale-normalized Nd/Yb < 0.22) and a strong Ce anomaly (Ce/Ce* < 0.20). These are driven by intermediate nepheloid layers from the margins, which act as both a source and a sink for trace metals through release and scavenging, evident 300–500 km away from the shore. This study highlights the dynamic role of continental margins in modulating terrestrial and anthropogenic inputs to the oceans.



Dissolved Pb isotope compositions along two cruise tracks (A18, J21) in the Eastern Mediterranean Sea. (A) $^{206}Pb/^{207}Pb$ (A18), (B) $^{206}Pb/^{207}Pb$ (J21), (C) $^{208}Pb/^{206}Pb$ (A18), and (D) $^{208}Pb/^{206}Pb$ (J21). White star denotes the crossover station (A18–4 and J21–3) occupied during both cruises.

Reference: Benaltabet, T., Lapid, G., Alkalay, R., Weinstein, Y., Steffens, T., Achterberg, E.P. and Torfstein, A., 2025. Dynamics of dissolved trace metals, rare earth elements and Pb isotopes across the eastern margins of the Mediterranean Sea. *Marine Chemistry*, *270*, p.104519.

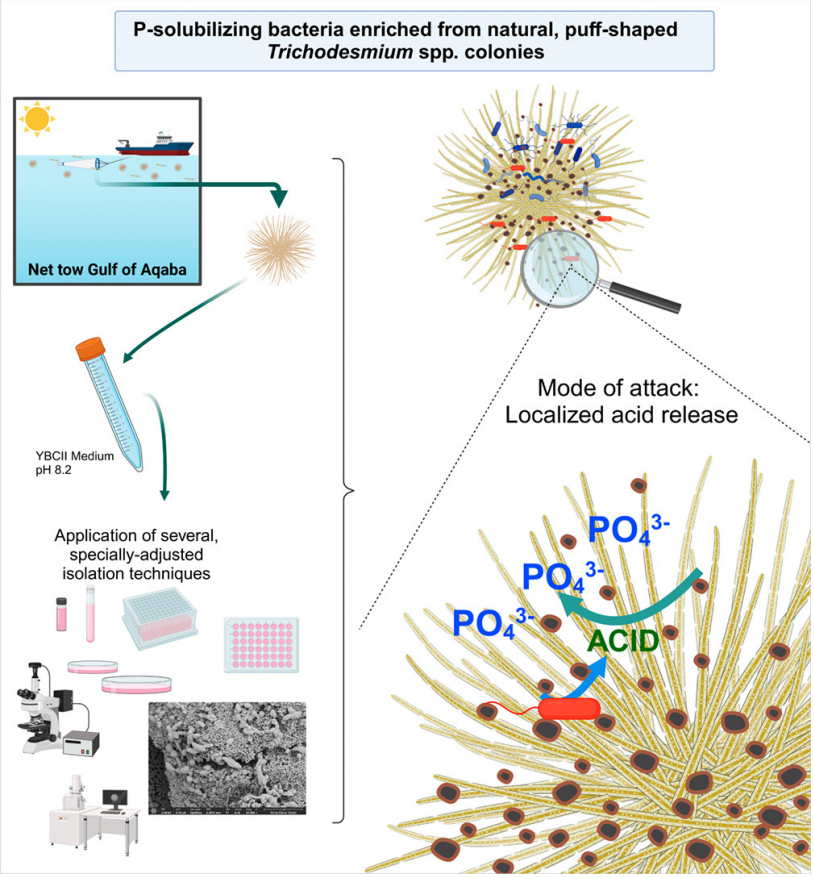
- Dynamics of marine inorganic carbon and silica: A field study of the mechanisms controlling seawater major element concentrations (Steiner et al., 2025): A highly resolved time series of dissolved major element (calcium, strontium, magnesium, and lithium) concentrations in the north Gulf of Aqaba, Red Sea, reveals variability in major cation concentrations beyond analytic uncertainties. This variability is composed of an interannual component that is most important for calcium, and a short-term daily-timescale component that is most important for lithium. As evident from covariation in calcium, potential alkalinity, and Sr/Ca, the calcium carbonate cycle of the Gulf of Aqaba is dominated by coral calcification, and there was an increase in calcification rates between 2017 and 2018. Variability in lithium concentrations, and larger changes in magnesium concentrations than expected from magnesium distribution coefficients in carbonate minerals, suggest an active cycle of aluminosilicate mineral dissolution, and precipitation of secondary silicate minerals.



Time series of salinity-normalized major element concentrations at *Station A* in the northern Gulf of Aqaba.

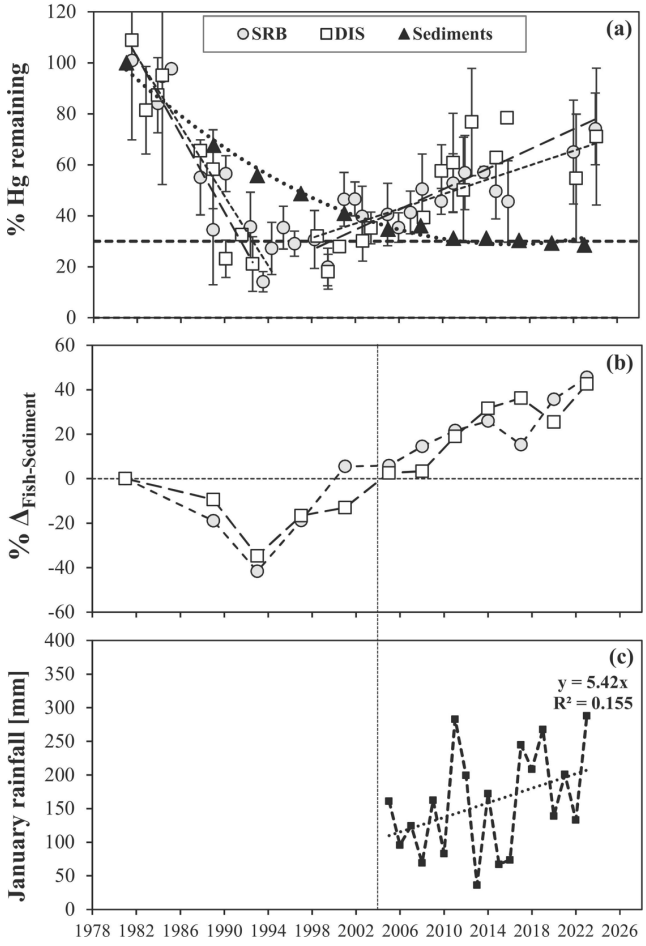
Reference: Steiner, Z., Benaltabet, T. and Torfstein, A., 2025. Dynamics of marine inorganic carbon and silica: A field study of the mechanisms controlling seawater major element concentrations. *Limnology and Oceanography*, 70, 650-666.

- Unveiling the P-solubilizing potential of bacteria enriched from natural colonies of Red Sea Trichodesmium spp. (Visser et al., 2025): Phosphorus (P) is pivotal for all organisms, yet its availability is, particularly in the marine habitat, limited. Natural, puff-shaped colonies of *Trichodesmium*, a genus of diazotrophic cyanobacteria abundant in the Red Sea, have been demonstrated to capture and centre dust particles. While this particle mining strategy is considered to help evade nutrient limitation, details behind the mechanism remain elusive. This study explores P-solubilizing bacteria (PSB) residing within *Trichodesmium*'s associated microbial community, their potential contribution to the host, and the possible implications for P cycling in marine ecosystems. Bacterial enrichment on YBCII medium resulted in 28 enrichment cultures, primarily comprising bacterial families such as *Rhodobacteraceae*, *Alteromonadaceae* and *Burkholderiaceae*. Five enrichment cultures were further grown on hydroxyapatite, revealing their ability to consume and release Nitrogen and P while forming strong physical interactions with the mineral. A drop in pH was observed, indicating acid production as the primary P-solubilizing pathway. Co-cultivation experiments confirmed a positive effect on *Trichodesmium erythraeum* strain IMS101 growth by the presence of putative PSBs. These results reveal that the enriched bacteria exhibit significant P-solubilizing activity, thus potentially increasing the bioavailability of P in seawater. Thus, PSB could play a vital role in maintaining the P balance in the Red Sea, supporting the growth of *Trichodesmium* spp. and other marine organisms. Overall, our results contribute to a deeper understanding of the P cycle in the Red Sea and have implications for developing novel strategies for P management in marine ecosystems.



Reference: Visser, A.N., Zhang, F., Guttman, L., Masasa, M., Wang, S., Koedooder, C. and Shaked, Y., 2025. Unveiling the P-solubilizing potential of bacteria enriched from natural colonies of Red Sea Trichodesmium spp. *Science of the Total Environment*, *963*, p.178446.

- Long-term (1979–2024) trends and remobilization process of mercury pollution, the case study of Haifa Bay, Southeast Mediterranean Sea (Sisma-Ventura et al., 2024): This study examines the interlink between long-term (1979–2024) trends of Hg contamination in sediments and commercial target fish species (*Sargocentron rubrum, Diplodus sargus*) and industrial Hg loads and their modes of entry to the marine system, using Haifa Bay (HB) in northern Israel and unpolluted reference sites as a case study. Historically, Hg levels in sediments and fish in HB fluctuated in response to industrial discharge from a former PVC factory. Despite a drastic regulatory reduction during the 1990s and the factory's closure in 2004, Hg levels in target fish species have shown an unexpected increasing trend, at rates of 1.45–1.94 % yr^{-1} over the last two decades (exceeding safe consumption limits), while the sediment levels remained enriched but stable over time. No similar trends were detected in the fish or sediments of unpolluted reference sites. We show that soils and groundwater under the former PVC factory site are anomalously Hg-enriched, acting as a source of total, and methylmercury (MeHg) pollution in Northern HB. We discuss possible explanations for the temporal decoupling trends in fish and sediments. This study highlights the ongoing risk of relic industrial Hg pollution buried in coastal areas to commercial fish species and human health.



Time trends of (**a**) the percentage of Hg remaining in sediments and fish of HB, (**b**) the difference in % Hg remaining between Fish and sediments, denoted as $\Delta_{F\text{-}S}$, and (**c**) January total rainfall mm yr^{-1} data set of the Acre station located near the ECI.

Reference: Sisma-Ventura, G., Segal, Y., Gertner, Y., Mori, M.M., Hadra, M.A., Biton, E., Shachnai, A. and Herut, B., 2025. Long-term (1979–2024) trends and remobilization process of mercury pollution, the case study of Haifa Bay, Southeast Mediterranean Sea. *Journal of Hazardous Materials*, *490*, p.137760.

GEOTRACES or GEOTRACES relevant cruises

- Ongoing campaigns:
  - The National Monitoring Program (NMP) for the Gulf of Eilat/Aqaba operates out of the IUI (http://www.iui-eilat.ac.il/Research/NMPAbout.aspx). Activities include monthly cruises across the north Gulf of Eilat/Aqaba, during which physical, chemical and biological measurements are performed in depth profiles (at a water depth of 700 meters) together with spatial-surface coverage. The main-relevant parameters monitored are: Temperature, salinity, dissolved oxygen, pH, alkalinity, POC, NO_2, NO_3, $Si(OH)_4$, PO_4, Chl-a. The samples are collected with the IUI Research Vessel, which has a powder coated aluminium Rosette (SeaBird) with 12 niskin bottles (12 liters each), and a CTD (SeaBird electronics). These measurements have been performed continuously since the year 2000.
  - The National Monitoring Program of Israel's Mediterranean waters –Hydrographic and sedimentological cruises on board R.V. Bat Galim along E-W transects across the Israeli Mediterranean EEZ (Water – bi-annual (nutrients, alkalinity, pH, DO, Chl-a, pico-phytoplancton, PP, BP); Sediments – annual).
  - Marine particulate fluxes, dust and dissolved seawater compositions are studied in the oligotrophic Gulf of Aqaba (GOA), northern Red Sea as part of the ***Re****d Sea* ***D****ust,* ***M****arine Particulates and* ***S****eawater* ***T****ime Series* (***REDMAST,*** *GIpr09*). This includes a continuously deployed bottom tethered mooring mounted with sediment traps (e.g., Torfstein et al., 2020).

New projects and/or funding

- *"Carbon export efficiencies in the oceans: the dynamics of aggregation and ballasting across abrupt daily timescale events and their impact on the biological pump"*, Israel Science Foundation, PI: Torfstein, 2024-2028, NIS1,270,000
- *"The MOSES observatory: Margins-Open Sea conveyor and the biological pump in the ultra-oligotrophic Eastern Mediterranean Sea under climate change"*, Israel Council for Higher Education, PIs: Torfstein, Amrani, Solodoch, Kranzler, Bar Ze'ev, Antler, Gildor, Sivan, Barkan, Abramovitch, Kiro, Toledo, Shaked, Weinstein, Ashkenazy, Lazar, Herut, Biton, Rahav, Katz, Hyams-Kaphzan, Ozer, Katz, Amitai, Rosenberg, 2024-2028, NIS12,500,000.
- *"Bridging the variability gaps to resolve the long-term impacts of climate change on the SE Levantine Basin: development and networking of advanced marine research infrastructures"*, PIs: Berman-Frank, Makovsky, Herut, Diament, Lehan, Paltiel, Keren, Lerner, Drimer, Groper, Schechner, Liberzon, Weinstein, Toledo, Katz, Guy-Haim, Rubin-Blum, Ozer, Rahav, 2024-2028, NIS10,000,000.

GEOTRACES workshops and meetings organised

- The Israel Association of Aquatic Sciences (IAAS) annual meeting (2024) included GEOTRACES relevant talks on trace metal concentrations, fluxes and availability in open ocean and coastal environments.

Outreach activities conducted (please list any outreach/educational material available that could be shared through the GEOTRACES web site) *(We are particularly interested in recordings from webinars from GEOTRACES research)*

Other GEOTRACES activities

New GEOTRACES or GEOTRACES-relevant publications (published or in press) *(If possible, please identify those publications acknowledging SCOR funding)*

- Benaltabet, T., Lapid, G., Alkalay, R., Weinstein, Y., Steffens, T., Achterberg, E.P. and Torfstein, A., 2025. Dynamics of dissolved trace metals, rare earth elements and Pb isotopes across the eastern margins of the Mediterranean Sea. *Marine Chemistry*, *270*, p.104519.
- Mahowald, N.M., Li, L., Vira, J., Prank, M., Hamilton, D.S., Matsui, H., Miller, R.L., Lu, P.L., Akyuz, E., Meidan, D. and Hess, P., 2025. AERO-MAP: a data compilation and modeling approach to understand spatial variability in fine-and coarse-mode aerosol composition. *Atmospheric Chemistry and Physics*, *25*(9), pp.4665-4702.
- Mayfield, K.K., Horner, T.J., Torfstein, A., Auro, M.E., Crockford, P.W. and Paytan, A., 2024. Barium cycling in the Gulf of Aqaba. *Frontiers in Earth Science*, *12*, p.1178487.
- Rathod, S.D., Hamilton, D.S., Nino, L., Kreidenweis, S.M., Bian, Q., Mahowald, N.M., Alastuey, A., Querol, X., Paytan, A., Artaxo, P. and Herut, B., 2024. Constraining present-day anthropogenic total iron emissions using model and observations. *Journal of Geophysical Research: Atmospheres*, *129*(17), p.e2023JD040332.
- Romanowicz, K.J., Zhang, F., Wang, S., Veličković, D., Chu, R.K., Shaked, Y. and Boiteau, R.M., 2024. Single-colony MALDI mass spectrometry imaging reveals spatial differences in metabolite abundance between natural and cultured Trichodesmium morphotypes. *Msystems*, *9*(10), pp.e01152-24.
- Shaked, Y., Twining, B. S., Browning, T. J., Koedooder, C., & Kranzler, C. F. (2025). Trace metal biogeochemistry in the ocean: From chemical principles to biological complexity. In Treatise on Geochemistry (pp. 371–414). Elsevier.
- Sisma-Ventura, G., Herut, B., Segal, Y., Stern, N., Makovsky, Y. and Rubin-Blum, M., 2024. Oviparous Catsharks Accumulate Mercury in Deep-Sea Brine Pool Nurseries. *Environmental Science & Technology Letters*, *11*(10), pp.1103-1109.
- Sisma-Ventura, G., Segal, Y., Gertner, Y., Mori, M.M., Hadra, M.A., Biton, E., Shachnai, A. and Herut, B., 2025. Long-term (1979–2024) trends and remobilization process of mercury pollution, the case study of Haifa Bay, Southeast Mediterranean Sea. *Journal of Hazardous Materials*, *490*, p.137760.
- Steiner, Z., Benaltabet, T. and Torfstein, A., 2025. Dynamics of marine inorganic carbon and silica: A field study of the mechanisms controlling seawater major element concentrations. *Limnology and Oceanography*, 70, 650-666.
- Strzepek, R.F., Latour, P., Ellwood, M.J., Shaked, Y. and Boyd, P.W., 2025. Microbial competition for iron determines its availability to the ferrous wheel. *The ISME Journal*, p.wraf015.
- Torfstein, A., & Hemming, S. R. (2025). Geochronometry of marine deposits. In Treatise on Geochemistry (pp. 533–571). Elsevier.
- Wang, S., Zhang, F., Koedooder, C., Qafoku, O., Basu, S., Krisch, S., Visser, A.N., Eichner, M., Kessler, N., Boiteau, R.M. and Gledhill, M., 2024. Costs of dust collection by

Trichodesmium: effect on buoyancy and toxic metal release. *Journal of Geophysical Research: Biogeosciences*, *129*(4), p.e2023JG007954.

- Visser, A.N., Zhang, F., Guttman, L., Masasa, M., Wang, S., Koedooder, C. and Shaked, Y., 2025. Unveiling the P-solubilizing potential of bacteria enriched from natural colonies of Red Sea Trichodesmium spp. *Science of the Total Environment*, *963*, p.178446.
- Zhang, F., Wang, S., Visser, A.N., Koedooder, C., Eichner, M., Anderson, O.R., Dyhrman, S.T. and Shaked, Y., 2024. Recurrent association between Trichodesmium colonies and calcifying amoebae. *ISME communications*, *4*(1), p.ycae137.

Please indicate if there is any forthcoming or planned GEOTRACES special issue publication

Completed GEOTRACES PhD or Master theses *(please include the URL link to the pdf file of the thesis, if available)*

- Aden Clarfield, MSc, 2022-2024, "Quantification of the ballasting effect during abrupt sediment resuspension events in the Gulf of Aqaba", supervisor: Adi Torfstein (HUJI)
- Gilli Edvardson, MSc, 2021-2024, "The impact of changes in DIC and alkalinity in the Gulf of Aqaba", supervisors: Eyal Wurgaft (Open University of Israel), Adi Torfstein (HUJI)
- Vasilisa Krekova, MSc, 2021-2024, "Time Series of heavy metal contamination using coastal foraminiferal shells", supervisors: Sigal Abramovich (BGU), Adi Torfstein (HUJI)

GEOTRACES presentations in international conferences

- Cohen A., Shalev N., Kiro Y. (2024) Characterizing the behavior of Mg and Sr isotopes in coastal aquifers, Goldschmidt meeting, Chicago.
- Kiro Y. (2024) Towards Quantifying the Chemical Composition of Coastal Aquifer Groundwaters as End-Members in Ocean Chemistry. AGU fall meeting.
- Torfstein A., Hartman A., Benaltabet T., Lapid G., Clarfield A., Tirosh O., Teutch N. and Erel Y. (2024) Rare Earth Elements and eNd in the Gulf of Aqaba, northern Red Sea: from source to sink. AGU fall meeting.

Submitted by Adi Torfstein (adi.torf@mail.huji.ac.il)