Annex T

State of the Cetacean Environment Report (SOCER) 2024

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INTRODUCTION

Several resolutions of the International Whaling Commission, including Resolutions 1997-7 (IWC, 1998) and 1998-5 (IWC, 1999), directed the Scientific Committee to provide regular updates on environmental matters that affect cetaceans. Resolution 2000-7 (IWC, 2001) welcomed the concept of the State of the Cetacean Environment Report (SOCER) and requested the annual submission of this report to the Commission. The first full SOCER (Stachowitsch et al., 2003) was presented in 2003 and subsequent editions initiated and continued a cycle of focusing on the following regions: Atlantic Ocean, Pacific Ocean, Arctic and Antarctic Oceans, Indian Ocean, and Mediterranean and Black Seas. Each SOCER also includes a Global section addressing the newest information that applies generally to the cetacean environment. The 2024 SOCER features the **Mediterranean and Black Seas**, summarising key papers and articles published from ca. 2022 through 2024 to date. This year's regional SOCER represents the fifth and final year of the current cycle, which will be combined in a second 5-year compendium (2020: Atlantic Ocean through 2024: Mediterranean and Black Seas; see first 5-year compendium at *https://iwc.int/socer-report*) to present to the Commissioners at IWC/70.

MEDITERRANEAN AND BLACK SEAS

General

The Ocean Health Index Gives Mixed Values for the Mediterranean and Black Seas

The Ocean Health Index (OHI) is based on 10 widely-held public goals or objectives for a healthy ocean, with each goal evaluated according to current status, likely future status, trend, pressures and resilience. The score ranges from 0 to 100 (optimal value), with 69 being the global average score in 2022. OHI ranked the waters of the following Mediterranean countries at or above that average: France (74), Slovenia (73), Spain (72), Greece (71), Italy (69) and Egypt (69). The following countries were ranked lower: Albania (67), Turkey (66), Cyprus (66), Croatia (65), Bosnia and Herzegovina (63), Morocco (63), Israel (61), Algeria (61), Tunisia (60), Libya (56), Montenegro (55) and Lebanon (55). In the Black Sea, the values were: Russia (73), Romania (67), Georgia (66), Turkey (66), Bulgaria (64) and Ukraine (59). The highest ranking (France) is at position 43 out of 220 regions; the lowest (Lebanon) lies at 213 of 220 regions.

(SOURCE: https://oceanhealthindex.org).

Common Dolphins Face Multiple Threats in the Mediterranean

The Mediterranean Sea is among the bodies of water most affected by human activities. In the case of the short-beaked common dolphin, which was once among the most numerous cetacean species here, these activities have led to a generalised and major reduction in geographic range and numbers. Ongoing depletion of key prey by overfishing and food web competition with fisheries are the most important threats. According to the FAO, this sea is the most overfished in the world. Incidental mortality in fishing gear, habitat degradation, chemical pollution, underwater noise and climate change are identified as further threat factors. The steep decline has led to social disruption in these dolphins; a scarcity of potential mates has probably contributed to the observed interbreeding and admixture with striped dolphins, a significant threat to rare species coexisting with more abundant species. The authors concluded that "[f]ormal commitments to protect Mediterranean common dolphins have been made repeatedly in national and international fora, but conservation action has remained largely on paper".

(SOURCE: Bearzi, G., Genov, T., 2021. Imperiled common dolphins of the Mediterranean Sea. In: DellaSala, Goldestein (Eds.), Imperiled: The Encyclopedia of Conservation (pp. 837-846). Elsevier Press. [Available at: https://doi.org/10.1016/B978-0-12-821139-7.00059-3]).

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THE STATUS OF CETACEANS IN THE MEDITERRANEAN AND BLACK SEAS, WITH A FOCUS ON THE EASTERN MEDITERRANEAN

David *et al*. (2024) evaluated 14 studies in the framework of 'Risks, threats, and conservation status of cetaceans in the Mediterranean and Black Seas', which addressed subjects ranging from the delineation of important habitats, genetic diversities and the assessment of human pressures, ranging from pollution, marine traffic and fisheries practices. The eastern Mediterranean generally stands out as one of the least known regions of the Mediterranean Basin. Nonetheless, a series of contributions to the literature, particularly in Turkish waters, highlights the presence of both shallow-water and deep-diving species (delphinids and e.g. sperm and Cuvier's beaked whales, respectively). This knowledge has contributed to identifying Antalya Bay as an 'Area of Interest' and helped the Marine Mammal Protected Areas Task Force (IUCN-MMPATF, 2024) select the Turkish Strait System as an IMMA. Akkaya *et al*. (2021) outlined the dedicated research and conservation efforts in the Istanbul Strait, Aegean Sea and eastern Mediterranean and, overall, pointed to alarming population declines among cetacean species in Turkish waters, noting threats such as habitat destruction, marine traffic and noise pollution. Awbery *et al*. (2022) identified two priority areas for deep-diving cetaceans and a large priority area for delphinids between Turkey and Rhodes, where high cetacean encounters and dense marine traffic overlap. The authors called for Species Conservation Action Plans for these species and relevant international management measures to reduce threats, such as rerouting marine traffic or creating MPAs. According to the current assessment for the eastern Mediterranean Sea of Turkey, a major threat for both sperm whales and Cuvier's beaked whales is loud and impulsive anthropogenic noise; an additional threat for sperm whales is shipping. Marine pollution and marine traffic pose the greatest threat for delphinid species (DMAD, 2023).

> *(SOURCES: David, L., Akkaya, A., Arcangeli, A., Gauffier, P., Mazzariol, S., Vighi, M., Carlucci R., 2024. Editorial: Risks, threats, and conservation status of cetaceans in the Mediterranean and Black Seas. Front. Mar. Sci. 11:1364527. [Available at: https://doi.org/10.3389/fmars.2024.1364527; IUCN-MMPATF, 2024. 'Alborán Sea IMMA', Marine Mammal Protected Areas Task Force. [Available at: https://www.marinemammalhabitat.org/imma-eatlas]; Akkaya, A., Brouwer, S., Awbery, T., Lyne, P., Senalp, D. Ö., Yalcin, D. G., Akkaya, K., 2021. Collecting Scientific Data to Fill Existing Data Gaps on Cetacean Conservation in Turkey. DMAD Marine Mammals Research Association Annual Report 2021. [Available at: http://dx.doi.org/10.13140/RG.2.2.35827.81444]; Awbery, T., Akkaya, A., Lyne, P., Rudd, L., Hoogenstrijd, G., Nedelcu, M., Kniha, D., Erdogan, M. A., Persad, C., Öztürk, A. A., Öztürk, B., 2022. Spatial distribution and encounter rates of delphinids and deep diving cetaceans in the Eastern Mediterranean Sea of Turkey and the extent of overlap with areas of dense marine traffic. Front. Mar. Sci. 9:860242. [Available at: https://doi.org/10.3389/fmars.2022.860242]; DMAD, 2023. Threat Assessment for Cetaceans of the Eastern Mediterranean Sea of Turkiye. [Available at: https://dmad.org.tr/wp-content/uploads/Threat-Assessment-for-Cetaceans-of-the-Eastern-Mediterranean-Sea-of-Turkey.pdf]).*

THE MEDITERRANEAN AS A HOTSPOT OF BIOLOGICAL INVASIONS

The Mediterranean is a recognised hotspot of global biotic and abiotic changes, including an unprecedented rate of Non-Indigenous Species (NIS) introductions. This largely reflects successive enlargements of the Suez Canal, connecting the Red and Mediterranean Seas. Tiralongo *et al.* (2022) reported a total of *ca*. 1,000 identified 'alien' species here. These range from algae (e.g. a green alga native to Australia) to fish (e.g. the lionfish), potentially disrupting all trophic levels. Zenetos *et al*. (2022) stated that molluscs have the highest diversity among established and casual NIS (230 taxa), followed by fish and crustaceans (173 and 170 NIS, respectively). The rate of introduction is accelerating. Golo *et al*. (2023) asserted that 20% of all species introduced into the Mediterranean have been misidentified, with a range of undesirable consequences for, *inter alia*, management strategies.

> *(SOURCES: Tiralongo, F., Hall-Spencer, J. M., Giovos, I., Kleitou, P., 2022. Editorial: Biological invasions in the Mediterranean Sea. Front. Mar. Sci. 9:1016168. [Available at: https://doi.org/10.3389/fmars.2022.1016168]); Zenetos, A., Albano, P. G., Garcia, E. L., Stern, N., Tsiamis, K., Galandi, M., 2022. Established non-indigenous species increased by 40% in 11 years in the Mediterranean Sea. Mediterr. Mar. Sci. 23(1). [Available at: https://doi.org/10.12681/mms.29106]; Golo, R., Vergés, A., Diaz-Tapia, P., Cebrian, E., 2023. Implications of taxonomic misidentification for future invasion predictions: Evidence from one of the most harmful invasive marine algae. Mar. Pollut. Bull. 191:114970. [Available at: https://doi.org/10.1016/j.marpolbul.2023.114970]).*

Habitat degradation

General

ANTHROPOGENIC EUTROPHICATION AFFECTS THE DIET OF A HIGHLY THREATENED DOLPHIN POPULATION IN GREECE

The diet and feeding behaviour of a highly threatened community of about 150 common bottlenose dolphins in the Gulf of Ambracia (northwest Greece) is apparently determined by anthropogenically induced bottom-water oxygen crises due to nutrient inputs by fish farms, agriculture, livestock and domestic sewage. The hypoxic and anoxic conditions here have reduced fish diversity. Demersal fishes are more affected than pelagic species, suggesting dolphins therefore feed on pelagic species that aggregate near the surface and the shoreline. However, the dolphins regularly damage fishing nets to access captured demersal sea breams. Accordingly, the degradation of part of the habitat and food web determines the diet and feeding behaviour of this cetacean population.

> *(SOURCE: Borrell, A., Vighi, M., Genov, T., Giovos, I., Gonzalvo, J., 2020. Feeding ecology of the highly threatened common bottlenose dolphin of the Gulf of Ambracia, Greece, through stable isotope analysis. Mar. Mam. Sci. 2020:1-13. [Available at: https://doi.org/10.1111/mms.12725]).*

INCREASINGLY INTENSE MARINE TRAFFIC IN THE SLOVENIAN GULF OF TRIESTE

The Slovenian part of the far north Adriatic Sea (Gulf of Trieste) is subject to intensive and increasing maritime transport (ports of Trieste and Koper). Despite disturbance in port channels, an ecological quality index classifies the benthic communities as Good/High. However, the authors listed several additional pressures, such as intensive fishing, sewage outfalls and mariculture, and highlighted that the harsh natural environmental conditions here (far north Mediterranean waters) are an even stronger influence on macrofauna. These, together with anthropogenic factors, have triggered a long history of major ecosystem collapses throughout the northern Adriatic, involving excessive and extensive marine snow (mucilage) events, along with large-scale anoxia and benthic mass mortalities. Accordingly, a single (benthic) biotic quality index is insufficient to capture true environmental status (the noise from vessel traffic, for example, would not be encompassed). The authors also noted that shifting baseline syndrome can negatively affect our perception and awareness about how marine communities are changing. The Slovenian coast is home to a resident population of bottlenose dolphins.

> *(SOURCE: Pitacco, V., Mavric, B., Lipej, L., 2023. A preliminary study of soft bottom benthic communities in an area affected by intense maritime traffic (Slovenian Sea, Northern Adriatic). Mar. Pollut. Bull. 188:114672. [Available at: https://doi.org/10.1016/j.marpolbul.2023.114672]).*

Fisheries Interactions

FISH FARMS CHANGE THE BEHAVIOUR, DIET AND SOCIAL STRUCTURE OF DOLPHINS IN GREECE

Common bottlenose dolphins in the Gulf of Corinth, Greece, inhabit a relatively small area of the Gulf around coastal aquaculture farms devoted to sea bass and sea bream. Bottlenose dolphin reliance on fish from these farms is particularly high (Greece has the highest number of aquaculture farms in the Mediterranean). Foraging around such farms can involve trade-offs between the costs and benefits of nourishment and social interaction. Generally, when animals have no option other than foraging near fishing gear, such behaviour can be maladaptive. The potential positive or negative effects should be considered in the context of ensuring favourable conservation status.

> *(SOURCE: Bonizzoni, S., Genov, T., Bearzi, G. 2023. Bottlenose dolphins share fish farm areas while maintaining sexual segregation: Investigating group memberships through spatially and temporally explicit parameters. Aquatic Conserv: Mar Freshw Ecosyst. 33:70-88. [Available at: https://doi.org/10.1002/aqc.3908]).*

NEW BYCATCH REGULATION FOR EUROPEAN WATERS IS NOT SUFFICIENT TO MITIGATE BYCATCH

Despite binding legal requirements to monitor and reduce cetacean bycatch in Europe, the level of bycatch monitoring has not been enough to accurately estimate bycatch rates. Moreover, practical efforts to reduce bycatch have been limited and often not effectively applied to the worst fisheries. Consequently, a new EU regulation (*Regulation on the conservation of fishery resources and the protection of marine ecosystems through technical measures (2019/1241)*) has been introduced, bringing together 30 pieces of fisheries conservation legislation, including legislation on cetacean bycatch. The regulation requires new or updated technical measures to be applied to high-risk fisheries and EU Members to report on the monitoring and effectiveness of bycatch mitigation measures. The regulation also allows for "the creation of real-time closures … for the protection of sensitive species (Article 19)". However, bycatch limits and thresholds are poorly defined and, as current bycatch monitoring fails to accurately assess bycatch rates, it is difficult to demonstrate when mitigation is required. Moreover, adopting new measures also requires unanimous agreement amongst member states, seriously limiting the likelihood of passing new relevant agreements on mitigation measures. Additionally, previous requirements for dedicated observer schemes on some types of fishing vessels in certain regions have been replaced with a vague clause that "Member States shall take the necessary steps to collect scientific data on incidental catches of sensitive species" (Annex XIII (2)). Moreover, there is no requirement under the new regulation for EU Members to report on the implementation of bycatch mitigation measures—the previous requirement for annual reporting has been lost. The authors expressed concerns that observers on fishery vessels will now be "expected to multi-task" and "will likely prioritize data collection on target commercial fish species", instead of providing accurate data on cetacean and other bycatch rates. The authors noted that the scientific advice of the ICES Bycatch Working Group, ASCOBANS and ACCOBAMS was not incorporated into the regulation. "The bycatch measures adopted for cetaceans are not sufficient to mitigate bycatch effectively in European waters".

> *(SOURCE: Dolman, S.J., Evans, P.G.H., Ritter, F., Simmonds, M.P., Swabe, J., 2021. Implications of new technical measures regulation for cetacean bycatch in European waters. Mar. Pol. 124:104320. [Available at: https://doi.org/10.1016/j.marpol.2020.104320]).*

DOLPHINS INTERACT DIFFERENTLY WITH TRAWLERS IN NORTH ADRIATIC THAN ELSEWHERE

Fishing activities can affect cetacean behaviour. The authors distinguished two segments (social clusters) of a common bottlenose dolphin population in the Gulf of Trieste (north Adriatic Sea), and determined that one regularly interacted with trawlers. Numerous trawlers here operate in shallow waters (<25m) year-round. Rather than feeding on discards, as has been reported elsewhere, the dolphins followed operating trawlers, presumably feeding actively inside/behind the net. Moreover, this segment of dolphins switched to following bottom trawlers after the closure of the pair trawler (pelagic/mid-water) fishery. Thus, different segments of populations can interact differently with human activities and

respond differently to anthropogenic impacts. This highlights that human activities may alter the behaviour and social structure of mammals.

(SOURCE: Genov, T., Centrih, T., Kotnjek, P., Hace, A., 2019. Behavioural and temporal partitioning of dolphin social groups in the northern Adriatic Sea. Mar. Biol. 166:11. [Available at: https://doi.org/10.1007/s00227-018-3450-8]).

BYCATCH LEVELS IN MEDITERRANEAN CETACEANS

The 'Cetacean Migration Corridor' is an important MPA for cetaceans in the western Mediterranean, but part of the MPA includes the main fishing grounds for the Valencia region of Spain. Izquierdo-Serrano *et al.* (2022) conducted interviews (*n*=282) with fishing operations to estimate possible cetacean bycatch rates. Bottom trawlers (*n*=148) reported a monthly bycatch rate of 0.01 dolphins per vessel (common bottlenose or striped dolphins, with approximately twice as many of the former being caught). The estimated total annual bycatch for the fleet was 23 dolphins. Artisanal vessels (*n*=114) reported only one incident of an unidentified dolphin being bycaught. The number of purse seiners was smaller (*n*=15; bycatch rate 0.04 dolphins/vessel) and these vessels bycaught an estimated 15 dolphins per annum (bottlenose and striped dolphin). Pelagic longline vessels (*n*=5) reported catching a single Risso's dolphin. From strandings data, 7.8% of examined cetacean carcasses showed fisheries interaction signs. However, 26.7% of bottlenose dolphin strandings and 6.45% of striped dolphin strandings showed evidence of bycatch. The authors suggested management actions to reduce bycatch, including the use of visual and acoustic deterrent devices and gear modifications. Papageorgiou *et al.* (2022) used logbook data, interviews (*n*=20; 63% of the longline fleet) and on-board observations to evaluate cetacean-fishery interactions in the albacore tuna pelagic longline fishery in the waters of Cyprus. A total bycatch of 62 bottlenose dolphins and one striped dolphin were reported in interviews. The authors noted possible biases and inaccurate reporting in interviews and stated that "acoustic deterrent devices are considered for the moment as the only practical solution to mitigate interactions" by the interviewees, but cautioning about the potential impacts of widespread use of such devices on ecosystems and dolphins (i.e. impacts on hearing and behaviour).

(SOURCES: Izquierdo-Serrano, M., Revuelta, O., Míguez-Lozano, R., Gozalbes, P., Ruiz-García, D., Raga, J. A., Tomás, J., 2022. Assessment of the interactions between cetaceans and fisheries at the south of the Cetacean Migration Corridor and neighboring waters (Western Mediterranean). Front. Mar. Sci. 9:981638. [Available at: https://doi.org/10.3389/fmars.2022.981638]; Papageorgiou, M., Hadjioannou, L., Jimenez, C., Georgiou, A., Petrou, A., 2022. Understanding the interactions between cetaceans and other megafauna with the albacore tuna fishery: A case study from the Cyprus' pelagic longline fishery. Front. Mar. Sci. 9:868464. [Available at: https://doi.org/10.3389/fmars.2022.868464]).

FIRST RECORD OF A CETACEAN KILLED IN A FISH AGGREGATING DEVICE IN THE MEDITERRANEAN

Fish Aggregating Devices (FADs) are floating structures that create shadows, which encourage pelagic fish to cluster and aggregate underneath them, increasing catch rates. The authors reported on the first known incident of a cetacean death caused by a FAD. A young, male striped dolphin was found on the coast of Lazio, Italy (central Tyrrhenian Sea), entangled in materials typically used in constructing illegal FADs (e.g. nylon rope, plastic sheets, branches and plastic bottles). The necropsy results suggested that the dolphin was alive when entangled. The authors concluded that "given the widespread use of illegal versions of these devices, the extent of the problem may be greatly underestimated" and that "actions and monitoring need to be implemented urgently to effectively protect and conserve marine biodiversity" from the threat that FADs pose.

(SOURCE: Manfrini, V., Fortuna, C. M., Cocumelli, C., 2023. First record of cetacean killed in an artisanal Fish Aggregating Device in the Mediterranean Sea. Animals 13:2524. [Available at: https://doi.org/10.3390/ani13152524]).

EXCESSIVE BYCATCH LEVELS OF HARBOUR PORPOISE IN THE BLACK SEA

Bycatch is a major mortality factor for the Black Sea harbour porpoise, which is an endemic subspecies listed as Endangered on the IUCN Red List. Bottom gillnets and trammel nets, in particular those targeting turbot, are the primary responsible gear. In Bulgaria, Romania, Turkey and Ukraine, a study estimated the annual bycatch level to be between 11,826 and 16,200 individuals. This represents between 4.6% and 17.2% of the estimated total population. This is among the highest bycatch levels worldwide and far exceeds the probable sustainable level of around 1.0-1.7%. Urgent measures are required to reduce this bycatch immediately if the population is to survive in the long-term, including, if necessary, spatio-temporal closure of fishing. First tests with the use of certain pingers, as well as modified nets with acrylic glass spheres to improve acoustical detectability of nets, are potentially promising bycatch reduction measures.

(SOURCE: Popov, D., Meshkova, G., Vishnyakova, K., Ivanchikova, J., Paiu, M., Timofte, C., Öztürk, A. A., Tonay, A. M., Dede, A., Panayotova, M., Düzgünes¸ E., Gol'din, P., 2023. Assessment of the bycatch level for the Black Sea harbour porpoise in the light of new data on population abundance. Front. Mar. Sci. 10. [Available at: https://doi.org/10.3389/fmars.2023.1119983]).

Marine Debris

MARINE DEBRIS ALONG TURKISH BLACK SEA COASTS

Turkey has one of the longest coastlines in the Black Sea (1175km), with a coastal population of 26 million people, and receives runoff from several rivers. Bat *et al*. (2022) reported that beaches in the central Turkish coast were 'moderate to extremely dirty' (~86,000 items of litter collected, mean 2.5 items/m²). Plastics made up 88–98% of this litter. The authors attributed this mostly to land-based sources, including illegal dumping, weak enforcement and poor waste management systems. Erüz *et al*. (2022) noted that a large portion of litter that enters the marine environment ends up on the seafloor. They examined the litter at 27 stations along the shallow shelf (10–36m) of the Turkish coast (southern Black Sea). The average density by number and weight were 460 items/km² and 80kg/km², respectively. Most recovered items were single-use plastic, dominated by bags. The authors noted new legislation charging customers for single-use carrier bags and suggested buyback programs that encourage fishers to collect litter. The authors also noted that discharge into the northern Black Sea from major European rivers makes up a large percentage (80%) of the overall freshwater input. Accordingly, the litter problem in the north can be expected to be correspondingly larger. Akarsu *et al*. (2022) reported that the amount of litter along four beaches in the Sea of Marmara, connecting the Black and Mediterranean Seas and home to several cetacean species, led to a classification as 'extremely dirty'.

> *(SOURCES: Bat, L., Öztekin, A., Öztürk, D. K., Gürbüzer, P., Özsandikci, U., Eyüboglu, B., Öztekin, H. C., 2022. Beach litter contamination of the Turkish middle Black Sea coasts: Spatial and temporal variation, composition, and possible sources. Mar. Pollut. Bull. 185:114248. [Available at: https://doi.org/10.1016/j.marpolbul.2022.114248]; Erüz, C., Terzi, Y., Öztürk, R. C., Karakoc, F. T., Özseker, K., Sahin, A., Ismail, N. P., 2022. Spatial pattern and characteristics of the benthic marine litter in the southern Black Sea shelf. Mar. Pollut. Bull. 175:113322. [Available at: https://doi.org/10.1016/j.marpolbul.2021.113322]; Akarsu, C., Sönmez, V. Z., Altay, M. C., Pehlivan, T., Sivri, N., 2022. The spatial and temporal changes of beach litter on Istanbul (Turkey) beaches as measured by the clean-coast index. Mar. Pollut. Bull. 176:113407. [Available at: https://doi.org/10.1016/j.marpolbul.2022.113407]).*

MACROLITTER ALONG THE BULGARIAN BLACK SEA COAST

The assessment of beach litter on 40 beaches along the Bulgarian coast of the Black Sea from 2018–2022 revealed an average increase of 260%. The Clean Coast Index categorised the beaches on average as 'moderately polluted', but 11 beaches were 'extremely dirty' in 2021 and 2022 during the "dirtiest period" (the COVID-19 pandemic). Land-based sources dominated (77%). The high percentage of public-sourced litter (61%) reflected high domestic tourist pressure then, followed by medical wastes (13%). Plastics accounted for 84% of the litter, followed by paper, glass, metal, processed wood, rubber and textiles. The authors emphasised the combined role of visual censuses, manual collection and unmanned aerial systems and call for improved public behaviours and better waste management practices.

> *(SOURCE: Bekova, R., Prodanov, B., 2023. Assessment of beach macrolitter using unmanned aerial systems: A study along the Bulgarian Black Sea Coast. Mar. Pollut. Bull. 196:115625. [Available at: https://doi.org/10.1016/j.marpolbul.2023.115625]).*

PLASTICS AND MARINE DEBRIS IN THE PELAGOS SANCTUARY

Ferries were used as platforms of opportunity to survey for macroplastics and other marine debris in the Pelagos Sanctuary in the Ligurian Sea, between Corsica and Sardinia (2013-2019). Floating marine debris (*n*=709 items) was encountered in almost all the surveys (*n*=63). Shopping bags, plastic sheets, polystyrene and bottles were the most common items sighted (65% of items). Paper (6.6%) and processed wood (4.8%) were also sighted. Maritime/shipping and food and fishing industries were the most frequent debris sources, with food-related debris more frequent in the autumn and winter and fishing-related items in the spring and summer. Densities were higher in the western part of the study area and the Asinara Gulf in autumn-winter, and this hotspot expanded further into the Gulf during spring-summer. In autumn-winter, debris tended to be more offshore and hotspots tended to be more concentrated, with wider distribution during spring-summer. These seasonal patterns suggest that sources are not only local (i.e. tourism and recreation).

> *(SOURCE: Campana, I., Angeletti, D., Giovani, G., Paraboschi, M., Arcangeli, A., 2022. Cetacean sensitivity and threats analysis to assess effectiveness of protection measures: An example of integrated approach for cetacean conservation in the Bonifacio Bouches. Biodivers. Conserv. 31:517-541. [Available at: https://doi.org/10.1007/s10531-021-02346-w]).*

LITTER UBIQUITOUS ON MEDITERRANEAN SHORES

Marine debris has been identified by the Scientific Committee of the IWC as one of the key threats (e.g. entanglement, ingestion) facing cetaceans worldwide. Such litter on beaches is one indication of the overall level of marine debris in the system. Numerous recent publications point to the Mediterranean as a hotspot of this pollutant category. In the western Mediterranean, the mean concentration was 1.9–2.4 macrolitter items/m² on six beaches of the Balearic Islands (Mallorca, Menorca, Ibiza). These beaches are within the Cabrera Archipelago Maritime-Terrestrial National Park (Cabrera MPA), underscoring that even protected beaches can be reservoirs for marine litter.

(SOURCE: Compa, M., Alomar, C., Morató, M., Álvarez A., Deudero, S., 2022. Setting thresholds is not enough: Beach litter as indicator of poor environmental status in the southern Adriatic Sea. Mar. Pollut. Bull. 177:113551. [Available at: https://doi.org/10.1016/j.marpolbul.2022.113551]).

PREDICTED MICROPLASTIC UPTAKE IN TWO DOLPHIN SPECIES IS HIGHER IN THE MEDITERRANEAN THAN THE ATLANTIC

The diets of two dolphin species (short-beaked common dolphin, common bottlenose dolphin) were linked to microplastics occurrence and abundance in prey. If these dolphins primarily ingest microplastics via their diet, then the former species would ingest 164 microplastics per day in the Mediterranean, the latter 179 microplastics per day. These values were 2 and 5 times higher than for these species in the Northeast Atlantic, respectively. The authors highlighted "the potential for microplastics to reach predatory animals through trophic transfer" and confirmed the Mediterranean as a microplastics hotspot.

(SOURCE: Dool, T., Bosker, T., 2022. Predicted microplastic uptake through trophic transfer by the short-beaked dolphin (Delphinus delphis) and common bottlenose dolphin (Tursiops truncatus) in the Northeast Atlantic and Mediterranean Sea. Mar. Pollut. Bull. 180:113745. [Available at: https://doi.org/10.1016/j.marpolbul.2022.113745]).

MICROPLASTICS IN COMMERCIALLY IMPORTANT FISH SPECIES IN THE SOUTHERN BLACK SEA

Plastics pollution is one of the most serious concerns in the Black Sea, which is supplied by the largest rivers of Europe (Danube, Dnieper, Don). Eryasar *et al*. (2022) examined the microplastics contamination in three commercially important fish species along the Turkish coast. Fibres were the most common form, pointing to municipal sewage. The highest values were recorded in demersal red mullet, probably reflecting the sinking habit of these particles and the species' feeding behaviour. Onay *et al*. (2023) reported 335 microplastics items in 120 red mullet sampled from the southeast Black Sea region (Turkey). In summer, most items were fragments; in the remainder of the year, fibre-shaped. The authors suggested intense fishing activities as the source.

(SOURCES: Eryasar, A. R., Gedik, K., Mutlu, T., 2022. Ingestion of microplastics by commercial fish species from the southern Black Sea coast. Mar. Pollut. Bull. 177:113535. [Available at: https://doi.org/10.1016/j.marpolbul.2022.113535]; Onay, H., Karsch, B., Minaz, B., Dalgic, G., 2023. Seasonal monitoring of microplastic pollution in the Southeast Black Sea: An example of red mullet (Mullus barbatus) gastrointestinal tracts. Mar. Pollut. Bull. 191:114886. [Available at: https://doi.org/10.1016/j.marpolbul.2023.114886]).

MISTAKING PLASTICS FOR PLANKTON POSES A THREAT FOR MARINE SPECIES IN THE MEDITERRANEAN

Marine species may mistake plastics for zooplankton and ingest this pollutant. To help quantify the problem, plastic debris and zooplankton were sampled via nets at 122 stations across the Mediterranean between June and November 2014. A machine-learning method was used to analyse and classify microplastics and the data were used to develop spatially-explicit maps of plastic debris and zooplankton abundance. The plastic to zooplankton ratio was also determined in regions with high abundances of pelagic fish. Two important areas for pelagic fish (the Gulf of Gabès and Cilician basin) had high ratios of plastic to zooplankton. The ratio was also high in the Pelagos Sanctuary. There was "a high potential risk of contamination of marine fauna by plastic" via consumption and magnification through the Mediterranean food chain.

(SOURCE: Fabri-Ruiz, S., Baudena, A., Moullec, F., Lombard, F., Irisson, J. O., Pedrotti, M. L., 2023. Mistaking plastic for zooplankton: Risk assessment of plastic ingestion in the Mediterranean Sea. Sci. Total. Environ. 856:159011. [Available at: http://dx.doi.org/10.1016/j.scitotenv.2022.159011]).

HIGH LEVELS OF PLASTICS IN BLACK SEA CETACEANS

The stomachs and intestines of three bottlenose dolphins and one harbour porpoise, stranded or bycaught on the Romanian shelf of the Black Sea, were examined. All the organs examined contained micro- and mesoplastics, with a total of 1059 items (fibres, fragments and beads), ranging in size from 22.86µm to 5776µm. This suggested a very high level of plastic contamination in the Black Sea, possibly reflecting the enclosed nature of the sea and the high level of human activity on its coasts.

(SOURCE: Filimon, A., Ciucă, A. M., Harcotă, G. E., Stoica, E., 2024. Preliminary study on microplastic contamination in Black Sea cetaceans: Gastrointestinal analysis of Phocoena phocoena relicta and Tursiops truncatus ponticus. Animals 14:*886. [Available at: https://doi.org/10.3390/ani14060886]).*

PLASTIC FISHING LURES IN A MEDITERRANEAN DOLPHIN

The stomach of a stranded individual of a small, isolated and poorly studied rough-toothed dolphin population in the eastern Mediterranean contained seven plastic bags and nine squid-like plastic fishing lures, causing complete gastric blockage. It remains unclear whether the dolphin focused on the lures themselves or on prey caught on these lures. The luminous lures were made from PVC. The authors suggested that apart from anthropogenic noise and bycatch, "this subpopulation may also be threatened by ingestion of macroplastics as is the case with other populations of toothed whales in the Mediterranean Sea".

(SOURCE: Foskolos, I., Alexiadou, P., Koutouzi, N., Frey, S., Thompson, K. F., Boisseau, O., Frantzis, A., 2023. Insights into the distribution and ingestion of prey-like plastic fishing lures in Mediterranean rough-toothed dolphins. Mar. Pollut. Bull. 188:114701. [Available at: https://doi.org/10.1016/j.marpolbul.2022.114701]).

DOLPHINS AND SPERM WHALE MORTALITIES IN TUNISIA RESULTING FROM THE INGESTION OF FISHING-RELATED PLASTIC DEBRIS

On the coast of Tunisia, four bottlenose dolphins were diagnosed with larynx strangulation (caused by swallowed gillnet filaments wrapped around the larynx). Their fore stomachs also contained gillnet pieces. Moreover, two sperm whales were diagnosed with acute stomach ulcers caused by ingesting gillnet pieces. One whale had a ruptured stomach with ~3kg of compacted net in its stomach. The second whale had a mass of net, nylon line and plastic bags in its stomach cavities. "These bottlenose dolphin and sperm whale strandings illustrate again that discarded nets can have severe impacts on marine mammal health".

(SOURCE: Jerbi, H., Pérez, W., Tellechea, J.S., 2021. Ingestion of floating net debris in sperm whales and larynx strangulation with gillnet parts in bottlenose dolphins on the coast of Tunisia. Aquat. Mamm. 47:239-244. [Available at: https://doi.org/10.1578/AM.47.3.2021.239).

HIGH LEVELS OF PLASTICS IN STRIPED DOLPHIN DIGESTIVE SYSTEMS IN SPAIN

The digestive system of Cuvier's beaked whales (*n*=2) and striped dolphins (*n*=14) stranded on the Almeria coastline, in southeast Spain, were analysed for plastics. The beaked whale digestive tracts contained no macro- or microplastics, but most of the striped dolphins' did (92.8%). Ten pieces of microplastics were found (two fragments, three films and five polystyrene foams), as well as 33 macroplastic fibres (mean 11.29mm ± 9.73; range 5.06-51.78mm) and 105 microplastic fibres (mean 2.57mm ± 1.12), with 10.9 (± 11.8) items of plastic per individual. The polymers identified (*n*=26) included: cellulose fibre (27%), polyacrylic fibre (23%), polypropylene (15%) and PET (11.5%). The plastic ingestion in these Mediterranean cetaceans is high, probably reflecting the high level of plastics concentrated in this enclosed sea.

(SOURCE: López-Martínez, S., Giménez-Luque, E., Molina-Pardo, J., Manzano-Medina, S., Arribas-Arias, H., Gavara, R., Morales-Caselles, C., Rivas, M. L., 2023. Plastic ingestion by two cetacean groups: Ziphiidae and Delphinidae. Environ. Pollut. 333:121932. [Available at: https://doi.org/10.1016/j.envpol.2023.121932]).

BEACH LITTER IN THE SOUTHERN ADRIATIC SEA INDICATES POOR ENVIRONMENTAL STATUS

Beach litter surveys (*n*=108) on nine beaches along the coasts of Albania, Italy and Montenegro showed that the threshold values adopted in the framework of the EU's Marine Strategy Framework Directive Good Environmental Status were significantly exceeded. Most of the litter was plastic, with many items related to food and beverage packaging. This suggested tourism and recreational use as key sources, along with poor waste management, although some categories with readable labels showed origins outside the Adriatic Basin, including Greece, Turkey, Lebanon and Israel, as well as northern European, non-Mediterranean countries (the latter pointing to sea-based sources, i.e. shipping lanes). The estimated total annual input of plastic into the Adriatic Sea ranges widely, from 10,000-250,000 tons.

(SOURCE: Mandic, M., Gvozdenovic, S., De Vito, D., Alfonso, G., Daja, S., Ago, B., Cela, E., Ivanovic, A., Zoto, A. et al., 2022. Setting thresholds is not enough: Beach litter as indicator of poor environmental status in the southern Adriatic Sea. Mar. Pollut. Bull. 177:113551. [Available at: https://doi.org/10.1016/j.marpolbul.2022.113551]).

MICROPLASTICS IN MEDITERRANEAN WATERS

Threats from microplastics include ingestion and transport of hazardous pollutants. The Mediterranean is recognised as a hotspot regarding microplastics concentrations, and several countries here are adopting regulations and policies to monitor, control, manage and prevent/reduce microplastics pollution (Marcuso *et al*., 2023). The authors summarised concentrations in marine biota, from invertebrates to fish and marine mammals. Gérigny *et al*. (2022) examined floating microplastics in the Bay of Marseille, a highly urbanised area. The average microplastics abundance ranged from 39,000 to 514,000 items/km². The mesoplastics values were 29,000 in summer, 6,000 in spring and 1,100 in winter. This region is highly contaminated compared to the Atlantic and other areas of the Mediterranean. The main sources are the Rhone River and the city's water treatment plant. The mean abundance ratio of microplastics to zooplankton was 0.09, with a potentially high impact of microplastics on the planktonic food web. This area is close to the Pelagos Sanctuary. Rubin *et al*. (2022) reported two highly contaminated sites (18,777 particles/m^2) on the Israeli coastline (Tel Aviv, Hadera). Local rivers were probably the main sources. The microplastics were contaminated with biofilm and metal residues. Accordingly, a small strip of the Israeli shoreline likely holds >2 tons of microplastics litter. This is a potential direct threat to the environment and human health.

(SOURCES: Marcuso, M., Porcino, N., Blasco, J., Romeo, T., Savoca, S., Spano, N., Bottari, T., 2023. Microplastics in the Mediterranean Sea. Impacts on Marine Environment. Springer Briefs in Environmental Science. [Available at: https://doi.org/10.1007/978-031-30481-1]; Gérigny, O., Pedrotti, M.-L., El Rakwe, M., Brun, M., Pavec, M., Henry, M, Mazeas, F., Maury, J., Garreau, P., Galgani, F., 2022. Microplastic accumulation in commercial fish from the Adriatic Sea. Mar. Pollut. Bull. 175:113353. [Available at: https://doi.org/10.1016/j.marpolbul.2022.113353]; Rubin, A. E., Omeysi, L.,

Zucker, I., 2022. Mediterranean microplastic contamination: Israel's coastline contributions. Mar. Pollut. Bull. 183:114080. [Available at: https://doi.org/10.1016/j.marpolbul.2022.114080]).

High Overlap in Levels of Marine Debris and Cetacean Distribution in the Central Mediterranean

Data on floating marine debris were collected via scientific vessels, ferries and cargo ships over a 2-year period, from routes in the Strait of Sicily and the Gulf of Catania, in the central Mediterranean. A total of 1,011 marine litter items were recorded, with an average sighting rate of 3.07 items per hour of monitoring. Most of the waste ranged in size from 20–50cm and the most common types of marine debris were packaging (*n*=267 items), food-related debris (*n*=140) and fishing gear (*n*=52 items, including buoys, nets, lines, ropes, strings and polystyrene fish boxes). Most items were made of plastic. The largest items (>50cm) tended to be found in the Strait of Sicily. These surveys also yielded 91 cetacean sightings (0.54 sightings per hour of effort) from five species. Striped (*n*=42; 1878 individuals) and bottlenose (*n*=32) dolphins were the most frequently sighted, followed by fin whales (*n*=7), Risso's dolphins (*n*=1) and common dolphins (*n*=2). The authors concluded that "an important overlapping between the zones in which cetaceans are regularly present and those with a high marine litter density has been found".

(SOURCE: Monaco, C., Raffa, A., Giarrusso, E., Arcangeli, A., Tumino, C., 2023. Presence of marine floating litter and vulnerable species in the Central Mediterranean Sea. In: 2023 IEEE International Workshop on Metrology for the Sea; Learning to Measure Sea Health Parameters (MetroSea) (pp. 311-315). [Available at: https://doi.org/10.1109/MetroSea58055.2023.10317334).

Marine Debris: A Major Threat in the Mediterranean Sea

The Mediterranean is one of the seas most polluted by plastic and its derivatives. An estimated annual input is 100,000 tons per year. The amount of floating material is "comparable to the subtropical gyres of the North Atlantic and North Pacific" (Rizzo *et al.*, 2022), a quantity that is particularly problematic considering the Mediterranean's semi-enclosed nature and the limited water exchange with the Atlantic Ocean. Plastic pieces (10–20cm) on the continental slope (400–600m depth) suggest a transfer to deep waters through floating and sinking. Based on beach and underwater clean-ups, Kouvara *et al*. (2022) reported that pandemic-related litter (e.g. face masks, gloves) exacerbated the plastic pollution of Greek coastal environments. Overall, pandemic-related items made up ca. 1% of the 100,000 items collected. Mghili *et al*. (2022) reported that the Moroccan Mediterranean is under pressure from plastics, with floating litter transporting fouling organisms and potentially introducing invasive species to this area.

(SOURCES: Rizzo, L., Minichino, R., Virgili, R., Tanduo, V., Osca, D., Manfredonia, A., Consoli, P., Colloca, F., Crocetta, F., 2022. Benthic litter in the continental slope of the Gulf of Naples (central-western Mediterranean Sea) hosts limited fouling communities but facilitates molluscan spawning. Mar. Pollut. Bull. 181:113915. [Available at:, https://doi.org/10.1016/j.marpolbul.2022.113915]; Kouvara, K., Papatheodorou, G., Kosmopoulou, A., Giovos, J., Charitou, A., Filippides, A., Kaberi, H., Kalaitzi, L., Kyrkitsos, F., Koundouri, P., Triantafyllou, C., Gletsos, M., Fakiris, E., Geraga, M., 2022. COVID-19-related litter pollution on Greek beaches and nearshore shallow water environments. Mar. Pollut. Bull. 185:114250. [Available at: https://doi.org/10.1016/j.marpolbul.2022.114250]; Mghili, B., De-la-Torre, G. E., Analla, M., Aksissou, M., 2022. Marine macroinvertebrates fouled in marine anthropogenic litter in the Moroccan Mediterranean. Mar. Pollut. Bull. 185:114266. [Available at: https://doi.org/10.1016/j.marpolbul.2022.114266]).

Plastic Ingestion and Entanglement in Fishing Gear in Cetaceans near the Balearic Islands

Marine debris was reported in the digestive systems of 30 cetaceans (five species) stranded around the Balearic Sea (bottlenose dolphins (*n*=9), striped dolphin (*n*=15), Risso's dolphins (*n*=2) and single sperm and fin whales). Two bottlenose dolphins had ingested ropes and lines from fishing gear and the sperm whales had ingested plastic bags, plastic straps and plastic sheeting. Seven cases of entanglement in discarded fishing gear (striped dolphin (*n*=2), bottlenose dolphin (*n*=3), sperm whale (*n*=1) and humpback whale (*n*=1)) were also reported. "[T]his is the first study to demonstrate the presence of plastic ingestion, and incidences of entanglement, with regard to cetaceans from the waters surrounding the Balearic Islands".

(SOURCE: Solomando, A., Pujol, F., Sureda, A., Pinya, S., 2022. Evaluating the presence of marine litter in cetaceans stranded in the Balearic Islands (western Mediterranean Sea). Biology 11. [Available at: https://doi.org/10.3390/biology11101468).

Microplastics Can Concentrate and Transport Heavy Metals

Among the many issues related to microplastics, potentially toxic trace elements can be absorbed onto plastic surfaces, which then act as a transport vector. Microplastics were extracted from plankton samples from the Mediterranean and analysed for trace element levels. Measured in concentrations of $\mu g.g^{-1}$, Al (30 ± 2.5), Cr (7.0 ± 0.008), Co (1.1 ± 0.01), Cu (1.0 ± 0.09), Fe (16 ± 1.9), Pb (1.5 ± 0.010), Mn (1.6 ± 0.02), Mo (2.2 ± 0.01), Ni (3.2 ± 0.09) and Zn (4.5 ± 0.16) were found. Other elements were found at trace amounts ($ng.g^{-1}$), including As (0.40 ± 0.008), Cd (0.033 ± 0.001), Rb (0.095 ± 0.007) and V (0.33 ± 0.01). Be, Bi, Ag, Tl, Sn and Se were below detection limits. "This has strong implications for the marine fauna since invertebrates, birds, and mammals feeding on zooplankton have the potential to mobilize chemical elements in their digestive systems … and a long-term exposure to ingestion of contaminated particles may potentially posing [sic] a serious threat to the survival of marine life".

(SOURCE: Squadrone, S., Pederiva, S., Bezzo, T., Sartor, R. M., Battuello, M., Nurra, N., Griglione, A., Brizio, P., Cesarina Abete, M. C., 2022. Microplastics as vectors of metals contamination in Mediterranean Sea. Environ. Sci. Pollut. Res. 29:29529-29534. [Available at: https://doi.org/10.1007/s11356-021-13662-7]).

MICROPLASTICS IN THE BLACK SEA

The Black Sea is unique in being semi-enclosed, having a drainage area divided into 107 sub-basins in more than 20 countries, and in receiving input by three large transboundary rivers (Danube, Dnieper, Don). European rivers are responsible for over half of microplastics pollution globally. Using models, the authors explored five scenarios to reduce river export of microplastics into the Black Sea. The 'baseline scenario' predicts an increase, whilst the 'optimistic scenario' would lead to an 84% reduction in microplastics input.

(SOURCE: Strokal, V., Kuiper, E. J., Bak, M. P., Vriend, P., Wang, M., van Eijnen, J., Strokal, M., 2022. Future microplastics in the Black Sea: River exports and reduction options for zero pollution. Mar. Pollut. Bull. 178:113633. [Available at: https://doi.org/10.1016/j.marpolbul.2022.113633]).

PLASTICS IN MEDITERRANEAN FISH

Valente *et al*. (2022) examined three fish species from three Italian marine areas (Adriatic Sea, Tyrrhenian Sea, western Sardinia). The microplastics ingestion frequencies depended on area, reflecting proximity to urban settlements and river flows. Feeding type (benthic vs demersal vs pelagic) affected the degree of ingestion. The authors therefore argued for a multispecies approach to monitoring microplastics ingestion. In the northeast Mediterranean, Kilic *et al.* (2022) reported that the frequency of microplastics occurrence in four commercial fish species was 60–100% (digestive tracts) and 68–90% (gills), with longer fish having higher levels. The values were generally higher than elsewhere in the Mediterranean and Black Seas. Turkey, Egypt and Italy are the top emitters of plastics in the Mediterranean due to intense discharge from major rivers and large urban areas. Fibres were the most common form detected, indicating "the poor water quality status of the region". Mistri *et al*. (2022) reported that, in the Adriatic Sea, the digestive tracts of nearly half of the 180 specimens of six fish species examined contained microplastics (total: 233 fragments). The Adriatic has significant plastics pollution, with the Po River being a main contributor. One-third of the entire freshwater input into the Mediterranean flows into the Adriatic. This study focused on human health because these six fish species are consumed without being eviscerated, transferring plastics directly to humans. Such a direct transfer would also be the case for higher-level fish predators, including cetaceans.

Compa *et al*. (2022) combined habitat maps and the spatial distribution of debris to quantify plastic exposure, then examined species-wise ingestion rates to map the risk of ingestion for 42 fish species in the Balearic Islands. The risks varied strongly between island regions and between species, with fish from higher trophic levels being the most vulnerable. "Overall, the calculated risk of plastic exposure/ingestion was quite high for most species". Such risk maps can help identify target areas for mitigation measures. Pittura *et al*. (2022) noted that microplastics in water provide a snapshot of that pollutant level, and their presence in organisms reflects their bioavailability. In fish and water surrounding Giglio Island, Italy, the microplastics values in 13 fish species were higher in 2019 than in 2017, "higher than those typically observed in other Mediterranean areas". Interestingly, higher values from an earlier study there (2014) were attributed to specific anthropogenic activities that resuspended microplastics, namely construction involving platforms, anchor blocks, cement grout bags and 4000 tons of debris.

Sciutteri *et al*. (2023) reported on seafloor macrolitter and ingestion by deep-sea fish in ca. 500–600m depth in the western Mediterranean Sea (Sicily). The density of seafloor litter (mostly single-use plastics) here was 128 items/km², values comparable with those reported elsewhere in the Mediterranean. The digestive tracts of three of nine fish species - grenadier hollow snout, shortnose greeneye, and Mediterranean slimehead - contained plastic. Most of the ingested particles were classified as microplastics. The shortnose greeneye showed the highest frequency of ingestion (9%). For some fish this was lower, for others higher, than reported elsewhere in the Mediterranean. The authors attributed the seafloor litter to poor waste management schemes. Nonetheless, they cited the EU's Single Use Plastic Directive and the Port Reception Facilities Directive (allowing fishers to deliver passively fished waste without being charged) as promising strategies to reduce plastics inputs.

(SOURCES: Valente, T., Pelamatti, T., Avio, C. G., Camedda, A., Costantini, M. L., de Lucia, G. A., Jacomini, C., Piermarini, R., Regoli, F., Sbrana, A., Ventura, D., Silvestri, C., Matiddi, M., 2022. One is not enough: Monitoring microplastic ingestion by fish needs a multispecies approach. Mar. Pollut. Bull. 184:114133. [Available at: https://doi.org/10.1016/j.marpolbul.2022.114133]; Kilic, E., Yücel, N., 2022. Microplastic occurrence in the gastrointestinal tract and gill of bioindicator fish species in the northeastern Mediterranean. Mar. Pollut. Bull. 177:113556. [Available at: https://doi.org/10.1016/j.marpolbul.2022.113556]; Mistri, M., Sfriso, A. A., Casoni, E., Nicoli, M., Vaccaro, C., 2022. Microplastic accumulation in commercial fish from the Adriatic Sea. Mar. Pollut. Bull. 174:113279. [Available at: https://doi.org/10.1016/j.marpolbul.2021.113279]; Compa, M., Wilcox, C., Hardesty, B. D., Alomar, C., March, D., Deudero, S., 2022. Quantifying the risk of plastic ingestion by ichthyofauna in the Balearic Islands (western Mediterranean Sea). Mar. Pollut. Bull. 183:114075. [Available at: https://doi.org/10.1016/j.marpolbul.2022.114075]; Pittura, L., Garaventa, F., Costa, E., Minetti, R., Nardi, A., Ventura, L., Morgana, S., Capello, M., Ingherese, G., Regoli, F., Gorbi, S., 2022. Microplastics in seawater and marine organisms: Site-specific variations over two-year study in Giglio Island (North Tyrrhenian Sea). Mar.

Pollut. Bull. 181:113916. [Available at: https://doi.org/10.1016/j.marpolbul.2022.113916]; Sciutteri, V., Pedà, C., Longo, F., Calogero, R., Cangemi, G., Pagano, L., Battaglia, P., Nannini, M., Romeo, T., Consoli, P., 2023. Integrated approach for marine litter pollution assessment in the southern Tyrrhenian Sea: Information from bottom trawling fishing and plastic ingestion in deep-sea fish. Mar. Pollut. Bull. 188:114661. [Available at: https://doi.org/10.1016/j.marpolbul.2023.114661]).

Ship Strikes

COLLISION RISKS IN THE PELAGOS SANCTUARY - FERRY SPEED RESTRICTIONS RECOMMENDED

Several studies collected cetacean sightings data via ferries and passenger vessels as platforms of opportunity in the Pelagos Sanctuary, combining environmental predictors of cetacean distribution (bathymetry and mean sea surface chlorophyll), ferry routes (Grossi *et al*., 2021; Campana *et al.,* 2022) and ferry density estimated from AIS data (Ham *et al*., 2021) to produce predictive models to assess ship strike risk in the sanctuary. Several possible collision hotspots were identified, including the canyon outside Savona Harbour (Italy), Nice Harbour (France), Calvi and Île-Rousse harbours (Corsica), the continental shelf front of Bastia (Corsica), the Bonifacio Strait (between Corsica and Sardinia) and the Asinara Gulf (Sardinia). The collision risk with fin whales was higher for ferry routes passing through the northern and eastern parts of the sanctuary. Possible sperm whale collision hotspots were determined off Savona and Nice, and in the Savona-Calvi shipping routes, particularly at the midway point of this route. There was an additional overlap between shipping traffic and cetacean distribution in the Asinara Gulf (bottlenose dolphins) and Bonifacio Strait (striped dolphins and fin whales). While some areas always had a high risk of collision, other high-risk areas were only temporary and varied spatially. Ham *et al*. (2021) concluded that, because of the dynamic nature of high-collision-risk areas, "vessel speed reduction may be a more practical measure to manage collision risk than re-routing shipping lanes". Sèbe *et al*. (2022) investigated the economic value of preventing fin whale collisions based on interviews and the public's 'willingness to pay' to prevent fin whale mortalities. The estimated 'cost of averting a Mediterranean fin whale fatality' was US$0.64 million (when converted to 2021 US dollars). One proposed mitigation measure to reduce the ship strike risk is the Real-Time Plotting of Cetaceans System, which allows communication of whale sightings between vessels to increase awareness of their presence, and thereby reduce this risk. This system costs US$120,000 over a vessel's lifetime (~25 years). The societal value of preventing whale mortality by using this system, therefore, outweighs the cost of implementing other mitigation measures.

(SOURCES: Grossi, F., Lahaye, E., Moulins, A., Borroni, A., Rosso, M., Tepsich, P., 2021. Locating ship strike risk hotspots for fin whale (Balaenoptera physalus) and sperm whale (Physeter macrocephalus) along main shipping lanes in the North-Western Mediterranean Sea. Ocean Coast. Manage. 212:105820. [Available at: https://doi.org/10.1016/j.ocecoaman.2021.105820]; Campana, I., Angeletti, D., Giovani, G., Paraboschi, M., Arcangeli, A., 2022. Cetacean sensitivity and threats analysis to assess effectiveness of protection measures: An example of integrated approach for cetacean conservation in the Bonifacio Bouches. Biodivers. Conserv. 31:517-541. [Available at: https://doi.org/10.1007/s10531-021-02346-w]; Ham, G. S., Lahaye, E., Rosso, M., Moulins, A., Hines, E., Tepsich, P., 2021. Predicting summer fin whale distribution in the Pelagos Sanctuary (north-western Mediterranean Sea) to identify dynamic whale-vessel collision risk areas. Aquatic Conserv: Mar. Freshw. Ecosyst. 31:2257-2277. [Available at: https://doi.org/10.1002/aqc.3614]; Sèbe, M., Kontovas, C. A., Pendleton, L., Gourguet, S., 2022. Cost-effectiveness of measures to reduce ship strikes: A case study on protecting the Mediterranean fin whale. Sci. Total Environ. 827:154236. [Available at: http://dx.doi.org/10.1016/j.scitotenv.2022.154236]).

THE ENVIRONMENTAL THREAT POSED BY RECREATIONAL VESSELS

More than 90% of the Mediterranean fleet of all vessels are recreational boats between 2.5 and 24m in length, of which 87% are motorboats and 11% sailboats. Ten percent of the recreational fleet are 'super yachts' (leisure vessels over 24m in length). Seventy percent of the world's super yachts are located in the Mediterranean, and this fleet is increasing by 3.5% per annum. The densities of recreational vessels are very high in the Mediterranean; e.g. in the Cap de Creus MPA (Spain) (average of 4.5 per hectare). In the Gulf of St Tropez (France), more than 350 leisure boats and over 100 super yachts were reported on just one day. Major environmental impacts include: anchors damaging seagrass beds and other benthic habitats; underwater noise; anti-fouling paint contaminants; transporting invasive species; oil leaks and spills; wastewater discharges; air pollution; and collisions (with cetaceans and other marine species). Additional impacts include stirring up sediments, artificial light pollution, marine debris and passengers feeding wildlife. "[T]here is an urgent need to raise awareness of the potential impacts of leisure boating in Mediterranean coastal environments", especially in MPAs, as "policy makers tend to ignore the impacts of recreational boating on coastal waters" and management of this vessel category tends to be poor in many Mediterranean countries.

(SOURCE: Carreño, A., Lloret, J., 2021. Environmental impacts of increasing leisure boating activity in Mediterranean coastal waters. Ocean Coastal Manage. 209:105693. [Available at: https://doi.org/10.1016/j.ocecoaman.2021.105693]).

MARINE PROTECTED AREA PROPOSED FOR RESIDENT COMMON DOLPHINS IN GIBRALTAR TO PROTECT FROM VESSEL TRAFFIC

A resident population of common dolphins inhabits the Bay of Algeciras (southern Spain and Gibraltar, UK). The dolphins' distribution is associated with a submarine canyon, and feeding, mating and calf rearing have been observed here. The authors mapped dolphin and vessel distributions to determine the overlap between the two. They noted, "The significant overlapping of small motorboats and cetaceans reflects the continuing and direct threat to pods of dolphins". Dolphins were particularly vulnerable to boat traffic in summer. Jet skis, small motorboats (including whale

watching and recreational vessels) and vessels dedicated to bluefin tuna fishing overlapped most with dolphin abundance and distribution. Moreover, tuna fishing activities were occurring outside the Spanish tuna season and were therefore illegal. The authors concluded that "an international Spanish-British micro-sanctuary urgently needs to be established in order to create a protected area specifically for the common dolphins".

(SOURCE: Olaya-Ponzone, L., Espada Ruíz, R., Patón Domínguez, D., Martín Moreno, E., Cárdenas Marcial, I., Serradilla Santiago, J., García-Gómez, J. C., 2023. Sport fishing and vessel pressure on the endangered cetacean Delphinus delphis. Towards an international agreement of micro-sanctuary for its conservation. J. Environ. Manage. 325:116546. [Available at: https://doi.org/10.1016/j.jenvman.2022.116546]).

WORLD'S LARGEST SHIPPING COMPANY CHANGING SHIPPING LANES OFF GREECE TO REDUCE COLLISIONS WITH WHALES

The Mediterranean Shipping Company, the world's largest shipping company, has shifted its shipping routes along the west coast of Greece to reduce collisions by its container and cruise ships with sperm whales. These whales congregate at the 1000m depth line about 20km offshore, which corresponds to the traditional shipping route. The sperm whale population in the eastern Mediterranean numbers only 200–300 animals and is decreasing. More than half of the stranded dead individuals on Greek shores have suffered ship strikes. If all shipping traffic would adopt this new route, then the ship strike threat would be reduced by an estimated 75%. Since then, some other shipping companies have also imposed similar routing and speed reduction measures.

(SOURCE: Press release by IFAW, OceanCare, Pelagos Cetacean Research Institute, WWF Greece, 27.1.2022 [Available at: https://www.oceancare.org/en/stories_and_news/major-shipping-company-helps-save-endangered-sperm-whales-in-the-mediterranean/; https://www.ifaw.org/uk/press-releases/dfds-shipping-company-alter-routes-sperm-whales-greece).

UNSUSTAINABLE SHIP STRIKE RISK FOR FIN WHALES IN THE MEDITERRANEAN

Because of the threat that ship strikes pose to fin whales, several Governments have proposed designating the Mediterranean Sea as a Particularly Sensitive Sea Area (PSSA), i.e. an area within which the IMO can implement voluntary or mandatory management measures. To provide evidence for this designation, the authors used data from strandings to estimate the number of lethal ship strikes within the proposed PSSA. This was then used to assess the probability that the number of collisions exceeded (a) the annual level of incidental human-caused mortality that could prevent the recovery of the population within 100 years (Potential Biological Removal [PBR]); (b) the threshold number at which there is a cause for concern about incidental mortality (Alert Reference Point [ARP]); and (c) the threshold beyond which there is a critical need to lower the incidental mortality (Critical Reference Point [CRP]). The study concluded that current ship strike mortality: (a) exceeds PBR; (b) exceeds ARP if confirmed and suspected collisions are considered; and (c) presents nearly a 35% chance of exceeding the CRP, "resulting in a population decline". If fishery-related mortality is added to ship strike mortality, then the probability of exceeding CRP is 60%. The authors concluded that "immediate action is required", but the PSSA designation and implementation process can be slow. Moreover, "there is a high probability that the ship strike and fishery mortality is beyond the critical threshold fixed by [ACCOBAMS]".

SOURCE: Sèbe, M., David, L., Dhermain, F., Gourguet, G., Madon, B., Ody, D., Panigada, S., Peltier, H., Pendleton, L., 2023. Estimating the impact of ship strikes on the Mediterranean fin whale subpopulation. Ocean Coast. Manage. 237:106485. [Available at: https://doi.org/10.1016/j.ocecoaman.2023.106485]).

FIN WHALE SHIP STRIKE RISK OFF THE CATALAN COAST OF SPAIN

Since 2018, at least four fin whales killed by ship strikes have been found in Barcelona Port (Spain) and seven live whales with ship-strike injuries have been observed. To protect whales, in June 2018 Royal Decree 699/2018 established the Mediterranean 'Cetacean Migration Corridor', a 46,385km^2 area between Catalonia and Valencia, within the Balearic archipelago. Fin whale distribution off the Catalan coast (Spain, northwest Mediterranean) was monitored out to 37km offshore. Whale distribution was compared with cargo, tanker and passenger ship shipping lanes and possible collision risk was calculated. Several shipping lanes crossed fin whale feeding habitat, with vessels travelling an average speed of 15kn. The fastest vessels here were cargo and passenger ships travelling to, or from, Barcelona Port. The highest ship strike risk was cargo vessels (during April) off the Garraf coast, as peak abundance in fin whale feeding areas overlapped with vessel traffic. During this period, cargo ships travel 10–20kn through the feeding area, resulting in an estimated 79% probability of a fatal strike. The authors noted that the Royal Decree should be used to establish, and enforce, ship strike reduction measures along the Mediterranean coast. The authors recommended that "slower vessel speeds … should be implemented along the Catalan coast, during the whale season [February to June]".

(SOURCE: Tort Castro, B., Prieto González, R., O'Callaghan, S. A., Dominguez Rein-Loring, P., Degollada Bastos, E., 2022. Ship strike risk for fin whales (Balaenoptera physalus) off the Garraf coast, Northwest Mediterranean Sea. Front. Mar. Sci. 9:867287. [Available at: https://doi.org/10.3389/fmars.2022.867287]).

Chemical Pollution

Flame Retardant Levels Decreasing But Still Remain a Risk for Mediterranean Dolphins

In the northwest Mediterranean, potential trends were examined for a variety of halogenated and organophosphate contaminants in stranded striped dolphins (*n*=42) over three periods: 1990, 2004-2009 and 2014-2018. The levels of halogenated flame retardants PBDE, PCDE and PCT declined (by 60%, 81% and 83%, respectively) from 1990 to 2018, but OPFRs remained at constant, relatively high levels. Substitutes for banned flame retardants, such as HBB and DBDPE, also decreased (by 94% and 89%, respectively) from 1990 to 2004–2009 and then remained stable. Dechloranes remained steady. Likewise, naturally occurring MeO-PBDEs were at a steady low level (6–7µg.g^{-1} lw). The study reported some contaminants (PCDEs and PCTs) for the first time in dolphin tissues. The conclusion: although some contaminants had decreased, "they still remain a health risk for dolphins". One third of dolphins sampled would be at risk of hyperthyroidism due to PBDE levels in their tissues. Moreover, 17–42% of dolphins were at risk because of PCDE levels. They concluded that "we will have to wait at least another decade [be]for[e] [sic] PBDEs and PCDEs do not pose a threat to Mediterranean striped dolphins".

Mean contaminant levels in 2014–2018 (µg.g^{-1} lw)—ΣPBDEs: 2.07; DBDPE: 0.028; HBB: 0.0015; PBEB: not detected; α-HBCD: 0.083; ΣDechloranes: 1.25; ΣOPFRs: 6.25; ΣMeO-PBDEs: 0.69; ΣPCDEs: 3.20; ΣPCTs: 0.77

> *(SOURCE: Aznar-Alemany, Ò., Sala, B., Jobst, K. J., Reiner, E. J., Borrell, A., Aguilar, A., Eljarrat, E., 2021. Temporal trends of halogenated and organophosphate contaminants in striped dolphins from the Mediterranean Sea. Sci. Total Environ. 753:142205. [Available at: https://doi.org/10.1016/j.scitotenv.2020.142205]).*

High Levels of Mercury in Western Mediterranean Swordfish

The Mediterranean is geologically located within a so-called mercuriferous belt, and higher levels of Hg in fish have long been reported here, e.g. in tuna. Biton-Porsmoquer *et al*. (2022) examined the mercury levels in swordfish, top predators in which the biomagnification of conservative pollutants can play an important role. This is also relevant for other top predators, including certain cetaceans. The study established the biomagnification of Hg along the food web from zooplankton to swordfish in the Catalan Sea (western Mediterranean). Cephalopods contributed significantly to the fish's Hg intake. While the levels in swordfish remained below the EU maximum regulatory levels, the authors concluded that they "may well be high enough to act as endocrine disruptors, which may cause dysfunctions in the swordfish reproductive system". Overall, swordfish condition seems to be impaired here. Girolametti *et al*. (2023) examined the muscle tissue of two stocks of Mediterranean swordfish and determined that the Italian specimens (near Sicily) showed significantly higher Hg concentrations than Spanish (Balearic) ones. Many samples (48%) exceeded the EU's safety limit. Accordingly, the allowable number of fish meals per month should be 0.6 (7 per year) for children and 1 per month for pregnant women, with the risk being relatively lower for fish from Spain.

> *(SOURCES: Biton-Porsmoguer, S., Banaru, D., Harmelin-Vivien, M., Béarez, P., Bouchoucha, M., Marco-Miralles, F. Marquèz, M., Lloret, J., 2022. A study of trophic structure, physiological condition and mercury biomagnification in swordfish (Xiphias gladius): Evidence of unfavourable conditions for the swordfish population in the Western Mediterranean. Mar. Pollut. Bull. 176:113411. [Available at: https://doi.org/10.1016/j.marpolbul.2022.113411]; Girolametti, F., Annibaldi, A., Illuminati, S., Carnevali, O., Varola, M., Truzzi, C., 2023. Determination of Hg and Se in swordfish (Xiphias gladius) from Mediterranean Sea: Implications for nutritional recommendations during pregnancy and childhood. Mar. Pollut. Bull. 197:115741. [Available at: https://doi.org/10.1016/j.marpolbul.2023.115741]).*

Zooplankton as an Indicator of Marine Pollution

Zooplankton has been used as a bioindicator of water pollution at the global level and the Mediterranean has long been considered a hotspot for chemical pollution. There is, however, a 40-year gap in studies on trace elements and POPs in Mediterranean zooplankton. This study on the Tyrrhenian Sea off Italy indicated that the POP levels appear to have decreased over the past 50 years. They were far lower than in other well-known contaminated areas with poor wastewater management. In contrast, the trace elements Zn, Cu, Pb and Ni showed values comparable to those in strongly polluted coastal areas elsewhere. Cd, Co and Hg were at intermediate levels between strongly affected and pristine areas. The authors concluded that the general pattern is stable to declining in the Mediterranean, potentially reflecting a general improvement in areas with particularly high trace element levels.

> *(SOURCE: Boldrocchi, G., Villa, B., Monticelli, D., Soanu, D., Magni, G., Pachner, J., Mastore, M., Bettinetti, B., 2023. Zooplankton as an indicator of the status of contamination of the Mediterranean Sea and temporal trends. Mar. Pollut. Bull. 197:115732. [Available at: https://doi.org/10.1016/j.marpolbul.2023.115732]).*

Pesticides and PCBs in Stranded Striped Dolphins

The concentrations of 31 PCBs and 15 banned pesticides or metabolites were measured in five tissues of 68 stranded striped dolphins along the northwest Mediterranean coast. Comparing the values from 2010–2016 with those of 1988–2009 showed a slowly decreasing trend but still elevated based on common cetacean toxicological thresholds. The more recent patterns point to more diffuse inputs (e.g. remobilisation from contaminated soils and sediments via rivers). The authors predicted a slow decline over decades and called for new efforts in reducing pollutant dispersal to aquatic

systems. They also noted that the 2007–08 morbillivirus epizootic in French waters likely preferentially affected the most contaminated individuals, designating PCBs, DDT and most organic carbon pesticides as aggravating factors.

Maximum ΣDDT plus ΣPCB levels (µg·g^{-1} lw) - blubber: 38.72; (µg·g^{-1} ww): liver: 23.81; kidney: 11.0; lung: 3.68; muscle: 8.42

> *(SOURCE: Dron, J., Wafo, E., Boissery, P., Dhermain, F., Bouchoucha, M., Chamaret, P., Lafitte, D., 2022. Trends of banned pesticides and PCBs in different tissues of striped dolphins (Stenella coeruleoalba) stranded in the Northwestern Mediterranean reflect changing contamination patterns. Mar. Pollut. Bull. 174:113198. [Available at: https://doi.org/10.1016/j.marpolbul.2021.113198]).*

Elevated Levels of Polycyclic Aromatic Hydrocarbons in Two Stranded Mediterranean Dolphin Species

PAHs in the marine environment largely reflect fossil fuel transport and use, with the Mediterranean being among the seas hardest hit by this contamination. The PAH levels in various tissues of 64 striped dolphins and 9 bottlenose dolphins stranded on the French coastline were at high (but not 'extreme') levels. The values were comparable in the two species, with the highest being recorded near urban and industrial centres. The authors confirmed that "PAH pollution remains a strong matter of concern in the Mediterranean marine environment, and that further monitoring in cetaceans will be essential to evaluate and better understand contamination trends and pathways".

> *(SOURCE: Dron, J., Wafo, E., Boissery, P., Dhermain, F., Bouchoucha, M. Chamaret, P., Lafitte, D., 2023. Occurrence and distribution of PAHs in stranded dolphin tissues from the Northwestern Mediterranean. Mar. Pollut. Bull. 191:114898. [Available at: https://doi.org/10.1016/j.marpolbul.2023.114898]).*

High Levels of Banned PFAS in Mediterranean Dolphins

This study investigated trends (over three decades) and bioaccumulation of PFAS in northwest Mediterranean striped dolphins. Samples of digestive contents (median 158.76ng.g^{-1} ww, range 43–1609) and liver (median 2326ng.g^{-1} ww, range 254–7010) were analysed. PFOS and FOSA were the two most abundant compounds, followed by PFUnDA, PFTrDA and PFNA. Long-chain PFAS biomagnified to a greater extent than short-chain PFAS, suggesting the former could be more of a health concern for dolphins. EU Environmental Quality Standard levels were exceeded in half the samples. This suggests that "polluted prey may pose potential health risks for striped dolphins". Levels of most long-chain PFAS increased from 1990 to 2009, but stabilised between 2014–2021. This possibly reflects regulations being introduced to limit these toxic compounds and industry switching to alternatives. However, dolphins still carry high levels of compounds that have been banned for decades, such as PFOS.

Maximum liver PFAS concentrations (ng.g^{-1} ww)—PFBS: 19.49; PFHxS: 26.56; n-PFOS: 3964.72; Br-PFOS: 115.31; PFDS: 19.97; PFDoDS: 16.31; FOSA: 2055.08; PFPA: 422.46; PFHxA: 225.85; PFHpA: 51.68; PFOA: 42.48; PFNA: 319.77; PFUnDA: 959.85; PFDoDA: 215.25; PFTrDA: 1105.19; PFTeDA: 197.19; ΣPFAS: 7010.44

> *(SOURCE: Garcia-Garin, O., Borrell, A., Colomer-Vidal, P., Vighi, M., Trilla-Prieto, N., Aguilar, A., Gazo, M., Jiménez, B., 2023. Biomagnification and temporal trends (1990–2021) of perfluoroalkyl substances in striped dolphins (Stenella coeruleoalba) from the NW Mediterranean Sea. Environ. Pollut. 339:122738. [Available at: https://doi.org/10.1016/j.envpol.2023.122738]).*

Persistent Organic Pollutants in Adriatic Bottlenose Dolphins

The Gulf of Trieste is one of the areas most affected by human activities in the Mediterranean. Although PCBs have declined in European seas since the 1970s-1980s ban, considerable levels still persist in European and Mediterranean waters. PCB and other organochlorine contaminants in 32 bottlenose dolphins were measured in the Gulf between 2011–2017. Over 87% of the individuals had PCB concentrations above the toxicity threshold for physiological effects in marine mammals, potentially causing population-level effects in this well-studied resident population of 150 individuals. Males had significantly higher concentrations than females, pointing to maternal offloading to offspring. The authors called for much greater compliance with the Stockholm Convention by many EU member states.

> *(SOURCE: Genov, T., Jepson, P. D., Barber, J. L., Hace, A., Gaspari, S., Centrih, T., Lesjak, J., Kotnjek, P., 2019. Linking organochlorine contaminants with demographic parameters in free-ranging common bottlenose dolphins from the northern Adriatic Sea. Sci. Total Environ. 657:200-212. [Available at: https://doi.org/10.1016/j.scitotenv.2018.12.025]).*

High Levels of Trace Elements in Mediterranean Elasmobranchs

Marine organisms higher on the food chain (top predators) tend to accumulate higher levels of persistent pollutants (biomagnification). Giovos *et al*. (2022) examined the edible tissues of 10 elasmobranch species from Greek waters (northern Aegean Sea, eastern Mediterranean) for 12 trace metals. The levels were above the permissible limits for Hg and Pb in some species. The lifetime consumption risk for human adults and children revealed a high risk for two of the most toxic substances (As, Hg). The authors argued for further studies here to determine the effects on the elasmobranchs themselves. Carrasco-Puig *et al*. (2024) examined the Cd, Pb and Cu concentrations in the muscle tissue of 17 species of sharks, rays and chimaeras in the western Mediterranean. Diet and depth (deeper waters) were determining factors for these heavy metal concentrations. Cu concentrations were generally higher than those of Cd and Pb in all the species. One species exceeded the EU Commission Regulation 2023/915 threshold for Cd; another had

very high Pb levels. Although the risk posed by consuming the analysed species is minimal for human adults, caution is advised for children and pregnant persons, considering the widespread consumption of elasmobranchs in many western Mediterranean areas. These levels in elasmobranchs have relevance for cetaceans, top predators in their ecosystems.

> *(SOURCES: Giovos, I., Brundo, M. V., Doumpas, N., Kazlari, Z., Loukovitis, D., Moutpopoulos, D. K., Spyridopoulou, R. N. A., Papadopoulou, A., Papapetrou, M., Tiralongo, F., Ferrante, M., Copat, C., 2022. Trace elements in edible tissues of elasmobranchs from the North Aegean Sea (Eastern Mediterranean) and potential risks from consumption. Mar. Pollut. Bull. 184:114129. [Available at: https://doi.org/10.1016/j.marpolbul.2021.114129]; Carrasco-Puig, P., Colmenero, A. I., Ruiz-Garcia, D., Molera, A. J., Hernandez-Martinez, A. M., Raga, J. A., Barria, C., 2024. Heavy metal concentrations in sharks, rays and chimaeras from the western Mediterranean Sea. Mar. Pollut. Bull. 199:115942. [Available at: https://doi.org/10.1016/j.marpolbul.2024.115942]).*

MAJOR LEVELS OF ORGANOCHLORINE POLLUTANTS IN PELAGOS SANCTUARY

Bottlenose dolphins stranded between 2019 and 2021 (*n*=21, of which 11 were fresh enough to be fully examined) along the Pelagos Sanctuary coast in Italy were examined for cause of death, pathogens and OC contaminants. Lesions likely caused by morbillivirus, with morbillivirus antigens confirmed, were detected in three animals out of eight tested. Ten dolphins were submitted for bacteriological analysis and three had major bacteria-associated pathologies. One had an *Enterococcus faecium* infection with swelling of the lymph nodes, and the bacteria was present in several major organs. Another had pneumonia and swollen lymph nodes also caused by *E. faecalis* and may have suffered from septicaemia, and one had an abscess and swollen lymph nodes caused by *Carnobacterium* spp. and *Serratia* spp. A *Toxoplasma gondii* infection was detected in six animals out of 11, with associated lesions in one animal. In addition, one animal had skin lesions associated with α-herpesvirus, and the virus was detected in two others. Cetacean poxvirus, with associated 'tattoo lesions', was found in another animal. Two animals apparently died as the result of fisheries bycatch.

PCB levels were higher than DDT levels, which were higher in turn than HCB. Levels of OC pollutants with serious health impacts (i.e. carcinogenic, mutagenic and teratogenic) made up more than half of the total OC contaminant load. Also, levels of immunosuppressant OC in 10 out of 11 animals were more than half of the total OC burden. PCB levels always exceeded the threshold for adverse health impacts (>17μg.g^{-1} lw). The authors concluded that "bottlenose dolphins living in the Pelagos Sanctuary undergo a high level of exposure to pathogens and OCs, betraying the designation of the Cetacean Sanctuary and, consequently, of a region created for their conservation".

Maximum contaminant levels (μg.g^{-1} dw in blubber) - HCB: 0.33; ΣPCB: 1043; ΣDDT: 123; Σendocrine-disrupting OC: 358 Σimmune-suppressing OC: 646; Σtoxic equivalent OC: 336.

> *(SOURCE: Grattarola, C., Minoia, L., Giorda, F., Consales, G., Capanni, F., Ceciarini, I., Franchi, E., Ascheri, D., Garibaldi, F., Dondo, A. et al., 2023. Health status of stranded common bottlenose dolphins (Tursiops truncatus) and contamination by immunotoxic pollutants: A threat to the Pelagos Sanctuary-Western Mediterranean Sea. Diversity 15:569. [Available at: https://doi.org/10.3390/d15040569]).*

POLYAROMATIC HYDROCARBONS FROM OIL FOUND IN MEDITERRANEAN DOLPHINS

PAH levels in Mediterranean cetaceans examined in previous studies have been very high (median: 29 455ng.g^{-1} ww, max: 198 368ng.g^{-1} ww [Marsili *et al*., 2001]), possibly due to oil spills here during the 1990s. A more recent study on levels in the blubber of striped dolphins (*n*=34; 100ng.g^{-1} ww ± 59.0) and common bottlenose dolphins (*n*=8; 109 ng.g^{-1} ww ± 44.0) reported relatively low levels compared to other cetacean populations. Of the 16 PAHs assessed, only six were detected, five of which were low molecular weight and one high molecular weight. The former tend to be more water soluble and therefore more common in cetacean tissues. Also, the low molecular weight PAHs tend to be less toxic than high molecular weight PAHs. The proportion of fluoranthene (the high molecular weight PAH) was relatively low (striped dolphin: 4.1%; bottlenose dolphin: 5.4%). The proportions of the PAHs in the sample suggest an almost exclusive origin from petroleum spills and leaks into the marine ecosystem. The proportion of naphthalene was relatively high amongst the PAHs in the samples (striped dolphin: 37%; bottlenose dolphin: 42%). Although the remaining PAHs are primarily low weight and less toxic, the authors "cannot dismiss the occurrence of non-carcinogenic toxic effects derived from the exposition [exposure] to the PAHs that we have reported in this work".

> *(SOURCE: López-Berenguer, G., Acosta-Dacal, A., Luzardo, O. P., Peñalver, J., Martínez-López, E., 2023. Assessment of polycyclic aromatic hydrocarbons (PAHs) in Mediterranean top marine predators stranded in SE Spain. Chemosphere 336:139306. [Available at: https://doi.org/10.1016/j.chemosphere.2023.139306).*

ORGANOCHLORINE LEVELS IN CETACEANS LOWER IN SPAIN THAN IN OTHER MEDITERRANEAN AREAS

The organochlorine contaminants in cetaceans from the Spanish coast (Gulf of Vera, Murcia, southeast Spain) PCB and PBDE levels were analysed in cetaceans that stranded between 2011 and 2018. DDT and its metabolites, PCBs and methoxychlor were found in the greatest proportions, with lower levels of PBDEs. Striped dolphins had the highest levels, whereby the different pollutant profiles may reflect different diets. The ratio between DDT and its metabolites suggested an older source of DDT exposure, which differs from some other studies in the Mediterranean. In terms of contributing to the total toxicological effect, PCB concentrations accounted for the highest proportion of toxicity, also differing from many other studies. The authors concluded that "we cannot guarantee the absence of health

consequences on populations studied, especially for those caused by PCBs" and levels of contaminants still remain an issue of concern.

Mean contaminant levels (µg.g^{-1} lw)—striped dolphin (*n*=33) ΣDDTs: 4.75 (± 7.42), ΣPCBs: 6.49 (± 9.55), ΣPBDEs: 0.073 (± 0.103); bottlenose dolphin (*n*=8) ΣDDTs: 2.27(± 1.74), ΣPCBs: 6.11 (± 5.61), ΣPBDEs: 0.053 (± 0.042); bottlenose dolphin (*n*=3) ΣDDTs: 2.16 (± 0.69), ΣPCBs: 3.86 (± 3.54), ΣPBDEs: 0.025 (± 0.025); long-finned pilot whale (*n*=3) ΣDDTs: 0.84 ± (0.87), ΣPCBs: 1.06 (± 1.02), ΣPBDEs: 0.049 (± 0.056).

(SOURCE: López-Berenguer, G., Acosta-Dacal, A., Luzardo, O.P., Peñalver, J., Martínez-López, E., 2023. POPs concentrations in cetaceans stranded along the agricultural coastline of SE Spain show lower burdens of industrial pollutants in comparison to other Mediterranean cetaceans. Sci. Total Env. 858:159743. [Available at: http://dx.doi.org/10.1016/j.scitotenv.2022.159743]).

MONITORING PATHOGENS AND HEAVY METALS IN MEDITERRANEAN WHALES VIA FAECAL SAMPLES

Protozoan parasites, bacteria and organic pollutant and heavy metal levels were analysed in faecal samples from fin (*n*=2) and sperm (*n*=2) whales from the Pelagos Sanctuary. Two fin whale and one sperm whale samples tested positive for the protozoan parasite *Blastocystis*. More genetic sequences related to the bacteria *Synergistetes* and *Spirochaetae* were found in the sperm whales than in the fin whales. As, Co and Hg were found only in sperm whale faecal samples, Pb only in fin whale samples. No PCBs or PAHs were detected. This is the first record of *Blastocystis* in either species. This low-impact methodology successfully assessed the trace element and pathogen status of free-ranging whales.

Maximum trace element levels in faecal samples (µg.g^{-1} dw)—sperm whale As: 7.34; Cd: 0.482; Co: 0.169; Cr: 1.085; Cu: 34.93; Hg: 1.56; Ni: 0.397; Se: 11.01; Zn: 98.12; fin whale Cd: 0.043; Cr: 1.165; Cu: 61.63; Ni: 1.211; Pb: 0.067; Se: 1.273; Zn: 60.62.

(SOURCE: Marangi, M., Airoldi, S., Beneduce, L., Zaccone, C., 2021. Wild whale faecal samples as a proxy of anthropogenic impact. Sci. Rep. 11:5822. [Available at: https://doi.org/10.1038/s41598-021-84966-4]).

PER- AND POLYFLUORALKYL SUBSTANCES (PFAS) IN STRANDED STRIPED DOLPHINS ALONG ITALIAN COAST

Eight different PFAS were found in all samples from 26 striped dolphins (the most common cetaceans in the Mediterranean) stranded along the coast of Tuscany (Italy) from 2020-2022. PFOS and related compounds are listed in Annex B 'Restriction' of the Stockholm Convention on Persistent Organic Pollutants and are among the priority hazardous substances that must be monitored in EU water bodies. The concentrations in the four tissues examined followed the trend PFOS>FOSA>PFHxS, and the PFOS concentration appeared to be inversely proportional to animal weight. The PFSA and PFCA concentrations in calves were significantly higher than in the older individuals, probably reflecting a maternal transfer during pregnancy and/or lactation. The authors concluded, "The presence of these high concern substances in striped dolphins underlines a remarkable impact of anthropic activities….".

(SOURCE: Mazzetti, M., Marsili, L. Valsecchi, S., Roscioli, C., Polesello, S., Altemura, P., Voliani, A., Mancusi, C., 2022. First investigation of per- and poly fluoralkylsubstances (PFAS) in striped dolphin Stenella coeruleoalba stranded along Tuscany coast (North Western Mediterranean Sea). In: L. Bonora, D. Carboni, D., M. De Vincenzi, G. Matteucci (Eds.), Monitoring of Mediterranean Coastal Areas: Problems and Measurement Techniques (pp. 729-737). CC BY-NC-SA 4.0, 10.36253/979-12-215-0030-1.69)

PERSISTENT ORGANIC POLLUTANTS IN STRANDED RISSO'S DOLPHINS IN ITALY

The levels of POPs, especially organochlorine compounds (OCs), were examined in four tissues of 20 Risso's dolphins stranded between 1998 and 2021. All three OC classes (HCB < DDTs < PCBs) were recorded in all animals and confirmed the high levels found in an earlier study on this species in Italy; the values were also higher than those of an individual from the west coast of the USA. The concentrations did not differ in relation to age, sex or stranding location. These compounds continue to be priority contaminants in the Mediterranean, even though their production and use is restricted in most areas of the world. The authors noted that Italy, until September 2022, was the only EU state that has not yet ratified the Stockholm Convention of 2001, which regulates these substances. Finally, the authors noted that the OC concentrations did not differ from those found in sperm whales: both species feed on oceanic cephalopods. The Risso's dolphin is classified as 'Vulnerable' in the Mediterranean by the IUCN.

(SOURCE: Minoia, L., Consales, G., Mazzariol, S., Mancusi, C., Terracciano, G., Ceciarini, I., Capanni, F., Neri, A., D'Agostino, A., Marsili, I., 2023. Preliminary assessment of persistent organic pollutants (POPs) in tissues of Risso's dolphin (Grampus griseus) specimens stranded along the Italian coasts. Mar. Pollut. Bull. 186:114470. [Available at: https://doi.org/10.1016/j.marpolbul.2022.114470]).

CALL TO REDUCE AIR POLLUTION BY SHIPS IN THE STRAIT OF GIBRALTAR

The Strait of Gibraltar, as the gateway into the Mediterranean, is one of the main shipping traffic lanes in Europe, with an average of *ca*. 115,000 ships transiting through every year. Beyond the noise produced by these vessels, the NO_2 emissions have been calculated to cause 57 human deaths per 100,000 inhabitants, $PM_{2.5}$ an additional 24 deaths in Spain. Accordingly, the authors suggested that the Strait be declared an Emission Control Area, defined by the IMO as "areas where special measures have to be introduced regarding emissions from ships to block, decrease and control air

pollution from nitrous oxides (NO_x), sulfur oxides (SO_x) and particulate matter (PM)". The model simulations show potential reductions of 76%, 94% and 73%, respectively. The first step would be converting ferries and Ro-Ro vessels to battery-electric propulsion or any other clean fuel, followed by "zero emission at berth standard" in Algeciras Port. The Strait of Gibraltar is home to many cetaceans, including a population of Critically Endangered killer whales.

> *(SOURCE: Moreno-Gutiérrez, J., Durán-Grados, V., 2023. Towards the declaration of the Strait of Gibraltar as an environmental controlled area. Mar. Pollut. Bull. 192:115042. [Available at: https://doi.org/10.1016/j.marpolbul.2023.115042]).*

PFAS IN ADRIATIC DOLPHINS AND THE CONTINUED PRESENCE OF LONG-BANNED CHEMICALS

Levels of PFAS were measured in hepatic tissue samples of 20 bottlenose dolphins stranded on the northern Adriatic coast. Levels in calves were higher than adults, suggesting dolphins can eliminate PFAS more efficiently with age. Interestingly, although PFOS production was phased out almost two decades ago and there are international restrictions on its production and use because of health concerns, it was the most common type of PFAS found in the dolphins and a major proportion of the dolphins' PFAS burden. The five main PFAS in dolphin tissues (PFOS, PFUnA, PFDA, PFDoA, PFTrDA) are long-chain PFAS, which are mostly no longer used by industry. This suggests an accumulation of historic PFAS and a slow loss from the marine ecosystem. The semi-enclosed Mediterranean basin may promote the accumulation of these chemicals. In particular, the slow loss of the long-banned PFOS from the ecosystem suggests that long-chain PFAS may further accumulate and levels rise in cetaceans for decades to come.

Maximum liver PFAS concentrations ($ng.g^{-1}$ ww)—PFBA: 0.08; PFPeA: 0.60; PFHxA: 1.75; PFHpA: 1.94; PFOA: 10.75; PFNA: 38.07; PFDA: 96.43; LPFBS: 0.13; LPFHxS: 7.33; LPFOS: 629.73; PFUnA: 130.05; PFDoA: 47.08; LPFPeS: 0.12; LPFHpS: 3.30; LPFDS: 3.67; PFTrDA: 34.50; PFTeDA: 7.85; ΣPFAS: 908.50.

> *(SOURCE: Sciancalepore, G., Pietroluongo, G., Centelleghe, C., Milan, M., Bonato, M., Corazzola, G., Mazzariol, S., 2021. Evaluation of per- and poly-fluorinated alkyl substances (PFAS) in livers of bottlenose dolphins (Tursiops truncatus) found stranded along the northern Adriatic Sea. Environ. Pollut. 291:118186. [Available at: https://doi.org/10.1016/j.envpol.2021.118186]).*

MERCURY IN THREE DOLPHIN SPECIES IN THE ADRIATIC SEA

Top predators such as dolphins can have high heavy metal concentrations due to biomagnification along the food chain. The Hg concentrations in 180 dolphin specimens stranded along the Croatian Adriatic coast between 1995 and 2014 increased significantly with dolphin age. Risso's dolphins exhibited the highest values in all seven tissues examined. In 67% of Risso's, 15% of bottlenose and one striped dolphin, the liver concentrations of Hg exceeded the highest toxic thresholds (400 $mg.kg^{-1}$ ww), defined as evidence of liver damage in marine mammals. The authors concluded that the very high concentrations in these populations reflect the highly contaminated status of this area and pose a serious health risk for the species. These species can also serve as a toxicological model because "they share the same coastal environment with humans and consume the same type of seafood".

> *(SOURCE: Sedak, M., Bilandzic, N., Dokic, M., Duras, M., Gomercic, T., 2022. Body burdens and distribution of mercury and selenium in bottlenose, striped and Risso's dolphins along the Adriatic coast: A 20-year perspective. Mar. Pollut. Bull. 185:114298. [Available at: https://doi.org/10.1016/j.marpolbul.2021.114298]).*

MAJOR RESEARCH EFFORT TO EXAMINE CONTAMINATION OF MEDITERRANEAN PLANKTONIC FOOD WEBS

The Mediterranean is characterised by high levels of chemical contamination, reflecting the intense human activities in its 23 bordering countries and its semi-enclosed geography. Plankton is a key vector for inorganic and organic contaminants in the marine food web. Bioaccumulation here leads to contaminant levels that are significantly higher in predators (crustaceans, sharks, cetaceans, teleost fishes) than in congeneric Atlantic Ocean species. Contaminant-plankton interactions are expected to evolve in coming years because the Mediterranean has been identified as a hotspot for climate change. Additional results are expected in an upcoming special issue of *Marine Pollution Bulletin*.

> *(SOURCE: Tedetti, M., Tronczynski, J., Carlotti, F., Pagano, M., Ismail, S.B., Sammari, C., Hassan, M.B., Desboeufs, K., Poindron, C. et al., 2023. Contamination of planktonic food webs in the Mediterranean Sea: Setting the frame for the MERITE-HIPPOCAMPE oceanographic cruise (spring 2019). Mar. Pollut. Bull. 189:114765. [Available at: https://doi.org/10.1016/j.marpolbul.2023.114765]).*

PLASTIC PRODUCTION CONTAMINANTS FOUND IN SPANISH MEDITERRANEAN DOLPHINS

Bisphenols (BPs) and phthalate esters (PAEs) are two classes of marine contaminant derived from the plastics industry. Levels of both were assessed in muscle tissue of 30 striped dolphins stranded along the Spanish coast in the northwest Mediterranean between 1990 and 2018 (maximum levels ΣBP 96.4$\mu g.g^{-1}$ lw; ΣPAE 80.26$\mu g.g^{-1}$ lw). In total, six BPs and six PAEs were found. BPZ was found in all of the animals (mean 16.06$\mu g.g^{-1}$ lw, range 0.12–94.9), followed by BPE (mean 0.67$\mu g.g^{-1}$ lw, range 0–6.17), which was detected in 90% of the samples. These two BPs are widely used in European countries in manufacturing epoxy resins and polycarbonate plastics. Although BPA has been banned from use in products in Europe, it was still detected in three dolphins (mean 0.29$\mu g.g^{-1}$ lw, range 0–4.93). BPFL has been recently used in the plastics industry as a BPA substitute, potentially explaining its presence in so many dolphins. Although the

detected concentrations were not high enough for concern, "the long-term exposure to these chemicals, combined with other multiple stressors, may potentially produce adverse effects to long living animals such as cetaceans".

(SOURCE: Vighi, M., Borrell, A., Sahyoun, W., Sopheak Net, S., Aguilar, A., Ouddane, B., Garcia-Garin, O., 2023. Concentrations of bisphenols and phthalate esters in the muscle of Mediterranean striped dolphins (Stenella coeruleoalba). Chemosphere 339:139686. [Available at: https://doi.org/10.1016/j.chemosphere.2023.139686]).

Disease and mortality events

Disease

MEDITERRANEAN CETACEANS HIGHLY SUSCEPTIBLE TO SARS-COV-2

Zoonotic transmission was responsible for human infection by Severe Acute Respiratory Syndrome Coronavirus-2 (SARS-CoV-2), which in turn caused the COVID-19 global pandemic. To determine if Mediterranean cetaceans are susceptible to SARS-CoV-2 infection, Audino *et al.* (2021) examined cetacean genomes for the gene for Angiotensin Converting Enzyme-2 (ACE-2), which serves as the main receptor for SARS-CoV-2. If that gene is present, then cetaceans are susceptible to viral infection. Most species analysed (78%, *n*=9) were predicted to be highly susceptible to SARS-CoV-2 infection (bottlenose and striped dolphins, killer and long-finned pilot whales and fin, humpback and minke whales). The remaining two species analysed (Cuvier's beaked whales and sperm whales) were predicted to have 'medium susceptibility'. The overlap between Italian wastewater outfalls and cetacean distribution made it likely that cetaceans were exposed to SARS-CoV-2, and Audino *et al.* (2022) assessed if infections had in fact occurred. Lung tissue from 59 cetaceans stranded during 2020–2022 in Italy (striped dolphin: *n*=42; bottlenose dolphin: *n*=14; Cuvier's beaked whale: *n*=1; Risso's dolphin: *n*=1; fin whale: *n*=1) underwent immune-histochemical analysis with anti-SARS-CoV-2 antibodies. Despite their susceptibility to infection, the authors "found no evidence of SARS-CoV-2 spillover in cetaceans stranded on the Italian coast".

(SOURCES: Audino, T., Grattarola, C., Centelleghe, C., Peletto, S., Giorda, F., Florio, C. L., Caramelli, M., Bozzetta, E., Mazzariol, S., Di Guardo, G. et al., 2021. SARS-CoV-2, a threat to marine mammals? A study from Italian seawaters. Animals 11:1663. [Available at: https://doi.org/10.3390/ani11061663]; Audino, T., Berrone, E., Grattarola, C., Giorda, F., Mattioda, V., Martelli, W., Pintore, A., Terracciano, G., Cocumelli, C., Lucifora, G. et al., 2022. Potential SARS-CoV-2 susceptibility of cetaceans stranded along the Italian coastline. Pathogens 11:1096. [Available at: https://doi.org/10.3390/pathogens11101096]).

HIGH LEVELS OF HEPATITIS E VIRUS EXPOSURE IN SPANISH CETACEANS

Blood and liver samples from 13 species were collected from 240 free-ranging cetaceans stranded along the coast of Spain and 64 captive cetaceans from six dolphinaria. The samples were screened for hepatitis E antibodies. The hepatitis E virus is the leading cause of acute viral hepatitis in humans. Sixty-nine out of 136 cetaceans (51%) tested positive for anti-hepatitis E antibodies. Positive results were higher in free-ranging animals (44/72; 61%) than captive (25/64; 39%), but a substantial proportion of both populations tested positive. Adult free-ranging cetaceans were significantly more likely to be positive (33/45; 73%) than young animals (11/27; 41%). Positive animals were found in five of the six dolphinaria, with positive results in about a quarter (28%) to more than half (56%) of the animals. The authors concluded that there is "high exposure to [hepatitis E virus] in free-ranging and captive populations of cetaceans in Spain". The authors also suggested that "the persistent and widespread presence of hepatitis E in the marine environment off the coast of Spain may be driven by terrestrial sources of contamination".

(SOURCE: Caballero-Gómez, J., Rivero-Juarez, A., Beato-Benítez, A., Fernández-Maldonado, C., Domingo, M., García-Párraga, D., Fernández, A., Sierra, E., Ulrich, R. G., Martínez-Nevado, E., Sierra-Arqueros, C., Canales-Merino, R., Rivero, A., García-Bocanegra, I., 2022. Hepatitis E virus infections in free-ranging and captive cetaceans, Spain, 2011-2022. Emerg. Infect. Dis. 28:2543-2547. [Available at: https://doi.org/10.3201/eid2812.221188]).

NEW SPECIES OF *NOCARDIA* BACTERIA REPORTED IN MEDITERRANEAN CETACEANS

Nocardia spp. are bacteria that can cause disease in humans and other animals. Several species have been reported from cetaceans. Nocardiosis was described in three striped dolphins stranded in Andalusia, Spain, and one striped dolphin and a bottlenose calf stranded in the Canary Islands. The animals displayed signs of pyogranulomatous inflammation (a chronic immune response by both macrophage and neutrophil white blood cells) and blood clots in blood vessels in two or more organs. Most affected organs were the lung, pulmonary lymph nodes, liver and then kidney, adrenal glands and central nervous system. The bacteria species were identified, via gene sequencing, as *Nocardia farcinica* in two of the striped dolphins stranded in Spain and *Nocardia otitidiscaviarum* in the dolphins stranded in the Canary Islands. Although infections of both species have been reported in captive cetaceans, this is the first record of *N. otitidiscaviarum* and *N. farcinica* in wild dolphins, with the first record of *N. farcinica* in Mediterranean cetaceans.

(SOURCE: Díaz-Santana, P., Fernández, A., Díaz-Delgado, J., Vela, A. I., Domínguez, L., Suárez-Santana, C., Puig-Lozano, R., Fernández-Maldonado, C., Sierra, E., Arbelo, M., 2022. Nocardiosis in free-ranging cetaceans from the Central-Eastern Atlantic Ocean and contiguous Mediterranean Sea. Animals 12:434. [Available at: https://doi.org/10.3390/ani1204043]).

First Report of *Sarcocystis* Spp. Infections in Mediterranean Cetaceans

Two striped dolphins stranded along the Ligurian coast of Italy were diagnosed with inflammation of the brain and meninges (the layer of tissue covering the brain). The inflammation was associated with cysts (pockets or blisters in tissues), probably due to infection by a protozoan parasite. Under a light microscope, the cysts were similar to those caused by *Sarcocystis* spp. Genetic sequencing of the parasite suggested similarities to *Sarcocystis* strains known to infect livestock. This is "the first report of *Sarcocystis*-like tissue cysts in the brain of stranded cetaceans", as well as "the first description of *Sarcocystis* sp. infection in muscle tissue of dolphins from the Mediterranean basin".

> *(SOURCE: Giorda, F., Romani-Cremaschi, U., Marsh, A. E., Grattarola, C., Iulini, B., Pautasso, A., Varello, K., Berio, E., Gazzuola, P., Marsili, L. et al., 2021. Evidence for unknown Sarcocystis-like infection in stranded striped dolphins (Stenella coeruleoalba) from the Ligurian Sea, Italy. Animals 11:1201. [Available at: https://doi.org/10.3390/ani11051201]).*

Frequent Skin Lesions and Injuries in Strait of Gibraltar Cetaceans

Nearly 30,000 cetacean photographs taken from whale watching vessels in the Strait of Gibraltar (2016–2020) were assessed for skin diseases and injuries. A variety of diseases, lesions and ectoparasites were recorded, including 23 animals with orange patches (bottlenose dolphins: *n*=5; common dolphins: *n*=1; striped dolphins: *n*= 6; long-finned pilot whales: *n*=2; killer whales: *n*=1; sperm whales: *n*=8) and 16 animals with tattoo skin disease-like lesions (bottlenose dolphins: *n*=12; common dolphins: *n*=1; long-finned pilot whales: *n*=3). Hypopigmented skin lesions (such as pale and white skin areas; *n*=291) were frequent. Hyperpigmented skin lesions (dark spots and dark skin areas) were also observed. Thirteen bottlenose dolphins exhibited ulcerative dermatitis on the leading edge of the dorsal fin and 28 animals had open wounds (bottlenose dolphins: *n*=2; long-finned pilot whales: *n*=23; sperm whales: *n*=3), some of which remained unhealed for several years. In terms of ecotoparasitic infections, bottlenose dolphins (*n*=29), common dolphins (*n*=9). striped dolphins (*n*=18). long-finned pilot whales (*n*=141) and killer whales (*n*=32) were observed with *Xenobalanus* spp., while sperm whales (*n*=14), fin whales (*n*=53) and humpback whales (*n*=1) exhibited *Pennella balaenopterae* infections. Up to 84 of the latter infections were seen on fin whales.

Signs of human interactions/human-induced injuries were detectable in 234 cases. These injuries may have been from boat propellers or fishing gear and ranged from skin scars to appendage lacerations to partial amputations. Five photos showed active entanglements, in all cases with what looked like longline gear. Two bottlenose dolphins had lower jaw injuries consistent with hooking entanglement. One scar on a pilot whale may have been from a tag.

Emaciation (ribs readily observed due to thin blubber layers) was observed in some bottlenose dolphins (*n*=36), as well as one striped dolphin. This state was more frequent in some years than others, potentially reflecting fluctuations in prey availability. The authors noted that "[novel] skin lesions, such as target-like lesions and expansive annular lesions, are a cause for concern and could indicate a deteriorating marine environment and the presence of new pathogens". They also added that "observation of potentially superinfected skin conditions, ulcerating and chronic wounds and cases of multimorbidity" may indicate increased disease susceptibility in these cetaceans. In particular, they expressed concerns about the health of bottlenose dolphins, due to the high number with dermal diseases (*n*=192) and emaciation.

> *(SOURCE: Hanniger, E.-M., Selling, J., Heyer, K., Burkhardt-Holm, P., 2023. Skin conditions, epizoa, ectoparasites and emaciation in cetaceans in the Strait of Gibraltar: An update for the period 2016–2020. J. Cetacean Res. Manage. 24:121-142. [Available at: https://doi.org/10.47536/jcrm.v24i1.401]; Hanniger, E.-M., Selling, J., Heyer, K., Burkhardt-Holm, P., 2023. Injuries in cetaceans in the Strait of Gibraltar: an update for the period 2016–2020. J. Cetacean Res. Manage. 24:143-160. [Available at: https://doi.org/10.47536/jcrm.v24i1.397).*

Potential Pathogens (*Giardia* and *Salmonella*) Found in Free-Ranging Cetaceans in Central-Eastern Mediterranean

In a first-of-its-kind study investigating four potential pathogens in free-ranging cetaceans in the Gulf of Taranto (northern Ionian Sea, central-eastern Mediterranean Sea), faecal samples were collected in 18 live-stranded or bycaught dolphins (striped dolphin: *n*=11; Risso's dolphin: *n*=7) and analysed via PCR for potential pathogens. The protozoan *Giardia duodenalis* was identified in two striped dolphins and the bacterium *Salmonella enterica* in two others. *Cryptosporidium parvum* (an intestinal parasite) was identified in sea turtles but not in dolphins. *Escherichia coli* was not found in either the dolphins or turtles. *Giardia* is zoonotic and can be transported via sewage systems and wastewater, but it is also carried by livestock. Sewage and wastewater or runoff from agricultural land are potential vectors bringing the pathogen into the marine environment. *Salmonella* is usually carried by cold-blooded animals, but could have entered the marine environment via rivers, terrestrial runoff or via sewage and wastewater.

> *(SOURCE: Marangi, M., Carlucci, R., Carlino, P., Fanizza, C., Cirelli, C., Maglietta, R., Beneduce, L., 2022. Dolphins and sea turtles may host zoonotic parasites and pathogenic bacteria as indicators of anthropic pressure in the Gulf of Taranto (Northern Ionian Sea, Central-Eastern Mediterranean Sea). Vet. Res. Commun. 46:1157-1166. [Available at: https://doi.org/10.1007/s11259-022-10011-y]).*

High Prevalence of an Atlantic Morbillivirus Strain in Stranded Cetaceans in Italy

The first cetacean morbillivirus outbreak documented in the Mediterranean Sea (1990–1992) killed thousands of striped dolphins. Several subsequent mass mortality events have been associated with cetacean morbillivirus (Spain: 2006–

2008 and 2011; France: 2007-2008; Italy: 2011-2013, 2014 and 2016). The 2016 mortality event in Italy was associated with a new strain of morbillivirus, with a northeast Atlantic origin, which had been circulating amongst cetaceans in the Mediterranean since 2012 (Mira *et al.*, 2019; Pautasso *et al.*, 2019). On the Italian coast between 2018 and 2021, 32% of stranded cetaceans examined (*n*=354) tested positive for cetacean morbillivirus (striped and bottlenose dolphins and sperm whales) (Vargas-Castro *et al.*, 2023). These positive animals came from all parts of the Italian coast except for the northern Adriatic. Sequencing of the morbillivirus strain confirmed that these viruses belonged to the northeast Atlantic strain. The authors noted, "This prevalence [of positive-testing cetaceans] is one of the highest reported without an associated outbreak".

> *(SOURCES: Mira, F., Rubio-Guerri, C., Purpari, G., Puleio, R., Caracappa, G., Gucciardi, F. et al., 2019. Circulation of a novel strain of dolphin morbillivirus (DMV) in stranded cetaceans in the Mediterranean Sea. Sci. Rep. 9:9792. [Available at: https://doi.org/10.1038/s41598-019-46096-w]; Pautasso, A., Iulini, B., Grattarola, C., Giorda, F., Goria, M., Peletto, S. et al., 2019. Novel dolphin morbillivirus (DMV) outbreak among Mediterranean striped dolphins Stenella coeruleoalba in Italian waters. Dis. Aquat. Org. 132:215-220. [Available at: https://doi.org/10.3354/dao03323]; Vargas-Castro, I., Peletto, S., Mattioda, V., Goria, M., Serracca, L., Varello, K., Sánchez-Vizcaíno, J. M., Puleio, R., Nocera, F. D., Lucifora, G., Acutis, P., Casalone, C., Grattarola, C., Giorda, F., 2023. Epidemiological and genetic analysis of Cetacean Morbillivirus circulating on the Italian coast between 2018 and 2021. Front. Vet. Sci. 10:1216838. [Available at: https://doi.org/10.3389/fvets.2023.1216838]).*

High Prevalence of Herpesvirus in Cetaceans from the Coast of Valencia in Spain

Cetaceans stranded on the coast of Valencia, Spain, were tested for the presence of herpesvirus. The virus was detected in 81% of the cetaceans via PCR analysis (*n*=47). Herpesvirus was more prevalent in females, juveniles and calves. Lesions associated with herpesvirus were found in the skin, upper digestive tract, genitalia and central nervous system, most prevalently in the latter two organs. More than half of the positive samples had DNA that contained herpesvirus RNA, indicating active replication in the host animals - this RNA was most frequently found in neonates. Nine of the 47 cetaceans (19%) were also infected with cetacean morbillivirus and all of these were coinfected with herpesvirus.

> *(SOURCE: Vargas-Castro, I., Melero, M., Crespo-Picazo, J. L., Jiménez, M. A., Sierra, E., Rubio-Guerri, C., Arbelo, M., Fernández, A., García-Párraga, D., Sánchez-Vizcaíno, J. M., 2021. Systematic determination of herpesvirus in free-ranging cetaceans stranded in the western Mediterranean: tissue tropism and associated lesions. Viruses 13:2180. [Available at: https://doi.org/10.3390/v13112180]).*

Harmful Algal Blooms (HABs)

Major Outbreaks of Mucilage in the Sea of Marmara

The Sea of Marmara, connecting the Black and Mediterranean Seas, was filled for six months with mucilage that clogged fishing nets, suffocated marine life and threatened tourism and the economy in this region of Turkey. This 2021 outbreak was the most severe ever recorded. The conditions leading to the formation of mucilage include eutrophication, high temperatures and stagnant sea conditions. The mucilage is associated with oxygen depletion and mass animal and plant mortalities, so-called 'dead zones'. The wastewater disposal of the five metropolitan municipalities here apparently involves "a liquid waste disposal called deep-sea discharge", pointing to a considerable anthropogenic component of this phenomenon. The authors predicted an increase in mucilage in the future. The Marmara Sea is home to a subpopulation of harbour porpoise.

> *(SOURCE: Savun-Hekimoğlu, B., Gazioğlu, C., 2021. Mucilage problem in the semi-enclosed seas: Recent outburst in the Sea of Marmara. Int. J. Environ. Geoinfor. 8(4):402-413. [Available at: https://doil.org/10.30897/ijegeo.955739]).*

Oil Spills

Satellite Imagery and Backtracking of Oil Spills Help Identify High-Priority Monitoring Areas for Oil Pollution

The Mediterranean, a main shipping route between oil-producers in the Middle East and consumers in Europe, is one of the world's most oil-polluted seas. In the past, this has been exacerbated by the short distances travelled, hampering use of the load-on-top procedure, designed to prevent oil residues remaining on the walls of emptied tanks from being discharged directly into the sea, along with the saltwater used as ballast during return trips for reloading. Oil spills are currently monitored by the Regional Marine Pollution Emergency Response (REMPEC: 385 spills between 1977-2009), the International Tanker Owners Pollution Federation Limited (ITOPF: 167 spills 1978-2018) and the CleanSeaNet satellite service of the European Maritime Satellite Agency (EMSA: 2066 detections 2015-2017) (Polinov *et al.*, 2021). Ciappa (2023) calculated the direction and source area of oil spills, based on backtracking documented spills for 10-day periods (2015-2019). This approach was applied to known risk areas across the Mediterranean and identified several offshore areas deserving high monitoring priority, including targeted SAR satellite image acquisition.

> *(SOURCES: Polinov, S., Bookman, R., Levin, N., 2021. Spatial and temporal assessment of oils spills in the Mediterranean Sea. Mar. Pollut. Bull. 167:112338. [Available at: https://doi.org/10.1016/j.marpolbul.2021.112338]; Ciappa, A. C. 2023. Oil trajectory analysis for oil spill surveillance by SAR in the Mediterranean Sea. Mar. Pollut. Bull. 190:114825. [Available at: https://doi.org/10.1016/j.marpolbul.2023.114825]).*

Strandings

PATTERNS OF FIN WHALE STRANDINGS AROUND THE ITALIAN COAST

Fin whale stranding records (1624-2021) along the Italian coast were analysed for patterns in distribution, frequency and causes of mortality. A total of 179 strandings were evaluated; cause of death was unknown for 125, with 24 attributed to ship strikes, 16 to directed takes (deliberate killing by humans), five to bycatch or entanglement and nine to natural causes (e.g. disease). However, the most recent bycaught whale was in 1997 (a likely underrepresentation) and only one ship strike was reported since 2010, although up to 20% of living Mediterranean fin whales display injuries probably caused by ship strikes. Of the stranded whales, signs of ship strike were seen more often in younger and immature whales. Stranding consistently occurred along the northern coast of the island of Sardinia, the central coast of Tuscany and the Gulf of Trieste in the northern Adriatic Sea. More recently, the central coast of Italy along the Tyrrhenian Sea and the coast of southern Sardinia and northern Sicily have also become stranding hotspots. Reported stranding rates significantly increased from the mid-1980s, which may reflect the implementation of a national strandings programme. Between 1985 and 2015, an average of 10 fin whales stranded per year (range: 11–21). The rates, however, were lower from 2015–2021, possibly due to a 10% decline in fin whale numbers in the Mediterranean. This analysis "supports the implementation of a conservation plan to ensure the survival of [fin whales] in the Mediterranean region". It also "provides relevant input to the development of [a Conservation Management Plan]."

> *(SOURCE: Manfrini, V., Pierantonio, N., Giuliani, A., De Pascalis, F., Maio, N., Mancia, A., 2022. Fin whale (Balaenoptera physalus) mortality along the Italian coast between 1624 and 2021. Animals 12:3111. [Available at: https://doi.org/10.3390/ani12223111]).*

CAUSES OF DEATH IN STRANDED CETACEANS IN SARDINIA

In a summary of causes of death in stranded cetaceans along the Sardinian coast, 59% were considered from natural causes (*n*=16). Eight of these (30%) were from bacterial pneumonia and sepsis deriving from skin infections, with three animals displaying parasitic infections and two signs of cetacean morbillivirus. Two bottlenose dolphins had neuron necrosis, with hypoxia and brain oedema, whilst one striped dolphin had gastritis caused by parasites. Regarding anthropogenic causes of death (*n*=10), entanglement in fishing gear was the most frequent (18.5%, *n*=5), especially for bottlenose dolphins (*n*=4). Four striped dolphins had traumatic lesions and cranium fractures, probably from ship strikes. The introduction of high-speed ferries in Sardinian waters has increased the number of ship strikes and generally ship traffic is high in cetacean habitats here. One dolphin died from ingesting a plastic bag. PCB and DDT levels were determined in 22 of the 48 stranded cetaceans (20 striped dolphins and two bottlenose dolphins). Blubber PCB concentrations ranged from 0.59–75.85µg.g^{-1}, DDT levels from 0.45–79.58µg.g^{-1}. In general, larger and older individuals showed higher concentrations of these contaminants.

> *(SOURCE: Pennino, M. G., Rufener, M. C., Giménez, J., Berlinguer, F., Bollo, E., Appino, S., Zucca, D., Chessa, G., Rotta, A., 2022. Understanding the causes of mortality and contaminant loads of stranded cetacean species in Sardinian waters (Italy) using Bayesian Hierarchical Models. J. Sea Ress 181:102170. [Available at: https://doi.org/10.1016/j.seares.2022.102170]).*

HIGH STRANDING RATES SUGGEST STRONG NEGATIVE IMPACT ON THE CETACEAN POPULATION IN THE BLACK SEA DUE TO WARFARE

To assess the impact of the war in Ukraine on cetacean populations, data were collected via social media, with strandings rates verified by field research, on ~2500 cetacean carcasses found on the Black Sea coast over a 3-month period. The mean number of dead cetaceans per kilometre of shoreline was 0.5 (mi*n*=0.2, max=1.0, s.d.=0.3). The stranding rate was then compared to a citizen science project along the coasts of Romania and Turkey over a similar 3-month period before the war began. The stranding rate was 0.08 cetaceans per kilometre of Black Sea shoreline in Romania, 0.014 in Turkey. For these specific stretches during the war, the rate was 0.7 in Romania and 0.2 in Turkey, suggesting an order of magnitude increase in strandings (range 8.8–14.3). Assuming that carcasses on a beach represent only a fraction of the actual mortality (e.g. only 8% of bycaught short-beaked common dolphins that were tagged and released eventually were found on the shore), the actual war-related mortality rate may be much higher. The authors estimated strandings along coastlines inaccessible because of hostilities. Assuming a stranding rate of 6–8%, the total mortality over three months in the Black Sea would range from 37,500 to 48,000 cetaceans. This value is one-sixth to one-fifth of the Black Sea cetacean population. The authors warned that "cetaceans in the Black Sea may face extinction".

> *(SOURCE: Węgrzyn, E., Rusev, I., Tańska, N., Miedviedieva, I., Kagalo, A. A., Leniowski, K., 2023. The use of social media in assessing the impact of war on cetaceans. Biol. Lett. 19:20220562. [Available at: https://doi.org/10.1098/rsbl.2022.0562]).*

Climate change

CLIMATE CHANGE RELATED TO BIODIVERSITY COLLAPSE IN THE EASTERN MEDITERRANEAN

In the semi-enclosed Mediterranean, warm-adapted species are constrained from replacing the trailing edges of the species that migrate further northward due to climate change. On the Israeli shelf, the warmest area of the Mediterranean, water temperatures have risen by ca. 3°C between 1980 and 2013. Based on molluscs, only 12% and 5% of the historically present native species remain in shallow subtidal soft and hard substrates, respectively. This is the largest recorded climate-driven regional-scale biodiversity loss in the oceans. Importantly, about 60% of the shallow subtidal native species do not reach reproductive size. Future assemblages, shaped by climate warming and biological

invasions (see Tiralongo *et al.,* 2022, Zenetos *et al*., 2022 and Golo *et al*., 2023 above), will yield a 'novel ecosystem', whose restoration to historical baselines may not be achievable, with major implications for ecosystem function.

> *(SOURCE: Albano, P. A., Steger, J., Bošnjak, M., Dunn, B., Guifarro, Z., Turapova, E., Hua, G., Kaufman, D. S., Rilov, G., Zuschin, M., 2021. Native biodiversity collapse in the eastern Mediterranean Sea. Proc. R. Soc. B 288:20202469. [Available at: https://doi.org/10.1098/rspb.2020.2469]).*

Climate Change Affecting Spring Phytoplankton Blooms in the Pelagos Sanctuary

The timing and intensity of the spring phytoplankton bloom is an important factor for the Mediterranean Sea ecosystem. The timing and intensity of phytoplankton in the northwest Mediterranean, including in the Pelagos Sanctuary, was analysed based on daily maps of chlorophyll-*a* concentrations. There were strong links between the chlorophyll-*a* concentration during spring blooms with seawater and atmospheric temperatures. The frequency of anomalous phytoplankton bloom years increased over the study period (2008-2022), with anomalies in terms of both bloom intensity and sea temperature. Bloom intensity increased steeply during the latter seven years at all sites. The high levels of phytoplankton here are essential to zooplankton, krill and the various squid and fish species that feed upon these. This in turn provides abundant prey for cetaceans. The abundance of fin whales suggests that larger feeding aggregations form during stronger phytoplankton bloom periods. In this study, an anomalously low bloom in 2014 was associated with lower fin whale presence and a contraction of the distribution of striped dolphins. "The anomalies and negative trends detected in the most productive area of the Mediterranean Basin call for urgent attention".

> *(SOURCE: Grossi, F., Lagasio, M., Napoli, A., Provenzale, A., Tepsich, P, 2024. Phytoplankton spring bloom in the NW Mediterranean Sea under climate change. Sci. Total Environ. 914:169884. [Available at: https://doi.org/10.1016/j.scitotenv.2024.169884]).*

Warming Temperatures Affect Dolphin Distribution and Group Sizes

Sea surface temperature, marine heat waves and distribution of common bottlenose dolphins were analysed in the Mediterranean based on 2013-2020 sightings data. Increasing sea surface temperatures negatively influenced both dolphin occurrence and group size. In addition, individual home range size increased from 5km^2 (in 2013-2016) to 15km^2 (2017-2020), as sea surface temperatures rose on average 1.34°C. The authors noted the importance of considering the potential impacts of future climate change when designating boundaries for marine protected areas for species such as bottlenose dolphins.

> *(SOURCE: La Manna, G., Ronchetti, F., Perretti, F., Ceccherelli, G., 2023. Not only wide range shifts: Marine warming and heat waves influence spatial traits of a Mediterranean common bottlenose dolphin population. Estuar. Coast. Shelf Sci. 285:108320. [Available at: https://doi.org/10.1016/j.ecss.2023.108320]).*

Ocean Acidification Impact on Mediterranean Plankton

Calcium carbonate shells from Mediterranean foraminifera plankton sampled from surface waters were compared to sediment cores to determine changes over time, in the face of global warming. Isotope levels were also investigated to identify the source of CO_2. Fossil fuel-derived CO_2 levels increased in the samples while pH levels decreased. Moreover, increased anthropogenic CO_2 levels, and the resulting acidification, reduced plankton shell mass. Although higher CO_2 levels and warmer waters may increase plankton productivity, this is "insufficient to offset acidification effects".

> *(SOURCE: Pallacks, S., Ziveri, P., Schiebel, R., Vonhof, H., Rae, J.W.B., Littley, E., Garcia-Orellana, J., Langer, G., Grelaud, M., Martrat, B., 2023. Anthropogenic acidification of surface waters drives decreased biogenic calcification in the Mediterranean Sea. Nature Commun. Earth Environ. 4:301. [Available at: https://doi.org/10.1038/s43247-023-00947-7).*

Projected Impacts on Cetaceans of Trawling and Climate Change Effects on Productivity

Ecosystem models were developed (Ecopath with Ecosim) to investigate the effect of climate change on primary productivity, in conjunction with the impact of trawl fisheries (i.e. increasing or decreasing effort) on cetaceans and their prey in the Northern Ionian Sea (central Mediterranean Sea). Four cetacean species were assessed (striped, common bottlenose and Risso's dolphins, and sperm whales), projecting through 2040. The climate change scenario suggested an increase in cetacean biomass due to an increase in primary productivity and key prey species. Some cephalopods, shrimp and small pelagic fish decreased, due to this increase in predators. Changes in fishing effort had only minor impacts on cetaceans, except for bottlenose dolphins, which were negatively affected when trawling increased, as this species tends to feed on bottom-dwelling species in the Mediterranean and Ionian Seas.

> *(SOURCE: Ricci, P., Serpetti, N., Cascione, D., Cipriano G., D'Onghia, G., De Padova D., Fanizza, C., Ingrosso, M., Carlucci, R., 2023. Investigating fishery and climate change effects on the conservation status of odontocetes in the Northern Ionian Sea (Central Mediterranean Sea). Ecol. Model. 485:110500. [Available at: https://doi.org/10.1016/j.ecolmodel.2023.110500).*

The Mediterranean Sea Is a Climate Change Hotspot

The Mediterranean will be among the global regions most affected by climate change and the IPCC considers it a primary climate change hotspot. The trend for more frequent, intense, severe and spatially extended marine heatwaves is projected to increase here. Beyond direct effects on cetaceans, this is predicted to indirectly affect them by altering

overall biodiversity, productivity, ecology, species assemblages and organisms on various levels of the trophic web. Rising water temperatures are also expected to promote HABs and the spread of pathogens and diseases, along with thermophilic and invasive species. Importantly, ocean acidification is currently occurring at a geologically unprecedented rate here. An example of potential effects on Mediterranean cetaceans: long-finned pilot whale distribution and population structure could be affected because some of their prey, e.g. squid, are sensitive to temperature and ocean acidification. These threats, combined with large-scale atmospheric events and multiple anthropogenic pressures (e.g. pollution), could have cascading effects on Mediterranean marine life, from plankton to cetaceans.

> *(SOURCE: Striegl, S., Nunny, L., Simmonds, M., 2023. An update on the implications of climate change for cetaceans - with a particular focus on the Mediterranean Sea. SC/69A/E/07 presented to the IWC Scientific Committee, Bled, 2023).*

Record European Temperatures Due to Arctic Ice Melting

Since the 1980s, Europe has been warming twice as fast as the global average (United Nations, 2023). Oltmanns *et al.* (2024) suggested that one reason behind these high European temperatures and heatwaves is due to an infusion of meltwater from shrinking Arctic ice altering ocean currents and regional air circulation patterns. Melting sea ice and glaciers in Greenland and North America are now adding 6000km^3 of water to the ocean each decade. This freshwater enters the North Atlantic, floating above heavier, warmer saltwater. This layering prevents warmer water below from mixing with surface waters and the ocean surface is thus colder in autumn and winter. The result is the so-called 'cold blob', an area where the North Atlantic is getting colder than the rest of the region. This causes atmospheric instability, a resulting northward shift in the North Atlantic Current and an enhanced sea surface temperature front. The following summer winds are deflected northward along this enhanced temperature front and the European coastline. This results in "a largescale atmospheric circulation anomaly" that causes warmer, drier air over Europe during the summer. Analysing the 10 hottest and 10 coldest summers in Europe since 1980, and oceanic conditions in the North Atlantic in the preceding autumn and winter, revealed that the hottest summers—but not the coldest—were all preceded by freshwater cold blob events.

> *(SOURCES: United Nations, 2023. Europe warming twice as fast as other continents, warns WMO. UN News, 19 June 2023. [Available at: https://bit.ly/3x1ODAJ]; Oltmanns, M., Holliday, N. P., Screen, J., Moat, B. I., Josey, S. A., Evans, D. G., Bacon, S., 2024. European summer weather linked to North Atlantic freshwater anomalies in preceding years. Weather Clim. Dynam. 5:109-132. [Available at: https://doi.org/10.5194/wcd-5-109-2024]).*

Noise impacts

Boat Noise a Problem even if Electrically Powered

An 8m trimaran pontoon boat with two outboard electric engines operating in the Miramare MPA (Trieste, Italy) produced underwater noise that reduced the 'listening space' for a local fish species and had frequencies similar to those used by odontocetes for echolocation-based foraging and navigation. Thus, electric engines may not ameliorate underwater noise pollution compared to more common combustion engines. The authors expected the continuous, tonal, high-frequency components generated by the electric boat to be highly detrimental for marine species that have high-frequency specialised hearing, such as bottlenose dolphins. Even if humans perceive electric boats to be quieter, some species of marine mammals may not.

> *(SOURCE: Gaggero, T., Armelloni, E., Codarin, A., Chicco, C., Spoto, M., Franzosini, C., Ciriaco, S., Picciulin, M., 2024. Electric boat underwater radiated noise and its potential impact on species of conservation interest. Mar. Pollut. Bull. 199:115937. [Available at: https://doi.org/10.1016/j.marpolbul.2024.115937]).*

Recreational Boating Affects Dolphins in the Northwest Mediterranean Sea

Boat surveys were used to determine the relative abundance of the most common cetacean species in the western Mediterranean (striped dolphins) along the French Riviera. Their occurrence decreased significantly in the inshore part of the study area (core feeding habitat) between 1988 and 2018. The authors attributed this to intense recreational boating. In summer, the traffic flow often exceeded one boat per minute. The underwater noise here was about 10 dB higher than in the open sea. The EU's Marine Strategy Framework Directive fails to provide a framework for regulating the higher frequency noise emitted by small vessels, requiring specific national or regional regulations. The authors expressed concern that the striped dolphins would eventually completely abandon this habitat.

> *(SOURCE: Gannier, A. J., Boyer, G., Gannier, A. C., 2022. Recreational boating as a potential stressor of coastal striped dolphins in the northwestern Mediterranean Sea. Mar. Pollut. Bull. 185:114222. [Available at: https://doi.org/10.1016/j.marpolbul.2022.114222]).*

Noise from Small Boats an Issue in a Protected Area in Croatia

Anthropogenic underwater noise is a recognised threat to cetaceans. The activity of smaller boats is poorly understood because they are not required to be equipped with AIS and reliable measurements on the noise they produce are lacking. In assessing the noise generated by smaller boats within a Natura 2000 Site of Community Importance in the Adriatic Sea, engine type and power, rather than boat length, proved to be the main factors. Highest speeds were

associated with highest sound levels only in a limited frequency range. This and the number of boats (each with different noise emissions) must be considered when setting speed limits. This is relevant in the Cres-Losinj area due to the resident common bottlenose dolphin population and because this is a popular destination for recreational boating. Previous studies reported changes in dolphin whistling structure and home range sizes when exposed to boat noise.

(SOURCE: Picciulin, M., Armelloni, E., Falkner, R., Rako-Gospic, N., Radulovic, M., Pleslic, G., Muslim, S., Mihanovic, H., Gaggero, T., 2022. Characteristics of the underwater noise produced by recreational and small fishing boats (<14 m) in the shallow water of the Cres-Losinj Natura 2000 SCI. Mar. Pollut. Bull. 183:114050. [Available at: https://doi.org/10.1016/j.marpolbul.2022.114050]).

FERRY NOISE CORRELATED WITH DECREASED SPERM WHALE PRESENCE IN THE PELAGOS SANCTUARY

A sonobuoy system off Toulon, southern France, recorded sperm whale occurrence and the effect of underwater noise in the Pelagos Sanctuary for cetaceans. This area is frequented daily by ferries travelling between Toulon or Marseille and Corsica. Their sound levels are between 183 and 192dB. When travelling through the study area, background noise increased by ~3dB. Sperm whales were significantly less frequently detected during these periods. The authors concluded that measures were urgently needed, such as "reduced ferry speeds or shifting of the ferry routes offshore to avoid areas of underwater canyons that are of importance for sperm whales".

(SOURCE: Poupard, M., Ferrari, M., Best, P., Glotin, H., 2022. Passive acoustic monitoring of sperm whales and anthropogenic noise using stereophonic recordings in the Mediterranean Sea, North West Pelagos Sanctuary. Sci. Rep. 12:2007. [Available at: https://doi.org/10.1038/s41598-022-05917-1]).

GLOBAL

General

RESEARCH AND MANAGEMENT HAVE DONE LITTLE TO REVERSE THE RISK OF EXTINCTION FOR SMALL CETACEANS

A review of cetacean species on the IUCN Red List (*n*=77) led to a model weighing threat levels. A quarter of small cetaceans may be threatened with extinction (Critically Endangered, Endangered or Vulnerable). The population trends of only 20 species were assessed: 19 are decreasing and one is increasing. The proportion of species threatened with extinction has remained roughly stable for ~30 years, suggesting small cetaceans are "likely to be experiencing a continued but gradual decline worldwide". Fisheries were the most frequent threat ('medium' to 'high' impact for 81% of species)—the only threat ranked 'high'. Incidental (56% of species) and direct (40%) catches in small-scale fisheries were more likely to be listed as threats than incidental catches in industrial fishing (38% of species). Various types of habitat degradation were noted and underwater noise was considered to have 'medium' impacts on 35% of small cetaceans. When modelling the predictive power of a threat to determine extinction risk, fisheries had the strongest predictive power. Small-scale fishing was three times stronger as a predictor than large-scale, industrial fishing. Fisheries management had little influence on extinction risk, suggesting "the implementation of existing measures have been largely ineffective". Habitat degradation was the second strongest predictor of extinction risk. Threats such as recreational vessel traffic, shipping and oil and gas exploration and extraction activity were weak predictors of small cetacean extinction risk. When compared to the scientific literature, however (*n*=13,507 publications), the proportions of small cetacean studies addressing fisheries (9%) and habitat degradation (4.6%) were low, considering their contribution to extinction risk. Although small-scale fisheries were the strongest predictor of extinction risk, only 0.9% of all small cetacean research was on this topic. "[R]esearch effort in both fisheries and habitat degradation are substantially underrepresented despite their importance". The authors concluded that "there needs to be a major shift in the prioritisation of research focus and research funding within the community towards priority threats".

(SOURCE: Temple, A.J., Langner, U., Berumen, M.L., 2024. Management and research efforts are failing dolphins, porpoises, and other toothed whales. Sci. Rep. 14:7077. [Available at: https://doi.org/10.1038/s41598-024-57811-7]).

UN EXPERTISE PROVIDES CRUCIAL INPUT INTO OCEAN SCIENCE-POLICY INTERFACE

There is growing concern about ocean health and the impacts of many stressors, including climate change, ocean acidification, overfishing, loss of biodiversity, pollution (e.g. sewage, POPs, plastics, excessive nutrients, noise, light), invasive species and habitat loss. This calls for timely and effective policy and decision-making. The information for such action has long been provided by the UN Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP). This makes GESAMP a key science-policy interface that provides credible and relevant information on a wide range of marine topics and emerging issues of concern to ten UN Sponsoring Organisations. GESAMP's work has also been utilised by numerous organisations outside the UN. Accordingly, the group's scientific output—published as peer-reviewed technical reports in the GESAMP Reports and Studies Series, as well as in peer-reviewed journals—is often cited by national governments and inter-governmental and non-governmental groups. The IWC's Scientific Committee has identified many of the above stressors as key environmental issues relevant to cetaceans.

(SOURCE: Watson-Wright, W. M., Wells, P. G., Duce, R. A., Gilardi, K. V., Girvan, A. S. T., Huber, M. E., Kershaw, P. J., Linders, J. B. H. J., Luit, R. J., Vivian, C. M. G., Vausden, D. H., 2024. The UN Joint Group of Experts on the Scientific Aspects of Marine

Environmental Protection (GESAMP) - An ocean science-policy interface standing the test of time. Mar. Pollut. Bull. 199:115917. [Available at: https://doi.org/10.1016/j.marpolbul.2024.115917]).

Habitat degradation

Fisheries Interactions

TOOTHED CETACEANS ADAPT TO FEEDING IN ASSOCIATION WITH TRAWLERS

At least 19 species of odontocetes are known to have modified their behaviour to feed in association with trawlers. This includes entering moving trawl nets to feed on trapped organisms, feeding on fish stirred up by the net, extracting fish from the outer mesh, feeding on catch lost during hauling and scavenging on discarded catch. Such interactions can last for minutes to several hours. While such specialised behaviours may compensate for scarcity of natural prey in areas subject to intensive fishing or environmental degradation, they risk potential injury or death in trawl gear. The overall positive or negative effect on such cetaceans remains unknown. The authors highlighted the changes to the animals' foraging type, diet, direction of movement, distribution, group size and social behaviour and structure. Moreover, such cetaceans encounter higher levels of noise and pollution. This spectrum of effects is a cause for concern. Most attempts to reduce depredation and/or bycatch in trawl gear are not consistently effective.

(SOURCE: Bonizzoni, S., Hamilton, S., Reeves, R. R., Genov, T., Bearzi, G., 2022. Odontocete cetaceans foraging behind trawlers, worldwide. Rev. Fish. Biol. Fisheries 32:827-877. [Available at: https://doi.org/10.1007/s11160-022-09712-z]).

Marine Debris

MICROPLASTICS FOUND IN CETACEAN BLUBBER AND OTHER TISSUES

A study described the translocation of microplastics from the cetacean digestive tract into organ tissues (species examined were bottlenose dolphin, beluga whale, pygmy sperm whale, pilot whale and minke, fin, humpback and gray whales). Lipid-rich tissues, such as blubber and acoustic fats, are particularly susceptible to invasion by lipophilic microplastics. Of the animals sampled, 68% had at least one microplastic particle in at least one type of tissue. The microplastics' size ranged from 24.4-1387µm and their concentrations from 0.59-5.20µg.g^{-1} and 0.04-0.39 particles/g. Microplastics had translocated to blubber, melon, acoustic fats and lung tissues, presumably after ingestion or inhalation. The most common forms of microplastics were fibres, followed by fragments and foams. The most common polymers were polyester and polyethylene; polyethylene terephthalate was found in acoustic fats and lung tissues; polypropylene in blubber samples; and vinyl acrylic acetate ester in melon tissue. The authors concluded, "Whether the concentration of microplastic in the tissues examined here present a health threat to marine mammals remains to be examined, however [sic] the presence of microplastics embedded in internal organs underscores the ubiquity of the pervasive plastic pollution problem afflicting the oceans and its inhabitants".

(SOURCE: Merrill, G. B., Hermabessiere, L., Rochman, C. M., Nowacek, D. P., 2023. Microplastics in marine mammal blubber, melon, and other tissues: Evidence of translocation. Environ. Pollut. 335:122252. [Available at: https://doi.org/10.1016/j.envpol.2023.122252]).

CETACEANS PLAYING WITH PLASTIC: A WIDESPREAD ACTIVITY WITH LIKELY SEVERE IMPACTS

A detailed review of the scientific literature and social media, combined with 12 years of observations (whale watching operator in the Azores, NE Atlantic), documented a total of 11 odontocete species in 50 events intentionally carrying or throwing plastic litter with their head and/or flippers. These interactions occurred in the Atlantic, Pacific and Indian Oceans, and the Mediterranean and Red Seas. Single-use plastics were the main type of objects, including sheet-like material, bags, raffia and a box. Although this behaviour suggested play, the authors concluded that this "can pose a significant risk through subsequent entanglement or ingestion". The incidence of plastic ingestion in cetaceans has been increasing, and the authors considered the role of playful interactions to be underestimated.

(SOURCE: Rodriguez, Y., Silva, M .A., Pham, C. K., Duncan, E. M., 2023. Cetaceans playing with single-use plastics (SUPs): A widespread interaction with likely severe impacts. Mar. Pollut. Bull. 194:115428. [Available at: https://doi.org/10.1016/j.marpolbul.2023.115428]).

Ship Strikes

SHIP STRIKES PROJECTED TO INCREASE IN THE FUTURE

The recovery of certain whale populations, combined with the rise in commercial shipping and recreational boating, is increasing negative interactions between whales and vessels. Humpback whales in Australia were largely unresponsive to approaching vessels, i.e. they did not initiate escape or avoidance responses based on vessel speed or noise levels. In most cases, the vessels had to take avoidance action. Accordingly, the most effective risk management strategies involve reducing the encounter rate between whales and vessels. Reducing ship speed gives vessel operators more time to take such action, but will not fully eliminate the collision risk in the studied humpback population (because ship speeds were already relatively low). Excluding vessels from areas of high use by whales would provide additional protection. The author underlined the considerable gap between reported and actual collision rates, implying that the impact may be much greater than that assumed based on ship strike data.

(SOURCE: Dunlop, R., 2024. Use of a behavioural response method to assess the risk of collision between migrating humpback whales and vessels. Mar. Pollut. Bull. 199:115986. [Available at: https://doi.org/10.1016/j.marpolbul.2023.115986]).

EVEN MINOR ENTANGLEMENT CAN REDUCE RIGHT WHALE REPRODUCTIVE SUCCESS AND SURVIVAL

Almost all (89%) female North Atlantic right whales have been entangled by fishing gear or marine debris at least once and almost two-thirds have been entangled twice or more. A Bayesian mark-recapture model determined the effect of entanglement, and its severity, on reproduction and survival here (*n*=199; 1977-2018). Severe entanglements resulted in a 27% decline in survival probability for experienced non-breeders (females that have produced a calf, but did not calve that year), 9% for breeders (whales that produced a calf that year) and 26% for pre-breeding females that have not yet given birth for the first time, when compared to non-entangled animals. Females that survived severe entanglement had a low probability of breeding afterwards. Even minor entanglement significantly decreased the likelihood of breeding, contrary to current management measures that consider minor entanglement to have a lesser impact. The authors concluded, "Management actions are needed to address the lethal and sub-lethal impacts of entanglements, regardless of severity classification". They "urge caution about dismissing the influence of *any* level of anthropogenic injury on critically endangered species" and urge that "value-laden terms such as 'minor', 'moderate' and 'severe' are no longer used to categorize entanglement injuries and scarring".

(SOURCE: Reed, J., New, L., Corkeron, P., Harcourt, R., 2024. Disentangling the influence of entanglement on recruitment in North Atlantic right whales. Proc. Royal Soc. B: Biol. Sci. 291:20240314. [Available at: https://doi.org/10.1098/rspb.2024.0314]).

Chemical pollution

GLOBAL REVIEW OF METAL AND TRACE ELEMENTS IN CETACEANS

A review of 49 scientific articles published in the period 2006–2021 indicated that Cd and Pb concentrations in cetaceans were generally low, but that Hg levels were high. The review confirmed the Mediterranean as having one of the highest metal contamination levels, the Atlantic one of the lowest. The highest Hg values were found in false killer whales, whereas those in mysticetes were comparatively low. The highest Hg (and Pb) concentrations in bottlenose dolphins were recorded in the Mediterranean, as were Hg in striped dolphins, Risso's dolphins, and Cuvier's beaked whales (the latter pointing to the Sicilian Channel as the most contaminated area in the Mediterranean). The highest Al and Pb values in short-finned pilot whales, however, were reported from the Canary Islands (Atlantic). The authors noted that, despite many studies on metals in cetaceans, very few examine the effects. In marine mammals in general, Pb can cause "unusual behaviour impairing survival, growth, learning and metabolism", whereas Hg "adversely affects the central nervous and endocrine systems and leads to dysfunction in reproduction, osmoregulation, orientation, prey location, and interspecific communication".

(SOURCE: Delgado-Suarez, I., Lozano-Bilbao, E., Hardisson, A., Paz, S., Gutiérrez, A. J., 2023. Metal and trace element concentrations in cetaceans worldwide: A review. Mar. Pollut. Bull. 192:115010. [Available at: https://doi.org/10.1016/j.marpolbul.2023.115010]).

Disease and mortality events

Strandings

RADIOFREQUENCY RADIATION (MILITARY RADAR) AS A POSSIBLE CAUSE OF CETACEAN STRANDINGS

Bats, echolocating mammals, are known to be affected by radar facilities. Anthropogenic electromagnetic fields produced by high-intensity (i.e. military) radar systems may disrupt the sensory systems, echolocation and navigation systems of similar echolocators, such as cetaceans. To investigate the possible link between military radar and cetacean mortalities, 31 mass strandings, where a definite cause was unknown, were compared to radar facilities: in 65% of cases, the stranding event occurred near (within 50km) a radar system. In addition, a linear regression analysis of the cumulative number of military radars in the UK showed significant correlation with stranding records (with animals involved in mass strandings counted individually). The authors noted that, in November 1962, a radar was installed in Genoa (Italy), shortly before the first recorded mass stranding event there (January and February, 1963). The Cornwall weather radar in Predannack (UK) was built in 1986, shortly before strandings began to increase there. In the Biobío region of Chile, two weather radars were installed in 2016; several strandings were reported in the area in 2017. The authors noted that radar waves have been posited *not* to affect cetaceans, as they are underwater, but radar-associated radiation can, in fact, penetrate the water surface. The authors also noted that, in addition to sonar, high-powered radars are often carried on military vessels and located in naval bases, which could be why, in a recent review of cetacean strandings, 27 mass strandings occurred near ships and naval bases, despite there being no evidence of sonar use. These data highlight a possible anthropogenic source of radiation that could be a causative factor in stranding events.

(SOURCE: Balmori-de la Puente, A., Balmori, A., 2024. Potential effects of anthropogenic radiofrequency radiation on cetaceans. Radiation *4:1-16. [Available at: https://doi.org/10.3390/radiation4010001]).*

Climate change

Climate Change Impacts on Phytoplankton Will Have Major Impact on Fish Biomass

Based on field data and computer modelling, the authors predicted that climate change will cause a decline in phytoplankton in low and mid latitudes as the water warms and the low-density surface layers become partitioned from the nutrient supply in waters below. This warming effect has already been observed in some areas (e.g. North Atlantic), where plankton has declined over the last 50 years. The North Atlantic will see an estimated 16-26% reduction in phytoplankton by the end of the century and the size of individual phytoplankton will decrease in response to low nutrient levels. This will have a major impact up the food chain, causing an estimated 38-55% reduction in fish biomass and a dramatic knock-on effect on species that depend upon these fish as prey, including cetaceans.

> *(SOURCE: Atkinson, A., Rossberg, A. G., Gaedke, U. et al., 2024. Steeper size spectra with decreasing phytoplankton biomass indicate strong trophic amplification and future fish declines. Nat. Commun. 15:381. [Available at: https://doi.org/10.1038/s41467-023-44406-5]).*

Bottom Trawling Is a Major Source of Carbon Dioxide Emissions

Bottom trawling damages seabed habitats and also adds to greenhouse gas emissions. Nearly 5 million km^2 is trawled each year, releasing ~370 million tonnes of CO_2 each year. About 40-45% of the total carbon dislodged from the ocean floor by trawling remains in the water, potentially leading to localised ocean acidification. The remaining 55-60% was estimated to reach the atmosphere within nine years. Areas in the Greenland, Baltic, North and East China seas produce the highest emissions. To put this into context, in 2022 the aviation industry produced 800 million tonnes of CO_2; therefore, bottom trawling alone (excluding the emissions produced by the four million trawling vessels in the global fleet) annually releases nearly half the CO_2 of that carbon-intensive industry.

> *(SOURCES: Atwood, T. B., Romanou, A., DeVries, T., Lerner, P. E., Mayorga, J. S., Bradley, D., Cabral, R. B., Schmidt, G. A., Sala, E., 2024. Atmospheric CO2 emissions and ocean acidification from bottom-trawling. Front. Mar. Sci. 10:1125137. [Available at: https://doi.org/10.3389/fmars.2023.1125137]; Sala, E., Mayorga, J., Bradley, D. et al., 2021. Protecting the global ocean for biodiversity, food and climate. Nature 592:397-402. [Available at: https://doi.org/10.1038/s41586-021-03371-z]).*

Marine Heatwave Causes Major Decline of Humpback Whales In Pacific

Humpback whales have generally been recovering since the IWC ended the commercial whaling of this species. Between 2002 and 2012, the average population growth rate in the North Pacific was 6%. This species was therefore delisted under the US Endangered Species Act in 2016. However, an extreme heatwave in the northeast Pacific between 2014 and 2016 caused temperatures to rise 3–6^{o}C above average. This heatwave likely affected phytoplankton levels and thus the prey species (e.g. small, schooling fish) of humpbacks. Between 2012 and 2021, the population declined 20% - from 33,488 (± 4455) to 26,662 (± 4192). This particularly affected those whales wintering in Hawai'i, where abundance declined by 34%, which could result in an IUCN listing of 'Vulnerable' for this population. The photo-identification data used in this study were collected by 46 organisations and 4292 community science contributors, whose images (from 2001–2022) were collated in the research collaboration and community science web platform Happywhale.com. The system uses image recognition algorithms to identify photos that are voluntarily uploaded by community contributors and scientists worldwide. It has a 97-99% accuracy rate for identifying humpback whales. This study demonstrates the major impact that climate change can have on cetacean populations.

> *(SOURCE: Cheeseman, T., Barlow, J., Acebes, J. M., Audley, K., Bejder, L., Birdsall, C., Bracamontes, O. S., Bradford A. L., Byington, J., Calambokidis, J., Cartwright, R., Cedarleaf, J., Chavez, A. J. G., Currie, J., … Clapham, P., 2024. Bellwethers of change: Population modelling of North Pacific humpback whales from 2002 through 2021 reveals shift from recovery to climate response. Roy. Soc. Open Sci. 11:231462. [Available at: https://doi.org/10.1098/rsos.231462]).*

Global Warming Reaches 1.5^{o}C above Pre-Industrial Levels in a Year of Record Temperatures

The year 2023 broke several climate records. August was the warmest ever recorded and the year was the hottest on average over the past 125,000 years, with the average global temperature 1.48°C above pre-industrial levels. It also marked the first year on record where every day was more than 1°C above 1850-1900 pre-industrial temperatures. Almost half of 2023 was more than 1.5°C warmer than the 1850-1900 level, and two days in November were, for the first time, more than 2°C warmer. The three most important greenhouse gases (CO_2, methane, nitrous oxide) were all at record levels, with CO_2 concentrations now at ~420 ppm. Last year also saw the lowest level of sea ice surrounding Antarctica since the advent of satellite data - 2.67 million km^2 below the 1991-2023 average. Ocean acidity, glacier thickness and Greenland ice mass all fell to record lows, whilst sea level rise was a record high and both global and North Atlantic sea surface temperatures broke records. These unprecedented sea surface temperatures were associated with marine heatwaves around the globe, including parts of the Mediterranean, Gulf of Mexico and the Caribbean, Indian Ocean and North Pacific, and much of the North Atlantic. Moreover, concerns are growing that AMOC could pass a tipping point and start to collapse in the near future, affecting global temperatures, water cycles and ecosystems. In 2023, climate change also contributed to extreme weather events and disasters, e.g. severe flooding in northern China,

deadly flash floods and landslides in northern India and Pakistan, intense Mediterranean storms and record-breaking heat waves in the United States.

(SOURCES: Copernicus Climate Change Service, 2024. 2023 is the hottest year on record, with global temperatures close to the 1.5 °C limit. Copernicus Climate Change Service, 9 January 2024. [Available at: https://climate.copernicus.eu/copernicus-2023-hottest-year-record]; Ripple, W. J., Wolf, C., Gregg, J. W., Rockström, J., Newsome, T. M., Law, B. E., Marques, L., Lenton, T. M., Xu, C., Huq, S., Simons, L., King, D. A., 2023. The 2023 state of the climate report: Entering uncharted territory. BioScience 73:841-850. [Available at: https://doi.org/10.1093/biosci/biad080]).

ATLANTIC CIRCULATION TO COLLAPSE BY MID-21ST CENTURY

AMOC is a major influence on climate and marine ecosystems in the North Atlantic, introducing both warm waters and nutrients and releasing heat to the atmosphere. Despite concern about the weakening of this circulation in recent years, the IPCC had considered that a full collapse of AMOC was unlikely in the 21st century. However, scientists have reported an increased slowing in the system and an increase in variance (indicating a loss of resilience in the system). This suggests that AMOC is rapidly reaching a 'tipping point'. The authors estimated that, under the current emissions scenarios, AMOC may collapse by 2050 (95% confidence interval 2025–2095). This is "a worrisome result, which should call for fast and effective measures to reduce global greenhouse gas emissions in order to avoid the steady change of the control parameter toward the collapse of AMOC (i.e., reduce temperature increase and freshwater input through ice melting into the North Atlantic region)".

(SOURCE: Ditlevsen, P., Ditlevsen, S., 2023. Warning of a forthcoming collapse of the Atlantic meridional overturning circulation. Nat. Commun. 14:4254. [Available at: https://doi.org/10.1038/s41467-023-39810-w]).

GREENLAND ICE LOSS IS GREATER THAN PREVIOUSLY ESTIMATED

An analysis of the Greenland glacier extent from 1985 to 2022 estimated that the Greenland Ice Sheet has lost 5091km^2 (± 72) in area, corresponding to 1034Gt (± 120) of ice lost. This latest estimate also suggests that recent studies have underestimated the ice mass loss here by up to 20%. The freshwater influx into the North Atlantic caused by this melting ice "is sufficient to affect ocean circulation and the distribution of heat energy around the globe".

(SOURCE: Greene, C. A., Gardner, A. S., Wood, M., Cuzzone, J. K., 2024. Ubiquitous acceleration in Greenland Ice Sheet calving from 1985 to 2022. Nature 625:523-528. [Available at: https://doi.org/10.1038/s41586-023-06863-2]).

THE WORLD IS RAPIDLY APPROACHING CRITICAL ENVIRONMENTAL 'TIPPING POINTS'

The world may be approaching a number of natural thresholds or 'tipping points', beyond which devastating domino effects and positive feedback loops could be triggered, leading to the loss of entire ecosystems. These tipping points include: the collapse of major ice sheets in Greenland and the West Antarctic; the death of coral reefs; the widespread melting of Arctic permafrost; and the collapse of AMOC in the North Atlantic. If warming exceeds 1.5°C (2.7°F) (above pre-industrial levels) by the 2030s, additional tipping points are possible: e.g. die-offs of mangroves and seagrass meadows (which could occur between 1.5°C and 2°C of warming), and, in the terrestrial environment, the loss of boreal forests (between 1.4°C and 5°C of warming). These changes would not likely occur proportionately to temperature rises, but rather at such thresholds, leading to loss or collapse of a system, i.e. tipping from one state into a new, potentially irreversible state. These tipping points may be interlinked; e.g. collapse of Greenland ice sheets and an inundation of freshwater into the North Atlantic could hasten the collapse of AMOC and/or intensify the El Niño southern oscillation, causing further, dramatic climatic changes.

(SOURCE: https://global-tipping-points.org/).

OCEAN WARMING IS ACCELERATING AT A RATE TEN TIMES GREATER THAN TERRESTRIAL AND ATMOSPHERIC WARMING

The warming of the world's oceans since 1960 has been accelerating at 0.15W/m^2 (± 0.05) each decade, a rate more than ten times greater than that for the cryosphere, land and atmosphere (0.013W/m^2 ± 0.003). This is reflected in a substantial increase in ocean warming (0.91W/m^2 ± 0.80 in the periods 1960-1970 and 2010-2020). Global ocean heat content changes account for approximately 90% of the total heat increase on the planet in the past 50 years. In contrast, warming of the cryosphere (3%), land (5%) and atmosphere (1%) play a much more minor role in global warming. The authors emphasised that their calculations "withstand a wide range of sensitivity analyses and are consistent across different observation-based datasets". Possible explanations for the accelerated warming in the past 20 years are an acceleration in human activities or anthropogenic feedback loops affecting the environment, a significant rise in radiative forcing as atmospheric aerosols have decreased, or changes in clouds and sea-ice causing climatic feedback loops. This acceleration has profound implications for ocean ecosystems.

(SOURCE: Minière, A., von Schuckmann, K., Sallée, J.B., Vogt, L. 2023. Robust acceleration of Earth system heating observed over the past six decades. Sci. Rep. 13:22975. [Available at: https://doi.org/10.1038/s41598-023-49353-1]).

Noise impacts

Ship Noise Alters the Behaviour of Harbour Porpoises

Ten tagged harbour porpoises were monitored for 5–10 days in North Sea waters off Denmark and Sweden to determine their reactions to ship noise (10–20kHz). The porpoises spent one third of their time experiencing ship noise. They regularly reacted by moving away during daytime and diving deeper at night. Ships >2km away caused the animals to react 5–9% of the time. The authors concluded that this has "worrying implications for fitness in coastal waters where anthropogenic noise from dense ship traffic repeatedly disrupts their natural behaviour".

> *(SOURCE: Frankish, C. K., Benda-Beckmann, A. M., Teilmann, J., Tougaard, J., Dietz, R., Sveegaard, S., Binnerts, B., de Jong, C. A. F., Nabe-Nielsen, J., 2023. Ship noise causes tagged harbour porpoises to change direction and dive deeper. Mar. Pollut. Bull. 197:115755. [Available at: https://doi.org/10.1016/j.marpolbul.2023.115755]).*

Sonar Exercises Could Lead to Beaked Whale Population Extinction

The population-level consequences of military sonar were modelled for populations of Cuvier's beaked whales on the US Navy's Southern California Anti-Submarine Warfare Range (SOAR) around San Clemente Island, California, and Blainville's beaked whales at the Atlantic Undersea Test and Evaluation Center (AUTEC), a US Navy training range in the Bahamas. The model predicated a rapid initial decline in beaked whale abundance at the SOAR range due to sonar exposure. If the whales were displaced from habitat *and* if they stopped feeding after sonar exposure, the population would be locally extirpated. If the whales exhibited *either* displacement *or* a cessation of foraging, but not both, the population would halve in size. For the behavioural response scenario where whales stopped foraging, within five years the population decreased by 25%, decreasing a further 25% over the next 26 years. In particular, lactating females demonstrated a high mortality rate. For beaked whales at the AUTEC range, if whales stopped foraging, then the population would be reduced by 45%, although the decline would be slower than at the SOAR range, with half of the decrease occurring over the first 24 years. It would take an additional 123 years to reach a 45% decline. The recovery of beaked whales after sonar use ceased would be, however, much slower: 156 years, with the first half of the recovery taking 59 years. Part of the difference between the two sites was more frequent sonar use at the SOAR range. In addition, beaked whales displaced on the AUTEC range should move to an alternative, but high quality, habitat, whereas on the SOAR range, displaced whales would be forced into poorer quality habitat. The combined effects of reduced foraging and displacement into marginal habitat led to the predicted extinction of the modelled population. The model assumed that areas outside of the ranges were free of sonar, but this is unlikely, potentially boosting the impacts.

> *(SOURCE: Hin, V., de Roos, A. M., Benoit-Bird, K. J., Claridge, D. E. et al., 2023. Using individual-based bioenergetic models to predict the aggregate effects of disturbance on populations: A case study with beaked whales and Navy sonar. PLoS ONE 18(8):e0290819. [Available at: https://doi.org/10.1371/journal.pone.0290819]).*

Strategies to Neutralise Munitions Dumped at Sea

Unexploded military ordnance threatens offshore development such as windfarms, damages the seabed and poses a risk to marine mammals and other fauna. Such material was either lost during military conflicts or disposed of in enormous amounts at sea after such conflicts (e.g. WWI). A trial to remove such munitions in Danish waters revealed that a 'low-order' disposal method substantially reduced the peak sound pressure level and sound exposure level compared to a 'higher-order' method. The former, newer alternative method involves placing a small charge that creates a plasma-like jet that penetrates the munition casing and triggers low-order combustion, whereas the latter involves exploding a new (larger) donor charge placed next to the munitions. The lower-order approach causes the munitions to rapidly burn ('deflagration') rather than explode outright. The remaining debris can then be more easily and safely collected by divers or ROVs. Even the new method, however, can create sound levels that can potentially injure or disturb some species at ranges of several kilometres, e.g. harbour porpoises.

> *(SOURCE: Lepper, P. A., Cheong, S.-H., Robinson, S. P., Wang, L., Tougaard, J., Griffiths, E. T., Hartley, J. P., 2024. In-situ comparison of high-order detonations and low-order deflagration methodologies for underwater unexploded ordnance (UXO) disposal. Mar. Pollut. Bull. 199:115965. [Available at: https://doi.org/10.1016/j.marpolbul.2023.115965]).*

Fin Whales React to Mid-Frequency Military Sonar

Behavioural changes were detected in 33% of fin whales during controlled exposure experiments using mid-frequency active sonar. The whales' responses were described as "mild to moderate" and included diving deeper and longer, with steeper ascent angles and more lunges associated with increasing received sound levels. Sixty-three percent of blue whales in a similar study demonstrated reactions to military sonar; fin whales may have experienced some habituation to the sounds, because they had previously had multiple exposures to military sonar in the area.

> *(SOURCE: Southall, B. L., Allen, A. N., Calambokidis, J. et al., 2023. Behavioural responses of fin whales to military mid-frequency active sonar. R. Soc. Open Sci. 10:231775. [Available at: https://doi.org/10.1098/rsos.231775]).*

Operating Windfarms Could Have an Impact on Mysticetes

Despite research on the impacts of constructing offshore windfarms on cetaceans, there has been little research on the impacts of the sounds turbines produce post-construction, during operation. A model of the potential effects on

cetaceans of 24-hour noise exposure from a 20MW turbine predicted a permanent threshold shift within 50m of the source or a temporary threshold shift out to at least 700m for low frequency-specialist cetaceans (e.g. mysticetes). The impact areas from single turbines could overlap and the entire windfarm could have a cumulative impact. Field observations and additional modelling are required to test these potential impacts.

SOURCE: Thomsen, F., Stöber, U., Sarnocińska-Kot, J., 2023. Hearing impact on marine mammals due to underwater sound from future wind farms. In: A. N. Popper, J. Sisneros, A. D. Hawkins, F. Thomsen (Eds.), The Effects of Noise on Aquatic Life (pp. 1-7). Springer. [Available at: https://doi.org/10.1007/978-3-031-10417-6_163-1].

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Appendix 1

GLOSSARY

Glossary of terms

ACCOBAMS: Agreement on the Conservation of Cetaceans of the Black Sea, Mediterranean Sea and contiguous Atlantic Area.

AIS: Automatic Information System, a system for tracking certain classes of ocean-going vessels.

AMOC: Atlantic Meridional Overturning Circulation, an ocean current that circulates water within the Atlantic Ocean. The circulating current brings warm water near the surface from the tropics to the poles (e.g. via the Gulf Stream in the North Atlantic), where it cools and forms sea ice. As the water turns into ice, salt is left behind in the remaining ocean water which then becomes denser. The dense, salty water sinks and moves southward in a slow current along the bottom of the ocean. Eventually, the water is forced back up toward the surface in a process called upwelling, completing the cycle. This circulation brings warmth to various parts of the globe and also carries nutrients necessary to sustain ocean life.

Anoxia (anoxic): Dissolved oxygen levels of zero.

Anthropogenic: Of human origin.

ASCOBANS: Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas.

Benthic: Of, relating to or occurring at the bottom of a body of water, such as the ocean.

Bioaccumulate: To increase the concentration of a pollutant within an organism compared to background levels in its diet.

Bioindicator: A living organism, such as a plant, plankton, animal or microbe, that is utilised to screen the health of an ecosystem.

Biomagnify: To increase the concentration of a contaminant from one link in a food chain to another. Pollutant levels are highest in top predators.

Bisphenol: A widely-used group of chemicals found in, *inter alia*, food and beverage can linings, thermal paper and polycarbonate plastic, as well as epoxy resins.

BPA: 4,4'-dihydroxy-2,2-diphenylpropane, used to make hard plastics (also known as bisphenol A).

BPE: Bis(4-hydroxyphenyl)ethane, a bisphenol.

BPFL: 4,4'-(9-fluorenylidene) diphenol, a bisphenol.

BPZ: 4,4-(cyclohexane-1,1-diyl) diphenol, a bisphenol.

Cephalopod: Member of the octopus and squid family of molluscs.

Congeneric: Belong to the same genus.

CO_2: Carbon dioxide.

Cryosphere: Wherever water is in solid form (snow or ice), e.g. the poles.

dB: Decibel - a logarithmic measure of sound pressure level.

DDT: The organochlorine pesticide dichlorodiphenyltrichloroethane, which tends to accumulate in the ecosystem and in the blubber and certain internal organs of cetaceans.

Dechloranes: 'Dechlorane' may refer to an obsolete insecticide or a flame retardant.

Demersal: Living in the water body just above the sea floor (see also pelagic).

Depredation: The partial or complete removal of fish from fishing gear by a non-target species.

Dermatitis: Swelling or irritation of the skin, including rashes.

DBDPE: Decabromodiphenyl ethane, used as a flame retardant.

Dw: Dry weight, a basis of measurement whereby concentration of a substance is determined when a material is dried to remove water.

Elasmobranch: Fish whose skeleton is composed of cartilage rather than bone, i.e. shark, skate or ray.

El Niño: A weather phenomenon in the Pacific Ocean, where trade winds weaken and warm water is pushed back toward the west coast of the Americas.

Endemic (endemism): Native and restricted to a certain place.

Endocrine disruption: When an outside substance (chemical) interferes with an organism's endocrine system.

Endocrine system: A system of ductless glands producing hormones that control and moderate metabolic processes in the body.

Eutrophication: Input of nutrients into an aquatic system, typically associated with excessive plant growth and oxygen depletion.

FAO: Food and Agriculture Organisation (of the United Nations).

Fluoranthene: A carcinogenic, high molecular weight PAH, found in coal tar.

Foraminifera: Single-celled organisms, characterized by streaming granular ectoplasm for catching food and other uses and often an external shell of diverse forms and materials.

FOSA: Perfluorooctanesulfonamide, a PFAS, used as an ingredient in furniture protection chemicals until 2003, and also to repel grease and water in food packaging, along with other consumer applications.

Gt: A gigatonne or 1,000,000,000,000kg.

Gyre: Large system of rotating ocean currents.

HBB: Hexabromobenzene, an industrial chemical.

HCB: Hexachlorobenzene, a chlorinated pesticide.

Hypoxia (hypoxic): Low levels of dissolved oxygen.

Hz: Hertz, a measure of sound frequency (pitch), in wave cycles per second (kHz=1000 Hz).

IMMA: Important Marine Mammal Area.

IMO: International Maritime Organisation.

IPCC: Intergovernmental Panel on Climate Change.

IUCN: International Union for Conservation of Nature.

Lw: lipid weight, a basis of measurement whereby concentration of a substance is compared to the lipid (fat) content of a material.

Macroplastics: Plastic pieces >5mm in diameter.

Marine heatwave: A period of unusually high ocean temperatures, defined by its duration and intensity.

Marine snow (mucilage): Small shapeless aggregates (e.g. of dead animal and plant material, sand, faecal matter, soot and other inorganic matter) present in all oceans of the world. When marine snow coalesces to form large aggregates, which warming waters may encourage, they become mucilage and can serve as ephemeral and extreme habitat for marine organisms. Mucilage is also known as 'sea snot'.

MeO-PBDE: Methoxylated polybrominated diphenyl ethers. See PBDE.

Mercuriferous belt: A region of high mercury concentration, from natural and anthropogenic sources.

Mesoplastics: Macroplastics that are >5mm and <10mm in size.

Methoxychlor: A manufactured chemical, not found in nature, used as an insecticide.

$\mu g.g^{-1}$: Microgram per gram.

µm: Micrometre.

Microplastics: Plastic particles 0.3–5mm in diameter, often the result of larger plastic pieces breaking down over time.

MPA: Marine Protected Area.

Mucilage: See marine snow.

Mutagenic: Causing DNA mutations.

MW: Megawatt

Mysticete: Baleen whale.

Naphthalene: A carcinogenic, low molecular weight PAH, used in mothballs.

Neuron necrosis: A condition where neurons have died in an organism's brain.

$Ng.g^{-1}$: Nanogram per gram.

Ocean acidification: A reduction in the pH of the ocean over an extended period of time, caused primarily by uptake of CO_2 from the atmosphere.

OC: Organochlorine compounds.

Odontocete: Toothed whale.

Oedema: Swelling caused by too much fluid trapped in the body's tissues.

OPFR: Organophosphorus flame retardants.

Osmoregulation: A process that regulates the osmotic pressure of fluids and electrolytic balance in organisms.

PAH: Polycyclic aromatic hydrocarbon, a class of chemicals that occur naturally in coal, crude oil and petrol.

PBDE: Polybrominated diphenyl ethers, used as flame retardants.

PCB: Polychlorinated biphenyls (209 different forms containing differing numbers of chlorine atoms arranged in various positions on the aromatic rings) are industrial organochlorines manufactured for use in electrical transformers and other applications. These man-made chemicals do not occur naturally and all traces reflect pollution.

PCDE: Polychlorinated diphenyl ethers, used as flame retardants.

PCR: Polymerase chain reaction, a method for making many copies of small sections of genetic material.

PCT: Polychlorinated terphenyl, an industrial chemical whose use has largely been phased out.

Pelagic: Living in the open water (see also demersal).

PET: Polyethylene terephthalate, a durable plastic used for many purposes, including containers for foods and liquids.

PFAS: Per- and polyfluoroalkyl substances, which have many manufacturing and industrial applications because they are fire resistant and repel oil, stains, grease and water.

PFCA: Perfluorocarboxylic acid, a PFAS, used, *inter alia,* in the making of Teflon.

PFDA: Perfluorodecanoic acid, a PFAS.

PFDoA: Perfluorododecanoic acid, a PFAS.

PFHxS: Perfluorohexanesulphonic acid, a PFAS.

PFNA: Perfluorononanoic acid, a PFAS.

PFOS: Perfluorooctanesulfonic acid, a PFAS, used in the making of furniture protection chemicals (see FOSA).

PFSA: Perfluoroalkyl sulfonate, a PFAs, with several industrial uses.

PFTrDA: Perfluorotridecanoic acid, a PFAS.

PFUnDA: Perfluoroundecanoic acid, a PFAS.

$PM_{2.5:}$ Particulate matter with a size smaller than 2.5µm.

POPs: Persistent organic pollutants, organic compounds that are resistant to degradation and thus persist in the environment.

ppm: Parts per million.

Protozoa: Single-celled organisms.

PVC: Polyvinyl chloride, a type of hard plastic often used in pipe manufacturing.

Ro-Ro: Roll-on, roll-off (used in the context of vehicle-carrying ferries).

ROV: Remotely Operated Vehicle

SAR: Synthetic Aperture Radar (satellite images).

Shifting baseline syndrome: A socio-psychological phenomenon in which changes to the environment do not register and therefore pre-exploitation/natural states are not recognised.

Teleost: Ray-finned fishes (making up 96% of all species of fish).

Teratogenic: Causing developmental abnormalities in a foetus.

Thermophilic: Of, or relating to, an organism living in a high temperature environment.

Toxic equivalent: A calculation designed to predict the toxicity of certain POPs relative to the most toxic form of dioxin.

Trophic: Related to feeding, used in ecology to indicate food web positions or levels (e.g. plant, herbivore, carnivore).

W: Watt.

Ww: Wet weight, a basis of measurement whereby concentration of a substance is determined when a material is not dried to remove water.

Xenobalanus spp.: Parasitic crustaceans (barnacles) seen on the appendages (and occasionally the teeth) of cetaceans.

Species glossary

Black Sea bottlenose dolphins	*Tursiops truncatus ponticus*	Sperm whale	*Physeter macrocephalus*
Black Sea harbour porpoise	*Phocoena phocoena relicta*	Striped dolphin	*Stenella coeruleoalba*
Blainville's beaked whale	*Mesoplodon densirostris*	Albacore tuna	*Thunnus alalunga*
Blue whale	*Balaenoptera musculus*	Black Sea turbot	*Scophthalmus maeoticus*
Common bottlenose dolphin	*Tursiops truncatus*	European sea bass	*Dicentrarchus labrax*
Cuvier's beaked whale	*Ziphius cavirostris*	Grenadier hollow snout	*Coelorhynchus coelorhynchus*
False killer whale	*Pseudorca crassidens*	Lionfish	*Pterois miles*
Fin whale	*Balaenoptera physalus*	Mediterranean slimehead	*Hoplosthethus mediterraneus*
Harbour porpoise	*Phocoena phocoena*	Red mullet	*Mullus barbatus*
Humpback whale	*Megaptera novaeangliae*	Sea bream	*Sparus aurata*
Killer whale	*Orcinus orca*	Shortnose greeneye	*Chlorophthalmus agassizi*
Long-finned pilot whale	*Globicephala melas*	Swordfish	*Xiphias gladius*
Risso's dolphin	*Grampus griseus*	Krill	Family *Euphausiidae* (euphausiids)
Rough-toothed dolphin	*Steno bredanensis*	Parasitic copepod	*Pennella balaenopterae*
Short-beaked common dolphin	*Delphinus delphis*	Green alga	*Caulerpa cylindracea*
Short-finned pilot whale	*Globicephala macrorhynchus*	Hepatitis E virus	*Paslahepevirus balayani*

Trace elements

Ag	Silver		
Al	Aluminium	Mn	Manganese
As	Arsenic	Mo	Molybdenum
Be	Beryllium	Ni	Nickel
Bi	Bismuth	Pb	Lead
Cd	Cadmium	Rb	Rubidium
Co	Cobalt	Se	Selenium
Cr	Chromium	Sn	Tin
Cu	Copper	Tl	Thallium
Fe	Iron	V	Vanadium
Hg	Mercury	Zn	Zinc