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DATA DESCRIPTOR

An integrated multi-source dataset of elasmobranchs in the Red Sea following the Red Sea Decade Expedition

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Red Sea elasmobranch populations are facing alarming declines. Effective conservation efforts require management strategies informed by extensive datasets and by developing an understanding of distribution patterns within the basin, which is currently lacking. This study introduces CERSE (Central and Eastern Red Sea Elasmobranchs), a comprehensive compilation of elasmobranch observations in the central and eastern Red Sea basin following the route of the Red Sea Decade Expedition. The data set was curated from surveys conducted during two scientific cruises, a time-series survey within Red Sea Global project areas (Tabuk province), and observations extracted from peer-reviewed literature. Through the use of diverse methodologies, we provide a holistic view of elasmobranchs distribution in the region, for a total of 2,847 sightings recorded. By consolidating dispersed information from across the region, this dataset forms a comprehensive foundation for future research and monitoring endeavors focused on elasmobranch fauna, and will serve as a cornerstone for informing targeted conservation initiatives aimed at safeguarding endangered elasmobranch species in this region.

Background & Summary

Global elasmobranch populations face severe threats mainly from overfishing and unregulated fisheries, leading to demographic changes and reduced abundance^{1–3}. Sharks and rays, as keystone species, play a pivotal role in maintaining the health and balance of marine ecosystems, sustain many global fisheries^{4,5}, and provide economic benefits such as ecotourism activities^{6–9}. The decline of elasmobranch populations poses significant repercussions for marine ecosystems, impacting not only the intricate web of ocean life but also posing a threat to humans relying on these resources.

The Red Sea, known as a biodiversity hotspot, is highlighted as a critical risk area for these species. It hosts an array of different habitats, including mangroves, seagrass beds, salt marshes, and extensive geophysically diverse coral reefs along its coastlines and beyond¹⁰. Its uniqueness is further underscored by the pronounced latitudinal gradients in temperature, salinity, and nutrient levels from North to South^{11–13}, significantly influencing the local fauna and flora^{14–16}. However, this area is affected by chronic overfishing and illegal fishing activities persisting well after the Saudi Arabia's 2008 shark-fishing ban, leading to declines in local abundances^{17,18}. Moreover, data

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on Red Sea sharks and rays remain scattered, lacking cohesion with limited information available for most species.

There is, therefore, an urgent need for an extensive dataset encompassing observations across wide spatial and temporal scales to inform future management strategies, that is accessible to science and policy-makers in a comprehensive repository. These data are indispensable for identifying focal points of elasmobranch abundance and distribution patterns, laying the groundwork for subsequent studies and ongoing monitoring efforts within the region. Effective protection measures depend on understanding the conservation status of target species from both ecological and distributional perspectives. Integrating diverse data sources and survey methods is essential for monitoring elasmobranch status and ensuring successful strategies to aid the recovery of threatened populations^{19–21}, aligning with the Saudi Arabian Vision 2030²² and, on a broader scale, with the scope of the Kunming-Montreal Global Biodiversity Framework's Goal A, Goal B, Target 4 and 5.

We present elasmobranch sighting data from two scientific cruises in the central and eastern Red Sea, a time-series survey at the Red Sea Project area (Tabuk Province, Saudi Arabia), and a comprehensive review of published literature. Out of the total, 49% of our dataset is derived from literature records. The dataset spans the entire route of the Red Sea Decade Expedition—the most extensive marine research cruise conducted to date along the eastern Red Sea.

The information reported was gathered through different survey approaches, spanning from aerial to manned submersible surveys, and represents the current state of knowledge on elasmobranch observations from the central and eastern Red Sea.

Political and national borders often pose significant challenges to the scientific community to integrate data at the basin level. This is the case also for research on elasmobranchs, which frequently cross exclusive economic boundaries. In the Red Sea, the western sector remains understudied. In the case of elasmobranchs, we are only aware of 4 studies that would have the requirements to be included in our dataset^{23–26}, and further research efforts are being disrupted by conflict in some of the coastal nations. Hence, it is not yet possible to integrate data at the basin level, provided the huge observational gaps in the western margin of the basin. The data set provided here is intended to lay the groundwork for future collaborative efforts with more nations bordering the Red Sea. There is, however, evidence that elasmobranch populations in the western sector of the Red Sea may be in better status than those reported here for the eastern sector. For instance, shark sighting was a major driver of tourism in Sudanese waters prior to the current civil war²³. We hope that the data set reported here would contribute to encourage collaboration whenever the conditions allow to deploy collaborative research efforts. Indeed, the Regional Organization for the Conservation of the Environment of the Red Sea and Gulf of Aden (PERSGA) was created with the aim of improving collaboration toward a shared stewardship of the Red Sea and coordinate research efforts focused on marine conservation. The current study provides valuable insight, yet the inclusion of novel data from surrounding areas would significantly enhance our understanding of the broader Red Sea region. Furthermore, establishing a more extensive dataset would lay the groundwork for long-term monitoring efforts, more robust regional assessments and enable better prediction models. As this project evolves, collaborations with other research initiatives and institutions could play a crucial role in ensuring that future datasets are both comprehensive and standardized, facilitating comparative studies across different ecosystems and geographical settings. Ultimately, this broader approach aligns with the growing recognition of the need for large-scale, integrative datasets to address complex environmental challenges effectively.

Methods

Red Sea Decade Expedition: study area and duration of the cruise. Observations of elasmobranchs were gathered during the Red Sea Decade Expedition (RSDE) from February to June 2022. The cruise was divided into four separate legs, which covered the entire eastern Red Sea coast of Saudi Arabia. Two vessels, R/V OceanXplorer (OceanX) and R/V Al Azizi, were each being used to explore deep and shallow waters of the Saudi Red Sea: R/V OceanXplorer surveyed deeper waters, while R/V Al Azizi focused on shallow coastal domains (<30 m). Each leg was further divided into three sections: Phase 1 covered deep stations (from 500 m to the limit of the Exclusive Economic Zone), Phase 2 covered shallower stations (from 500 to 10 m), and a Discovery Phase dedicated to exploring specific seafloor features (e.g., brine pools). Manned submersibles and helicopters were deployed only during Phase 2 and the Discovery phases of the RSDE.

RSDE ROV & submersible surveys. R/V OceanXplorer was equipped with deep-sea vehicles, including a remotely operated vehicle (ROV) Chimera (Argus Mariner XL model) featuring 360-degree benthic cameras, as well as two Triton manned submersibles, Neptune (designed for scientific sampling operations) and Nadir (designed for media operations). Cameras and media equipment on the media submersible and ROV are listed in details in Table 1, while the scientific submersible was equipped only with Mini Cam Arctic Rays EagleRay 4 K. The duration of ROV and submersible dives were limited by weather and sea conditions, with an average duration of 5.3 hours per dive.

The ROV was outfitted with RBRmaestro³ CTD profilers (RBR), each featuring an RBRduo³ sensor measuring conductivity and temperature, an RBR Oxyguard sensor for measuring oxygen, and an RBR depth (pressure) sensor. The CTD underwent factory calibration prior to each expedition at the RBR laboratory. Footage and video clips of elasmobranch sighting were recorded and stored in an external hard drive (Western Digital, 2TB). Depth (m), time (UTC), habitat type, oxygen concentration (mg L⁻¹), temperature (C°), salinity (PSU) and coordinates of sighting were recorded for each observation.

ROV Chimera	• HDTV 1080p F/Z Colour camera • Imenco Night Shark Lowlight BW camera • DSPL Super wide-angle CCD camera • Imenco Silvertip CCD camera with LED • Imenco Greypip CCD utility camera • Mini Cam Arctic Rays EagleRay 4 K, Blackmagic design micro studio 4 K sensor, Blackmagic design micro studio 4 K sensor, Olympus M. Zuiko 12–50 mm f/3.5– 6.3 lenses
Triton submersible Nadir	• Benthic camera (Red DSMC2 Monstro 8k) Wide Angle (Canon CN-E 15.5–47 mm lens, Zacuto Gratical HD electronic view finder) • Benthic camera (Red DSMC2 Monstro 8k) Macro camera (Nikon 70–180 mm f/4.5–5.6 AF-D). • Low-light camera was mounted (Canon ME20F-SH 1080 P, Canon EF 50 mm 1:1.2 L USM, Zacuto Gratical HD electronic view finder) • Mini Cam (Arctic Rays EagleRay 4 K, Blackmagic design micro studio 4 K sensor, Olympus M. Zuiko 12–50 mm f/3.5– 6.3 lens).

Table 1. Specifics on the media equipment mounted on the ROV and media submarine.

RSDE drop cameras. To obtain video data, we deployed customized deep baited remote underwater lander systems (dBRUV^{27,28}) to record mobile teleost and elasmobranch fishes in deep waters along the Saudi Arabian coast, across water depths ranging from 376 m to 1,500 m, totalling ~33 hours of drop camera deployments. The dBRUV systems consisted of a vertical carbon-fiber frame with pressure-tolerant flotation (G2200, McLane Research Laboratories Inc., East Falmouth, MA, USA) and an acoustic release system (CAT, EdgeTech, MA, USA). On each system, a single GoPro camera (GoPro Hero 5/6/7) was housed within a protective deepwater casing (GoBenthic, GroupB Incorporated, USA) and recorded video footage (1080p – 2.7 K video at 60 frames per second). The camera was attached to the frame ~1.5 m above the bottom of the unit. For each unit, two LED lights were used to illuminate the seafloor (SiteLite, Juice Robotics, Rhode Island, USA), with all electronics powered by a custom lithium-ion battery pack. Approximately 500 g of bait (e.g., skipjack tunas) was placed in a bait cage mounted on a carbon-fiber pole in front of the camera. After 4–7 hours of recording, the acoustic release system was manually triggered to release the drop weight and recover the system. We monitored temperature and depth using a calibrated Starmon TD stand-alone logger (Star Oddi, Iceland) or LAT1400 temperature and depth loggers (LOTEK). A depth-rated radio transmitter (F1845B, Advanced Telemetry Systems, Minnesota, USA) and float equipped with an orange flag were attached to facilitate surface retrieval with a YAGI antenna and VHF radio receiver (R410, Advanced Telemetry Systems, Minnesota, USA). Upon retrieval of the dBRUVs, videos were downloaded from micro-SD cards and reviewed at regular speed, noting elasmobranchs presence and maximum number (MaxN) of individuals observed within a single video frame during the recording, starting from the moment the dBRUV touched the sea bottom until retrieval.

RSDE aerial surveys. R/V OceanXplorer is equipped with an onboard helicopter (Airbus H125). Flights were designed to follow a series of predetermined U-shaped flight plans that spanned along the entire coast of Saudi Arabia. Individual legs were separated by approximately ~3.7 km to avoid double counting individual sightings. A reference marker pole extending from either side of the helicopter allowed for a standardised 400 m belt transect along the flight path. Flights were operated at an altitude of ~200 m at a speed of ~130 km/h, with course and altitude held by autopilot except in instances where observer effort was discontinued to circle back for species identification. Flight durations was typically limited to ~3 h due to fuel limitations. Total flight time for the expedition was 131 hours covering a distance of 6,026 km with transect coverage of 4,248.5 km².

RSDE SCUBA operations. SCUBA diving operations throughout the RSDE were undertaken with 2 main goals, media dives focused on underwater photography and underwater videography, and benthic habitat surveys conducted from the R/V Al Azizi. During the latter, 20 m transects (between 3 and 5 individual surveys per site) were conducted to study coral reefs and seagrass meadows. During dives elasmobranch observations were recorded opportunistically. The dives lasted an average of 45 minutes, reaching a maximum depth of 20 m. When possible, pictures of elasmobranch species were gathered for further analysis and identification (camera models Olympus TG5 and TG6), together with data on the surrounding environment and depth of the observation.

Southern Red Sea Expedition. The Southern Red Sea Expedition (SRSE) was a collaborative scientific cruise undertaken by the Japan Agency for Science and Technology (JAMSTEC) and King Abdullah University of Science and Technology (KAUST). The cruise was part of an integrated project entitled “*Biodiversity and related geological controls of the southern deep Red Sea*”. The cruise took place from 4 to 13 May 2023 onboard the vessel R/V Thuwal, in the southern Saudi Arabian Red Sea. The elasmobranch sightings from these surveys were opportunistic as the ROV was primarily deployed to survey the seafloor and targeted potential hydrothermal vent sites. The ROV survey started from the desired location and moved across a range of several meters to tens of meters from the targeted coordinate. At each station, the video recordings began at the water surface (ROV deployment) and ended when the ROV was retrieved onboard.

The videos were inspected, and the presence and depth of elasmobranchs was recorded. A sighting was defined as the observation of an individual in the field of view of the forward-facing ROV camera. A separate CTD deployment was carried out at each station. The CTD was a Seabird SBE-9, equipped with SBE11plus temperature, conductivity and pressure sensor, SBE-43 oxygen sensor, WET Labs ECO AFL/FL fluorometer, WET Labs ECO NTU turbidity meter, PAR sensor and SUNA nitrate sensor.

Study area	Literature reference	Method
Northern Red Sea, Gulf of Aqaba	Goldshmidt <i>et al.</i> ³⁸	Fishing gear
Central Red Sea (Jeddah)	Clarke <i>et al.</i> ³⁹	Acoustic tag
Central Red Sea (Jeddah)	Clarke <i>et al.</i> ⁴⁰	UVC
Central Red Sea (Al Lith/Qunfudah)	Braun <i>et al.</i> ⁴¹	Acoustic and satellite tag
Northern, Central and Southern Red Sea	Spaet <i>et al.</i> ¹⁸	BRUV and Longline
Central Red Sea	Kattan <i>et al.</i> ⁴²	Underwater visual census
Central Red Sea (Thuwal)	Arostegui <i>et al.</i> ⁴³	Satellite tag
Central Red Sea (Thuwal)	McIvor <i>et al.</i> ⁴⁴	UAV and BRUV
Northern Red Sea and Gulf of Aqaba	Garzon <i>et al.</i> ^{21,45}	BRUV, Aerial, Opportunistic, submersible and ROV
Northern Red Sea and Gulf of Aqaba	Williams <i>et al.</i> ⁴⁵	BRUV
Central Red Sea (Al Lith/Qunfudah)	Cochran <i>et al.</i> ⁴⁶	Acoustic and satellite tag
Central Red Sea (Al Lith/Qunfudah)	Berumen <i>et al.</i> ⁴⁷	Satellite tag
Central Red Sea	Spaet <i>et al.</i> ⁴⁸	Satellite tag
Central Red Sea (Suakin Trough, Sudan)	Pearce <i>et al.</i> ⁴⁹	BRUV

Table 2. Selected literature on diversity and distribution of central and eastern Red Sea elasmobranchs.

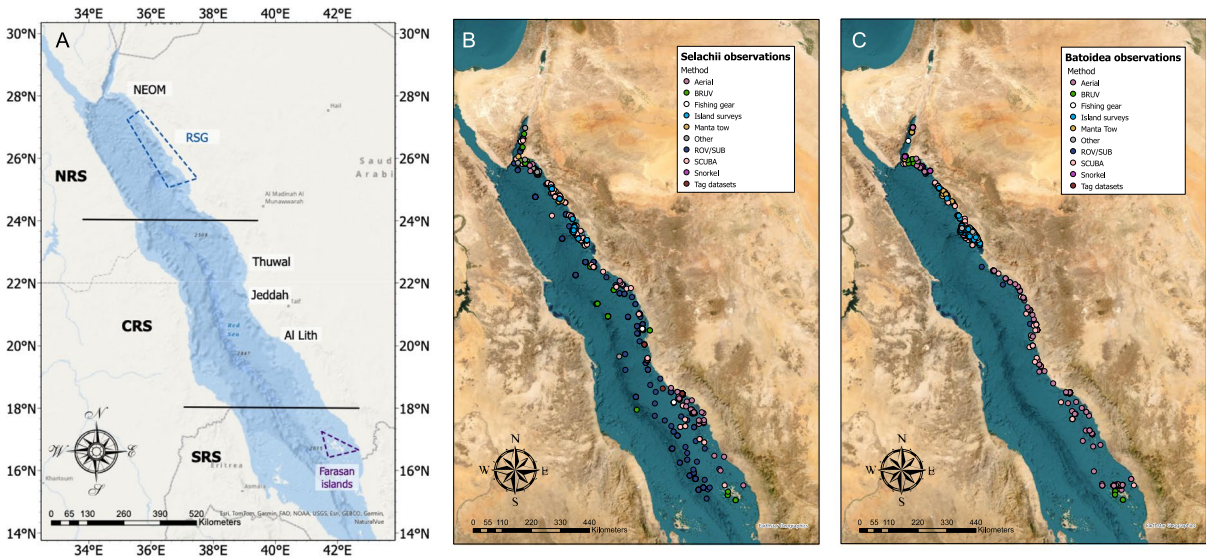


Fig. 1 (A) Principal sites mentioned in the manuscript. NRS (Northern Red Sea), CRS (Central Red Sea), SRS (Southern Red Sea), this division follows the approach proposed by Wang *et al.*⁵⁰. (B) Spatial distribution of Selachii sightings and (C) spatial distribution of Batoidea sightings, with different colors representing various survey methods. Map created using Esri ArcGIS Pro version 2.6.0 (Esri, 2020).

Red Sea Global dataset. The Red Sea Global (RSG) dataset was generated with data gathered during monitoring efforts at project sites under the control of RSG including The Red Sea Project (TRSP) and Amaala, between Umluj and Duba (Tabuk Province, KSA). Different survey methods were used: underwater fish surveys (all sharks and rays observed in the course of fish survey dives, typically of around 40 minutes, on complex reef habitats in 20 m or less), manta tows operations, island surveys (observation of sharks and rays made by teams visiting island for bird or turtle nesting surveys), and opportunistic sightings (observations made at any other time by survey teams, typically traveling between survey sites). The data were collected from November 2020 to November 2022 and include shallow sightings (at the surface) down to 40 m depth.

Published datasets review. Additional data were gathered from a comprehensive literature review performed using Google Scholar (last accession date 10/08/2024). The search retrieved previously published reports of elasmobranch sightings in the eastern and central Red Sea. The search terms used include: elasmobranchs, Red Sea, sharks, Selachii, Batoidea, Saudi Arabia. We selected only papers presenting specific coordinates and depth of sightings. Data related to surveys which did not report the specific location or depth of recordings were excluded from our analysis. We extracted data from 14 published articles (Table 2). Coordinates for *Rhincodon typus* individuals presented in the study by Cochran *et al.* 2019 and Berumen *et al.* 2014 were retrieved from Sharkbook - wildbook for sharks (<https://www.sharkbook.ai>).

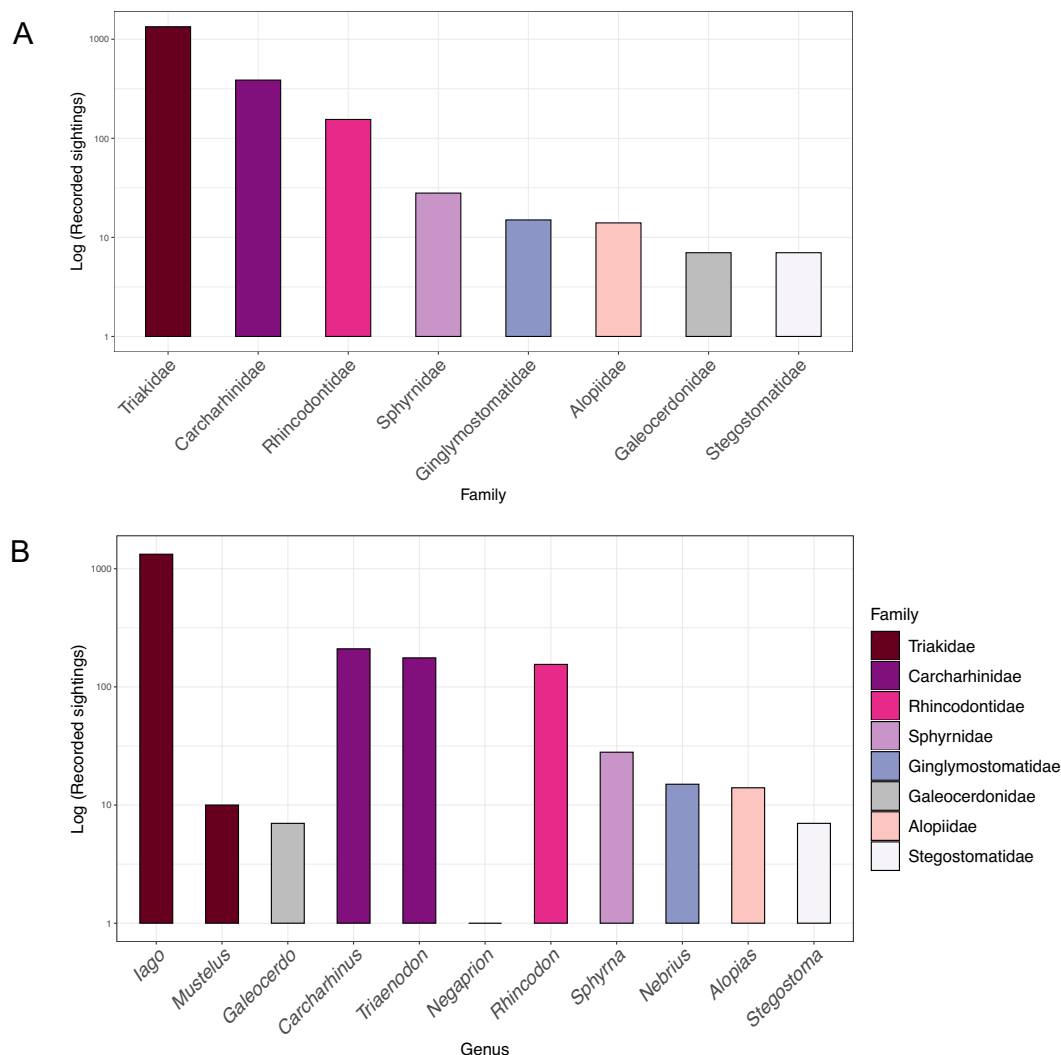


Fig. 2 Taxonomic distribution of Selachii recorded in our dataset across different families (A) and different genera (B).

Figure 1 provides an overview of the principal sites discussed in this manuscript (Fig. 1A), along with maps depicting the spatial distribution of Selachii (Fig. 1B) and Batoidea (Fig. 1C), as recorded using various survey methods.

Traits of the dataset. The dataset includes 2,847 elasmobranch sightings, consisting of 897 batoid records and 1,950 shark records. The Selachii data represent 20 identified species from 11 genera across 8 families (Fig. 2A,B, Table 3). The Batoidea data include observations from 14 genera across 8 families, with 13 species identified (Fig. 3A,B, Table 4). Among Selachii genera within our dataset, *Iago* was the most abundant, with sightings exceeding 1,000 individuals (1,327 in total). Following the genus *Iago*, *Carcharhinus*, *Triaenodon*, and *Rhincodon* were the most abundant, with 210, 176, and 155 individual recordings, respectively. *Sphyrna* encompassed 28 sightings, *Nebrius* 15, *Alopias* 14, *Mustelus* 10, and *Galeocerdo* only 7 sightings, same as *Stegostoma*. *Negaprion* had the lowest numbers, with only 1 record.

Among the Batoidea recordings, *Rhinoptera* exhibited high abundance, due to the presence of a huge aggregation of 125 individuals recorded during helicopter surveys in the southern Red Sea, 16.99279 N, 41.72041 S. The genera *Taeniura*, *Aetobatus*, and *Glaucostegus* recorded 235, 180, and 168 individuals, respectively. *Himantura* accounts for 71 individual sightings, while *Pastinachus* and *Urogymnus* had 42 and 23 sightings, respectively. The genus *Mobula* exhibited 39 sightings in total.

Low numbers of sightings were recorded for the genera *Taeniurops* with 6 observations and *Rhinobatus* with 4 observations. The least abundant genera are *Rhynchobatus*, *Maculabatis*, and *Torpedo*, with only 1 single record each.

In respect to the novel observations not derived from literature, a team of experts conducted the identification of various individuals down to the lowest taxonomic level possible, using species guides and references specific to the Red Sea. The World Register of Marine Species (WoRMS) served as the primary source for taxonomic

Infraclass	Family	Genus	Species
Selachii	Alopiidae	<i>Alopias</i>	<i>Alopias pelagicus</i> Pelagic thresher shark
	Carcharhinidae	<i>Carcharhinus</i>	<i>Carcharhinus albimarginatus</i> Silvertip shark
			<i>Carcharhinus altimus</i> Bignose shark
			<i>Carcharhinus amblyrhynchos</i> Grey reef shark
			<i>Carcharhinus brevipinna</i> Spinner shark
			<i>Carcharhinus falciformis</i> Silky shark
			<i>Carcharhinus longimanus</i> Oceanic whitetip shark
			<i>Carcharhinus melanopterus</i> Blacktip Reef Shark
			<i>Carcharhinus obscurus</i> Dusky shark
			<i>Carcharhinus plumbeus</i> Sandbar shark
			<i>Carcharhinus sorrah</i> Spot-tail shark
		<i>Negaprion</i>	<i>Negaprion acutidens</i> Sickletfin lemon shark
		<i>Triaenodon</i>	<i>Triaenodon obesus</i> Whitetip reef shark
	Galeocerdonidae	<i>Galeocerdo</i>	<i>Galeocerdo cuvier</i> Tiger shark
	Sphyrnidae	<i>Sphyrna</i>	<i>Sphyrna lewini</i> Scalloped hammerhead
	Triakidae	<i>Iago</i>	<i>Iago omanensis</i> Bigeye houndshark
		<i>Mustelus</i>	<i>Mustelus mosis</i> Arabian smooth-hound
	Ginglymostomatidae	<i>Nebrius</i>	<i>Nebrius ferrugineus</i> Tawny nurse shark
	Rhincodontidae	<i>Rhincodon</i>	<i>Rhincodon typus</i> Whale shark
	Stegostomatidae	<i>Stegostoma</i>	<i>Stegostoma tigrinum</i> Zebra shark

Table 3. List of Selachii identified at species level in the CERSE dataset.

classification. Elasmobranch species were visually identified based on key distinguishing features, such as body shape, coloration patterns, and the position and size of fins. Guidebooks and dichotomous keys were consulted throughout this process^{29–33}.

Table 5 summarizes the number of sightings recorded using each survey method. A total of 302 sightings were documented through aerial surveys, with batoids representing the majority. The deployment of Baited Remote Underwater Video Systems (BRUVs and dBRUVs) accounted for 96 sightings, showing a relatively balanced distribution between Selachii and batoids. In contrast, fishing gear mostly reported shark sightings.

Island surveys offered insight into nearshore habitats with 337 encounters, although the effort predominately identified batoids. Manta tow operations contributed 110 sightings, with Selachii and Batoidea accounting for similar numbers. We also included 69 additional elasmobranch sightings referred as “Other”, considering records coming from incidental observations (e.g., boat observations).

ROVs and submersibles registered 257 sightings, primarily of Selachii, with only seven batoids identified. SCUBA operations, encompassing Underwater Visual Census (UVC) and off-transect data, recorded 308 sightings, highlighting its effectiveness in studying both sharks and batoids within their natural habitats. Although limited, snorkeling operations recorded higher batoid presence in shallower waters and few shark observations. Finally, tagging operations yielded 148 sightings, predominantly of sharks.

A total of 293 new observations were recorded from aerial surveys, supplemented by 9 additional observations from the literature. BRUV observations included 22 new RSDE records and 74 from the literature. All 1,194 fishing gear records were sourced exclusively from the literature. Island surveys contributed 336 records from the RSG dataset and 1 from the literature. Manta tow surveys yielded 24 records from the RSG dataset and 86 from the literature. For the “Other” category, 9 records were derived from the literature, while 60 were newly reported. ROV/SUB surveys included 33 records from the literature and 224 newly reported observations. Scuba surveys comprised 59 records from the literature and 249 new reports. All 26 snorkel survey records were sourced from the literature. Lastly, 148 tag dataset records were drawn entirely from the literature.

Data Record

The dataset is publicly accessible in Dryad repository³⁴. The CERSE Dataset provides comprehensive information on all observations gathered from various datasets analyzed in this study. It encompasses taxonomic details at different levels, such as group, family, genus, and species, as well as the depth and coordinates of records, pelagic habitat, survey methods, and environmental factors, when available. Key data fields include the date of recording in the format dd/mm/yy, and the time of sighting in UTC. Species identification is provided at the species level when possible. Latitude and longitude are recorded in decimal degrees (DD), and the water depth of the observation is noted in meters.

The dataset classifies observations as Batoidea (rays) or Selachii (sharks). The specific pelagic zone where each observation was recorded is also detailed, along with the method used to gather the observation. The dataset sources include the Red Sea Decade Expedition (RSDE), Literature (a review of published literature), the Red Sea Global Dataset (RSG, within The Red Sea Project area), and the Southern Red Sea Expedition (SRSE). Habitat specifics describe the characteristics of the habitat where sightings were recorded, although this information is not available for all sightings. Additionally, the dataset provides temperature in degrees Celsius,

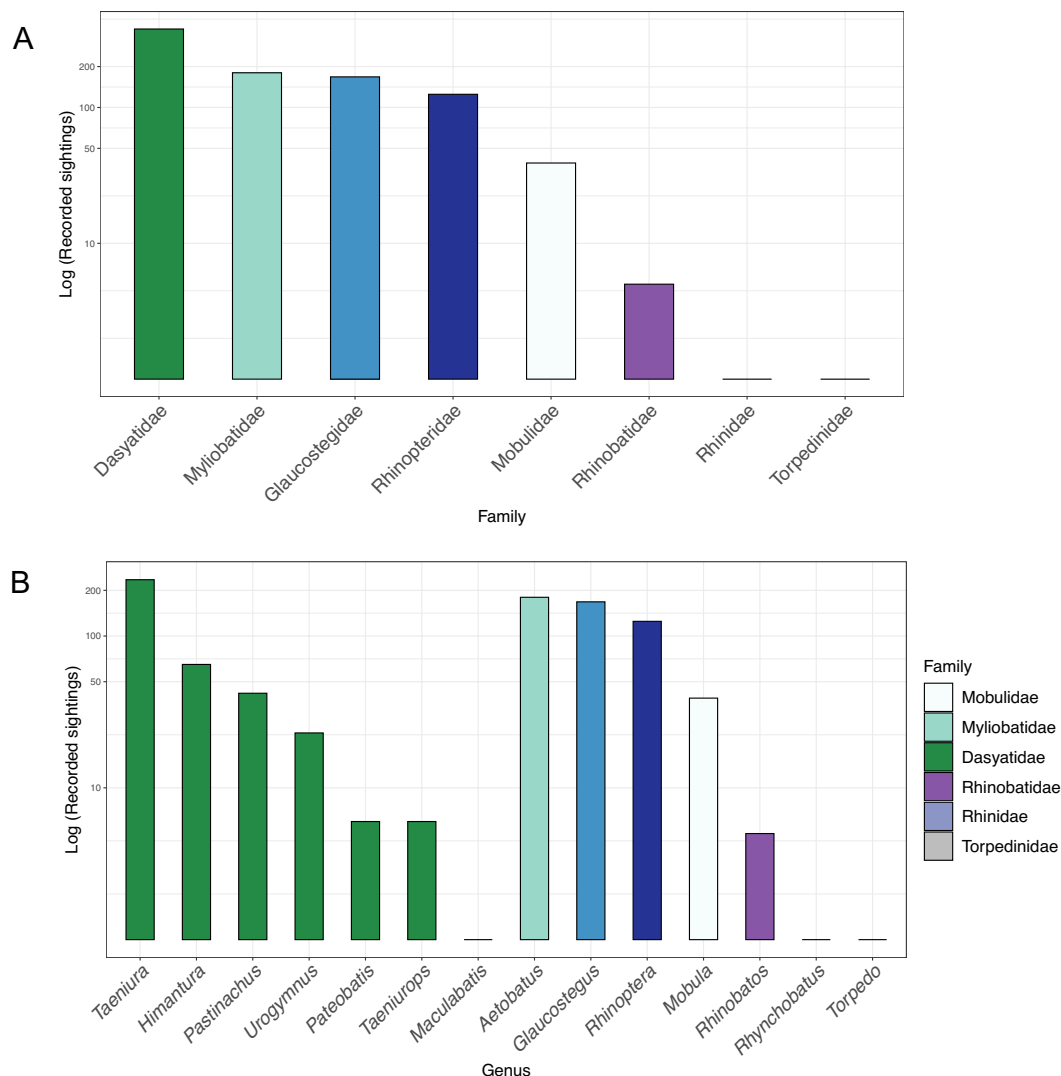


Fig. 3 Taxonomic distribution of Batoidea recorded in our dataset across different families (A) and different genera (B).

salinity in practical salinity units (PSU), and oxygen values in mg L^{-1} at the time and depth of each observation, when available. Finally, the column titled ‘Video Reference’ indicates the name of the video or picture used for identifying the species observed, when available.

Technical Validation

Identification of Elasmobranchs. The nomenclature source used for taxonomic assignment is WoRMS (World Register of Marine Species <https://www.marinespecies.org/>). Sightings, photos and videos collected from all survey methods during the RSDE and SRSE, as well as from RSG area, were reviewed in the same manner.

Visual identification of elasmobranch species was conducted using distinguishing characters, such as body shape, coloration/patterns, as well as the position and size of fins. Guide books and dichotomous keys were referenced in all instances^{29–32}. For sharks of the genus *Carcharhinus* we also followed Identification guidelines from Voigt and Weber³³.

Oxygen data. Throughout the campaign, discrete water samples were taken at various depths ($N = 110$, from 42.8 – 2,268.7 m water depth) to verify dissolved oxygen concentrations measured by the RBR Oxygaurd sensor, according to ref. ³⁵. Seawater was syphoned from the Niskin bottles using a sterilized drawing tube into 120 mL borosilicate flasks with glass stoppers, which were pre-calibrated for volume. The seawater was overflowed at least two volume equivalents (i.e., >240 mL), sealed, and fixed with 1 mL Manganese sulfate monohydrate ($\text{H}_2\text{MnO}_5\text{S}$) and 1 mL sodium hydroxide (NaOH)/sodium iodide (NaI) solution before being stored at 21 °C in darkness for at least 2 hours. After two hours, 1 mL sulfuric acid (H_2SO_4 , 10 N) was added and the measurements were performed using sodium thiosulfate ($\text{Na}_2\text{S}_2\text{O}_3$) with a T50 Titrator (Mettler Toledo) configured with an InMotion Pro autosampler (Mettler Toledo; after^{36,37}).

Infraclass	Family	Genus	Species
Batoidea	Aetobatidae	Aetobatus	<i>Aetobatus ocellatus</i> Ocellated eagle ray
	Glaucostegidae	Glaucostegus	<i>Glaucostegus halavi</i> Halavi guitarfish
	Dasyatidae	Himantura	<i>Himantura uarnak</i> Honeycomb stingray
		Maculabatis	<i>Maculabatis ambigua</i> Baraka's whipray
		Pastinachus	<i>Pastinachus sephen</i> Cowtail stingray
		Pateobatis	<i>Pateobatis fai</i> Pink whipray
		Taeniura	<i>Taeniura lymma</i> Bluespotted ribbontail ray
		Taeniurops	<i>Taeniurops meyeri</i> Round ribbontail ray
		Urogymnus	<i>Urogymnus granulatus</i> Mangrove whipray
	Mobulidae	Mobula	<i>Mobula alfredi</i> Reef manta ray
			<i>Mobula birostris</i> Giant oceanic manta ray
	Rhinobatidae	Rhinobatos	<i>Rhinobatos punctifer</i> Spotted guitarfish
	Torpedinidae	Torpedo	<i>Torpedo panthera</i> Panther electric ray

Table 4. List of Batoidea identified at species level in the CERSE dataset.

Method	Selachii	Batoidea	Tot. observations
Aerial surveys	42	260	302
BRUV	57	39	96
Fishing gear	1,193	1	1,194
Island surveys	46	291	337
Manta tow	64	46	110
Other*	13	56	69
ROV/SUB	250	7	257
SCUBA	151	157	308
Snorkel	4	22	26
Tag datasets	130	18	148
Total sightings per group	1,950	897	2,847

Table 5. Count of Batoidea and Selachii observations across the different methodologies used. *Other refers to incidental observations (e.g., boat observations).

The data from the RBR Oxygaurd sensor and Winkler titrations showed high agreement ($R^2 = 0.975$), but with a negative offset of -16.03 , -24.82 , -33.61 , and $-38.48 \mu\text{mol O}_2 \text{ L}^{-1}$ for legs 1 – 4 in the RBR Oxygaurd measurements, respectively. Acknowledging this apparent sensor drift, we elected to align the RBR Oxygaurd with the calculated average offset for each leg. After the corrections were applied, the RBR Oxygaurd and Winkler titrations showed higher agreement with an $R^2 > 0.982$. Data were processed using ‘respirometry’ package in R (R version 4.3.2 2023-10-31).

Code availability

The authors declare that no custom code was used to generate or process the data described in the manuscript.

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Author contributions

S.F., I.A.C., A.K., C.W., R.H., S.H., L.S., A.G., T.B., O.S., M.R., S.G.K., S.A. collected the data used in this study. Data analysis and visualization performed by S.F., S.K., I.A.C., A.K., A.S., O.F.D., S.A. S.F. and C.M.D. conceptualized and structured the study. C.M.D. supervised the project. S.F. prepared the first draft of the manuscript, with contributions from C.M.D. The draft was reviewed by all authors. Resources and Founding acquisition: C.M.D., M.A.Q., V.P., B.J. M.A.Q., V.P. and C.M.D. designed the R.S.D.E. expedition.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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