Class I. Data set descriptors

A. Data set identity

Trophic markers and biometric measurements in Southern Ocean sea stars (1985–2017)

B. Data set identification code

SouthernOcean_SeaStars_TrophicBiometric_1985-2017.csv

C. Data set description

Originators

Moreau, Camille

Marine Biology Lab, Université Libre de Bruxelles (ULB), 1050 Brussels, Belgium.

Le Bourg, Baptiste

Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, 4000 Liège, Belgium.

Balazy, Piotr

Institute of Oceanology, Polish Academy of Sciences (IOPAN), 81-712 Sopot, Poland.

Danis, Bruno

Marine Biology Lab, Université Libre de Bruxelles (ULB), 1050 Brussels, Belgium.

Eléaume, Marc

Institut de Systématique, Evolution, Biodiversité (ISYEB), Muséum national d'Histoire naturelle (MNHN), CNRS, Sorbonne Université, EPHE, 75005 Paris, France.

Jossart, Quentin

Marine Biology, Vrije Universiteit Brussel (VUB), 1050 Brussels, Belgium.

Marine Biology Lab, Université Libre de Bruxelles (ULB), 1050 Brussels, Belgium.

Kuklinski, Piotr

Institute of Oceanology, Polish Academy of Sciences (IOPAN), 81-712 Sopot, Poland.

Lepoint, Gilles

Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, 4000 Liège, Belgium.

Saucède, Thomas

Biogéosciences, UMR CNRS 6282, Université Bourgogne Franche-Comté, 21000 Dijon, France.

Van de Putte, Anton
Marine Biology Lab, Université Libre de Bruxelles (ULB), 1050 Brussels, Belgium.
OD Nature, Royal Belgian Institute of Natural Sciences, 1000 Brussels, Belgium.

Michel, Loïc N.
Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, 4000 Liège, Belgium.
Ifremer, Centre de Bretagne, REM/EEP, Laboratoire Environnement Profond, 29280 Plouzané, France.

Abstract

Sea stars (Echinodermata: Asteroidea) are a key component of Southern Ocean benthos, with 16% of the known sea star species living there. In temperate marine environments, sea stars commonly play an important role in food webs, acting as keystone species. However, trophic ecology and functional role of Southern Ocean sea stars are still poorly known, notably due to the scarcity of large-scale studies. Here, we report 24332 trophic marker (stable isotopes and elemental contents of C, N and S of tegument and/or tube feet) and biometric (arm length, disk radius, arm to disk ratio) measurements in 2456 specimens of sea stars. Samples were collected between 12/01/1985 and 08/10/2017 in numerous locations along the Antarctic littoral and Subantarctic islands. The spatial scope of the dataset covers a significant portion of the Southern Ocean (Latitude: 47.717° South to 86.273° South ; longitude: 127.767° West to 162.201° East ; depth: 6 to 5338 m). The dataset contains 133 distinct taxa, including 72 currently accepted species spanning 51 genera, 20 families and multiple feeding guilds / functional groups (suspension feeders, sediment feeders, omnivores, predators of mobile or sessile prey). For 505 specimens, mitochondrial CO1 genes were sequenced to confirm and/or refine taxonomic identifications, and those sequences are already publicly available through the Barcode of Life Data System. This number will grow in the future, as molecular analyses are still in progress. Overall, thanks to its large taxonomic, spatial, and temporal extent, as well as its integrative nature (combining genetic, morphological and ecological data), this dataset can be of wide interest to Southern Ocean ecologists, invertebrate zoologists, benthic ecologists, and environmental managers dealing with associated areas. Please cite this data paper in research products derived from the dataset, which is freely available without copyright restrictions.

D. Key words

Antarctica, Asteroidea, benthos, biometric measurements, Echinodermata, elemental contents, invertebrates, marine ecosystems, sea stars, Southern Ocean, stable isotopes, Subantarctic Islands.

Class II. Research origin descriptors

A. Overall project description

1. Identity

Trophic ecology of Southern Ocean sea stars: Influence of environmental drivers on trophic diversity.

2. Originators

Le Bourg, Baptiste

Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, 4000 Liège, Belgium.

Lepoint, Gilles

Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, 4000 Liège, Belgium.

Michel, Loïc N.

Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, 4000 Liège, Belgium.

Ifremer, Centre de Bretagne, REM/EEP, Laboratoire Environnement Profond, 29280 Plouzané, France.

3. Period of study

Samples were collected between 12/01/1985 and 08/10/2017. Subsequent work (sample preparation and analysis) was performed between 01/10/2015 and 01/07/2020.

4. Objectives

Sea stars are a key component of Southern Ocean benthos and are considered to be resistant to changes in seawater temperature. However, they will likely be affected by changes of other environmental conditions and food web structure. Indeed, a reduction in the abundance or disappearance of common prey can lead to an increased competition in sea star assemblages. In order to determine the ecological role of sea stars in the Southern Ocean and to understand how they might be impacted by climate change, a study of their trophic ecology and its drivers is necessary. Therefore, the objectives of this project were to determine the trophic role of sea stars in the Southern Ocean, and how environmental factors such as turbidity, depth and sea ice cover impact their trophic diversity and plasticity.

5. Abstract

Sea stars (Echinodermata: Asteroidea) are a key component of Southern Ocean benthos, with 16% of the known sea star species living there. In temperate environments, this class plays an important role in ecosystem functioning, as they exert top-down control on the populations of other organisms, which themselves have a large effect on the ecosystems. While Antarctic sea stars are typically considered quite resistant to changes in seawater temperature, they are likely to be influenced by future ecosystem changes, e.g. through resource availability modifications. In this context, this project aimed to unravel links between environmental factors and sea stars feeding habits in Antarctic and Subantarctic regions. To do so, stable isotope values of carbon ($\delta^{13}C$), nitrogen ($\delta^{15}N$) and sulfur ($\delta^{34}S$) were analyzed in tissues of sea star sampled across the Southern Ocean (n = 2456 individuals). A significant proportion of the sea star samples came from collections archived in research institutes and/or museums, which significantly increased the spatial and temporal coverage of the study.

Isotopic niches (i.e. a proxy of ecological niches) of sea stars were compared at a local scale, and the possible relationship between ontogenetic changes, i.e. changes during growth, and trophic ecology were studied (Le Bourg et al. 2021). The analysis of stable isotope values in sea stars sampled during the 35th expedition to Arctowski Station in Ezcurra Inlet (Admiralty Bay, King George Island, South Shetland Islands) showed that the size, and especially the central disc radius, can be linked to stable isotope values in some species, indicating the occurrence of ontogenetic diet shifts. This was observed only in some species, and notably omnivore species, for which the trophic position increased with body size. The relationship between the disc radius and the trophic ecology may be explained by larger sea stars being able to evert their stomach over larger areas and thus consume larger prey and/or prey with higher trophic level. For sediment feeding and potentially suspension feeding species, no clear correlation between size and stable isotope values was observed, suggesting lower variability of the trophic ecology between size classes in these species. The analysis of stable isotope values in sea stars sampled in Ezcurra Inlet also indicates that the diet variability of some sea star species may be important, which in part determines their interspecific trophic interactions. The turbidity generated by the terrestrial inputs provided by meltwater run-off from terrestrial glaciers results in an important environmental gradient from the inner to the outer Ezcurra Inlet, which determines the habitat conditions and the characteristics of the resources available for sea stars. Some species may adapt their diet depending on those variable conditions. Interspecific interactions were also impacted. Indeed, *Diplasterias brandti* and *Odontaster validus* displayed more different $\delta^{13}C$ values (i.e. more different food sources) and lower isotopic niche overlap in the inner inlet, where high turbidity occurs, than in the outer inlet, where turbidity is lower. Similarly, *O. validus* had a smaller isotopic niche in the inner Ezcurra Inlet than in the outer. This is probably the result of a more limited availability and diversity of resources in the inner inlet. This may lead to the constriction of *O. validus* isotopic niche and to resource segregation that may limit interspecific competition between the few species able to survive in these unfavorable conditions.

The impact of trophic group, depth, sea ice concentration and sea ice season duration on the trophic ecology of sea stars was also assessed through a global analysis of the dataset at the scale of the whole Southern Ocean (Le Bourg 2020). The Southern Ocean was subdivided into different benthic ecoregions according to environmental (seabed temperature, sea ice, bathymetry) and biotic data (species distribution), to study biogeographic variations in the trophic ecology of sea stars. This subdivision notably highlighted the separation between Antarctic and Subantarctic environments, and the different $\delta^{13}C$ values in organic matter from surface waters were reflected in sea star tissues. The compilation of the available information on their diet allowed classifying sea star taxa from the Southern Ocean into trophic groups, ranging from suspension feeders to predators of active prey. The differences of stable isotope values between trophic groups and their variability in some of them suggested a diversity of food sources and/or of feeding strategies between and within trophic groups. These results confirm that, contrary to what is sometimes stated in the literature, sea stars in the Southern Ocean show a great trophic diversity. Depth has important effects on the trophic ecology of sea stars, both across the entire Southern Ocean and within ecoregions. Indeed, coastal sea stars may exploit food webs supported by a variety of pelagic and benthic primary producers while deeper sea stars may depend on the sedimentation of the surface primary production. Coastal sea stars are then characterized by a high diversity of food sources, while deeper sea stars have a higher diversity of trophic positions than coastal ones. The lower diversity and availability of food sources in deep waters may induce the diversification of sea star feeding behaviors (e.g. omnivory, predation, sediment feeding), which would reduce competition between species.

The impact of sea ice on the trophic ecology of sea stars was also investigated. The sympagic communities may be used as a food source by sea stars in cases of high sea ice concentrations. Furthermore, increasing reliance on degraded phytodetritus during longer periods of sea ice cover may occur in several trophic groups. This may dampen the impacts of sea ice presence on resource availability during long periods of sea ice cover. Our results also suggest that multiple relationships do exist between sea ice and the diet of benthic consumers, but they are not easy to interpret. Finally, not all of them are consistent across ecoregions, probably as a result of their contrasted oceanographic features. In addition, the impacts of the environmental parameters may differ between trophic groups, highlighting the importance of trophic diversity to predict the sensitivity of sea stars to future environmental changes, whether natural or anthropogenic.

To summarize, this project showed that the trophic ecology of sea stars from the Southern Ocean is driven by a combination of intrinsic (body size, trophic group) and extrinsic features (turbidity, depth, sea ice). Information on the influence of environmental parameters may provide hypotheses regarding the possible impacts of climate change on sea stars and on their role in benthic food webs of the Southern Ocean. Indeed, the environmental parameters may influence the trophic ecology of sea stars and the trophic interactions between taxa thanks to their impact on resource availability. The lower diversity and availability of food sources in turbid and deep waters have been considered as potential sources of diversification of feeding behaviors to avoid competition between species. By contrast, their greater availability in less turbid and coastal environments allows the consumption of similar prey with limited risks of competition. Sea ice has more variable impacts on resource availability, being a habitat for sympagic communities and inducing phytoplankton blooms after its breakup, but inhibiting them in case of persistence. Consequently, changes in the ice cover and its dynamics because of climate change will induce changes in the resource availability for the Southern Ocean benthos. Similarly, changes in turbidity in coastal areas as a result of modifications in the dynamics of terrestrial glaciers could have consequences on resource availability in this type of environment. These changes are likely to modify the trophic interactions between sea star taxa, with an increase or decrease of the importance of competition, which may result in modifications of the structure of sea star assemblages in the Southern Ocean.

6. Sources of funding

Belgian Federal Science Policy (BELSPO)

BRAIN-be grant number BR/132/A1/VERSO: Ecosystem Responses to Global change: a multiscale approach in the Southern Ocean (vERSO).

Belgian Federal Science Policy (BELSPO)

BRAIN-be grant number BR/154/A1/RECTO: Refugia and ecosystem tolerance in the Southern Ocean (RECTO).

Belgian Fund for Scientific Research (F.R.S.-FNRS)

FRIA doctoral grant number 1.E091.16: Feeding of Antarctic asteroids: identification of trophic resources and investigation of trophic plasticity and diversity.

French Polar Institute Paul-Emile Victor (IPEV)

IPEV research program 1044 PROTEKER: Effects of global change on coastal habitats of the Kerguelen Islands. Establishment of a base line for ecological and genetic monitoring, protection and conservation.

French Polar Institute (IPEV)

IPEV research program 1124 REVOLTA: Ressources Ecologiques et Valorisation par un Observatoire à Long terme en Terre Adélie.

National Science Center Poland (NCN)

OPUS grant number 2020/37/B/ST10/02905: Influence of rapidly progressing climate change on polar marine organisms - investigations along naturally occurring environmental analogues of future climate changes.

Australian Antarctic Division (AAD)

IPY project 53 CEAMARC: Collaborative East Antarctic MARine Census.

B. Specific subproject description

1. Site description

a. Site type

Marine benthic ecosystems.

b. Geography

Latitude: 47.717 °S to 86.273° S. Longitude: 127.767° West to 162.201° East. Depth: 6 to 5338 m. A full map of all sampling stations can be found in Fig. 1.

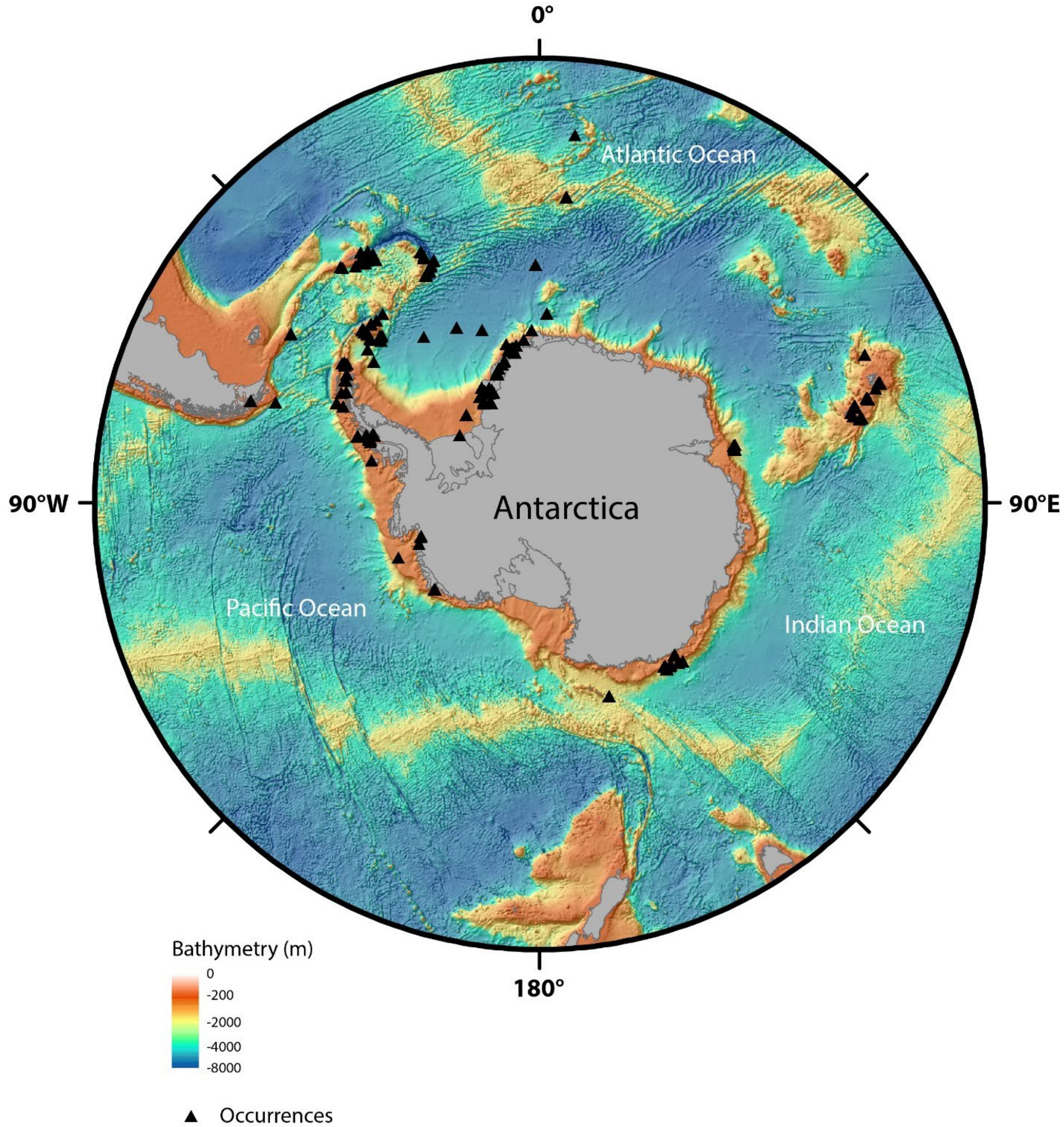

Figure 1: Map of sampling stations.

c. Habitat

Highly variable according to the considered region. Precise details are outside the scope of this article and can be found in each cruise report (cf. Table 1).

d. Geology, landform

Abyssal plain, bank, coastal terrane, cross shelf valley, island arc, island coastal terrane, lower slope, margin ridge, plateau, plateau slope, ridge, rugose ocean floor, sea mount, sea mount ridge, shelf deep, structural slope region, upper slope.

e. Watersheds, hydrology

Antarctic regions: Admiralty Bay, Antarctic Peninsula, Atlantic Basin, Filchner Depression, Halley Bay, Kapp Norvegica, Lazarev Sea, Marguerite Bay, Prydz Bay, Siple Island (Amundsen Sea), Adelie Land, Vest Kapp, Young Island, South Shetland Islands, Weddell Sea, Bellingshausen Sea, Ross Sea.

Subantarctic regions: Falkland Islands, South Georgia, Bouvet Island, South Sandwich Islands, Kerguelen Islands, Patagonia, South Orkney Islands.

f. Site history

Highly variable according to the considered region. Precise details are outside the scope of this article and can be found in each cruise report (cf. Table 1).

g. Climate

Polar but highly variable according to the considered region. Precise details are outside the scope of this article and can be found in each cruise report (cf. Table 1).

Table 1: List of research cruises and expeditions during which samples of this dataset were collected. Whenever possible, a link towards the relevant cruise or expedition report is provided.

Sampling campaign	Research station / vessel	Start date	End date	Preservation	N_{taxa}	$N_{samples}$
2nd International Biomass Expedition (MD 42)	RV Marion Dufresne	1985-01-11	1985-02-10	Ethanol	28	133
EPOS leg 3	RV Polarstern	1989-01-13	1989-03-10	Formaldehyde & ethanol	24	422
ANT-XXII/3 (ANDEEP-III)	RV Polarstern	2005-01-02	2005-04-06	Ethanol	23	91
JR144	RRS James Clark Ross	2006-02-26	2006-04-17	Frozen	24	133
Sue-Ann Watson Expedition	Carlini station	2006-03-08	2006-03-08	Frozen	1	22
ANT-XXIV/2 (ANDEEP-SYSTCO)	RV Polarstern	2007-11-28	2008-02-04	Ethanol	27	113
CEAMARC	RV Aurora Australis	2008-01-01	2008-01-27	Ethanol	22	103
JR179	RRS James Clark Ross	2008-02-18	2008-04-11	Frozen	5	8
ARGOS	Bycatches from fishing vessels	2009-03-07	2009-03-20	Frozen	12	27
JR230	RRS James Clark Ross	2009-12-01	2009-12-11	Frozen or ethanol	18	72
35th expedition to Arctowski Station (ZA)	Arctowski station	2010-12-06	2010-12-23	Formaldehyde & ethanol	8	286
REVOLTA II 2010-2011	Dumont d'Urville station	2010-12-29	2011-02-04	Ethanol	12	60
JR262	RRS James Clark Ross	2011-10-21	2011-11-22	Frozen	17	77
REVOLTA IV 2012-2013	Dumont d'Urville station	2012-11-27	2013-02-04	Ethanol	10	39
JR287	RRS James Clark Ross	2013-04-28	2013-06-07	Frozen	8	23
JR308	RRS James Clark Ross	2014-12-31	2015-01-07	Frozen or ethanol	15	39
PS96	RV Polarstern	2015-12-06	2016-02-14	Frozen	31	241
JR15005	RRS James Clark Ross	2016-02-22	2016-03-28	Frozen	26	142
Proteker 5	Port-Aux-Français station	2016-11-03	2016-12-31	Frozen	9	124
REVOLTA VIII 2016-2017	Dumont d'Urville station	2017-01-24	2017-01-26	Frozen	3	23
Antarctic Circumnavigation Expedition (ACE)	RV Akademik Tryoshnikov	2016-12-20	2017-03-19	Ethanol	29	207
Uni_Magellan	Fuerte Bulnes and Puerto del Hambre	2017-03-08	2017-03-08	Dried	11	71
				Total	**133**	**2456**

2. Experimental or sampling design

a. Design characteristics

To maximize the scope of this project, a double sampling strategy was set up. First, sea stars were collected in the Southern Ocean during campaigns taking place in the framework of the vERSO and RECTO projects from December 2015 to March 2017. Second, suitable samples originating from multiple oceanographic campaigns and surveys from January 1985 to January 2015 were retrieved from archived collections stored in museums or institutions. Institutions that provided samples included the Université Libre de Bruxelles (Belgium), the National Museum of Natural History (Paris, France) and the Institute of Oceanology of the Polish Academy of Sciences (Sopot, Poland). Table 1 lists all research cruises and expeditions during which samples were collected.

b. Permanent plots

Not applicable.

c. Data collection period, frequency, etc.

Cf. section II.B.2.a and table 1.

3. Research methods

a. Field/laboratory

Storage

Depending on the sampling campaign, sea stars were either frozen at -28°C, dried, stored in ethanol or fixed with formaldehyde and then stored in ethanol (table 1).

Body size measurements

For each specimen, the arm length (distance from the mouth to the tip of the longest arm) and the disc radius (distance from the mouth to the interradial margin, i.e. the point separating two arms) were measured to the nearest 0.1 mm with a caliper, and the ratio between those two measurements was computed.

Sample preparation

For each sea star, one or several arms were separated from the central disc. Internal organs and podia (tube feet) were removed from each arm. Stable isotope composition of animal material can vary from one tissue to another, in relation to these tissues' biochemical compositions and/or turnover rates (Tieszen et al. 1983). In a preliminary phase of this project, we investigated inter-tissue variation of stable isotope ratios in Antarctic sea stars. We therefore performed analyses in both tegument and podia from a subset of specimens. Regardless of the analyzed tissue, and with the exception of the already dried samples, samples were washed with demineralized water and oven-dried at 50°C during 48 hours. All samples were then homogenized into powder. Carbonates were removed from subsamples by exposing subsamples to 37 % hydrochloric acid vapor during 48 hours (Hedges and Stern 1984). The acidification procedure's efficiency was tested by adding a drop of acid on a subsample and ensuring no effervescence was visible ("Champagne test"; Jaschinski et al. 2008).

Acidified subsamples were then kept at 60°C until precise weighing (ca 2.5 - 3 mg) in 5 × 8 tin cups with ca 3 mg of tungsten trioxide for stable isotope analysis (cf. section II.B.3.b).

Impact of preservation on stable isotope values

Preservation in formaldehyde and ethanol can alter stable isotope ratios of sea stars. Consequently, experimentally measured correction factors (Le Bourg et al. 2020) were added to the $\delta^{13}C$ and $\delta^{34}S$ values of sea stars fixed when relevant. For samples stored in ethanol, a correction factor of -0.6 ‰ was subtracted to raw $\delta^{13}C$ values. For samples fixed with formaldehyde and then stored in ethanol, a correction factor of 0.2 ‰ was added to raw $\delta^{13}C$ values to take into account the effects of both ethanol (-0.6 ‰) and formaldehyde (+0.8 ‰) on $\delta^{13}C$ values. A correction factor of 1.5 ‰ was also added to $\delta^{34}S$ values for samples fixed with formaldehyde.

b. Instrumentation

Stable isotope ratio measurements were performed by continuous flow–elemental analysis–isotope ratio mass spectrometry (CF-EA-IRMS) at University of Liège (Belgium), using a vario MICRO cube C-N-S elemental analyzer (Elementar Analysensysteme GmbH, Hanau, Germany) coupled to an IsoPrime100 isotope ratio mass spectrometer (Isoprime, Cheadle, United Kingdom).

c. Taxonomy and systematics

To cope with the wide taxonomic range (an entire class of echinoderms) and geographic/bathymetric extent (an entire ocean) of the present study, an integrative approach using both morphological molecular methods was set up.

First, in the laboratory, sea stars were identified to the lowest taxonomic level possible using visual examination of morphological characters.

Second, for 505 specimens, sequences of a fragment (barcode) of mitochondrial cytochrome C oxidase subunit I gene (COI) were used to ensure a proper identification of the specimens and assign them to a genetic unit (clade). DNA was extracted using a salting-out protocol (modified from Sunnucks and Hales 1996; with larger volumes and incubation at 70°C for 10 minutes to inhibit protein activity after digestion). A fragment (658 nucleotides) of the mitochondrial gene cytochrome c oxidase subunit I (COI) was then amplified using the specific forward primer LCOech1aF1 (Layton et al. 2016) for the class Asteroidea and the universal HCO2198 Reverse primer (Folmer et al. 1994) or its degenerated version jgHCO2198 (Geller et al. 2013). Sequencing was performed by the company Macrogen Europe. Sequences were edited and assembled using CodonCode Aligner v6.0.2 and translated using the echinoderm mitochondrial genetic code to ensure the absence of a stop codon. Sequences were then uploaded to the Barcode of Life Data System (BOLD; Ratnasingham and Hebert 2007).

DNA barcoding has proven to be an efficient method to differentiate echinoderm species (Ward et al. 2008). It is particularly interesting when studying small specimens and/or polymorphic species but also to segregate between clades of species complexes (Moreau et al. 2019). In the Southern Ocean in particular, the evolutionary history of benthic faunas (mainly linked to climatic and geologic processes) has led to numerous examples of species complexes which can be partly resolved using COI barcoding (Moreau et al. 2021). Here, in several genera where clades showed a clear pattern of geographic or bathymetric distribution, results of genetic analyses were used as proxies to assign non-barcoded specimens to a probable species (Moreau 2019, Moreau et al. 2019). *Bathybiaster* sp. individuals sampled between 0 and 1000 m on the Antarctic continental shelf were considered as *Bathybiaster loripes*, those sampled deeper than 2000 m as well as in the Kerguelen Plateau ecoregion were considered as *Bathybiaster vexillifer* (Moreau 2019) while no species was assigned to one individual sampled in the South Sandwich Islands between 1000 and 1500 m. *Chitonaster* sp. individuals sampled in Western Antarctic Peninsula and South Orkney Island were considered as *Chitonaster* sp. 2. *Diplasterias* sp. individuals sampled in Western Antarctic Peninsula and South Orkney Island were considered as *Diplasterias* sp. 1, those sampled in South Sandwich Islands and Adelie Land as *Diplasterias* sp. 2 while no species was assigned to individuals sampled in the Weddell Shelf. *Lysasterias* sp. individuals sampled in Oates were considered as *Lysasterias* sp. 1. *Notasterias* sp. individuals sampled in South Orkney Islands were considered as *Notasterias* sp. 1. *Odontaster* sp. individuals sampled on the Kerguelen Plateau were considered as *Odontaster penicillatus*. *Psilaster charcoti* individuals sampled near Bouvet Island, in the South Atlantic ecoregion, were considered as *Psilaster charcoti* – clade 2. By contrast, this method could not be used for genera for which no clear geographic or bathymetric patterns of distribution were recorded (e.g. *Acodontaster*). Consequently, these individuals remained identified down to the genus. Similarly, individuals that could not be identified further than the family were referred to by their family name (Echinasteridae and Pterasteridae).

Nomenclature was thoroughly checked using the Taxon Match Tool implemented in the World Register of Marine Species, WoRMS (WoRMS Editorial Board 2021).

d. Permit history

Permit requirements are specific to each cruise or expedition, and can be found in relevant cruise reports (cf. table 1).

e. Legal/organizational requirements

Legal requirements are specific to each cruise or expedition, and can be found in relevant cruise reports (cf. table 1).

C. Project personnel

Principal investigators

Moreau, Camille

Marine Biology Lab, Université Libre de Bruxelles (ULB), 1050 Brussels, Belgium.

Le Bourg, Baptiste
Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, 4000 Liège, Belgium.

Danis, Bruno
Marine Biology Lab, Université Libre de Bruxelles (ULB), 1050 Brussels, Belgium.

Lepoint, Gilles
Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, 4000 Liège, Belgium.

Michel, Loïc N.
Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, 4000 Liège, Belgium.
Ifremer, Centre de Bretagne, REM/EEP, Laboratoire Environnement Profond, 29280 Plouzané, France.

Associate investigators
Balazy, Piotr
Institute of Oceanology, Polish Academy of Sciences (IOPAN), 81-712 Sopot, Poland.

Eleaume, Marc
Institut de Systématique, Evolution, Biodiversité (ISYEB), Muséum National d'Histoire Naturelle (MNHN), CNRS, Sorbonne Université, EPHE, 75005 Paris, France.

Gan, Yi-Ming
OD Nature, Royal Belgian Institute of Natural Sciences, 1000 Brussels, Belgium.

Jossart, Quentin
Marine Biology, Vrije Universiteit Brussel (VUB), 1050 Brussels, Belgium.
Marine Biology Lab, Université Libre de Bruxelles (ULB), 1050 Brussels, Belgium.

Kuklinski, Piotr
Institute of Oceanology, Polish Academy of Sciences (IOPAN), 81-712 Sopot, Poland.

Saucède, Thomas
Biogéosciences, UMR CNRS 6282, Université Bourgogne Franche-Comté, 21000 Dijon, France.

Van de Putte, Anton
OD Nature, Royal Belgian Institute of Natural Sciences, 1000 Brussels, Belgium.

Students

Blanchard, Alice

Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, 4000 Liège, Belgium.

Charpentier, Anouk

Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, 4000 Liège, Belgium.

Class III. Data set status and accessibility

A. Status

1. Latest update

28/09/2021

2. Latest archive date

28/09/2021

3. Metadata status

28/09/2021, documentation complete.

4. Data verification

Complete.

B. Accessibility

1. Storage location and medium

The full dataset is available as supplementary material to this article. It can also be directly accessed from the Zenodo repository at https://doi.org/10.5281/zenodo.5041317.

In addition, derived versions of the dataset were published in relevant thematic portals such as the Global Biodiversity Information facility (GBIF; DwC occurrence with measurement or fact extensions; https://doi.org/10.15468/p8gcpe), the Scientific Committee on Antarctic Research biodiversity portal (biodiversity.aq / AntOBIS ; https://ipt.biodiversity.aq/resource?r=antarctic_subantarctic_asteroidea_isotopes), the Southern Ocean Diet and Energetics Database (Raymond et al. 2011 ; https://doi.org/10.26179/5d1aec22f41d5), IsoBank (Pauli et al. 2017 ; https://isobank.tacc.utexas.edu/), and DeepIso – the Global open database of stable isotope ratios and elemental contents for deep-sea ecosystems (Michel et al. 2020 ; https://doi.org/10.17882/76595). While all these derived versions differ slightly in format to match each repository's requirements, sea star specimens can always be identified through the "catalogNumber" field which is both unique to each specimen and common to all dataset versions.

All the genetic sequences associated with this work are publicly available on the Barcode of Life Data System (BOLD, https://boldsystems.org/) along with associated metadata under the following project names: ASULB, BASEC, SOA and ASTAN.

2. Contact persons

Michel, Loïc N.

Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, Sart-Tilman Campus, Quartier Agora, Institute of Chemistry (Building B6c), 11 Allée du 6 Août, 4000 Liège, Belgium.

E-mail: loic.michel@uliege.be, loicnmichel@gmail.com

Lepoint, Gilles

Laboratory of Oceanology, Freshwater and Oceanic Sciences Unit of reSearch (FOCUS), University of Liège, Sart-Tilman Campus, Quartier Agora, Institute of Chemistry (Building B6c), 11 Allée du 6 Août, 4000 Liège, Belgium.

Phone: + 32 4 366 33 27

Fax: +32 4 366 33 25

E-mail: G.Lepoint@uliege.be

3. Copyright restrictions

The dataset is freely available without any copyright restriction. The only usage requirement is that users cite this paper in research products (publications, presentations, reports, etc.) derived from the dataset.

4. Proprietary restrictions

a. Release date

Not applicable.

b. Citation

Please cite this article in research products derived from the dataset.

c. Disclaimer

If the envisioned research heavily relies on the dataset, we encourage users to inform us or consider the possibility of an academic collaboration. We also encourage users to disseminate research products derived from the dataset as openly as possible, in accordance with the FAIR principles (https://www.go-fair.org/fair-principles/).

C. Costs

No costs are associated with use of this dataset.

Class IV. Data structural descriptors

A. Data set file

1. Identity

SouthernOcean_SeaStars_TrophicBiometric_1985-2017.csv

2. Size

2456 specimens (24332 measurements), 57 variables for a total of 1.31 Mb.

3. Format and storage mode

A single table available in .csv format.

4. Header information

The first row of the file contains variable names.

5. Alphanumeric attributes

Mixed.

6. Special characters/fields

Optional comments about specimens are detailed in the "occurenceRemarks" field. Optional comments about their taxonomic assignment procedure are detailed in the "identification remarks" field.

7. Authentication procedures

MD5 checksum: db43e55028f7c55edd9cbaeb85852359

B. Variable information

1. Variable identity

Variable identities are detailed in table 2. Most terms are derived from the Darwin Core standard (Wieczorek et al. 2012), see https://dwc.tdwg.org/terms/ for details.

2. Variable definition

Variable definitions are detailed in table 2. Most terms are derived from the Darwin Core standard (Wieczorek et al. 2012), see https://dwc.tdwg.org/terms/ for details.

Table 2: Variable information. "Precision" refers to the number of significant decimal places for floating point variables.

Identity	Definition	Unit	Storage type	Range	Precision	Length	Column
parentEventID	The identifier for the broader event that groups this and potentially other sampling events, i.e. the research cruise or expedition.	-	String	-	-	Variable	1
eventID	The identifier for the set of information associated with each sampling event, i.e. the station of the research cruise or expedition.	-	String	-	-	Variable	2
occurrenceID	The unique identifier for each specimen, specific to this dataset.	-	String	-	-	Variable	3
catalogNumber	The identifier originally assigned to the specimen or group of specimens at the time of sampling.	-	String	-	-	Variable	4
type	The nature or genre of the resource. Here, always "PhysicalObject".	-	String	-	-	Fixed	5
basisOfRecord	The specific nature of the data record. Here, always "PreservedSpecimen".	-	String	-	-	Fixed	6
occurrenceStatus	A statement about the presence or absence of a Taxon at a Location. Here, always “Present”.	-	String	-	-	Fixed	7
scientificName	The full scientific name of the lowest level taxonomic rank that could be determined.	-	String	-	-	Variable	8
kingdom	The full scientific name of the kingdom in which the taxon is classified. Here, always "Animalia".	-	String	-	-	Fixed	9
phylum	The full scientific name of the phylum in which the taxon is classified. Here, always "Echinodermata".	-	String	-	-	Fixed	10
class	The full scientific name of the class in which the taxon is classified. Here, always "Asteroidea".	-	String	-	-	Fixed	11
order	The full scientific name of the order in which the taxon is classified.	-	String	-	-	Variable	12
family	The full scientific name of the family in which the taxon is classified.	-	String	-	-	Variable	13
genus	The full scientific name of the genus in which the taxon is classified.	-	String	-	-	Variable	14
subgenus	The full scientific name of the subgenus in which the taxon is classified.	-	String	-	-	Variable	15
specificEpithet	The name of the first or species epithet of the scientificName.	-	String	-	-	Variable	16
scientificNameID	The identifier for the nomenclatural (not taxonomic) details of a scientific name. Here, we used the World Register of Marine Species AphiaID.	-	String	-	-	Variable	17
scientificNameAuthorship	The authorship information for the scientificName formatted according to the conventions of the applicable nomenclatural Code.	-	String	-	-	Variable	18
identifiedBy	The list (concatenated and separated) of names of people, groups, or organizations who assigned the Taxon to the subject.	-	String	-	-	Variable	19
collectionCode	The name, acronym, coden, or initialism identifying the collection or data set from which the record was derived.	-	String	-	-	Variable	20
Paris_MNHN_Number	Specimen number linked to the Muséum national d’Histoire naturelle in Paris (France) collections.	-	String	-	-	Variable	21
preparations	A list (concatenated and separated) of preparations and preservation methods for a specimen.	-	String	-	-	Variable	22
year	The four-digit year in which the sampling event occurred, according to the Common Era Calendar.	-	Integer	1985 to 2017	-	Fixed	23
month	The integer month of the year in which the sampling event occurred.	-	Integer	1 to 12	-	Variable	24
day	The integer day of the month on which the sampling event occurred	-	Integer	1 to 31	-	Variable	25

eventDate	The date at which the sampling event occurred, under yyyy-mm-dd format.	-	Date	1985/01/12 to 2017/10/08	-	Fixed	26
decimalLatitude	The geographic latitude (using the spatial reference system given in geodeticDatum) at which the sample was taken. Positive values are north of the Equator, negative values are south of it. Legal values lie between -90 and 90, inclusive.	Decimal degrees	Floating point	-76.7148 to -47.7170	4	Fixed	27
decimalLongitude	The geographic longitude (using the spatial reference system given in geodeticDatum) at which the sample was taken. Positive values are east of the Greenwich Meridian, negative values are west of it. Legal values lie between -180 and 180, inclusive.	Decimal degrees	Floating point	-127.2673 to 162.2009	4	Fixed	28
coordinatePrecision	A decimal representation of the precision of the coordinates given in the decimalLatitude and decimalLongitude. Here, always 0.0001.	Decimal degrees	Floating point	-	4	Fixed	29
coordinateUncertaintyInMeters	The horizontal distance from the given decimalLatitude and decimalLongitude describing the smallest circle containing the whole of the Location. Here, always 11.	Meters	Integer	-	-	Fixed	30
occurenceRemark	Comments or notes about the specimen.	-	String	-	-	Variable	31
identificationRemarks	Comments or notes about the Identification.	-	String	-	-	Variable	32
identificationQualifier	A brief phrase or a standard term ("cf.", "aff.") to express the determiner's doubts about the Identification.	-	String	-	-	Variable	33
higherGeography	A list (concatenated and separated) of geographic names less specific than the information captured in the locality term.	-	String	-	-	Variable	34
geodeticDatum	The ellipsoid, geodetic datum, or spatial reference system (SRS) upon which the geographic coordinates given in decimalLatitude and decimalLongitude are based. Here, always "WGS84".	-	String	-	-	Fixed	35
maximumDepthInMeters	The greater depth below the local surface at which the sample was taken.	Meters	Integer	6 to 5338	-	Variable	36
Arm_length_R_cm	Measurement of the arm length (R) in centimeters	Centimeters	Floating point	0.1 to 50.2	1	Variable	37
Disc_radius_r_cm	Measurement of disc radius (r) in centimeters	Centimeters	Floating point	0.1 to 5.9	1	Variable	38
R_r_ratio	Ratio or the arm length on the disc radius	Unitless	Floating point	1.0 to 53.5	1	Variable	39
d13C_tegument	The $\delta^{13}C$ measured in the tegument of the considered sea star specimen, expressed in per mille and relative to the international reference Vienna Pee Dee Belemnite.	Per mille	Floating point	-26.0 to -8.5	1	Variable	40
d15N_tegument	The $\delta^{15}N$ measured in the tegument of the considered sea star specimen, expressed in per mille and relative to the international reference Atmospheric Air.	Per mille	Floating point	4.3 to 19.8	1	Variable	41
d34S_tegument	The $\delta^{34}S$ measured in the tegument of the considered sea star specimen, expressed in per mille and relative to the international reference Vienna Canyon Diablo Troilite.	Per mille	Floating point	2.1 to 23.8	1	Variable	42
C_N_tegument	The ratio between carbon and nitrogen elemental contents measured in the tegument of the considered sea star specimen, expressed as mass ratio.	Unitless	Floating point	1.85 to 9.56	1	Variable	43
PcN_tegument	The nitrogen elemental content measured in the tegument of the considered sea star specimen, expressed in relative percentage of dry mass.	Relative percentage of dry mass	Floating point	0.44 to 10.33	1	Variable	44
PcC_tegument	The carbon elemental content measured in the tegument of the considered sea star specimen, expressed in relative percentage of dry mass.	Relative percentage of dry mass	Floating point	1.48 to 42.45	1	Variable	45
PcS_tegument	The sulfur elemental content measured in the tegument of the considered sea star specimen, expressed in relative percentage of dry mass.	Relative percentage of dry mass	Floating point	0.00 to 2.95	1	Variable	46
d13C_podia	The $\delta^{13}C$ measured in podial vesicles of the considered sea star specimen, expressed in per mille and relative to the international reference Vienna Pee Dee Belemnite.	Per mille	Floating point	-27.9 to -13.1	1	Variable	47

d15N_podia	The $\delta^{15}N$ measured in podial vesicles of the considered sea star specimen, expressed in per mille and relative to the international reference Atmospheric Air.	Per mille	Floating point	5.2 to 18.8	1	Variable	48
d34S_podia	The $\delta^{34}S$ measured in podial vesicles of the considered sea star specimen, expressed in per mille and relative to the international reference Vienna Canyon Diablo Troilite.	Per mille	Floating point	12.7 to 17.7	1	Variable	49
C_N_podia	The ratio between carbon and nitrogen elemental contents measured in podial vesicles of the considered sea star specimen, expressed as mass ratio.	Unitless	Floating point	0.00 to 6.77	1	Variable	50
PcN_podia	The nitrogen elemental content measured in podial vesicles of the considered sea star specimen, expressed in relative percentage of dry mass.	Relative percentage of dry mass	Floating point	1.25 to 13.04	1	Variable	51
PcC_podia	The carbon elemental content measured in podial vesicles of the considered sea star specimen, expressed in relative percentage of dry mass.	Relative percentage of dry mass	Floating point	4.05 to 43.08	1	Variable	52
PcS_podia	The sulfur elemental content measured in podial vesicles of the considered sea star specimen, expressed in relative percentage of dry mass.	Relative percentage of dry mass	Floating point	0.00 to 2.31	1	Variable	53
Bold_ProjectCode	The Barcode of Life Data System project code under which sequence(s) associated to the specimen can be found.	-	String	-	-	Variable	54
Bold_ProcessID	The Barcode of Life Data System process ID under which sequence(s) associated to the specimen can be found.	-	String	-	-	Variable	55
Bold_SampleID	The Barcode of Life Data System sample ID under which sequence(s) associated to the specimen can be found.	-	String	-	-	Variable	56
Bold_FieldID	The Barcode of Life Data System field ID under which sequence(s) associated to the specimen can be found.	-	String	-	-	Variable	57

3. Units of measurement

Units of measurement are detailed in table 2.

4. Data type

a. Storage type

Data storage types are detailed in table 2.

b. List and definition of variable codes

Not applicable.

c. Range for numeric values

Range for numeric values are detailed in table 2.

d. Missing value codes

Missing values are left blank in the dataset.

e. Precision

Whenever relevant, data precision is given in table 2 as the number of significant digital places.

5. Data format

a. Length

Data length status (fixed or variable) is detailed in table 2 for each variable.

b. Columns

Links between column numbers and variables are detailed in table 2.

c. Optional number of decimal places

Whenever relevant, this parameter is detailed in table 2 under "Precision".

C. Data anomalies

No significant issues to report.

Class V. Supplemental descriptors

A. Data acquisition

1. Data forms or acquisition methods

Stable isotope and elemental content data were generated automatically under digital format (see section V.D below). Metadata were digitized manually by the two co-first authors.

2. Location of completed data forms

The full analysis reports and raw analytical data are archived at University of Liège's stable isotope facility, operated and maintained by the Stable Isotope in Environmental Science and Trophic Ecology (SIESTE) workgroup, managed by Gilles Lepoint.

3. Data entry verification procedures

Random manual checks of portions of the data were performed by the two co-first and the last author. A thorough automatized check was performed by the co-author with the most experience on that aspect (AVDP).

B. Quality assurance/quality control procedures

Isotopic ratios were expressed in ‰ using the widespread δ notation (Coplen 2011) and relative to the international references Vienna Pee Dee Belemnite (for carbon), Atmospheric Air (for nitrogen) and Vienna Canyon Diablo Troilite (for sulfur). Sucrose (IAEA-C-6; $\delta^{13}C$=−10.8 ± 0.5‰; mean ± standard deviation), ammonium sulfate (IAEA-N-1; $\delta^{15}N$= 0.4 ± 0.2‰; mean ± SD) and silver sulfide (IAEA-S-1; $\delta^{34}S$ = −0.3‰) were used as primary analytical standards for stable isotope ratios. Sulfanilic acid (Sigma-Aldrich; $\delta^{13}C$=−25.6 ± 0.4‰; $\delta^{15}N$=−0.13 ± 0.4‰; $\delta^{34}S$ = 5.9 ± 0.5‰; means ± SD) was used as a secondary analytical standard for stable isotope ratios and as elemental standard. Standard deviations on multi-batch replicate measurements of secondary and internal laboratory standards (sea star tegument), analyzed interspersed with samples (one replicate of each standard every 15 analyses), were 0.3‰ for $\delta^{13}C$ and $\delta^{15}N$ and 0.5‰ for $\delta^{34}S$. After analysis, each data point was manually checked. Whenever inconsistent values were spotted, the sample was analyzed again whenever possible, or the data point was discarded otherwise.

C. Related materials

Not applicable.

D. Computer programs and data-processing algorithms

Stable isotope ratios and elemental contents data were generated automatically through the specialized software suites also used to interact with the machines and perform the analysis, i.e. IonVantage v. 1.6.1.13 (Isoprime, Cheadle, United Kingdom) for stable isotope ratios, and varioMICRO v. 2.0.3 (Elementar Analysensysteme GmbH, Hanau, Germany) for elemental contents.

E. Archiving

1. Archival procedures

The dataset is stored as supplementary material to this article and available on the Zenodo repository at https://doi.org/10.5281/zenodo.5041317. In addition, it is archived in several other repositories (cf. sections III.B.1 and V.E.2). Finally, backup copies are held by several of this article's authors on their professional computers and/or hard drives.

2. Redundant archival sites

Global Biodiversity Information Facility, GBIF: Moreau C, Le Bourg B, Balazy P, Danis B, Eléaume M, Jossart Q, Kuklinski P, Lepoint G, Saucède T, Van de Putte A, Gan Y, Michel L (2021). Stable isotope ratios of C, N and S in Southern Ocean sea stars (1985-2017). SCAR - AntOBIS. Occurrence dataset. https://doi.org/10.15468/p8gcpe.

SCAR Antarctic Biodiversity Portal, AntOBIS: Moreau C, Le Bourg B, Balazy P, Danis B, Eléaume M, Jossart Q, Kuklinski P, Lepoint G, Saucède T, Van de Putte A, Gan Y, Michel L (2021): Stable isotope ratios of C, N and S in Southern Ocean sea stars (1985-2017). Dataset/Occurrence.
https://ipt.biodiversity.aq/resource?r=antarctic_subantarctic_asteroidea_isotopes

Southern Ocean Diet and Energetics Database: https://doi.org/10.26179/5d1aec22f41d5

IsoBank: https://isobank.tacc.utexas.edu/ (Dataset IDs 242, 245 & 246)

DeepIso: https://doi.org/10.17882/76595 (Dataset ID 018)

BOLD: All the genetic sequences associated with this work are publicly available on the Barcode of Life Data System (BOLD, https://boldsystems.org/) along with associated metadata under the following project names: ASULB, BASEC, SOA and ASTAN.

F. Publications and results

Le Bourg B (2020). Trophic ecology of Southern Ocean sea stars: Influence of environmental drivers on trophic diversity. PhD Thesis, University of Liège (Belgium), Laboratory of Oceanology. 261 pp. Available from ULiège's institutional repository at http://hdl.handle.net/2268/248221

Le Bourg B., Kuklinski P., Bałazy P., Lepoint G. & Michel L. N (2021). Interactive effects of body size and environmental gradient on the trophic ecology of sea stars in an Antarctic fjord. *Marine Ecology Progress Series*, 674:189–202. https://doi.org/10.3354/meps13821

G. History of data set usage

1. Data request history

Not applicable.

2. Data set update history

V1.6 (2021/09/29): Minor formatting changes to maximize GBIF compatibility, and discardal of 4 unreliable data points highlighted by one of the present article's reviewers.

v 1.5 (2021/06/30): Corrections of minor formatting issues following review, addition of BOLD IDs and codes.

v 1.4 (2021/05/19): Corrections of minor formatting issues following review.

v 1.3 (2021/05/19): Changes of metadata format and variable names to better adhere to Darwin Core standards.

v 1.2 (2021/04/27): Corrections of minor formatting issues following second review.

v 1.1 (2021/04/27): Corrections of minor formatting issues following initial review.

v 1.0 (2021/04/27): Initial release.

3. Review history

Last data entry: 2021/04/27. Last data and metadata review: 2021/09/29.

4. Questions and comments from secondary users

Not applicable.

References

Coplen, T. B. 2011. Guidelines and recommended terms for expression of stable-isotope-ratio and gas-ratio measurement results. Rapid Communications in Mass Spectrometry 25:2538–2560.

Folmer, O., M. Black, W. Hoeh, R. Lutz, and R. Vrijenhoek. 1994. DNA primers for amplification of mitochondrial cytochrome c oxidase subunit I from diverse metazoan invertebrates. Molecular Marine Biology and Biotechnology 3:294–299.

Geller, J., C. Meyer, M. Parker, and H. Hawk. 2013. Redesign of PCR primers for mitochondrial cytochrome c oxidase subunit I for marine invertebrates and application in all-taxa biotic surveys. Molecular Ecology Resources 13:851–861.

Hedges, J. I., and J. H. Stern. 1984. Carbon and nitrogen determinations of carbonate-containing solids. Limnology and Oceanography 29:657–663.

Jaschinski, S., T. Hansen, and U. Sommer. 2008. Effects of acidification in multiple stable isotope analyses. Limnology and Oceanography: Methods 6:12–15.

Layton, K. K. S., E. A. Corstorphine, and P. D. N. Hebert. 2016. Exploring Canadian Echinoderm Diversity through DNA Barcodes. PLOS ONE 11:e0166118.

Le Bourg, B. 2020. Trophic ecology of Southern Ocean sea stars: Influence of environmental drivers on trophic diversity. PhD thesis, University of Liège, Liège, Belgium.

Le Bourg, B., P. Kuklinski, P. Balazy, G. Lepoint, and L. N. Michel. 2021. Interactive effects of body size and environmental gradient on the trophic ecology of sea stars in an Antarctic fjord. Marine Ecology Progress Series 674:189–202.

Le Bourg, B., G. Lepoint, and L. N. Michel. 2020. Effects of preservation methodology on stable isotope compositions of sea stars. Rapid Communications in Mass Spectrometry 34.

Michel, L. N., J. B. Bell, S. F. Dubois, M. Le Pans, G. Lepoint, K. Olu, W. D. K. Reid, J. Sarrazin, G. Schaal, and B. Hayden. 2020. DeepIso - a global open database of stable isotope ratios and elemental contents for deep-sea ecosystems.

Moreau, C. 2019. Diversité et phylogéographie des astéries de l'Océan Austral (Asteroidea). PhD Thesis, Université Libre de Bruxelles, Brussels, Belgium.

Moreau, C., B. Danis, Q. Jossart, M. Eléaume, C. Sands, G. Achaz, A. Agüera, and T. Saucède. 2019. Is reproductive strategy a key factor in understanding the evolutionary history of Southern Ocean Asteroidea (Echinodermata)? Ecology and Evolution 9:8465–8478.

Moreau, C., Q. Jossart, B. Danis, M. Eléaume, H. Christiansen, C. Guillaumot, R. Downey, and T. Saucède. 2021. The high diversity of Southern Ocean sea stars (Asteroidea) reveals original evolutionary pathways. Progress in Oceanography 190:102472.

Pauli, J. N., S. D. Newsome, J. A. Cook, C. Harrod, S. A. Steffan, C. J. O. Baker, M. Ben-David, D. Bloom, G. J. Bowen, T. E. Cerling, C. Cicero, C. Cook, M. Dohm, P. S. Dharampal, G. Graves, R. Gropp, K. A. Hobson, C. Jordan, B. MacFadden, S. Pilaar Birch, J. Poelen, S. Ratnasingham, L. Russell, C. A. Stricker, M. D. Uhen, C. T. Yarnes, and B. Hayden. 2017. Opinion: Why we need a centralized repository for isotopic data. Proceedings of the National Academy of Sciences 114:2997–3001.

Ratnasingham, S., and P. D. N. Hebert. 2007. BOLD: The Barcode of Life Data System (http://www.barcodinglife.org). Molecular Ecology Notes 7:355–364.

Raymond, B., M. Marshall, G. Nevitt, C. L. Gillies, J. van den Hoff, J. S. Stark, M. Losekoot, E. J. Woehler, and A. J. Constable. 2011. A Southern Ocean dietary database. Ecology 92:1188.

Sunnucks, P., and D. F. Hales. 1996. Numerous transposed sequences of mitochondrial cytochrome oxidase I-II in aphids of the genus *Sitobion* (Hemiptera: Aphididae). Molecular Biology and Evolution 13:510–524.

Tieszen, L. L., T. W. Boutton, K. G. Tesdahl, and N. A. Slade. 1983. Fractionation and turnover of stable carbon isotopes in animal tissues: Implications for δ13C analysis of diet. Oecologia 57:32–37.

Ward, R. D., B. H. Holmes, and T. D. O'hara. 2008. DNA barcoding discriminates echinoderm species. Molecular Ecology Resources 8:1202–1211.

Wieczorek, J., D. Bloom, R. Guralnick, S. Blum, M. Döring, R. Giovanni, T. Robertson, and D. Vieglais. 2012. Darwin Core: An Evolving Community-Developed Biodiversity Data Standard. PLOS ONE 7:e29715.

WoRMS Editorial Board. 2021. World Register of Marine Species.