

Fatty acid profiles of more than 470 marine species from the Southern Hemisphere

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Abstract

Lipid and fatty acid datasets are commonly used to assess nutritional composition of organisms, trophic ecology, and ecosystem dynamics. Lipids and their fatty acid constituents are essential nutrients to all forms of life because they contribute to essential biological processes such as energy flow and metabolism. Assessment of total lipids in tissues of organisms provides information on energy allocation and life-history strategies and can be an indicator of nutritional condition. The analysis of an organism's fatty acids is a widely used technique for assessing nutrient and energy transfer, and dietary interactions in food webs. While there are many published regional studies that assess lipid and fatty acid compositions, most only report mean values of the most abundant fatty acids, and there are limited individual records available for wider use in intercomparison or macro-scale studies. This dataset consists of 4,856 records of individual and pooled samples of at least 470 different marine consumer species sampled from tropical, temperate, and polar regions around Australia and in the Southern, Indian, and Pacific Oceans from 1989 to 2018. This includes data for a diverse range of taxa (zooplankton, fish, cephalopods, chondrichthyans, and marine mammals), size ranges (0.02 cm to ~ 13 m), and that cover a broad range of trophic positions (2.0 to 4.6). Where known, we provide a record of species name, date of sampling, sampling location, body size, relative (%) measurements of tissue-specific total lipid content and abundant fatty acids, and absolute content (mg 100 g⁻¹ tissue) of eicosapentaenoic acid (EPA, 20:5n3) and docosahexaenoic acid (DHA, 22:6n3) as important long-chain ($\geq C_{20}$) polyunsaturated omega-3 fatty acids. These records form a solid basis for comparative studies that will facilitate a broad understanding of the spatial and temporal distribution of marine lipids globally. The dataset also provides reference data for future dietary assessments of marine predators and model assessments of potential impacts of climate change on the availability of marine lipids and fatty acids. There are 480 data records within our data file for which the providers have requested that permission for reuse be granted, with the likely condition that they are included as a co-author on the reporting of the dataset. Records with this condition are indicated by a 'yes' under 'Conditions_of_data_use' in Data S1: Marineconsumer_FAdata.csv (see Table 2 in Metadata S1 for more details). For all other data records marked as 'No' under 'Conditions_of_data_use', there are no copyright restrictions for research and/or teaching purposes. We request that users acknowledge use of the data in publications, research proposals, websites, and other outlets via formal citation of this work and original data sources as applicable.

Keywords: *crustaceans, ecology, food web, fish, lipids, marine consumers, nutritional composition, trophodynamics, seafood, squid.*

METADATA

CLASS I. DATASET DESCRIPTORS

Dataset title: Fatty acid profiles of more than 470 marine species from the Southern Hemisphere

Dataset identification code: Marineconsumer_FAdata.zip

Principal investigators:

PETHYBRIDGE Heidi, CSIRO Oceans and Atmosphere, Hobart, Tasmania, Australia

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Dataset description:

We compiled ecological and biochemical research done at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) marine lipid laboratories in Hobart, Tasmania over the last three decades in a dataset of 4,856 fatty acid records from samples of marine consumers. Samples were collected from around Australia, in the south-western Indian Ocean, in the south-west Pacific Ocean, or in the Southern Ocean from 1989 to 2018.

We obtained 4,529 individual sample records from 23 data providers (> 35 regional datasets and studies), with another 431 records of mean (pooled) data from 21 published papers. There are records for 516 different taxon (classified to class or lower) which includes 470 known species (classified to genus or lower) (Table 1). Most of the records are for marine vertebrates ($n = 3,555$), particularly from fishes and chondrichthyans, although there are four invertebrate taxa with > 100 records each (Table 1). The most records for any given species were from albacore tuna (*Thunnus alalunga*; $n = 478$), Antarctic krill (*Euphausia superba*; $n = 465$), spurdog sharks (*Squalus acanthias*; $n = 364$), humpback whales (*Megaptera novaeangliae*; $n = 335$), and white sharks (*Carcharodon carcharias*; $n = 277$). There were another four species that had > 100 records (including Weddell seal – *Leptonychotes weddellii*, New Zealand fur seal – *Arctocephalus forsteri*, arrow squid – *Nototodarus gouldi*, and whale shark – *Rhincodon typus*), and 42 species with between 10 and 100 records. Most (41%) records are for muscle or connective tissue ($n = 2,009$), followed by whole specimens ($n = 1,167$), liver ($n = 649$), blubber ($n = 497$), reproductive tissues ($n = 392$), plasma ($n = 79$) and other tissues ($n = 44$).

Table 1. Number (*n*) of records and known species (classified to genus or species level) for each taxon represented in the dataset.

	Taxa	Taxa group	<i>n</i> species	<i>n</i> records
invertebrates	crustaceans	krill	16	504
		zooplankton	21	226
		other	52	174
	molluscs	cephalopods	36	365
		shellfish	18	20
	other	echinoderms, gastropods, annelida, cnidarians	2	12
vertebrates	teleost	fishes	271	1473
	chondrichthyans	sharks and chimaeras	40	1167
		rays and skates (Batoidea)	5	50
	mammals	seals	5	488
		whales	3	367
	seabirds	penguins	1	10

For each record, percentages are provided for 34 fatty acids, including 28 of the most abundant fatty acids (maximum values typically > 1%). Five fatty acid values represent percentages that are the sum of two or three fatty acids with similar nomenclatures and compound structures (e.g., 22:1n11 + 22:1n13). This was because the summed data were often provided in the raw data files. We summed all fatty alcohols and glyceryl ether diols (GED) as well as selected branched and iso-saturated fatty acids. The dataset includes percentages for the sum of the three main groups of fatty acids — saturated (SFA), mono-unsaturated (MUFA), and polyunsaturated (PUFA) — and the ratio of n3 to n6 PUFAs. We provide information on the percentage total lipid content for 1,927 records, with additional information on the percentage of polar lipid classes or triacylglycerol for 921 records. We provide concentration data (mg per 100 g⁻¹ tissue) for EPA (eicosapentaenoic acid, 20:5n3) and DHA (docosahexaenoic acid, 22:6n3) for 2,434 records. Highest concentrations of DHA and EPA were found in shark liver with high concentrations of DHA also in fish reproductive tissues, and EPA in krill.

The records include, where available, biological information on length (cm, for *n* = 2,751) and weight (g, *n* = 1,368) of individual specimens. Specimens range from 0.8 cm to 13.0 m highlighting the range of taxa included (from zooplankton to whales). Each record also entails additional information on the biome or environment and habitat type where the sample was collected. There was a quasi-uniform spread of specimen records acquired from tropical (*n* = 1,828), temperate (*n* = 1,922), and polar (*n* = 1,095) biomes. Most samples were from oceanic (*n* = 2,703) and pelagic (*n* = 3,308) habitat types.

The metadata outline the structure of all data fields and include references for each source. The metadata are a resource for future regional or global ecological and nutritional studies on marine lipids and fatty acids.

CLASS II RESEARCH ORIGIN DESCRIPTORS

A. Overall project description

Identity: Fatty acid profiles of more than 470 marine species from the Southern Hemisphere

Originators:

PETHYBRIDGE Heidi, CSIRO Oceans and Atmosphere, Hobart, Tasmania, Australia

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NICHOLS Peter D., CSIRO Oceans and Atmosphere, Hobart, Tasmania, Australia

VIRTUE Patti, IMAS, University of Tasmania, Hobart, Tasmania, Australia

MEYER Lauren, Southern Shark Ecology Group, Flinders University, Adelaide, South Australia, Australia

Period of study: 1989–2018

B. Project methodology

Sampling design:

A total of 4,856 marine consumer samples were collected around Australia and in the Indian, Pacific, and Southern Oceans over 30 years from 1989 to 2018. Sampling was done during monitoring programs, fisheries surveys, research cruises, or field trips. Animal ethic permits were obtained for all vertebrates and cephalopods as per the Australian code for the care and use of animals for scientific purposes as reported in the respective publications. All samples were kept at either -20 °C or -80 °C directly upon collection until lipid and fatty acid analysis. Often samples were kept on dry ice or ice packs during transit. The time frame in which samples were stored for, in at least -20 °C, varied between each regional study but was typically within 6 months of collection (with information provided for each record in the database, see Table 2).

Table 2. Details of variables used in data file “Marineconsumer_FAdata.csv”. NA = not applicable; ND = not determined, detected, or reported; percentage composition for total lipids is % of lipid present in a specific tissue sample; while % FA = percentage of fatty acids as a proportion of all fatty acids detected in the lipid of a tissue. WW = wet weight.

Variable	Variable definition	Unit	Storage type	Number of records	Value ranges
ID_record	unique record identifier	NA	integer	4856	1:4856
Source_ID	unique identifier of data provider(s) of record including person(s), organisation(s), funding bodies, any publications that analysed the record (linked to Table 3)	NA	integer	NA	1:24

Conditions_of_data_use	conditions in which data should be used (No = data can be used without permission of provider; Yes = data can only be used with permission of provider; refer to information provided in Table 3)	NA	integer	NA	NA
Sample_size	number of samples (n, 1 = individual sample; > 1 indicates mean value taken from pooled samples)	NA	integer	NA	NA
Taxa_group	broad taxonomic group (25 different groups)	NA	string	NA	NA
Species_common_name	common English species name	NA	string	NA	NA
Species_latin_name	Latin species name	NA	string	NA	NA
Tissue	type of tissue analysed for fatty acids (9 types: whole, muscle, stomach, blubber, mantle, milk, blood, liver, dermis, bone, reproductive organ)	NA	integer	NA	NA
Day	day of month sample was obtained	NA	integer	1180	1:31
Month	month of the year sample was obtained	NA	integer	3287	1:12
Year	year sample was obtained	NA	integer	4776	1989:2018
Sample_location	location or region where sample was obtained	NA	integer	NA	NA
Environment	environment or biome where samples obtained (tropical; warm temperate; cold temperate; polar)	NA	integer	NA	NA
Habitat_vertical	vertical habitat type (P = pelagic; B = benthic; BP = bathypelagic)	NA	integer	NA	NA
Habitat_horizontal	horizontal habitat type (C = coastal; O = oceanic; E = estuarine; SO = Southern Ocean/Antarctica; S = continental shelf/seamount)	NA	integer	NA	NA
Longitude	location longitude where sample was obtained (corresponds to accurate position when available, or centroid of different fishing positions from which specimens might originate)	decimal degrees	numeric	4454	-61.4:178
Latitude	location latitude where sample was obtained (corresponds to accurate position when available, or centroid of different fishing positions from which specimens might originate)	decimal degrees	numeric	4460	-76.0:3.02
MeanTroph_FB	average from two trophic-position metrics from <i>FishBase</i> or <i>SeaLifeBase</i> (accessed October 2020)	NA	numeric	3456	2.0:4.6
Length_type	type of length measurement (total, fork, mantle, standard, carapace); averages from pooled samples indicated with ‘_mean’	NA	integer	NA	NA
Length_cm	length (linked to Length_type) of specimen in centimetres	cm	string	2751	1.1:1300
Total_weight_g_WW	total wet weight of specimen in grams	g WW	numeric	1368	0.2:57500

Extraction_method	method used to obtain fatty acid data (full extraction – follows an adapted Bligh & Dyer 1959 method; direct transmethylation follows Parrish et al. 2015)	NA	string	NA	NA
Storage_time	time frame samples were stored, in at least - 20°C, after collection before lipid and FA analysis; weeks (between 1-4 weeks); months1_6 (1 to 6 months); months6_12 (6 to 12 months); years1_2 (1 to 2 years); years3_5 (3 to 5 years); years_longer5 (> 5 years)	NA	string	NA	NA
Total_lipid_content_%WW	% total lipid content in tissue analysed	% WW	numeric	1927	0:92.5
PL_%	polar lipids (PL) as % total lipid content detected in tissue analysed	% WW	numeric	921	0:96.9
TAG_%	triacylglycerol (TAG) as % total lipid content detected in tissue analysed	% WW	numeric	772	0:100
Total_SFA_%	sum of all saturated fatty acids (SFA) as % total fatty acids detected	% WW	numeric	4848	7.5:79.6
Total_MUFA_%	sum of all mono-unsaturated fatty acids (MUFA) as % total fatty acids detected	% WW	numeric	4848	3.8:88.8
Total_PUFA_%	sum of all poly-unsaturated fatty acids (PUFA) as % total fatty acids detected	% WW	numeric	4848	0.6:66.5
ratio_n3_n6	ratio of omega-3 PUFA to omega-6 PUFA	NA	numeric	4839	0:145.5
SUM_Alcs_GED_%	sum of all alcohols (Alcs)- and glyceryl ether diol- (GED) based fatty acids	% WW	numeric	2737	0.01:17.4
SUM_brSFA_brMUFA_%	sum of all mid-chain mythl branched (br) SFA and MUFA (including br16:0, br17:0, br17:1, and br19:1)	% WW	numeric	1386	0.01:14.3
SUM_isoSFA_%	sum of all iso-SFA (including: i14:0, i15:0, i16:0, i17:0, i18:0, i19:0)	% WW	numeric	4404	0.01:17.2
14.0_%	% 14:0 fatty acid	% WW	numeric	4594	0:31.1
15.0_%	% 15:0 fatty acid	% WW	numeric	4364	0:9.7
16.0_%	% 16:0 fatty acid	% WW	numeric	4856	5.0:63.7
17.0_%	% 17:0 fatty acid	% WW	numeric	4635	0:5.5
18.0_%	% 18:0 fatty acid	% WW	numeric	4856	0:55.0
20.0_%	% 20:0 fatty acid	% WW	numeric	4248	0:15.6
22.0_%	% 22:0 fatty acid	% WW	numeric	4147	0:10.2
14:1n5+n7_%	% 14:1n5 and 14:1n7 fatty acids	% WW	numeric	4856	0:5.7
16.1:n5_%	% 16:1n5 fatty acid	% WW	numeric	3976	0:11.3
16:1n7_%	% 16:1n7 fatty acid	% WW	numeric	4856	0:27.2
18:1n7_%	% 18:1n7 fatty acid	% WW	numeric	4856	0:33.1
18:1n9_%	% 18:1n9 fatty acid	% WW	numeric	4808	0:57.1
20:1n7+5_%	% 20:1n7 and 20:1n5 fatty acids	% WW	numeric	4856	0:23.2
20:1n9+11_%	% 20:1n9 and 20:1n11 fatty acids	% WW	numeric	4856	0:29.4
22:1n11+13_%	% 20:1n11 and 20:1n13 fatty acids	% WW	numeric	4856	0:34.2
22:1n9_%	% 22:1n9 fatty acid	% WW	numeric	4856	0:24.1
24:1n7+9+11_%	% 24:1n7, 20:1n9 and 20:1n11 fatty acids	% WW	numeric	4856	0:13.4
18:2n6_%	% 18:2n6 fatty acid	% WW	numeric	4840	0:13.4

18:4n3_%	% 18:4n3 fatty acid	% WW	numeric	4159	0:18.3
20:4n3_%	% 20:4n3 fatty acid	% WW	numeric	4540	0:11.8
20:4n6_%	% arachidonic acid (ARA, 20:4n6)	% WW	numeric	4520	0:30.6
20:5n3_%	% eicosapentaenoic acid (EPA, 20:5n3)	% WW	numeric	4856	0:43.9
22:4n6_%	% 22:4n6 fatty acid	% WW	numeric	4516	0:19.3
22:5n3_%	% 22:5n3 fatty acid	% WW	numeric	4820	0:24.3
22:6n3_%	% docosahexaenoic acid (DHA, 22:6n3)	% WW	numeric	4855	0:52.9
FAmg_known	if absolute fatty acid data were either (i) supplied, (ii) calculated (based on equations 1 and 2), or (ii) not determined (ND)	NA	string	NA	NA
EPA_mg_100g	content of EPA measured in tissue	mg 100g ⁻¹	numeric	2284	0:3995.1
DHA_mg_100g	content of DHA measured in tissue	mg 100g ⁻¹	numeric	2284	0:17473.6

Dataset collection and compilation:

We acquired 35 individual datasets (group of records) from 23 data providers. Most of the data included here come from regional ecological tracer studies, with two nutritional studies (Mooney et al. 2002; Nichols et al. 1998). Data quality was ensured for each dataset by including checking measurement types and the attribute names and removing records for which the sum of the percentage composition data was < 80% or > 100%. We used one of the more abundant fatty acids, palmitic acid (PA, 16:0), to test data quality, and we removed any record with < 5% PA from the dataset. We converted length and weight measurements to centimetres (cm) and grams (g wet weight) where relevant for inter-comparability. Dry to wet weight conversions were based on expert opinion and literature values (e.g., Cresson et al. 2017; Gogina et al. 2022) and ranged from 4.0 to 6.0 depending on the species. We manually completed record metadata by reviewing peer-reviewed articles or reports where fatty acids were first published. Once we had checked all datasets, we compiled them into a larger dataset using the *merge* function in the *tidyverse* R package (Wickham, 2017).

Laboratory procedures:

All lipid and fatty acid analyses were done at CSIRO laboratories in Hobart between 1989 and 2019.

Full extraction of lipids and lipid class compositions

Most records (94.6%; $n = 4,676$) are from samples extracted via modified Bligh and Dyer (1959) method. In brief, this included tissue samples being mixed in separatory funnels with a solvent mixture of nanograde chloroform (or dichloromethane):methanol (MeOH): Milli-Q H₂O (at a ratio of 10:20:0.8 ml), shaken and left overnight. The following day, a second solvent mixture of chloroform or dichloromethane:saline Milli-Q H₂O (9 g NaCl l⁻¹) (10:10 ml) was added and left for at least 2 hours. The lower, lipid-containing organic solvent layer was then drained into a round bottom flask and rotary-evaporated in a 40 °C water bath. Chloroform or dichloromethane was used to transfer the extract into a pre-weighed glass vial. Each glass vial was then placed on a heated block and blown down under nitrogen gas where the total lipid extract was retained. At this stage, the percentage (%)

and absolute (mg g^{-1} tissue) quantities of lipid content in tissues were analysed gravimetrically. Chloroform or dichloromethane were added to the glass vials at a known concentration and the extract stored at $-20\text{ }^{\circ}\text{C}$ until further processing.

Lipid class composition was determined using an Iatroscan Mark V TH10 thin layer chromatograph coupled with a flame ionisation detector. All samples were run in duplicate or triplicate along with standard solutions, with fractions of the two most abundant classes, triacylglycerols and phospholipids, reported as % of total lipids wet weight (ww).

Fatty acid analysis

To release the individual fatty acids, known concentrations of the total lipid extract were placed in clean test tubes rinsed with dichloromethane before the solvent was blown down under nitrogen gas. From there, 3 ml of methylating solution of 10:1:1 MeOH:HCl:chloroform or dichloromethane was added to each tube. Tubes were capped, vortexed, and placed on a heating block at $\sim 100\text{ }^{\circ}\text{C}$ for 2 hours prior to removal and allowed to cool. After cooling, 1 ml Milli-Q® water was added to samples and extracted with 1.8 ml 4:1 hexane:chloroform or hexane:dichloromethane. Extracts were then vortexed and centrifuged at 3000 rpm for 5 minutes. The upper layer was transferred to a clean, labelled vial, and blown down under inert nitrogen gas. The extractions were repeated twice and blown down after each upper layer was transferred to the labelled vial.

Fatty acid records determined by direct transmethylation (271 records) followed the methodology described by Parrish et al. (2015). This includes bypassing the lipid extraction steps as described above and instead placing the tissue sample into a transmethylation solvent system, following similar protocols described above. Instead of obtaining a total lipid content weight, some samples were weighed to obtain a total fatty acid weight.

For all samples, fatty acid peaks were identified through gas chromatography using an Agilent Technologies 6890N GC with an HP-5 crosslinked methyl silicone fused silica capillary column ($50 \times 0.32\text{ mm i.d.}$), a flame ionization detector, a splitless injector, and an Agilent Technologies 7683 Series auto-sampler and injector. Helium was used as the carrier gas. Post 2008, analyses were performed using an Agilent Technologies 7890A gas chromatography (Palo Alto, CA, USA) equipped with a nonpolar Equity-1™ fused silica capillary column ($15\text{ m} \times 0.1\text{ mm i.d.}$, 0.1 mm film thickness), flame ionization detector, and split/splitless injector. Samples were injected in splitless mode at an oven temperature of $120\text{ }^{\circ}\text{C}$, and after injection, the oven temperature was increased to $270\text{ }^{\circ}\text{C}$ at $10\text{ }^{\circ}\text{C min}^{-1}$ and then to $310\text{ }^{\circ}\text{C}$ at $5\text{ }^{\circ}\text{C min}^{-1}$. Peaks were quantified with Agilent Technologies ChemStation software (Palo Alto, CA, USA).

To ensure data quality, fatty acids samples were run on the gas chromatography in batches that included multiple solvent blanks and replicate analysis of tissue samples and laboratory standards. For each study, selected representative fatty acid samples were further analysed using gas chromatography-mass spectrometry to validate peak identifications. A Finnigan Thermoquest system

fitted with an oncolumn injector was used to do gas chromatography-mass spectrometry with Thermoquest Xcalibur software. Post 2012, analyses were performed with a ThermoFisher gas chromatography-mass spectrometry system. While analytical error is not often reported in fatty acids studies, Bierwagen et al. (2019) used replicate analysis to report a mean coefficient of variation (CV) of 12% (range: 0–92% for different fatty acid per wet weight) for the full extraction method. Error associated with the direct transmethylation method was higher with a mean CV of 28% (range: 0–97% for individual fatty acids).

Calculated absolute fatty acid estimates

Where absolute concentration values were not provided for fatty acids, we derived an equation to calculate the absolute wet weight of docosahexaenoic acid and eicosapentaenoic acid based on knowledge of the tissue or whole animal wet weight (WW) and the lipid content (% or mg/g) in the tissue, given by the equation (1):

$$\text{mg fatty acid } 100 \text{ g}^{-1} \text{ tissue} = \%FA(100ab) \quad (\text{Eq. 1})$$

where a = known organ or tissue sample weight (g wet weight); b = total lipid content (% wet weight); where this was unknown, we based estimates of absolute total lipid content (mg g⁻¹ wet weight), where possible, on mean values reported for fish taxa by Nichols et al. (1998) and Mooney et al. (2002). Where absent, we did not calculate absolute concentrations. If a was not known, we estimated it using the equation (2):

$$\hat{a} = cd/100 \quad (\text{Eq. 2})$$

where c = total body weight of specimen (g wet weight) and d = proportion, or %, organ or tissue weight to total body weight. These estimates were 35% for blubber, 50% for squid mantle or fish muscle, 20% for shark muscle, 2% for fish liver, 20% shark liver, 8% squid digestive gland, and 0.5% for fish and shark gonads. We based these estimates on published literature, including for fish (Graham et al. 1983), marine mammals (Lockyer et al. 2003 and Caon et al. 2007), squid (Pethybridge et al. 2011), and chondrichthyans (Pethybridge et al. 2010).

Additional biological and environmental information

Where possible, we included information on the habitat type (vertical and horizontal), trophic position or level, and environment for each record. For most (~ 70%) records, information on habitat and environment were detailed by the provider. We obtained all other information, including trophic position estimates, from the R package *rfishbase* to extract additional biological and distribution information from *FishBase* and *SeaLifeBase* databases (Boettiger et al. 2012). We matched estimates of trophic position at the species level and calculated it as a mean of two *FishBase* metrics: (i) food trophic position gives a Monte Carlo estimate of trophic level based on known food items, and (ii) diet trophic position uses the mean or median of trophic levels derived from actual measures of diet composition.

Caveats of the dataset

It is important to note some potentially important caveats to using this dataset, which are mostly attributed to the data coming from different data providers and over many years for which research questions and laboratory instruments and procedures were different. The most obvious caveat is that some datasets have a high number of individual fatty acids, and particularly those that are typically less abundant, that were not determined (shown as 'ND' in the database). Incomplete datasets are also likely to have skewed, to various extents, the percentage calculations. It is also important to be aware that some records are the means of pooled group and number of individuals and thus incorporate intraspecific variability.

CLASS III. DATASET STATUS AND ACCESSIBILITY

A. Status

Latest update: 29 March 2022

Latest archive data: 29 March 2022

Metadata status: Metadata are complete for this period and are stored with the data.

Data verification: The raw data passed through several rounds of review so that units were correct. Most (90%) records have been published and as such have gone through quality assurance by the data contributors and the journal peer-review process. Compilers of this database reviewed raw data and have verified all variables in the database by cross-correlations, checking credible ranges, and outlier detection (and removal where relevant). We appropriately matched raw data to variables in the `Marineconsumer_FAdata.csv`.

B. Accessibility

Storage location and medium: The data is stored as Supporting Information to this publication in the Ecological Society of America's journal *Ecology*. URL published in each issue. The data is stored in non-proprietary digital form on the CSIRO Data Portal (<https://data.csiro.au/collection/csiro:54636>) where it can be publically accessed and downloaded (Pethybridge et al. 2022).

Contact persons:

Heidi Pethybridge (e-mail: heidi.pethybridge@csiro.au)

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Where there are copyright restrictions, users of this dataset should contact the person responsible for this record (indicated under 'data_owner' in `source_id.csv`)

Copyright restriction: There are 480 data records within our data file for which the providers have requested that permission for reuse be granted, with the likely condition that they are included as a co-

author on the reporting of the dataset. Records with this condition are indicated by a 'yes' under 'Conditions_of_data_use' in Data S1: Marineconsumer_FAdata.csv (see Table 2 in Metadata S1 for more details).

For all other data records marked as 'No' under 'Conditions_of_data_use', there are no copyright restrictions for research and/or teaching purposes. Using the dataset must follow the citation instructions below

Proprietary restriction: We request that users acknowledge use of the data in publications, research proposals, websites, and other outlets following the citation instructions below.

Citation: Please cite the data paper when using any data records.

If you have used data from a small number of individual sources (check the "source_id" values of the data you used), please cite the original data sources (see details in CLASS IV Section B2 and see: Source_ID.csv file) and additionally acknowledge this database.

Nichols PD, Pethybridge HR, Zhang B, Virtue P, Meyer L, Dhurmeea Z, Marcus L, Ericson JA, Hellesey N, Every S, Wheatley K, Parrish CC, Eisenmann P, Baylis AMM, Bradshaw CJA, Bierwagen SL, Young JW, Couturier LIE, Rohner CA, Groß J, Waugh C, Phleger CF, Jackson C, Jackson G, Huveneers C, Bengtson Nash S, Brock M, Mansour P. (2022) Fatty acid profiles of more than 470 marine species from the southern hemisphere. *Ecology*.

Costs: None

CLASS IV. DATA STRUCTURAL DESCRIPTORS

A. Dataset file

Identity: Marineconsumer_FAdata.csv

Size: 1.58 MB, 4,856 records excluding header row

Format/storage mode: ASCII text, comma-separated values (.csv). No compression scheme used.

Header information: Headers describe contents of columns. Detailed description of column headers and contents is provided in Table 2.

Alphanumeric attributes: Mixed

Characters/fields: None

Authentication procedures: None

Data anomalies: None

Variable information: Provided in Table 2

B. Dataset file

Identity: source_id.csv

Size: 4 KB, 23 records excluding header row

Format/storage mode: ASCII text, comma-separated values (.csv). No compression scheme used.

Header information: Headers describe contents of columns. Detailed description of column headers and contents is provided in Table 3.

Table 3. Details of variables used in data file “Source_ID.csv”. NA = not applicable

Variable	definition	unit	storage type	value range
source_id	unique record identifier (linked to Table 2)	NA	Integer	1:23
data_owner	name of person responsible for record	NA	String	NA
institution	name of primary institution doing research	NA	String	NA
email	e-mail address of person responsible for record	NA	String	NA
funding	name(s) of organisation(s) and/or program(s) providing funding for research contributing to acquisition of record	NA	String	NA
citation	original literature reference(s) for record	NA	String	NA

Alphanumeric attributes: Mixed

Characters/fields: None

Authentication procedures: None

Data anomalies: None

Variable information: Provided in Table 3

CLASS V. SUPPLEMENTAL DESCRIPTORS

A. Data acquisition, processing, and archiving

Data entry/verification procedures: See CLASS II and CLASS III

Quality assurance/quality control procedures: See CLASS II and CLASS III

Related material: Electronic and/or paper copies of data sources (articles, reports, etc.) are held by the authors.

Computer programs and data processing algorithms: N/A

Archival Procedures: All data are archived by the Australian Antarctic Data Centre.

Redundant Archival Sites: NA

B. Publications using the dataset:

- Arnould, J.P.Y., Nelson, M.M., Nichols, P.D. and Oosthuizen, W.H., 2005. Variation in the fatty acid composition of blubber in Cape fur seals (*Arctocephalus pusillus pusillus*) and the implications for dietary interpretation. *Journal of Comparative Physiology B*, 175(4), 285-295.
- Baylis, A. M. M., and P. D. Nichols. 2009. Milk fatty acids predict the foraging locations of the New Zealand fur seal: continental shelf versus oceanic waters. *Marine Ecology Progress Series* 380, 271–286.
- Baylis, A. M. M., D. J. Hamer, and P. D. Nichols. 2009. Assessing the use of milk fatty acids to infer the diet of the Australian sea lion (*Neophoca cinerea*). *Wildlife Research* 36, 169.
- Bierwagen, S.L., Pethybridge, H., Heupel, M.R., Chin, A. and Simpfendorfer, C.A., 2019. Trophic niches determined from fatty acid profiles of sympatric coral reef mesopredators. *Marine Ecology Progress Series*, 632, 159-174.
- Bradshaw, C.J.A., Hindell, M.A., Best, N.J., Phillips, K.L., Wilson, G. and Nichols, P.D., 2003. You are what you eat: describing the foraging ecology of southern elephant seals (*Mirounga leonina*) using blubber fatty acids. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 270(1521), 1283-1292.
- Couturier L.I.E., Rohner C.A., Richardson A.J., Marshall A.D., Jaine F.R.A., Bennett M.B., Townsend K.A., Weeks S.J. and Nichols P.D., 2013a. Stable isotope and signature fatty acid analyses suggest reef manta rays feed on demersal zooplankton. *PLoSOne* 8, e77152 DOI: 10.1371/journal.pone.0077152
- Couturier, L.I.E., Rohner, C.A., Richardson, A.J., Pierce, S.J., Marshall, A.D., Jaine, F.R.A., Townsend, K., Bennett, M.B., Weeks, S.J. and Nichols, P.D., 2013b. Unusual high levels of n-6 polyunsaturated fatty acids in whale sharks and reef manta rays, *Lipids*, 48(10), 1029-1034.
- Dhurmea, Z., Pethybridge, H., Appadoo, C. and Bodin, N., 2018. Lipid and fatty acid dynamics in mature female albacore tuna (*Thunnus alalunga*) in the western Indian Ocean. *PLoSOne*, 13(4), p.e0194558.

- Dhurmeea, Z., Pethybridge, H., Romanov, E.V., Appadoo, C. and Bodin, N., 2020. Diet of albacore *Thunnus alalunga* from the waters of Mauritius (western Indian Ocean) inferred from stomach contents and fatty acid analysis. *African Journal of Marine Science*, 42(2), 131-140.
- Ericson, J.A., Hellesey, N., Nichols, P.D., Kawaguchi, S., Nicol, S., Hoem, N. and Virtue, P., 2018. Seasonal and interannual variations in the fatty acid composition of adult *Euphausia superba* Dana, 1850 (Euphausiacea) samples derived from the Scotia Sea krill fishery. *Journal of Crustacean Biology*, 38(6), 662-672.
- Ericson, J.A., Hellesey, N., Nichols, P.D., Nicol, S., Kawaguchi, S., Hoem, N. and Virtue, P., 2019. New insights into the seasonal diet of Antarctic krill using triacylglycerol and phospholipid fatty acids, and sterol composition. *Polar Biology*, 42(11), 1985-1996.
- Every, S.L., Pethybridge, H.R., Crook, D.A., Kyne, P.M. and Fulton, C.J., 2016. Comparison of fin and muscle tissues for analysis of signature fatty acids in tropical euryhaline sharks. *Journal of Experimental Marine Biology and Ecology*, 479, 46-53.
- Every, S.L., Pethybridge, H.R., Fulton, C.J., Kyne, P.M. and Crook, D.A., 2017. Niche metrics suggest euryhaline and coastal elasmobranchs provide trophic connections among marine and freshwater biomes in northern Australia. *Marine Ecology Progress Series*, 565, 181-196.
- Gallagher, A. J., Meyer, L., Pethybridge, H. R., Huveneers, C., & Butcher, P. A., 2019. Effects of short-term capture on the physiology of white sharks *Carcharodon carcharias*: amino acids and fatty acids. *Endangered Species Research*, 40, 297-308.
- Groß, J., Virtue, P., Nichols, P.D., Eisenmann, P., Waugh, C.A. and Bengtson Nash, S., 2020. Interannual variability in the lipid and fatty acid profiles of east Australia-migrating humpback whales (*Megaptera novaeangliae*) across a 10-year timeline. *Scientific Reports*, 10(1), 1-14.
- Guest, M.A., Hirst, A.J., Nichols, P.D. and Frusher, S.D., 2010. Multi-scale spatial variation in stable isotope and fatty acid profiles amongst temperate reef species: implications for design and interpretation of trophic studies. *Marine Ecology Progress Series*, 410, 25-41.
- Guest, M.A., Nichols, P.D., Frusher, S.D. and Hirst, A.J., 2008. Evidence of abalone (*Haliotis rubra*) diet from combined fatty acid and stable isotope analyses. *Marine Biology*, 153(4), 579-588.
- Jackson, C.H., Gales, R., Virtue, P. and Nichols, P.D., in press. Stratification, sex and ontogenetic effects on the lipid and fatty acid profiles in the blubber of sperm whales from Tasmanian waters. *Journal of Comparative Physiology B*.
- Jackson, G.D., Jackson, C.H., Virtue, P., Fluckiger, M., Nichols, P.D., 2021. Dietary fatty acid analyses of the squid *Idioteuthis cordiformis* – further evidence for predation on deepwater sharks. *Marine Ecological Progress Series* 675, 67-79.
- Jeffs, A.G., Nichols, P.D., Mooney, B.D., Phillips, K.L. and Phleger, C.F., 2004. Identifying potential prey of the pelagic larvae of the spiny lobster *Jasus edwardsii* using signature lipids. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*, 137(4), 487-507.
- Lea, M.A., Cherel, Y., Guinet, C. and Nichols, P.D., 2002. Antarctic fur seals foraging in the Polar Frontal Zone: inter-annual shifts in diet as shown from fecal and fatty acid analyses. *Marine Ecology Progress Series*, 245, 281-297.
- Marcus, L., Virtue, P., Pethybridge, H.R., Meekan, M.G., Thums, M. and Nichols, P.D., 2016. Intraspecific variability in diet and implied foraging ranges of whale sharks at Ningaloo Reef, Western Australia, from signature fatty acid analysis. *Marine Ecology Progress Series*, 554, 115-128.

- Meyer, L., Chambers, S., Gervais, C., Pethybridge, H., Beckmann, C., Bruce, B., and Huveneers, C., 2021. The use of muscle lipids and fatty acids to assess shark diet and condition. *Journal of Fish Biology* 98(2), 566-571.
- Meyer, L., Pethybridge, H., Beckmann, C., Bruce, B. and Huveneers, C., 2019a. The impact of wildlife tourism on the foraging ecology and nutritional condition of an apex predator. *Tourism Management*, 75, 206-215.
- Meyer, L., Pethybridge, H., Nichols, P.D., Beckmann, C. and Huveneers, C., 2019b. Abiotic and biotic drivers of fatty acid tracers in ecology: A global analysis of chondrichthyan profiles. *Functional Ecology*, 33(7), 1243-1255.
- Meyer, L., Pethybridge, H., Nichols, P.D., Beckmann, C., Bruce, B.D., Werry, J.M. and Huveneers, C., 2017. Assessing the functional limitations of lipids and fatty acids for diet determination: the importance of tissue type, quantity, and quality. *Frontiers in Marine Science*, 4, 369.
- Meyer, L., Whitmarsh, S.K., Nichols, P.D., Revill, A.T. and Huveneers, C., 2020. The effects of wildlife tourism provisioning on non-target species. *Biological Conservation*, 241, p.108317.
- Mooney, B.D., Nichols, P.D., and Elliott, N.G., 2002. Seafood the Good Food II. Oil profiles for further Australian seafoods, and influencing factors. FRDC Project 99/331. Guide prepared for the Fisheries Research and Development Corporation.
- Newland C., Field, I.C., Nichols, P.D., Bradshaw, C.J. and Hindell, M.A., 2009. Blubber fatty acid profiles indicate dietary resource partitioning between adult and juvenile southern elephant seals. *Marine Ecology Progress Series*, 384, 303-312.
- Nichols, P. D., Virtue, P., Mooney, B. D., Elliott, N. G. and Yearsley, G. K., 1998a. Seafood the Good Food. The oil content and composition of Australian commercial fishes, shellfishes and crustaceans. FRDC Project 95/122. Guide prepared for the Fisheries Research and Development Corporation.
- Nichols, P. D., Mooney, B., Virtue, P. and Elliott, N., 1998b. Nutritional value of Australian Fish: oil, fatty acid and cholesterol of edible species. Final report, August 1998. FRDC Project 95/122. Report prepared for the Fisheries Research and Development Corporation.
- Nichols, P.D., Danaher, K.T. and Koslow, J.A., 2003. Occurrence of high levels of tetracosahexaenoic acid in the jellyfish *Aurelia* sp. *Lipids*, 38(11), 1207-1210.
- Nichols, P.D., Mooney, B.D. and Elliott, N.G., 2002. Nutritional value of Australian seafood II. Factors affecting oil composition of edible species. Final Report FRDC Project 99/331. Prepared for the Fisheries Research and Development Corporation.
- Parrish, C.C., Nichols, P.D., Pethybridge, H. and Young, J.W., 2015a. Direct determination of fatty acids in fish tissues: quantifying top predator trophic connections. *Oecologia*, 177(1), 85-95.
- Parrish, C.C., Pethybridge, H., Young, J.W. and Nichols, P.D., 2015b. Spatial variation in fatty acid trophic markers in albacore tuna from the southwestern Pacific Ocean—a potential ‘tropicalization’ signal. *Deep Sea Research Part II: Topical Studies in Oceanography*, 113, 199-207.
- Pethybridge, H., Daley, R., Virtue, P. and Nichols, P., 2010a. Lipid composition and partitioning of deepwater chondrichthyans: inferences of feeding ecology and distribution. *Marine Biology*, 157(6), 1367-1384.
- Pethybridge, H., Daley, R., Virtue, P. and Nichols, P.D., 2011a. Lipid (energy) reserves, utilisation and provisioning during oocyte maturation and early embryonic development of deepwater chondrichthyans. *Marine Biology*, 158(12), 2741-2754.
- Pethybridge, H., Daley, R., Virtue, P., Butler, E.C.V., Cossa, D. and Nichols, P.D., 2010b. Lipid and mercury profiles of 61 mid-trophic species collected off south-eastern Australia. *Marine and freshwater research*, 61(10), 1092-1108.

- Pethybridge, H., Daley, R.K. and Nichols, P.D., 2011b. Diet of demersal sharks and chimaeras inferred by fatty acid profiles and stomach content analysis. *Journal of Experimental Marine Biology and Ecology*, 409(1-2), 290-299.
- Pethybridge, H., Virtue, P., Casper, R., Yoshida, T., Green, C.P., Jackson, G. and Nichols, P.D., 2012. Seasonal variations in diet of arrow squid (*Nototodarus gouldi*): stomach content and signature fatty acid analysis. *Journal of the Marine Biological Association of the United Kingdom*, 92(1), 187-196.
- Pethybridge, H.R., Parrish, C.C., Bruce, B.D., Young, J.W. and Nichols, P.D., 2014. Lipid, fatty acid and energy density profiles of white sharks: insights into the feeding ecology and ecophysiology of a complex top predator. *PLoS One*, 9(5), e97877
- Pethybridge, H.R., Parrish, C.C., Morrongiello, J., Young, J.W., Farley, J.H., Gunasekera, R.M. and Nichols, P.D., 2015. Spatial patterns and temperature predictions of tuna fatty acids: tracing essential nutrients and changes in primary producers. *PloS One*, 10(7), e0131598.
- Phillips, K.L., Jackson, G.D. and Nichols, P.D., 2001. Predation on myctophids by the squid *Moroteuthis ingens* around Macquarie and Heard Islands: stomach contents and fatty acid analyses. *Marine Ecology Progress Series*, 215, 179-189.
- Phleger, C.F., Nelson, M.M., Mooney, B.D. and Nichols, P.D., 2002. Interannual and between species comparison of the lipids, fatty acids and sterols of Antarctic krill from the US AMLR Elephant Island survey area. *Comparative Biochemistry and Physiology Part B: Biochemistry and Molecular Biology*, 131(4), 733-747.
- Phleger, C.F., Young, J.W., Guest, M., Lansdell, M. and Nichols, P.D., 2007. Signature fatty acids: a robust method for evaluating trophic relationships in open ocean ecosystems. *Global Ocean Ecosystem Dynamics*, p.64.
- Rohner C.A., Couturier L.I.E., Richardson A.J., Pierce S.J., Prebble C., Gibbons M.J. and Nichols P.D. 2013. Diet of whale sharks *Rhincodon typus* inferred from stomach content and signature fatty acid analyses. *Marine Ecology Progress Series* 493, 219-235 DOI: 10.3354/meps10500
- Tierney, M., Nichols, P.D., Wheatley, K.E. and Hindell, M.A., 2008. Blood fatty acids indicate inter-and intra-annual variation in the diet of Adélie penguins: comparison with stomach content and stable isotope analysis. *Journal of experimental marine biology and ecology*, 367(2), 65-74.
- Virtue, P., Johannes, R.E., Nichols, P.D. and Young, J.W., 1995. Biochemical composition of *Nyctiphanes australis* and its possible use as an aquaculture feed source: lipids, pigments and fluoride content. *Marine Biology*, 122(1), 121-128.
- Wagh, C.A., Nichols, P.D., Noad, M.C. and Nash, S.B., 2012. Lipid and fatty acid profiles of migrating Southern Hemisphere humpback whales *Megaptera novaeangliae*. *Marine Ecology Progress Series*, 471, 271-281.
- Wheatley, K.E., Nichols, P.D., Hindell, M.A., Harcourt, R.G. and Bradshaw, C.J.A., 2008. Differential mobilization of blubber fatty acids in lactating Weddell seals: evidence for selective use. *Physiological and Biochemical Zoology*, 81(5), 651-662.
- Wheatley, K.E., Nichols, P.D., Hindell, M.A., Harcourt, R.G. and Bradshaw, C.J.A., 2007. Temporal variation in the vertical stratification of blubber fatty acids alters diet predictions for lactating Weddell seals. *Journal of Experimental Marine Biology and Ecology*, 352(1), 103-113.
- Wilson, G.A., 2004. The lipid composition of Patagonian toothfish from the Macquarie Island region: ecological and dietary implications within a regional food web. Doctoral dissertation, University of Tasmania.

Young, J.W., Guest, M.A., Lansdell, M., Phleger, C.F. and Nichols, P.D., 2010. Discrimination of prey species of juvenile swordfish *Xiphias gladius* (Linnaeus, 1758) using signature fatty acid analyses. *Progress in Oceanography*, 86(1-2), 139-151.

C. History of dataset usage

Data request history: N/A

Dataset update history: Latest update: 26 July 2022

Review history: N/A

Questions and comments from secondary users: N/A

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LITERATURE CITED ON METADATA

- Bierwagen, S.L., Pethybridge, H., Heupel, M.R., Chin, A. and Simpfendorfer, C.A., 2019. Trophic niches determined from fatty acid profiles of sympatric coral reef mesopredators. *Marine Ecology Progress Series*, 632, 159-174.
- Bligh EG, Dyer W (1959) A rapid method of total lipid extraction and purification. *Canadian Journal of Biochemistry and Physiology*, 37:911–917
- Boettiger, C., Lang, D.T. and Wainwright, P.C., 2012. rfishbase: exploring, manipulating and visualizing FishBase data from R. *Journal of Fish Biology*, 81(6), 2030-2039.
- Caon, G., Fialho, C.B. and Danilewicz, D., 2007. Body fat condition in franciscanas (*Pontoporia blainvillei*) in Rio Grande do Sul, southern Brazil. *Journal of Mammalogy*, 88(5), 1335-1341.
- Cresson, P., Travers-Trolet, M., Rouquette, M., Timmerman, C.A., Giraldo, C., Lefebvre, S. and Ernande, B., 2017. Underestimation of chemical contamination in marine fish muscle tissue can be reduced by considering variable wet: dry weight ratios. *Marine Pollution Bulletin*, 123(1-2), 279-285.
- Gogina, M., Zettler, A. and Zettler, M.L., 2022. Weight-to-weight conversion factors for benthic macrofauna: recent measurements from the Baltic and the North seas. *Earth System Science Data*, 14(1), 1-4.
- Graham, J.B., Koehn, F.J. and Dickson, K.A., 1983. Distribution and relative proportions of red muscle in scombrid fishes: consequences of body size and relationships to locomotion and endothermy. *Canadian Journal of Zoology*, 61(9), 2087-2096.
- Lockyer, C., Heide-Jørgensen, M.P., Jensen, J. and Walton, M.J., 2003. Life history and ecology of harbour porpoises (*Phocoena phocoena*) from West Greenland. *NAMMCO Scientific Publications*, 5, 177-194.

- Mooney, B.D., Nichols, P.D., and Elliott, N.G., 2002. Seafood the Good Food II. Oil profiles for further Australian seafoods, and influencing factors. FRDC Project 99/331. Guide prepared for the Fisheries Research and Development Corporation.
- Nichols, P. D, Virtue, P., Mooney, B. D., Elliott, N. G. and Yearsley, G. K., 1998. Seafood the Good Food. The oil content and composition of Australian commercial fishes, shellfishes and crustaceans. FRDC Project 95/122. Guide prepared for the Fisheries Research and Development Corporation.
- Parrish, C.C., Nichols, P.D., Pethybridge, H. and Young, J.W., 2015. Direct determination of fatty acids in fish tissues: quantifying top predator trophic connections. *Oecologia*, 177(1), 85-95.
- Pethybridge, H., Daley, R., Virtue, P. and Nichols, P., 2010. Lipid composition and partitioning of deepwater chondrichthyans: inferences of feeding ecology and distribution. *Marine Biology*, 157(6), 1367-1384.
- Pethybridge, H., Daley, R., Virtue, P. and Nichols, P.D., 2011. Lipid (energy) reserves, utilisation and provisioning during oocyte maturation and early embryonic development of deepwater chondrichthyans. *Marine Biology*, 158(12), pp.2741-2754.
- Pethybridge, H., Nichols, P., Zhang, B., Virtue, P., Meyers, L., Dhurmeea, Z., Marcus, L., Ericson, J., Hellessey, N., Every, S., Wheatley, K., Parrish, C., Eisenmann, P., Baylis, A., Bradshaw, C., Bierwagen, S., Young, J., Couturier, L., Rohner, C., Groß, J., Waugh, C., Phleger, C., Jackson, C., Jackson, G., Huveneers, C., Bengtson Nash, S., Brock, M., Mansour, P., 2022. Fatty acid profiles of marine consumer from the Southern Hemisphere. v1. CSIRO. Data Collection. <https://doi.org/10.25919/pdxr-cf66>
- Wickham H, Averick M, Bryan J, Chang W, McGowan LD, François R, Golemund G, Hayes A, Henry L, Hester J, Kuhn M, Pedersen TL, Miller E, Bache SM, Müller K, Ooms J, Robinson D, Seidel DP, Spinu V, Takahashi K, Vaughan D, Wilke C, Woo K, Yutani H., 2019. “Welcome to the tidyverse.” *Journal of Open Source Software*, 4(43), 1686. doi: 10.21105/joss.01686.