Marine and Freshwater Energy Density Integrated and Organized by Taxonomy from Previous Research Sources Discovered by a Literature Review through June 2024

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Project
» Nutritional ecology of climate change: Impacts on Northwest Atlantic fishes (NECC)

Contributors	Affiliation	Role
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Abstract
Energy is the currency of exchange within ecosystems which defines the strength and influence of interactions, particular between predator and prey. The ability to estimate the productivity of an ecosystem is, therefore, dependent upon the estimation of consumer diet contents and their energetic quality. To estimate growth, reproduction, and, ultimately, survival of individuals, measures of prey quality for predators are essential both at the individual level and for scaling to ecosystem-wide fluxes and pools. Among measures of prey quality, energy density (kJ/g) is the most used in ecology. Considerable efforts have established estimates of energy densities for many aquatic taxa. However, a database of aquatic organism energetics constructed by integrating and organizing across multiple sources spawning marine and freshwater habitats across the globe is needed to add both depth (more samples to measure within-taxa variation) and breadth (more taxa). To generate a comprehensive energy density database of aquatic organisms, we performed a multifaceted review to find sources from the peer-reviewed and grey literature with a broad search on Web of Science, from citations of related literature, and a haphazard recommendation from experts. Estimates of energy density of whole organism live weights (kJ/g wet weight) were prioritized to better relate to diet and energetics studies. When energy density was only provided per gram dry weight, the dry weight and percentage water was used to calculate energy density per gram wet weight. Sub-organism (i.e. tissue specific) energy density estimates are included (e.g. muscle, liver, egg) when only these were reported. A total of 3810 records are included from 134 sources, covering 2016 unique taxa, of which 1771 (87.76%) are identified at the species level. Species or taxa-specific energy densities ranged from 0.015 – 17.949 kJ/g wet weight (WW) with a mean ± SD = 4.509 ± 1.94 kJ/g WW and median = 4.225 kJ/g WW. Among those phyla with more than three species (n phyla = 9), chordates (n taxa = 1283) had the highest average energy density (mean ± SD; 4.92 ± 1.90; 0.162 – 17.9 kJ/g WW) and ctenophores (n taxa = 4) had the lowest average (0.0988 ± 0.074; 0.03 – 0.205 kJ/g WW). Each record includes the organism taxonomy to the lowest resolution listed in the original source, energetic data available from the source including body composition and energy density data, number of replicates and methodology for measuring energetics information—primarily split between bomb calorimetry and proximate composition—as well as the source's author(s), year, and publication. Additional meta-data are included whenever possible based on details from the original source including the 1) environmental features: area, method, and timing of capture; 2) methodological features: storage method, storage duration, and tissue type measured; and 3) organismal features: weight, length, and sex; as well as any additional notes about the source. This comprehensive database integrates those data discoverable by our search and which met inclusion criteria identified above in a taxonomic and spatial organization framework to facilitate modeling trophic interactions, bioenergetics, growth, productivity, and energy fluxes through marine and freshwater ecosystems.

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Coverage

Location: GLOBAL
Spatial Extent: **N**:90 **E**:180 **S**:-90 **W**:-180
Temporal Extent: 1961 - 2024

Methods & Sampling

Original sources utilized variable sampling techniques. Our approach for integrating across these sources began by identifying sources containing energy density data for aquatic organisms. First, we conducted a literature search on Web of Science using the search string: “("energy densit*" OR "energy content*" OR "energy equivalen*") AND (marine OR Atlantic)” The 745 results were rough filtered by a check of the abstract to identify whether they followed the correct topic, with potential sources being inspected more closely for containing data on energy density as a per weight unit (~2/3 sources following the first filter had suitable data). Appropriate conversions were made as necessary with a particular emphasis on conducting a conversion to energy density per gram wet weight as the focal measure of interest within the database. All sources which contained one or more taxon with an energy density measure were included within the database. Additional metadata about the record was gleaned from the source as available including the location and method of capture, storage and analytical technique, and number of replicate samples. Locations of estuarine and marine coastal data were also categorized by large marine ecosystem (LME; Sherman 1991, 2014); open ocean locations were defined by the ocean body; locations of freshwater data were categorized by continent. Additional sources were sought out through a snowball method by which references for relevant papers on energetics which did not contain measures of energy density but cited sources of data were searched, of note as a source for other original records was the Pelagic Traits Database (Gleiber et al. 2024). Efforts to locate original sources of energy density data were always taken, but in some instances a review paper was included due to complications with accessibility or reference obscurity. The use of data from reviews may result in a “double counting” of individuals when both an original source and review include them in their average. Finally, grey literature was included through a haphazard search and through communications with experts.

Taxonomic classification for each record began with that reported by the original source, primarily a Genus species name but occasionally at broader grades such as Family and Order. Taxonomy for all records was retrieved 26-Apr-2024, from the Integrated Taxonomic Information Service (ITIS), www.itis.gov, CC0, https://doi.org/10.5066/F7KH0KBK. Species names from original records were changed to agree with valid ITIS names as of this date.

Data was acquired from the original sources as they were published and available online or in print. They were then transferred by copy-paste automation whenever possible and manually in all other instances. The accurate entry of all data was checked by the principal investigator following each source being entered in completion. Missing data represents instances when a variable was not provided by the original source, often due to variable study designs or methodologies, e.g., Bomb Calorimetry studies do not collect data on percent of body mass that was lipid. Errors in values were identified by visualizing (for numeric variables) or tabulating (for character variables) each variable independently. The dataset was thoroughly examined by the principal investigator and original creator of the database, but was checked by the remaining members of the team for any anomalies. Additional independent review of an early draft was provided by S. Gaichas.

Data Processing Description

Data processing used a simple R script (preyEDs_processing.R) to input input data files of both raw record and summarized averages to the central database. Quality Assurance steps are performed for confirming data completeness. The script also includes the creation of a summary figure for the raw data.

Code is operated with R version 4.3.2 "Eye Holes".
See Supplemental Files section for "preyEDs_processing.R"

BCO-DMO Processing Description

- Imported data from source file "preyEDs_integrated_12_24.csv" into the BCO-DMO data system.
- Missing data identifiers of NA, N/A, and "N/A" were replaced with blanks.

Problem Description

Inconsistencies in data reporting by previous sources, most notably information on percent water by mass which enables a conversion from energy density dry weight to wet weight. Sources which did not report this were excluded from the database, but occasional values are still included.

Collection years are not consistently reported by previous sources, relying then on publication years for addressing broader temporal effects.

Methodologies vary between sources, but are primarily documented and recorded in each record of this database. Bomb calorimetry and proximate composition are the primary methods for analysis, but additional sources of variation my result from storage, tissue selection, or external values used in calculations.

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Related Publications

Hermann, N.T., Wuenschel, M.J. and Furey, N.B. (in review). Marine and Freshwater Organism Energy Densities Integrated Across Previous Sources. Ecology.
Results

R Core Team (2023). R: A language and environment for statistical computing. R v4.3.2. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/
Software

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Related Datasets

Related Research

U.S. Geological Survey. (2013). Integrated Taxonomic Information System (ITIS). U.S. Geological Survey. https://doi.org/10.5066/F7KH0KBK

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Parameters

Parameter	Description	Units
Phylum	Phylum of the organism in the record	unitless

Class	Class of the organism in the record	unitless
Order	Order of the organism in the record	unitless
Family	Family of the organism in the record	unitless
Genus	Genus name of the organism in the record	unitless
Species	Species name for the organism in the record	unitless
Taxa	Genus + species name for the organism in the record	unitless
TSN	Taxonomic Serial Number from the Integrated Taxonomic Information System (ITIS) for the taxa on record	unitless
Common_name	English name for organism in the record	unitless
Sex	Information from the original source about the sex of the organism for the record	unitless
Size_Maturity	Information from the original source about the age/maturity or a broad size category (Small, Medium, Large) for the record	unitless
Season_or_doy	Information from the original source about the time of year when the sample(s) were collected. Includes the season, month, or—when a number is provided—the median day of year across sampling dates.	unitless
Capture_method	Information from the original source on how individuals were captured for analysis	unitless
Region	Name of the water body from which the samples were collected or the median latitude, longitude position	unitless
LME_Continent	Large Marine Ecosystem (for marine taxa) or Continent (for freshwater taxa) where collections occurred	unitless
Ocean_Freshwater	Naming the larger ocean (of the 5 major oceans) where collection occurred or identifying samples as being from freshwater	unitless
Storage_method	After samples were collected, how were they preserved until analysis	unitless

Storage_duration_years	How long samples were stored between collection and analysis; only the maximum amount is listed.	years
Methodology	How samples were analyzed for energy density; bomb calorimetry or proximate composition analysis	unitless
Sample_Type	Composition of the sample analyzed either as a portion of the individual or pooling of individuals	unitless
N_replicates	Number of replicate samples analyzed (e.g., combustions, extractions) from the study on record	count
Size_min_mm	The smallest recorded length for the individual(s) from the study on record	mm
Size_max_mm	The largest recorded length for the individual(s) from the study on record	mm
Size_min_g	The smallest recorded weight for the individual(s) from the study on record	grams (g)
Size_max_g	The largest recorded weight for the individual(s) from the study on record	grams (g)
Ash_perc	The percentage of the sample body mass that was ash (inorganic material after combustion)	percent (%)
H2O_perc	The percentage of the sample body mass that was water (after drying)	percent (%)
Lipid_perc	The percentage of the sample body mass that was lipid	percent (%)
AFLDM	Ash Free Lean Dry Mass, percentage of the sample body mass that was protein	percent (%)
Dry_KJg_mean	Mean reported energy density of the dry sample. May have been reported by source or calculated from other data reported.	kiloJoules per gram (kJ/g)
Dry_KJg_SD	Standard deviation of energy density of the dry sample. May have been reported by source or calculated from other data reported.	kiloJoules per gram (kJ/g)
Ash_KJg	Mean reported energy density of the sample ash mass. May have been reported by source or calculated from other data reported.	kiloJoules per gram (kJ/g)

Wet_KJg_mean	Mean reported energy density of the wet sample. May have been reported by source or calculated from other data reported.	kiloJoules per gram (kJ/g)
Wet_KJg_SD	Standard deviation of energy density of the wet sample. May have been reported by source or calculated from other data reported.	kiloJoules per gram (kJ/g)
Wet_KJg_min	Minimum reported energy density of the wet sample. May have been reported by source or calculated from other data reported.	kiloJoules per gram (kJ/g)
Wet_KJg_max	Maximum reported energy density of the wet sample. May have been reported by source or calculated from other data reported.	kiloJoules per gram (kJ/g)
Indigestible_perc	The percentage of the sample wet mass that was shell weight	percent (%)
Publication_Type	Classifying the type of source where data comes from as either one where data were measured by the authors (original) or collected from previous work (review)	unitless
Publication_Author	The author name(s) from the original source of record	unitless
Publication_Journal	The publishing location of the original source of record, either a peer-reviewed journal or agency	unitless
Publication_Year	The year when the original source on record was last updated/published. Does not equate to sample collection year(s).	year
Notes	Additional notes regarding the source	unitless

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Project Information

Nutritional ecology of climate change: Impacts on Northwest Atlantic fishes (NECC)

Coverage: Northwest Atlantic Shelf 42 N 69 W

NSF Award Abstract:

Warming oceans are changing the distributions of fish populations worldwide. However, observed shifts in distribution differ from one species to the next, which lead to changes in the marine community and the biological interactions. Altered predator-prey relationships could force a switch in diet, which might influence growth and affect a fish's ability to persist in the environment. This project aims to predict how fish behaviors contribute to responses of species, populations, and ecosystems to continued environmental change. The study is focused on the distribution and diets of fishes in the Northwest Atlantic Ocean, one of the most rapidly warming marine systems on the planet. An existing long-term data set (1973 – present) forms the basis for a retrospective analysis of how fish populations and their diets have changed over the past five decades.

The model developed from these data is testing how observed changes in distribution and diet are related to species-specific behaviors and movements. This information is incorporated into predictions of the nature and quality of fish diets in the year 2055 using different climate projections. The broader impacts are focused on broadening participation in STEM careers, which includes training of students and a post-doc. To advance the recruitment and education of future scientists, project results are being integrated into the Gulf of Maine Research Institute's LabVenture program, which serves 10,000 elementary students in Maine annually. In parallel, the project is partnering with the Seacoast Science Center in New Hampshire to develop and test educational modules. Research findings are being communicated to fisheries managers locally and nationally and are contributing to science-based resource management.

Increased water temperatures impact the energetics of individual organisms directly by increasing metabolism and indirectly by altering overlap with prey as a result of taxon-specific shifts in population distributions. Species-specific shifts in spatial distributions and diets could mediate or exacerbate the metabolic consequences of warming waters. Furthermore, food web structure, and any temporal shifts in its composition, could affect ecosystem stability. Behavioral flexibility in diet and space use could confer resilience of individual species to climate change, but empirical evidence is lacking. This project combines spatial statistics, multivariate analyses, and food web models to understand how warming waters impact individuals, species interactions, and community stability, as well as identify taxon-specific behaviors that could confer resilience. This project is conducting retrospective analyses to quantify both decadal-scale shifts in fish distributions and diet, and species-level flexibility in diet and movements. From these analyses, spatially explicit predator-prey interactions are being projected into the future (2055) using three climate change scenarios to predict novel interactions and changes in diet for important predatory fishes. Linkages between behavior and resilience to warming waters are being tested by comparing the energetic consequences of diet shifts between behaviorally flexible and inflexible species. Quantifying interaction strengths among food web components is providing insight into how flexibility of individual taxa affects broader food web structure and how community stability is maintained.

This project is jointly funded by the Biological Oceanography Program and the Established Program to Stimulate Competitive Research (EPSCoR).

This award reflects NSF's statutory mission and has been deemed worthy of support through evaluation using the Foundation's intellectual merit and broader impacts review criteria.

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Funding

Funding Source	Award
NSF Division of Ocean Sciences (NSF OCE)	OCE-2023536

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