**Reef fish growth dataset: annual otolith sagittal growth for Pacific coral reef fishes**

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**Introduction**

Anthropogenic disturbances such as overexploitation of resources and climate change can significantly alter the structure and functioning of marine ecosystems (Dulvy et al. 2000, Jackson et al. 2001, Hoegh-Guldberg and Bruno 2010). Assessing the vulnerability of species enables us to predict how species will respond to these major stressors (William et al. 2007, Graham et al. 2011), but requires high-resolution data on the life history and ecological traits of species (Dulvy et al. 2000, 2003, Cheung et al. 2005). Somatic growth, the increase of body mass across time, is a critical biological trait for the assessment of physiological as well as population to ecosystem-level processes. For fishes, this trait is particularly important as it pertains to past, present, and future population trajectories in the context of fisheries and stock management. Several temperate species have been studied extensively due to their commercial importance, but much less information exists for the majority of coral reef associated species, which are targeted mainly by subsistence fishing (but see, for instance, Taylor et al. 2014).

Somatic growth is an essential parameter to quantify ecosystem processes such as the production of biomass (Depczynski et al. 2007, Brandl et al. 2019, Morais and Bellwood 2019). Moreover, the rate of somatic growth is directly correlated to the energetic demand of organisms, their metabolism and the influence they may have on important ecological processes such as nutrient cycling (Barneche and Allen 2015, 2018). As such, the rate of somatic growth is one of the key-parameters that drive bioenergetic models, one of the main tools to quantify fluxes from the individual to the ecosystem level (Schreck and Moyle 1990, Schindler and Eby 1997, Frost et al. 2006).

Fish growth parameters can be estimated from several approaches, but those linking age to body size are predominantly used. Hard structures such as scales, vertebrae, fin spines, cleithra, opercula, and otoliths present growth increments used for age estimations (Campana 2001). For teleost fish, age is mostly estimated from otolith, calcified structures of the inner ear that grow with the deposition of successive calcium carbonate layers and respond to both circadian and seasonal rhythms (Pannella 1971, Panfili et al. 2002, Jolivet et al. 2008, 2013). Fish growth parameters can be obtained from various models such as Gompertz, Logistic, Power or Von Bertalanffy (the most commonly used). Growth can be modelled by sampling across a large number of individuals that represent the complete size range of studied species. However, such analyses are extremely time consuming, and the raw data are generally unpublished or available only from “grey literature” and/or for commercial species. In most cases, sample sizes are small due to difficulties with sampling or the rarity of fishes in multi-species assemblages as observed on coral reefs. In this context, another approach is to apply a back-calculation model to estimate size at previous ages to model growth, as suggested by Vigliola and Meekan (2009).

Here, we provide a database of otolith readings, accompanied by the back-calculated size at age for 45 species (709 individuals) of coral reef fishes collected across different islands in French Polynesia. We provide back-calculation data calculated by site when more than 5 individuals were available; and in all case, global estimates across all sites for each species. We provide back-calculation data rather than model data so that users may choose models in accordance to their scientific questions. We emphasize that these data can also be used to estimate length weight relationships.

**Metadata**

**Class I. Data set descriptors**

1. **Data set identity**

**Title:** Reef fish growth dataset: annual otolith sagittal growth for Pacific coral reef fishes

1. **Data set identification code**

size\_at\_age\_coral\_reef\_fishes\_data.csv

1. **Data set description**
2. **Principal Investigators**

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1. **Abstract**

Somatic growth, the increase of body mass over time is a critical biological trait for the assessment of physiological as well as population to ecosystem level processes. Indeed, the rate of somatic growth is directly correlated to the energetic demands of organisms, their metabolism and the influence they may have on important ecological processes such as nutrient cycling. As such, the rate of somatic growth is one of the most basic parameters that drives bioenergetic models, one of the main tools to quantify fluxes from the individual to the ecosystem level. For marine fishes, this information is available predominantly for temperate species targeted by commercial fisheries and aquaculture, which often limits our capacity to perform analyses at the community level across a large number of species. Quantifying the sagittal growth of fish otoliths, calcium carbonate structures in the inner ear, is a powerful tool to estimate individual growth. However, this type of raw data is rarely available due to the time-consuming nature of otolith processing. This is especially true for coral reef fishes, which are extremely diverse and commercially important mainly for local subsistence fisheries. Here, we report the sagittal otolith growth and back-calculated fish size at age of 709 individuals belonging to 45 species of coral reef fishes. All fishes were caught in French Polynesia across six islands (Nuku Hiva, Manuae, Moorea, Mataiva, Hao and Mangareva) belonging to different archipelagos with distinct temperature ranges. No copyright or proprietary restrictions are associated with the use of this dataset other than citation of this paper.

1. **Key words**

French Polynesia, coral reef, fish, otolith, back-calculation , growth

**Class II. Research origin descriptors**

1. **Overall project description**
2. **Identity**

Project title: REEF SERVICES

1. **Originator(s)**

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1. **Period of study**

The project started in January 2016 with sampling for the NECTAR project and RETROMAR (Funding by the LABEX CORAIL), and it was continued by the REEF SERVICES project in 2017. The collections were completed in November 2018.

1. **Objectives**

We aimed to collect important ecological data to understand how climate change impacts ecosystem processes and key services (e.g. food provisioning, coastal protection) to humans.

1. **Abstract**

Climate change and anthropogenic activities have already triggered profound impacts on ecosystems and concerns are emerging about the potential for impacted systems to deliver key services to humans. In the marine realm, coral reefs host the highest marine biodiversity and provide crucial services (e.g. edible biomass, coastal protection, etc.), which sustains 500 million people worldwide. However, coral reefs are degrading due to increasing frequencies of climate-induced (e.g. due to El Niño) coral bleaching events and chronic disturbances such as overfishing. Since 1998, a significant body of literature has been produced to document these impacts. The mechanisms linking climatic extremes with coral die-off are now clear, but we still do not know the consequences of widespread coral mortality for the services that sustain human populations. Mathematical models suggest that reduced habitat complexity after bleaching impacts small-bodied fishes and this effect propagates through food webs to species of high commercial value. The gap of knowledge on the effects of climate change on ecosystem services is due to a lack of assessments across a large set of species. Considering the millions of people that depend on coral reefs, this is a considerable concern. Here, we aim to fill these gaps by testing how extreme climatic event can impact productivity across coral reef ecosystems.

1. **Sources of funding**

The project was supported by the BNP Paribas Foundation (REEF SERVICES project), the Agence Nationale de la Recherche (ANR-17-CE32-006), the Fondation de France, a Make our Planet Great Again Postdoctoral Grant (mopga-pdf-0000000144), and “Direction des ressources marines” (convention number 09419).

1. **Specific subproject description**
2. **Study sites**

Spread over 2.500.000 km2, there are 118 islands across French Polynesia, including 5 different archipelagos: the Society Islands, Tuamotus, Marquesas, Austral Islands and Gambiers. Collections were made across four archipelagos, including six islands: Moorea and Manuae (Society Islands), Hao and Mataiva (Tuamotus), Mangareva (Gambiers), and Nuku Hiva (Marquesas) (Figure 1). Fishes were collected in the lagoon and/or the outer slope according to the accessibility of the site.

Sea surface temperatures vary across the archipelagos of French Polynesia, and Table I show the sea surface temperatures (SST) recorded around each study island based on Bio-ORACLE data (Tyberghein et al. 2012). Bio-ORACLE provides high-resolution biotic and environmental datasets across global marine realms.

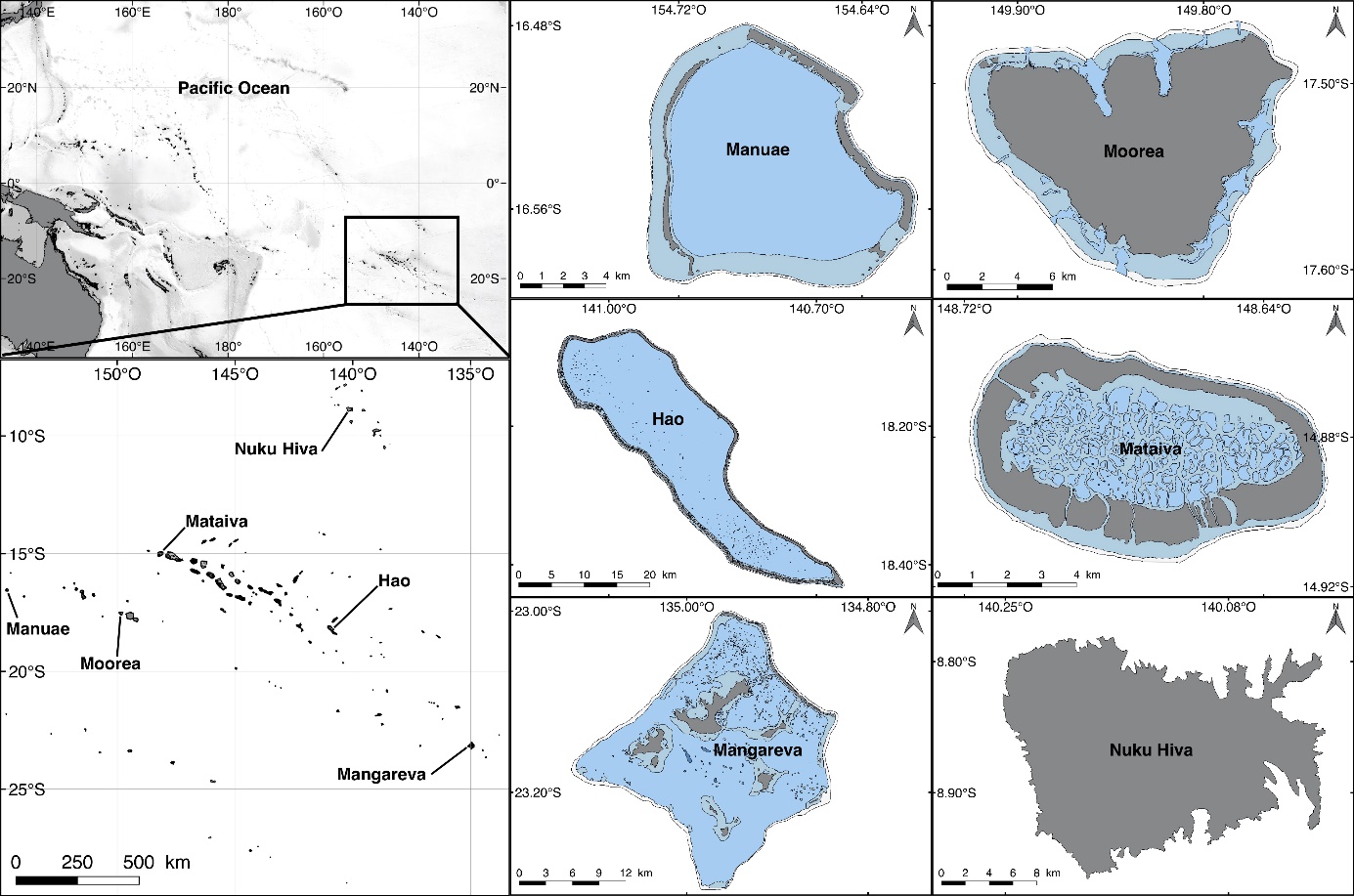


Figure 1: Map of French Polynesia and the islands where fishes were collected.

Table I: Minimum, mean, and maximum temperatures (°C) across the six islands where fishes were collected.

|  |  |  |  |
| --- | --- | --- | --- |
| **Island** | **Minimum** | **Mean** | **Maximum** |
| Hao | 25.72 | 27.53 | 29.26 |
| Mangareva | 23.20 | 25.44 | 27.74 |
| Manuae | 26.83 | 28.39 | 29.78 |
| Mataiva | 27.26 | 28.60 | 29.66 |
| Moorea | 26.62 | 28.29 | 30.94 |
| Nuku Hiva | 27.41 | 28.21 | 29.33 |

1. **Sampling design**

Fishes from Moorea, Manuae (Society Islands) and Nuku Hiva (Marquesas) were collected with spearfishing and clove oil. Fishes from Hao (Tuamotus) and Mangareva (Gambiers) were collected by spearfishing. Additional fishes from Mataiva (Tuamotus) were bought at the fish market in Tahiti. All applicable international, national, and/or institutional guidelines for the care and use of animals were followed.

Fishes from Moorea were collected in March 2016, March 2018, July 2018 and November 2018. Fishes from Manuae were collected in December 2014. Fishes from Nuku Hiva were collected in August 2016 and March 2017. Fishes from Hao were collected in March 2017 and July 2017. Fishes from Mangareva were collected in June 2018.

1. **Research methods**
2. Field/Laboratory

In the laboratory, total fish length (TL) was measured to the nearest millimeter and pairs of sagittae (largest otolith of the inner ear) were extracted, cleaned with distilled water, dried and stored in microtubes.

For each species, otoliths were cut transversely, using a diamond disc saw (Presi Mecatome T210) to obtain a section of 500 µm. Sections were then fixed on a glass side with thermoplastic glue (Crystalbond TM). Small section otoliths were obtained by sanding both sides. Otoliths were sanded with abrasive discs of decreasing grain size (2 400 and 1 200 grains cm-²) and polished with a 0.25 µm diameter diamond suspension in order to be closest to the nucleus. All sections were photographed under a Leica DM750 light microscope with a Leica ICC50 HD microscope camera and LAS software (Leica Microsystems). When sections were too large, multiple photographs were taken and assembled with Photostitch software (Canon).

For each species, a reading transect was chosen and distances between annual growth increments were measured with ImageJ software. This procedure was done twice by two readers in order to limit observer bias on age estimation. When the coefficient of variation between observers was greater than 5 %, a common reading was reached by averaging the measurements for each section (Panfili et al. 2002).

The back-calculation procedure (Vigliola and Meekan 2009) was used to estimate fish length at previous ages. This method requires an examination of the shape of the relationship between the length at capture (Lcpt) and the radius of the otolith at capture of all samples (Rcpt) as follows:

(eq. 1)

Where L0p and R0p are the fish size and radius of otolith at hatching. The regression parameters b and c were estimated by fitting Bayesian models with Rstan (Stan Development Team 2018). We used informative priors for both parameters b ~ normal (200, 50); and c ~ normal (1, 0.2).

In some case, it was not possible to measure R0p. These missing values were included in the back-calculation model and estimated by using standard methods for missing data (Stan Development Team 2018).

Afterwards, the back-calculation by the Modified Fry (MF) model (eq. 2) (Vigliola et al. 2000) was applied for each individual.

MF model: (eq. 2)

Where Li and Ri are the fish length and otolith radius at age *i*, L0p and R0p are the fish size and radius of otolith at hatching. The L0p parameter was given for each species in table II.

Table II. Fish size at hatching (L0p) for each species in this study. Level refers to the taxonomic level at which L0p was obtained. When not possible, L0p from different studies were averaged.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Species** | **Family** | **Lop (mm)** | **Level** | **Reference** |
| *Abudefduf sexfasciatus* (Lacepède, 1801) | Pomacentridae | 2.65 | Species | Shadrin and Emel’yanova (2007) |
| *Acanthurus achilles* (Shaw, 1803) | Acanthuridae | 1.70 | Genus | Mccormick (1999) |
| *Acanthurus lineatus* (Linnaeus, 1758) | Acanthuridae | 1.70 | Genus | Mccormick (1999) |
| *Acanthurus nigricans* (Linnaeus, 1758) | Acanthuridae | 1.70 | Genus | Mccormick (1999) |
| *Acanthurus pyroferus* (Kittlitz, 1834) | Acanthuridae | 1.70 | Genus | Mccormick (1999) |
| *Acanthurus triostegus* (Linnaeus, 1758) | Acanthuridae | 1.70 | Species | Mccormick (1999) |
| *Balistapus undulatus* (Tilesius, 1820) | Balistidae | 1.80 | Family | Leis and Carson-Ewart (2000) |
| *Caranx melampygus* (Cuvier, 1833) | Carangidae | 3.15 | Family | Leis and Carson-Ewart (2000) |
| *Centropyge bispinosa* (Günther, 1860) | Pomacanthidae | 1.95 | Family | Leis and Carson-Ewart (2000) |
| *Centropyge flavissima* (Cuvier, 1831) | Pomacanthidae | 1.95 | Family | Leis and Carson-Ewart (2000) |
| *Cephalopholis argus* Schneider, 1801 | Serranidae | 1.90 | Family | Leis and Carson-Ewart (2000) |
| *Cephalopholis urodeta* (Forster, 1801) | Serranidae | 1.90 | Family | Leis and Carson-Ewart (2000) |
| *Chaetodon citrinellus* (Cuvier, 1831) | Chaetodontidae | 1.45 | Genus | Leis and Carson-Ewart (2000) |
| *Chaetodon ornatissimus* (Cuvier, 1831) | Chaetodontidae | 1.45 | Genus | Leis and Carson-Ewart (2000) |
| *Cheilinus chlorourus* (Bloch, 1761) | Labridae | 1.97 | Genus | Hutapea and Slamet (2006) |
| *Chlorurus spilurus* (Valenciennes, 1840) | Scaridae | 1.65 | Family | Leis and Carson-Ewart (2000) |
| *Chromis iomelas* (Jordan & Seale, 1906) | Pomacentridae | 3.05 | Family | Leis and Carson-Ewart (2000) |
| *Chromis viridis* (Cuvier, 1830) | Pomacentridae | 3.05 | Family | Leis and Carson-Ewart (2000) |
| *Ctenochaetus marginatus* (Valenciennes, 1835) | Acanthuridae | 1.70 | Family | Leis and Carson-Ewart (2000) |
| *Ctenochaetus striatus* (Quoy & Gaimard, 1825) | Acanthuridae | 1.70 | Family | Leis and Carson-Ewart (2000) |
| *Dascyllus aruanus* (Linnaeus, 1758) | Pomacentridae | 2.10 | Genus | Emel’yanova et al. (2009) |
| *Dascyllus flavicaudus* (Randall & Allen, 1977) | Pomacentridae | 2.10 | Genus | Emel’yanova et al. (2009) |
| *Epibulus insidiator* (Pallas, 1770) | Labridae | 2.10 | Family | Leis and Carson-Ewart (2000) |
| *Epinephelus fasciatus* (Forsskål, 1775) | Serranidae | 1.50 | Species | Kawabe and Kohno (2009) |
| *Epinephelus hexagonatus* (Forster, 1801) | Serranidae | 1.70 | Genus | Ukawa et al. (1966), Hussain and Higuchi (1980), Lim (1993), Colin et al. (1996), Duray et al. (1996), (1997), James et al. (1997), Glamuzina et al. (1998), (2000), Leu et al. (2005), Jagadis et al. (2006), Yoseda et al. (2006), Ma et al. (2013) |
| *Epinephelus merra* (Bloch, 1793) | Serranidae | 1.50 | Species | Jagadis et al. (2006) |
| *Epinephelus polyphekadion* (Bleeker, 1849) | Serranidae | 1.65 | Species | James et al. (1997) |
| *Gnathodentex aureolineatus* (Lacepède, 1802) | Lethrinidae | 1.55 | Family | Leis and Carson-Ewart (2000) |
| *Gymnosarda unicolor* (Rüppell, 1836) | Scombridae | 2.75 | Family | Leis and Carson-Ewart (2000) |
| *Halichoeres trimaculatus* (Quoy & Gaimard, 1834) | Labridae | 1.58 | Genus | Kimura and Kiriyama (1993) |
| *Lutjanus fulvus* (Forster, 1801) | Lutjanidae | 1.83 | Genus | Suzuki and Hioki (1979) |
| *Lutjanus gibbus* (Forsskål, 1775) | Lutjanidae | 1.83 | Genus | Suzuki and Hioki (1979) |
| *Lutjanus kasmira* (Forsskål, 1775) | Lutjanidae | 1.83 | Species | Suzuki and Hioki (1979) |
| *Monotaxis grandoculis* (Forsskål, 1775) | Lethrinidae | 1.55 | Family | Leis and Carson-Ewart (2000) |
| *Mulloidichthys flavolineatus* (Lacepède, 1801) | Mullidae | 2.50 | Family | Leis and Carson-Ewart (2000) |
| *Myripristis berndti* (Jordan & Evermann, 1903) | Holocentridae | 1.80 | Family | Leis and Carson-Ewart (2000) |
| *Naso lituratus* (Forster, 1801) | Acanthuridae | 1.70 | Family | Leis and Carson-Ewart (2000) |
| *Naso unicornis* (Forsskål, 1775) | Acanthuridae | 1.70 | Family | Leis and Carson-Ewart (2000) |
| *Odonus niger* (Rüppell, 1836) | Balistidae | 1.80 | Family | Leis and Carson-Ewart (2000) |
| *Ostorhinchus angustatus* (Smith & Radcliffe, 1911) | Apogonidae | 4.25 | Family | Leis and Carson-Ewart (2000) |
| *Ostorhinchus apogonoides* (Bleeker, 1856) | Apogonidae | 4.25 | Family | Leis and Carson-Ewart (2000) |
| *Parupeneus barberinus* (Lacepède, 1801) | Mullidae | 1.95 | Genus | Pavlov et al. (2011) |
| *Plectropomus laevis* (Lacepède, 1801) | Serranidae | 1.62 | Genus | Masuma et al. (1993) |
| *Pristiapogon taeniopterus* (Bennett, 1836) | Apogonidae | 4.25 | Family | Leis and Carson-Ewart (2000) |
| *Sargocentron microstoma* (Günther, 1860) | Holocentridae | 1.80 | Family | Leis and Carson-Ewart (2000) |
| *Scarus psittacus* (Forsskål, 1775) | Scaridae | 1.65 | Family | Leis and Carson-Ewart (2000) |
| *Siganus argenteus* (Quoy & Gaimard, 1825) | Siganidae | 2.02 | Genus | May et al. (1974), Popper et al. (1976), Bryan and Madraisau (1977), Hara et al. (1986) |
| *Siganus spinus* (Linnaeus, 1758) | Siganidae | 2.02 | Genus | May et al. (1974), Popper et al. (1976), Bryan and Madraisau (1977), Hara et al. (1986) |
| *Stegastes albifasciatus* (Schlegel & Müller, 1839) | Pomacentridae | 3.05 | Family | Leis and Carson-Ewart (2000) |
| *Stegastes nigricans* (Lacepède, 1802) | Pomacentridae | 3.05 | Family | Leis and Carson-Ewart (2000) |
| *Zebrasoma scopas* (Cuvier, 1829) | Acanthuridae | 1.70 | Family | Leis and Carson-Ewart (2000) |

1. Taxonomy and systematics

Fish were identified using Bacchet et al. (2006) and Moore and Colas (2016). Families and the validity of fish name were verified on the World Register of Marine Species (WORMS) website (<http://www.marinespecies.org/index.php>).

1. Permits

Sample collection was permitted by the French Polynesia government (authorization number: 681MCE/ENV)

1. **Project personnel**

This study was designed by FM, JW and VP. Field collections were made by FM, SJB, JC, JMC, SD, PF, RG, AM, YL, PS, NMDS, and VP. Otolith analyses were conducted by FM, JW, GDS, and JB. Funds were obtained by VP, PS, YL, and JMC. Statistical analyses were conducted by JW and NMDS. Temperature data were compiled by JV. FM and JW led the writing, and all authors contributed to writing and approved the final draft of the manuscript.

**Class III. Data set status and accessibility**

1. **Status**
2. **Latest update**

2019-10-25

1. **Latest archive date:**

2019-10-25

1. **Accessibility**
2. **Storage location and medium**

Data linked to this data paper and otolith slides are stored at the Centre de Recherches Insulaires et Observatoire de l’Environnement (CRIOBE) in Perpignan.

1. **Contact person(s)**

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1. **Copyright restrictions**

No copyright restriction

1. **Proprietary restrictions**

None. When using the dataset, we request that the users cite this data paper.

1. **Costs: None**

**Class IV. Data structural descriptors**

1. **Data set file**
2. **Identity**: size\_at\_age\_coral\_reef\_fishes\_data.csv
3. **Size**: 1.28 Mb
4. **Format and storage mode**: comma-separated values, no compression
5. **Header information**: The header row indicates variable names as described in Table III (see part IV.B).
6. **Variable information**
   1. **Variable identity**: see Table III
   2. **Variable definition**: see Table III
   3. **Units of measurement**: see Table III
   4. **Data type**
      1. **Storage type**: see Table III
      2. **List and definition of variable codes**: None.
      3. **Range for numeric values**: see Table III
      4. **Missing values codes**: NA
      5. **Precision**:
   5. **Data format**

Table III. Description of the variables included in the dataset

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Column** | **Variable identity** | **Variable definition** | **Unit** | **Storage type** | **Range** |
| 1 | Family | Family names according to Fishbase (https://www.fishbase.de/search.php) | - | Factor | - |
| 2 | Genus | Genus names according to Fishbase (https://www.fishbase.de/search.php) | - | Factor | - |
| 3 | Species | Species names according to Fishbase (https://www.fishbase.de/search.php) | - | Factor | - |
| 4 | ID | Unique code identifying each individual | - | Factor | - |
| 5 | Agei | Age *i* | years | Integer | 0 - 30 |
| 6 | Ri | Otolith radius at age *i* | mm | Numeric | 0.008 - 3.784 |
| 7 | Agecpt | Age at capture | years | Integer | 0 - 30 |
| 8 | Rcpt | Otolith radius at capture | mm | Numeric | 0.152 - 3.859 |
| 9 | Lcpt | Total length at capture | mm | Numeric | 28.11 - 984.69 |
| 10 | L0p | Total length at hatching | mm | Numeric | 1.45 - 4.25 |
| 11 | R0p | Otolith radius at hatching | mm | Numeric | 0.008 - 0.136 |
| 12 | Li\_sp\_m | Total length (mean) at age *i* calculated by species | mm | Numeric | 1.45 - 948.131 |
| 13 | Li\_sp\_sd | Standard deviation around the value of Li\_sp\_m | mm | Numeric | 0 - 51.27 |
| 14 | Li\_sploc\_m | Total length (mean) at age *i* calculated by species and location | mm | Numeric | 1.45 - 945.55 |
| 15 | Li\_sploc\_sd | Standard deviation around the value of Li\_sploc\_m | mm | Numeric | 0 - 49.044 |
| 16 | Biomass | Wet body mass at capture | g | Numeric | 0.4 - 12950 |
| 17 | Location | Island or archipelago of the sampling | - | Factor | - |
| 18 | Observer | Name of the person who made the otolith reading | - | Factor | - |

1. **Data anomalies**

Within the dataset, ‘NA’ indicates missing values. Missing values are present in the variables ‘Ri’ (n = 377), ‘R0p’ (n = 2780), ‘Li\_sp\_m’ (n = 398), ‘Li\_sp\_sd’ (n = 398), ‘Li\_sploc\_m’ (n = 745), ‘Lp\_sploc\_sd’ (n = 745) and ‘Biomass’ (n = 603). For the variable ‘Ri’, missing values correspond to individuals for whom it was not possible to estimate the radius at hatching from photographs. The ‘R0p’ values correspond to ‘Ri’ values for whom Agei is equal to 0. Because the R0p value is the same for all Agei of a given individual (‘ID’), it results in a large number of NA as soon as the ‘Ri’ value where Agei is equal to 0 is missing. For the variables ‘Li\_sp\_m’, ‘Li\_sp\_sd’, ‘Li\_sploc\_m’ and ‘Lp\_sploc\_sd’, missing values correspond to values where the Bayesian model was not able to converge. Logically, the number of NA for variables ‘Li\_sp\_m’ and ‘Li\_sp\_sd’ (estimation by species) is lower than the number of NA for variables ‘Li\_sploc\_m’ and ‘Lp\_sploc\_sd’ (estimation by species and location). Finally, for the variable ‘Biomass’ missing values are due to no measurement during sampling.

**Class V. Supplemental descriptors**

1. **Data acquisition**
   1. **Data forms or acquisition methods**
   2. **Location of completed data forms**
   3. **Data entry verification procedures**
2. **Quality assurance/quality control procedures**
3. **Related materials**
4. **Computer programs and data processing algorithms**
5. **Archiving**
   1. **Archival procedures**: https://github.com/JWicquart/fish\_growth
   2. **Redundant archival sites**
6. **Publications and results**:None
7. **History of data set usage**
   1. **Data request history:** None
   2. **Data set update history:** None
   3. **Review history:** None
   4. **Questions and comments from secondary users**: None

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**References**

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