Ordering the alphabet soup: strategies to improve consistency and develop a framework of tools for fisheries science vocabulary

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Abstract

Quantitative methods for assessing the status of marine fish populations began in the 19th century with simple catch-curve analysis and have evolved through the decades to use more advanced integrated statistical modeling. The corresponding assessment documents that communicate model estimates to other scientists and fisheries managers, generally, have grown in length and complexity, often describing hundreds of parameter estimates and population dynamics. These documents use a wide range of synonyms or similar terms that can vary either within a single assessment document or among other documents within or across fisheries management regions. The lack of standardization of terms used in assessment documents can lead to challenges in scientific reviews, communicating scientific results to fisheries managers, and for understanding assessments from other management regions. We analyzed the text of 134 assessment documents used to communicate the results of assessment software to managers from the varying management regions in the United States, Australia, and European International Council for the Exploration of the Sea (ICES) to quantify the presence of synonyms or similar terms that are often used interchangeably and highlight ways in which the output language could be harmonized without modifying meaning. Next, we developed an open source web-based dictionary and schema for

fisheries science where the community can propose and adopt terms to create an agreed upon terminology. Finally, looking forward to future development, we propose approaches to leverage pre-existing frameworks such as Google coding standards to guide the development of tools to merge long-term ecological data sets, name objects in code bases, and report output. While this guidance is tailored to fisheries practitioners working within the U.S. management system, we aim to align with international standards to increase consistency across the international fisheries science community.

1. Introduction

Quantitative methods for assessing the status of marine fish populations began in the 19th century with simple catch curve analysis and have evolved through the decades to use more and more advanced integrated statistical modeling (Maunder and Punt, 2013; Dichmont et al., 2016) with continued calls for further advancement in the development of next-generation modeling tools (Punt et al., 2020). However, as researchers continue to push the envelope by suggesting new and improved methods for conducting analyses (e.g., random effects, machine learning approaches, and linking environmental drivers to estimate either changes in productivity or time-varying recruitment processes at the end of time series when composition data may contain little to no information on recent recruitment), challenges continue to grow in the field due to inconsistent coding practices, documentation standards, and naming conventions. This lack of standardization often leads to difficulties in communicating results, adding and integrating new features into scientific software, and comparing the output of the new software to existing, approved methods. These challenges even extend beyond fisheries sciences, where there are often differing terms for similar modelling across ecological modeling that impedes the ability to communicate across disciplines (Schaub et al., 2024).

Existing scientific software is essential to support the needs of resource managers, who require periodic, predictable, and consistent reporting of population and catch projections to set management arrangements or limits informed by the best scientific information available. However, the lack of standardization between software leads to difficulties comparing results across software frameworks and can lead to challenges in interpretation. Moreover, the majority of scientific software in fisheries science does not adhere to widely used coding conventions (e.g., Google guides: Google Style Guides | styleguide) in its programming language (Sletholt et al., 2012; Wilson et al., 2014). Lack of time, funding, and formal training are the typically cited constraints limiting implementation of best practices (Hannay et al., 2009; Wilson et al., 2014). The software used to conduct these complex assessments and population projections is typically regionally based, differing in structure, naming, and input data processing approaches, all of which often leads to institutional inertia favoring historically-used frameworks. Even when identical software is used across regions, vast regional differences can exist in how input data are processed and entered into software, model estimates are analyzed, and population estimates are presented to regional fisheries management organizations (RFMOs).

In the best case, scientific software tools rival commercial software in their accuracy, estimation speed, and complexity. However, even for these tools, systems by which input and output are described often lack clear documentation and fail to follow standard naming conventions, resulting in inconsistencies among modeling platforms that are often hidden until a software test reveals them (Li et al., 2021). Many population dynamics modeling tools used in fisheries science have adopted high standards for accuracy and shareability but also have variations that are not well documented across platforms. For example, there is variability in how year-specific recruitment is defined in two commonly used software platforms, Age Structured Assessment Program (Legault and Restrepo, 1999) and Stock Synthesis (Methot and Wetzel, 2013; a platform that is used globally to assess the status of marine fish populations). Age-structure population modeling often starts at age one in the Age Structured Assessment Program, however, in Stock Synthesis, the population routinely starts at age zero (though this can be changed to an older age if users modify the spawning month and settlement age of the population; Li et al., 2021), which has led to difficulties comparing model outputs. Even when processes are mathematically the same across modeling frameworks, it can be difficult to compare the output when non-standard naming conventions are used for the same population processes, which can be the case for selectivity (Li et al., 2021). The lack of standardization across modeling platforms can present barriers to comparing and integrating output from alternative modeling platforms for ensemble modeling and, in the worst case, this lack of standard conventions can lead to incorrect science (e.g., Stanley and Spence, 2018) or non-reproducible science (e.g., Feng et al., 2019).

Within the field of fisheries science, standardization has been a goal for decades. Schnute et al. (2007) identified that “new computing technology will doubtless make new analyses possible in the future” but “without a common framework at some level, results from disparate computer programs simply are not comparable”. Schnute (2007) suggested object-oriented programming (OOP) practices as the framework needed to standardize analyses; however, even object-oriented structured systems for fisheries analysis such as the Fisheries Library for R (FLR, Kell et al., 2007) have not fully achieved the goals presented in Schnute (2007). What goals remain unachieved? Extending OOP to other assessment platforms such as Stock Synthesis and MULTIFAN-CL has been difficult, despite the benefits, given OOP was not a goal from the onset and given the lack of documentation on how to create OOP within assessment software programming languages such as ADMB and R.

As a first step, a way forward to promote best practices is for the field of fisheries science to agree upon and adhere to a common glossary of terms for communication. Additionally, software parameter naming conventions and standards flowing from a common glossary would assist in creating much needed consistency and transparency in software development. Adhering to common standards reduces the amount of time and effort needed to develop and maintain frameworks for processing input data, running analyses, and generating output reports because tools can be reused across different types of models, data, and regions. The fisheries community could save considerable time and effort by building software in an agreed upon, well-documented framework from the ground up. This would then let scientific researchers spend more time on researching new best practices and integrating them into existing frameworks, reducing the lag from research to operations and increasing the pace of scientific software development.

There has long been a need for improved adherence to unified terminology. A number of glossaries for fisheries and related fields have arisen in recent years. Regional and international fishery management organizations, such as Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR, www.ccamlr.org/en/organisation/glossary-acronyms-and-abbreviations), International Council for Exploration of the Seas (ICES, www.ices.dk/Lists/Glossary), National Ocean and Atmospheric Administration (NOAA, fisheries.noaa.gov/resource/document/noaa-fisheries-glossary), International Commission for the Conservation of Atlantic Tunas (ICCAT, iccat.int/Documents/SCRS/Other/glossary.pdf), and the Fisheries and Agriculture Organization

(FAO) AGROVOC (agrovoc.fao.org/browse/agrovoc), have published glossaries and dictionaries that contain fisheries terms. Many of these resources do not appear to be actively maintained. Additionally, many of these glossaries define common terms used within fisheries science but do not provide guidance on preferred terminology, limiting their ability to create a unified language in the field. The best of them (FAO's AGROVOC, ICES vocabulary server) have the benefit of allowing programmatic and graphical user interface access. However, AGROVOC is not fisheries-specific and is lacking contributions from the Western Hemisphere. ICES vocabulary server has the benefit of active development and connections to management processes. However, many of the terms are specific to the ICES process and intended for data management and standardization, not for the purpose of coalescing the vocabulary around assessment science. Consistency within the U.S. has increased following implementation of top-down requirements such as the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act that required the implementation of Annual Catch Limits for all federally managed stocks, resulting in terminology changes by RFMOs. While there may be a movement towards consistency in terminology within the U.S., particularly when it comes to management catch targets (e.g., Overfishing Limit, Annual Catch Limit, Annual Catch Target), there still exists large variations in terminology among RFMOs and the international fisheries science community. An example that is commonly encountered for groundfish stocks managed by the PFMC, and has been observed in other U.S. RMFOs, is the interchangeable use of the terms spawning biomass, spawning stock biomass, spawning stock output, and spawning output; leading to confusion around how these terms may differ and the units associated with these terms. It becomes difficult to distinguish when terminology is used interchangeably and when it is intended to denote small nuances in units or policy, such as spawning biomass (in metric tons) and spawning outputs (in millions of eggs).

In the absence of standardized terminology, considerable time and discussion is often needed for those conducting scientific review to understand the methods, applications, and results that are being reviewed. Scientific reviews are a critical step in ensuring that the reviewed products reflect the best scientific information. Applying standardized naming conventions within both scientific software and the description of inputs and outputs in documents and presentations would considerably ease the burden on reviewers, resulting in more of the review time focusing on critical scientific questions. Efforts to improve communications can provide substantial improvement in ensuring modeling practices and interpretations of results align with current best practices, resulting in improved scientific advice to meet the goals of fisheries management.

In this manuscript, we aim to demonstrate the need for a framework of tools to standardize fisheries assessment terminology within the U.S., in a way that could eventually extend internationally within the field. The framework aims to be comprehensive, providing standardized, scientifically-accurate terminology; naming conventions for software development; notation for documenting assessment code basis; and tools to assist users to ensure assessment documents adhere to agreed upon standards.

2. Review Assessments

2.1 Assessment Document Selection

First, we sought to characterize the terminology currently used within documents produced by assessment scientists both regionally within the U.S. and internationally. A subset of available documents from six regionally based Fisheries Science Centers in the U.S., Alaska (NOAA-AFSC), Northeast (NOAA-NEFSC), Northwest (NOAA-NWFSC), Pacific Islands (NOAA-PIFSC), Southeast (NOAA-SEFSC), and the Southwest (NOAA-SWFSC); the Australian Fisheries Management Authority from various jurisdictions, Federal, Queensland, and other areas (South Australia, Tasmania, Torres Strait, Victoria, and Western Australia) ; and several ICES working groups that summarize output from tactical assessment software were collated and compared. These documents, often referred to as assessments, are structured to provide regional and species-specific information to inform management decisions by Regional Management Councils in the U.S.; various jurisdictions in Australia; and members of the European Union. The reviewed documents consisted of 81 U.S. assessment documents covering a wide range of assessed marine taxonomic families pulled from the Species Information System database (apps-st.fisheries.noaa.gov/sis), 45 assessment documents for marine populations off the coast of Australia available on the Stock Assessment Toolbox (toolbox.frdc.com.au/assessment-reports), and 8 assessment documents available for European marine fish populations managed under ICES and available on DTU Orbit (orbit.dtu.dk). A list of all assessment documents reviewed is available in the Supplemental Materials.

2.2 Text Analysis

Each of the 134 assessment documents were scanned using text-mining software to track the presence/absence of 19 pre-selected terms (Table 1). The authors identified these pre-selected terms prior to running the analysis because they were seen as commonly encountered but ambiguous terms or terms with frequently used synonyms within fisheries science. The range of synonyms identified may not be comprehensive of all synonyms used within the U.S. or internationally but were considered illustrative of the variability of terms used in fisheries science. After transforming the text in each assessment document into workable data using the R package tm (version 0.7.8, Feinerer et al., 2008), the presence of each term within a document was summed across all documents from a given region (U.S. Science Center, Australia, or ICES) as well as for the full set of documents. The primary text, tables, and figure captions from each assessment document were included in the analysis, with special symbols, punctuations, and extra white spaces excluded. For example, searching for "age composition" would identify both "age composition" and "age-composition". The search also included known acronyms for the search terms, e.g., instances of F were included in the counts of fishing mortality. Summaries were performed on presence/absence rather than frequency because some documents were longer than others, which would have biased regional comparisons when considering total frequency.

The presence of each of the 19 terms listed in Table 1 and the identified synonyms terms, across the 134 assessment documents, were first analyzed by creating a word cloud. A word cloud allowed for the visualization of the frequency of specific terms being present across the analyzed assessment documents with terms that were commonly encountered appearing as bigger and bolder text in the word cloud. An additional word cloud was created where all synonyms terms were changed to the main term identified in Table 1.

The 19 original terms (Table 1) were narrowed down to the seven terms that had at least one synonym or similar term present in the assessed documents: catch, catch per unit effort, landings, projection, sex, spawning biomass, and mass. The presence/absence of each of the seven terms and their identified synonyms or similar terms across 134 documents was summarized, facilitating a comparison of term presence across different regions (Figure 2).

Table 1. Ninteen pre-selected terms and their associated synonyms or similar terms where the main term is the term identified as the suggested term to use going forward of the synonyms, in most cases. Similar terms (shown in italics) include terms that are not actually synonyms but are often, incorrectly, used interchangeably with the main term.

Main Term	**Searched Synonyms or *Similar Terms***
biomass	*abundance*[1]
spawning biomass (SB)[2]	spawning stock biomass (SSB), *spawning output* (SO), *spawning stock output* (SSO), mature biomass, spawners, effective spawning output
unfished	virgin, initial equilibrium, unfished equilibrium
recruitment	
recruit(s)	age-0 fish, age-1 fish
catch	*total mortality*[3], harvest, total removals
catch per unit effort (CPUE)	catch rate, index of abundance, catch per effort, fishing success
landings	retained catch
spawner per recruit (SPR)	spawning potential ratio (SPR)

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[1] The currency used to inform species importance, e.g., mass or numbers, are often not equivalent but are related (Henderson and Magurran, 2010). Here, we searched for both biomass and numbers because some assessment models can measure population status using either term, and thus, we would expect each document to contain at least one of the terms.

[2] Spawning output is a more comprehensive term compared to spawning biomass in that spawning biomass is a specific case where spawning output is set such that the number of eggs is equal to total body mass (typically only females). An intentional choice was made here to separate spawning biomass and spawning output to provide clear separation in language when the population spawning metric is measured in terms of either mass or numbers of eggs.

[3] Total mortality is often used in assessments to express mortality from the fishery via landed and discarded fish mortality, rather than true total mortality from both natural and fishery causes.

maximum sustainable yield (MSY)	
instantaneous total mortality rate (Z)	
fishing mortality (F)	instantaneous fishing mortality rate, harvest rate, exploitation rate, finite fishing mortality, apical F
fishing mortality at maximum sustainable yield (F_{MSY})	
mass	*weight*
length composition	length frequency, length observation, size frequency, size composition
age composition	age frequency, age observation
projection	*forecast*, *prediction*
sex	gender
plus group	

2.3 Analysis Results

Many of the 19 terms included in the analysis (Table 1) were identified in most of the analyzed documents with the terms abundance (129 documents), recruitment (127), spawning biomass (117), harvest (117), fishing mortality (134), biomass (134), and catch (134) having the highest frequency of being present (Figure 1A). It becomes apparent when comparing the two visualizations (Figure 1A versus 1B) that the language across assessment documents (and potentially within) varies greatly with a large number of terms being used synonymously (e.g., spawning biomass and spawning stock biomass, unfished equilibrium and virgin).

The most common term across regions was catch, which was used in all assessment documents reviewed (Figure 2). A large number of synonyms for catch were also used across documents. The term harvest was found in nearly all documents, except those from NOAA-NEFSC, while the terms total mortality and total removals occurred far less frequently. Given the usage of catch in all assessment documents reviewed, it was somewhat surprising that the word landings did not also occur in all documents because we assumed documents would define what catch means, i.e., catches are comprised of both landings and discard mortality.

The terms spawning biomass or spawning output had the largest variations in which synonym/similar term (e.g., spawning stock biomass, spawning stock output, effective spawning output, and spawners) was used, and that variation was present within and amongst regions. While spawning biomass was present in many assessment documents across regions, the term spawning stock biomass was also present in many of those same documents indicating that the terms may have been used interchangeably. Spawning output is a technically more comprehensive term than spawning biomass because spawning biomass is the specific case where the number of eggs produced are equal to the total body mass (Rothschild and Fogarty, 1989). The term spawning output had relatively low usage across regions except for NOAA-NWFSC that commonly assess rockfish populations, often with fecundity relationships in terms of number of eggs by body mass, size, or age. There also was a lack of consistency in the assessment documents where those that included the term spawning output often also included spawning biomass. This result was examined further because both terms could occur if an author used each term to describe how they were related, however, looking at the frequency of the usage of each term indicated that it was generally the case that each term was used a number of times within the same document.

The usage of terms such as gender, forecast, and weight in assessment documents across regions illustrates the need for the field of fisheries to move towards terms that are scientifically accurate (Figure 2). Sex refers to biological and physiological characteristics such as reproductive organs, chromosomes, etc. that align with sex traits. In contrast, gender is a term that is broadly defined as multidimensional socially constructed characterics encompassing gender identity and expression (Muehlenhard and Peterson, 2011). The terms projection, forecast, and prediction are also often incorrectly used interchangeably in assessments to describe the process for calculating population trajectories into the future based on specific assumptions around population dynamics and future catches. The scientifically accurate term for this process is project or projections because they describe the future conditions based on a dependent scenario (e.g., catches). In contrast, forecast should be used when making predictions based on what is expected to occur and the term prediction when describing outcomes under very specific conditions and is not restricted to the future (Bray and Storch, 2009). Finally, the term weight is a measurement of the gravitational force on an object, where mass is the fundamental measurement of matter within an object. The reported unit of mass varied by country and sampling organization. At present, the lack of standardization and documentation creates challenges for combining disparate datasets. ICES, for example, lists both gram and kilogram (kg) as acceptable units for reporting mass of a fish (ICES, 2022). Meanwhile, some organizations measure fish in pounds rather than kg.

Instantaneous mortality rate (*Z*) is an important parameter in the modeling of population dynamics and, subsequently, fisheries management (Wang, 2015). *Z* has widespread acceptance and adoption internationally as the standard notation to represent the instantaneous rate of the total removal of individuals from a population by both anthropogenic and natural causes, which is equivalent to the natural logarithm of the change in abundance due to all sources of mortality (i.e., natural (M) and fishing (F) mortality per year; $Z = F + M$) per unit of time (Anon, 2001; NOAA, 2005). Additionally, *Z* is one of the few terms that we found where the agreed-upon usage is well understood with no identified synonym or similar terms (Table 1). It is difficult to trace the exact timing of widespread adoption and standard use of *Z* but the use of instantaneous mortality rates as a principal notation in discussing mortality in a fish population appear in 1940s fisheries science literature (Graham, 1935, 1938; Ricker, 1940, 1944) and historical methods of estimating mortality predate these references to Heincke's (1913) method of estimating annual mortality. Furthermore, *Z* appears to be used ubiquitously throughout other disciplines outside of fisheries.

Figure 1. A) Word cloud of the 19 pre-selected terms (Table 1) including their synonyms or similar terms across 134 stock assessment documents. B) Word cloud of the 19 pre-selected terms if only the main terms were to be consistently used in the stock assessment documents. The size of the text indicates the percentage of presence of the terms.

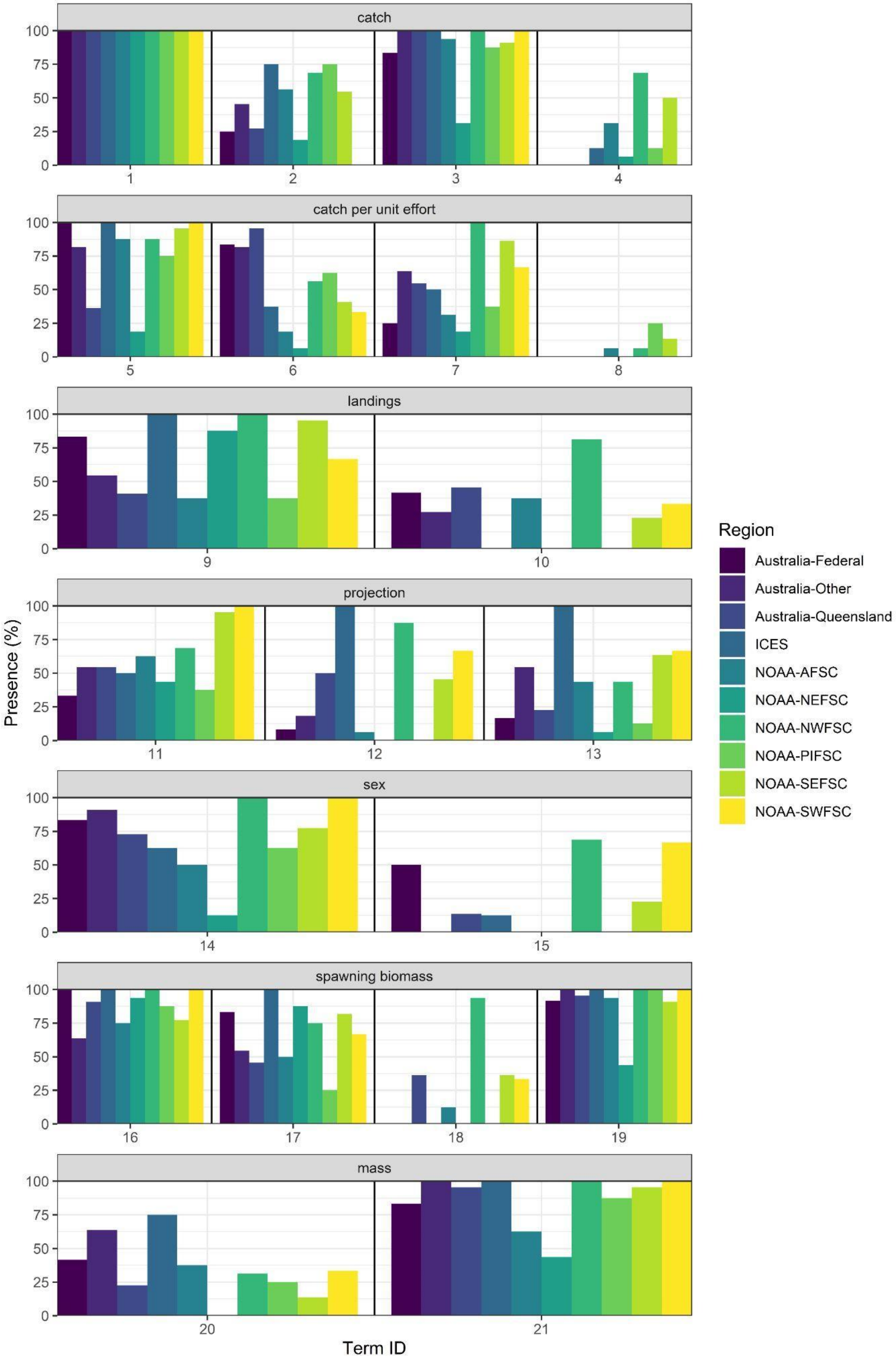

catch
catch per unit effort
landings
projection
sex
spawning biomass
mass
Presence (%)
0
25
50
75
100
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
Term ID
Region
Australia-Federal
Australia-Other
Australia-Queensland
ICES
NOAA-AFSC
NOAA-NEFSC
NOAA-NWFSC
NOAA-PIFSC
NOAA-SEFSC
NOAA-SWFSC

Figure 2. The percentage of presence of 7 terms across 134 stock assessment documents and their synonyms or similar terms from different Regions (colors). The numerical identifiers on the x axis (Term IDs) represent recommended and synonym/similar terms for each group: 1) catch, 2) total mortality, 3) harvest, 4) total removals, 5) catch per unit effort, 6) catch rate, 7) index of abundance, 8) catch per effort and fishing success, 9) landings, 10) retained catch, 11) projection, 12) forecast, 13) prediction, 14) sex, 15) gender, 16) spawning biomass, 17) spawning stock biomass, 18) spawning output, 19) spawning stock output, mature biomass, spawners, and effective spawning output, 20) mass, and 21) weight.

2.4 Development of a Data Dictionary

A comprehensive dictionary for fishery science should contain a large repository of terms and provide a method to increase coherence in the vocabulary used by fisheries scientists. Given that each term proposed for inclusion in the dictionary must be carefully considered prior to onboarding to ensure consistency, clarity, and scientific accuracy, the 19 terms included in this analysis represent initial steps towards vetting and onboarding terms. Some terms in fisheries science have widely accepted definitions and agreed upon standardized usage (e.g., Z) making the onboarding process for these terms relatively easy. Other terms may lack consistent definition or usage, potentially requiring clear guidance why a specific terms is being recommended and why synonyms or similar terms should be avoided. Additionally, terms should be carefully considered to ensure that the language used in fishery sciences promotes inclusion, equity, and environmental justice in the scientific community (Judd and McKinnon, 2021; Branch et al., 2022; Cheng et al., 2023).

Each term in the dictionary must include information for several predefined required fields (i.e., description of term, usage examples, rationale for the selected terminology, synonyms or similar terms, range of possible values, and units) to ensure that users understand why the exemplary term was chosen and why synonyms should generally be avoided. Specifically, the synonym and similar terms field allows users to connect synonymous terms that they may have encountered or used historically and provides a clear linkage to the agreed upon term for future usage. The dictionary would also include additional recommendations for a standardized unit for appropriate terms. The metric system is an internationally agreed-upon system of measurement and, more specifically, the International System of Units (SI) is used in science and should therefore be used for fisheries science and the dictionary entry. For example, the mass of individual fish should be reported in kg but the size of pooled biomass estimates are typically great enough that they should be reported in metric tons. Finally, specific terms may need additional fields that would not be applicable for every term in the dictionary. Including the flexibility to create and populate term specific additional fields would provide the ability for the data dictionary to be a one-stop-shop for all relevant information.

Even widely adopted terms across fisheries science should be included within the dictionary for continued consistency in their usage moving forward (e.g., Z). Additionally, creating a comprehensive dictionary can provide a platform for discussion to ensure that even widely used terms can evolve if concerns around their use are identified. For example, we acknowledge that replacing commonly used terms with terms that are more scientifically accurate (e.g., replacing weight with mass) is a non-trivial change and is likely to provoke discussion, likely requiring a forum for weighing the pros and cons of revising this terminology.

The forum could also be beneficial for tracking more long-term discussions even after terms are onboarded. Such as what will likely be needed surrounding the desire of some to move towards eliminating the term spawning biomass in favor of effective spawning output (Table 2). As a reminder, spawning biomass is the unique case of spawning output where the number of eggs produced by size is equal to body mass resulting in the measurement of biomass being equal to the number of eggs. In these instances we currently recommend using the term spawning biomass for clarity given that the select term provides additional information to the reader on how the mature population is being measured and reported (e.g., biomass or numbers of eggs). In contrast if the mature population is measured in terms of egg production the term spawning output should be used. Ultimately, if there was agreement across the field, the data dictionary could be revised to recommend the use of spawning output (or effective spawning output) in all instances which would further streamline terminology and improve scientific accuracy. While spawning biomass continues to be used, we propose the standardized terminology of “spawning biomass” with the acronym of SB rather than “spawning stock biomass (SSB)” because it reduces the length of the term and complexity without sacrificing meaning. Additionally, modifiers could still be needed to clarify whether spawning biomass is in terms of the mature female and male fish combined or only mature female fish. The modifier and units may only be needed upon its first appearance, depending upon the document length (i.e., reiterating the modifier and units throughout the longer assessments document may be useful for readers).

In addition to brevity, an added strength of the omission of “stock” is clarity and removal of a term associated with extractive natural resources practices (Bridge, 2017). Even though stock is a scientifically standard term, meaning all fish that are part of the same reproductive process and are considered self-contained with no emigration or immigration (NOAA 2005), regional assessments often assess populations along political or management boundaries which may or may not include the entirety of a reproductive fish process. Even when the entirety of a fish stock lies within a single management region, there are situations where localized population dynamics, exploitation, and management may lead to a stock being assessed using multiple assessment models. Additionally, the usage and definition of the term stock varies across the field which can contribute to confusion. Finally, the term stock is part of a larger discussion of the linkages between natural resources exploitation and injustice. Increasingly, terminology and structures which imply acceptance of this disparity as the status quo are in tension with movements working toward re-distributive justice and recognition of rights, including a revitalized legal movement recognizing rights of nature (UNHR, 2011; Squires et al, 2020; Wenar and Gilbert, 2021; Moutrie, 2020; see timeline CELDF, 2022).

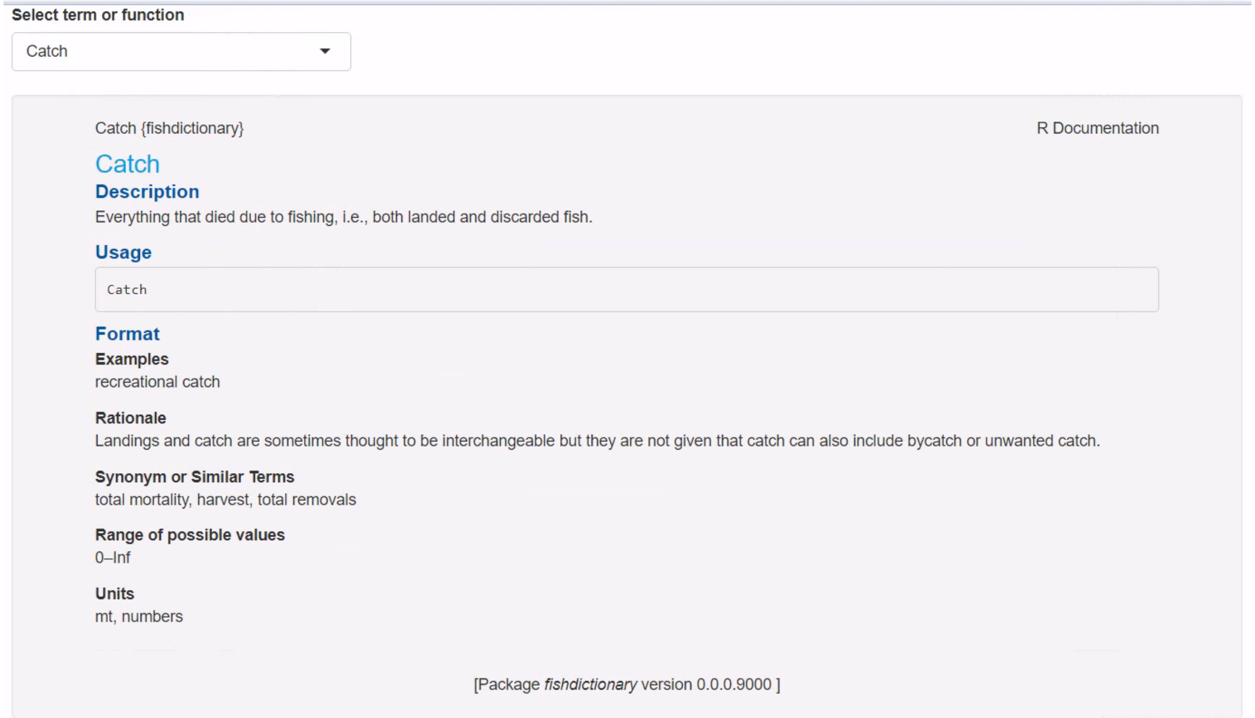
Table 2. Example data fields and entries within the dictionary for spawning biomass (SB).

Term	**Entry**
spawning biomass (SB)	**Description**: 1. The mass of fish (males and females or females only) in the population that contribute to reproduction. Often conventionally defined as the product of weight-at-age and the proportion mature-at-age. Alternatively it can be defined as the biomass of all individuals at or above “age at 50 percent maturity” or “size at 50 percent maturity.” or the total biomass of fish of reproductive age during the breeding season of a stock. Most often used as a proxy for measuring egg production, the spawning biomass depends on the abundance of the various age classes composing the stock and their past exploitation pattern, rate of growth, fishing and natural mortality rates, onset of sexual maturity, and environmental conditions.
	Examples: female spawning biomass, female and male spawning biomass

	Rationale: Spawning biomass and spawning stock biomass have both been used historically, though the former is shorter without sacrificing clarity. For single-sex models, spawning biomass often pertains only to females but text should be specific, e.g., female spawning biomass. The similar term, spawning output, should be used rather than spawning biomass for species with fecundity-at-size relationships and is reported in numbers of eggs (see entry for spawning output for more information).
	Synonyms or Similar Terms: spawning stock biomass, spawning output, spawning stock output, mature biomass, spawners
	Range of Possible Values: 0 - Inf
	Units: metric tons (mt)

The framework being proposed here includes a dictionary for interpreting and communicating assessment results for common types of fisheries data and common outputs used to support management of fisheries. These conventions and schema are published on the web in a consistent format, which is designed as an open source database that can be updated, improved, and used collaboratively in the way that best serves the fisheries assessment community. We intend these conventions and dictionaries to guide development and formatting of tools with structured software code that standardize inputs and outputs. Using these tools will lead to simplified workflows for researchers and stock assessment reviewers. We tailor this guidance to fisheries practitioners working within the U.S. management system. This guidance aims to not only standardize the communication of fisheries science within the U.S. but also aligns with the global fisheries community when feasible. This schema is designed to facilitate translation between U.S. and international standards (e.g., International Council for the Exploration of the Sea Transparent Assessment Framework; ICES TAF, and the ICES vocabulary server) in a way that increases consistency across the international fisheries science community. A key difference between this approach and others is the coupled R package, Shiny application, and schema. Rather than producing a static document, this system is designed to integrate with new and future tools to make it easier for researchers to standardize their software and terminology.

The information for each of the identified terms, was incorporated into a publicly available R package on GitHub (nmfs-fish-tools/fishdictionary: A dictionary scheme for fisheries (github.com)) that uses Shiny (Winston et al., 2022) to deploy an interactive, accessible web-based application and displays the documentation generated for each term (Figure 3). The tools (R Core Team, 2022) and htmltools (Cheng et al., 2021) R packages are used to display the dictionary entries as HTML via the Shiny application. The Shiny application is hosted on a National Oceanic and Atmospheric Administration (NOAA) Fisheries Posit Connect site (https://connect.fisheries.noaa.gov/fishdictionary/) and relies on the rsconnect R package (version 0.8.27, Atkins et al., 2022) to deploy content to the NOAA server; however, the R package encapsulating the Shiny app and dictionary files is meant to be an open source software product. The use of a GitHub discussion board and issue tracking provides an avenue for conversations among the user community and the ability to suggest revisions or additions to the repository. The interactive dictionary provides a single one-stop location for guidance on term usage design to increase consistency across regions and assessments while also facilitating discussions around and the ability to evolve suggested term usage among users.



Select term or function

Catch

Catch {fishdictionary} R Documentation

Catch

Description

Everything that died due to fishing, i.e., both landed and discarded fish.

Usage

```
Catch
```

Format

Examples

recreational catch

Rationale

Landings and catch are sometimes thought to be interchangeable but they are not given that catch can also include bycatch or unwanted catch.

Synonym or Similar Terms

total mortality, harvest, total removals

Range of possible values

0–Inf

Units

mt, numbers

[Package *fishdictionary* version 0.0.0.9000]

Figure 3. The Shiny application allows users to select a term or function that is defined within the package and see a number of fields including Description, Usage, Examples, Rationale, Synonyms or Similar Terms, Range of possible values, and Units. The included example is for the term “catch”.

3. Future Development

This work represents the initial steps to create a unified vocabulary for fisheries science. This initial development of a dictionary focuses on an approach that aims for scientific accuracy by carefully considering the proper terminology while also considering how terms align with current considerations of inclusion, equity, and environmental justice (Judd and McKinnon, 2021; Branch et al. 2022; Cheng et al., 2023). The dictionary, as designed, provides a single location for fishery scientists to refer to, contribute to, and to promote discussion around unifying terminology. Adherence to a unified vocabulary will improve the ability to effectively communicate scientific products, particularly to scientists working in other regions or conducting science across varying species types (e.g., tuna versus crabs), by creating a clearer description of the estimated population based on the model. Creating a designated dictionary for communication across regions lays the groundwork for future development that can provide guidance on best practices for unifying naming conventions for input and output objects and coding best practices and standards. This work can help developers save time on vocabulary discovery during tool development and makes it easier to onboard new tools. Finally, this can lead to more productive scientific reviews by eliminating the need for external reviewers to not only learn about the scientific product being reviewed but also the regional or assessment specific terminology leading to more productive and comprehensive scientific reviews.

One factor contributing to the current situation of regional or assessment specific vocabularies is the presence of differences in specific modeling frameworks that are commonly used to provide management advice. In the U.S. alone, more than a half a dozen frameworks are currently used, which has led to challenges in understanding how parameterizations, model inputs, and outputs relate across frameworks (Li et al., 2021). The authors of the dictionary would like to build on the work done for Li et al. (2021) and suggest small incremental changes to the maintainers of each modeling framework to work towards using the agreed upon vocabulary to structure naming conventions for inputs (e.g., data) and outputs (e.g., estimates and derived quantities). As the U.S. works towards building a next-generation stock assessment framework, unified inputs and outputs of current frameworks will make it easier to compare multiple models to future frameworks. Additionally, the authors would like this work to extend beyond the U.S. to incorporate feedback from the international fishery science community to increase consistency where we can, whether that means changes or extensions to the dictionary to reach consensus among users.

The decisions guiding the development of the dictionary have focused on identifying an approach that will allow collaboration and continued development as needs grow and evolve in the future. GitHub was carefully selected to host the dictionary because it is a prevalent tool used by fishery scientists to share code and projects and applies a version control system (i.e., Git), facilitating ongoing communication and contributions from a variety of users (Brisson et al., 2020; Crystal-Ornelas et al., 2023). Additionally, open source tools (i.e., Shiny app) allow users to interact with information through interactive visualizations leading to deeper and collective understanding (Ellis and Merdian, 2015) and are increasingly used in fishery sciences (Regular et al., 2020). Creating a single location in a user-friendly environment for fishery scientists to guide the language we use to communicate and framework development best-practices lowers the barrier for adoption, usage, and collaboration across regions.

Scientists developing software are primarily self-taught (Hannay et al., 2009) and lack exposure to software development best practices evoked in computer science. We hope that the development and growth of the dictionary will extend to include coding standards and naming conventions that can provide a clear pathway to guide software developers and to improve the interpretability of modeling inputs and outputs across regions. As development continues on the dictionary we plan to liberally rely on existing frameworks and publications to provide guidance on coding standards, most notably, Google coding standards, Edwards and Auger-Methe’s codification of ecological mathematical notation (2019), best practices for units in the R programming language (Pebesma et al., 2016), the ecological metadata (EML) project, and guidance from a set of experienced software developers within the fisheries science community (Punt et al. 2020, Taylor et al. 2021).

Future development of additional tools within the Shiny dictionary platform can facilitate the transition to naming conventions, coding standards, and terminology. For example, the creation of a tool to check documents for adherence to preferred terminology identified in the dictionary could allow users to easily scan scientific documents and ensure language follows the agreed upon best practices. Additionally, many code-styling products exist that can modify existing code to align with style guides (e.g., styler R package, Mùller and Walthert, 2022). The development of a specialized code checking tool that identifies whether input or output variable naming follows the identified best practices and naming conventions within the dictionary can provide easy pathways for developers to create software that is “self-documenting”, making source code easier to understand and simplifying maintenance. Tools of this nature can provide clear pathways for users to adopt best practices while limiting the burden on the user to ensure coherence, especially as best practices and terminology evolve. Ultimately, the dictionary and the guidance on coding standards and naming standards is designed to be a living product with a development schema that facilitates continual development and refinement to grow with the needs of the fisheries science community.

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Supplemental Materials

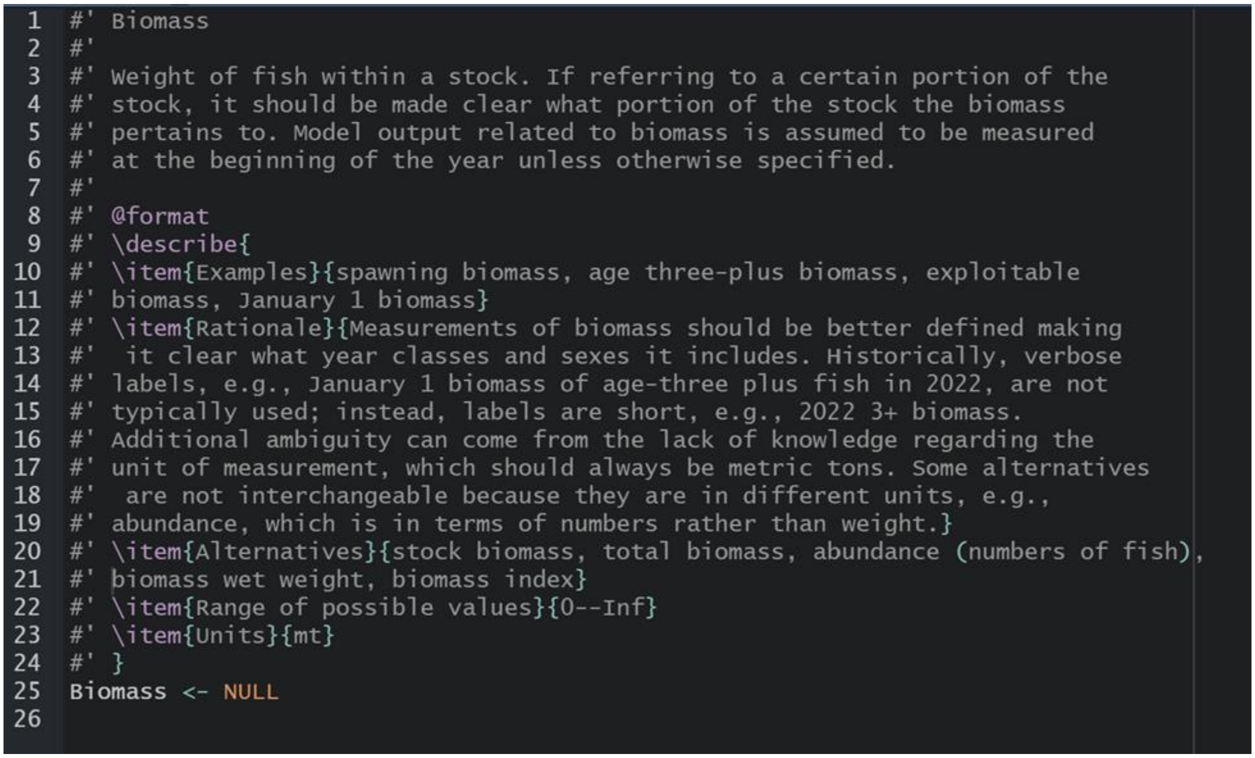
Adding Entries in the Data Dictionary

We chose to use the roxygen2 (version 7.2.1, Wickham et al., 2022) style of documentation to define the fields for each term included in the dictionary because the user community is generally familiar with roxygen2 given its use in R package development and documentation standards. Users within and outside NOAA Fisheries are welcome to add new entries and modify existing entries through user generated GitHub pull requests or through posting suggestions or requested revisions within GitHub issues. Using git automates version control and provides a complete and public history of all changes made through time to each term. We hope that our due diligence in writing verbose commit messages will provide clear rationale for future users of the dictionary regarding changes that are made to include terms should they be necessary. Additionally, using git version control and comprehensive commit messages allows for the ability to auto-generate version release notes based on recent package changes. Next, we describe the process of adding an entry.

To add or modify an entry, a developer must:

1. Check out a new branch from the GitHub repository.
2. Install the roxygen2 and rsconnect R packages.
3. Add or modify the .R file with a roxygen2 block above a single line of code setting the value of the term to NULL (Figure 4).
4. After the .R file is populated and saved, run `roxygen2::roxygenize()` to create a corresponding .Rd file to display the documentation entry with proper formatting.
5. Check that the .Rd file appears to be formatted properly.
6. Run the command rsconnect::writeManifest("./inst/Shiny") which will create a new manifest.json file that will update the Shiny app on Rstudio connect.
7. Add the new .R, .Rd, and manifest.json file to a GitHub commit, push it to the remote repo, and open a pull request.

Contributors will be able to edit the dictionary programmatically with suggestions being reviewed by a team of peer reviewers to ensure consistency with other database terms and standards.



```
#' Biomass
#'
#' Weight of fish within a stock. If referring to a certain portion of the
#' stock, it should be made clear what portion of the stock the biomass
#' pertains to. Model output related to biomass is assumed to be measured
#' at the beginning of the year unless otherwise specified.
#'
#' @format
#' \describe{
#' \item{Examples}{spawning biomass, age three-plus biomass, exploitable
#' biomass, January 1 biomass}
#' \item{Rationale}{Measurements of biomass should be better defined making
#'  it clear what year classes and sexes it includes. Historically, verbose
#' labels, e.g., January 1 biomass of age-three plus fish in 2022, are not
#' typically used; instead, labels are short, e.g., 2022 3+ biomass.
#' Additional ambiguity can come from the lack of knowledge regarding the
#' unit of measurement, which should always be metric tons. Some alternatives
#'  are not interchangeable because they are in different units, e.g.,
#' abundance, which is in terms of numbers rather than weight.}
#' \item{Alternatives}{stock biomass, total biomass, abundance (numbers of fish),
#' biomass wet weight, biomass index}
#' \item{Range of possible values}{0--Inf}
#' \item{Units}{mt}
#' }
Biomass <- NULL
```

Figure 4: How the .R file for each dictionary needs to be specified to generate the Shiny app website for the term "biomass", shown in Figure 3. Each field needs to be described with either an @ (if it is a roxygen2 tag) or as an \item{} within a \describe{} block. Note that this format is sensitive to white space.

Stock Assessment Documents Reviewed

Stock assessment documents from each U.S. Fisheries Science Center were used to analyze common terminology used by stock assessment documents by region and organization (Table A.1). The assessments were for species and stocks managed within the U.S. by Regional Management Councils and select International Management Organizations that included Science Center co-authors (e.g., U.S./Canada Joint Management Committee for Pacific Hake/Whiting). Assessment documents were downloaded from the Species Information System (SIS) database which serves as the national repository for U.S. assessments. Assessment documents for European stocks managed by International Council for the Exploration of the Sea (ICES) were downloaded from DTU Orbit. Australian assessment documents were downloaded from the Stock Assessment Toolbox (toolbox.frdc.com.au/assessment-reports).

Table A.1. Stock assessment documents used within the key word analysis to evaluate used terminology across stocks assessed produced by either Science Center or International Organization. Stock assessment documents were produced by scientists Science Centers or International Organization: Alaska Fisheries Science Center (AFSC), Northeast Fisheries Science Center (NEFSC), Northwest Fisheries Science Center (NWSC), Pacific Island Science Center (PISC), Southeast Fisheries Science Center (SEFSC), Southwest Fisheries Science Center (SWFSC), Inter-American Tropical Tuna Commission (IATTC), International Commission for the Conservation of Atlantic Tunas (ICCAT), Joint Technical Committee (JTC) of the Pacific Hake/Whiting Treaty, and Western and Central Pacific Fisheries Commission (WCPFC), International Council for the Exploration of the Sea (ICES), and the following Australian juridictions: Federal, Queensland, South Australia, Tasmania, Torres Striat, Victoria, and Western Australia.

Population	**Organization**	**Author**
Albacore (*Thunnus alalunga*)	SEFSC/ICCAT	ICCAT 2020
Arrowtooth Flounder (*Atheresthes stomias)*	AFSC	Shotwell et al. 2021
Atka Mackerel (Pleurogrammus monpterygius)	AFSC	Lowe et al. 2020
Atlantic Blacktip Shark (*Carcharhinus limbatus)*	SEFSC	SEDAR 2020
Atlantic Bluefish (*Pomatomus saltatrix)*	NEFSC	NEFSC 2022c
Atlantic Cod (*Gadus morhua*)	NEFSC	NEFSC 2022d
Atlantic Herring (*Clupea harengus*)	NEFSC	NEFSC 2022a
Atlantic Mackerel (*Scomber scombrus*)	NEFSC	NEFSC 2006
Australian Herring (*Arripis georgianus*)	Australia Western	Duffy et al. 2021
Australian Sardine (*Sardinops sagax*)	Australia South	Grammer et al. 2021
Banana Prawn (*Penaeus indicus*)	Australia Federal	Plagányi et al. 2022
Barramundi (*Lates calcarifer*)	Australia Queensland	Streipert et al. 2019
Bight Redfish (*Centroberyx gerrardi*)	Australia Federal	Sporcic et al. 2019
Black Jewfish (*Protonibea diacanthus*)	Australia Queensland	Leigh et al. 2022
Black Sea Bass (*Centropristis striata*)	SEFSC	SEDAR 2018
Blacknose Shark (*Carcharhinus acronotus*)	SEFSC	SEDAR 2011
Black Teatfish (*Holothuria whitmaei*)	Australia Queensland	Helidoniotis 2021a
Blackspotted and Rougheye Rockfish (*Sebastes melanostictus* and *aleutianus*)	AFSC	Spencer et al. 2020
Blacktip Shark (*Carcharhinus limbatus*)	SEFSC	SEDAR 2020
Blue and Deacon Rockfishes (*Sebastes mystinus* and *diaconus*)	NWFSC/SWFSC	Dick et al. 2018

Blue Grenadier (*Macruronus novaezelandiae*)	Australia Federal	Tuck and Bessell-Brown 2021
Blue Swimmer Crab (*Portunus armatus*)	Australia Queensland	Lovett et al. 2020
Atlantic Bluefin Tuna (*Thunnus thynnus*)	SEFSC/ICCAT	ICCAT 2021
Shortfin Mako (*Isurus oxyrinchus*)	SEFSC/ICCAT	Anon. 2017
Bottomfish	PIFSC	Langseth et al. 2019
Cabezon (*Scorpaenichthys marmoratus*)	NWFSC/SWFSC	Cope et al. 2019
California Scorpionfish (*Scorpaena guttata*)	NWFSC/SWFSC	Monk et al. 2017
Category 3 Stocks	ICES	Berg. et al. 2021
Cobia (*Rachycentron canadum*)	SEFSC	SEDAR 2020
Coral Trout (*Plectropomus leopardus*)	Australia Queensland	Campbell and Northrop 2020
Baltic cod	ICES	Alessandro et al. 2019
Northern shelf cod	ICES	Andersen et al. 2023
Coral reef fishes	PIFSC	Nadon 2017
Cowcod (*Sebastes levis*)	NWFSC/SWFSC	Dick and He 2019
Crimson Snapper (*Lutjanus erythropterus*)	Australia Queensland	Fox et al. 2021
Deep 7 bottomfish complex	PIFSC	Langseth et. al. 2018
Deepwater flatfish stock complex	AFSC	McGilliard et al. 2019
Deepwater Flathead (*Neoplatycephalus conatus*)	Australia Federal	Tuck and Burch 2019
Demersal species	ICES	Boenish et at. 2020
Demersal Stocks North Sea and Skagerrak	ICES	Orio et al. 2019
Dover Sole (*Microstomus pacificus*)	NWFSC/SWFSC	Wetzel and Berger 2021
Dusky Flathead (*Platycephalus fuscus*)	Australia Queensland	Yang et al. 2022
Dusky Shark (*Carcharhinus obscurus*)	SEFSC	SEDAR 2016
Flatfish stocks in the North Sea and Celtic Sea	ICES	Andersen, et al. 2020
Flatfish stock complex	AFSC	Monnahan 2020
Gag grouper (*Mycteroperca microlepis*)	SEFSC	SEDAR 2021
Golden Tilefish (*Lopholatilus chamaeleonticeps*)	NEFSC	Nitschke 2021

Atlantic Goliath Grouper (*Epinephelus itajara*)	SEFSC	SEDAR 2011
Gopher and Black-and-yellow Rockfishes (*Sebastes carnatus* and *chrysomelas*)	NWFSC/SWFSC	Monk and He 2019
Grey Mackerel (*Scomberomorus semifasciatus*)	Australia Queensland	Bessell-Browne et al. 2018
Gray Snapper (*Lutjanus griseus*)	SEFSC	SEDAR 2018
Gray Triggerfish (*Balistes capriscus*)	SEFSC	SEADAR 2020
Greenspotted Rockfish (*Sebastes chlorostictus*)	NWFSC/SWFSC	Dick et al. 2011
Guam coral reef fishes	PIFSC	Nadon 2019
Gummy Shark (*Mustelus antarcticus*)	Australia Federal	Thomson 2020
Haddock (*Melanogrammus aeglefinus*)	NEFSC	TRAC 2020
Eastern Jackass Morwong (*Macruronus novaelelandiae*)	Australia Federal	Day et al. 2021
Western Jackass Morwong (*Macruronus novaelelandiae*)	Australia Federal	Day and Castillo-Jordán 2018
King Mackerel (*Scomberomorus cavalla*)	SEFSC	SEDAR 2020
King Prawn (*Melicerus plebejus*)	Australia Queensland	Helidoniotis et al. 2020
King Threadfin (*Polydactylus macrochir*)	Australia Queensland	Leigh et al. 2021
Lingcod (*Ophiodon elongatus*)	NWFSC/SWFSC	Taylor et al. 2021
Longnose Skate (*Raja rhina*)	NWFSC/SWFSC	Gertseva et al. 2019
Mud Crabs (primarily *Scylla serrata*)	Australia Queensland	Northrop et al. 2019
Northern Rock Sole (*Lepidopsetta polyxystra*)	AFSC	McGilliard et al. 2020
Northern shortfin squid (*Illex illecebrosus*)	NEFSC	NEFSC 2006
Northern Silver Hake (*Merluccius bilinearis*)	NEFSC	NEFSC 2020b
Octopus stock complex	AFSC	Ormseth et al. 2020
Other rockfish complex	AFSC	Sullivan et al. 2020
Pacific Albacore (*Thunnus albacares*)	PIFSC/WCPFC	Harley et al. (015
Pacific Cod (*Gadus macrocephalus*)	AFSC	Thompson et al. 2021
Pacific Hake (*Merluccius productus*)	JTC	Johnson et al. 2021

Pacific Mackerel (*Scomber japonicus*)	SWFSC	Crone et al. 2019
Pacific Ocean Perch (*Sebastes alutus*)	AFSC	Spencer and Ianelli 2021
Pacific Ocean Perch (*Sebastes alutus*)	NWFSC/SWFSC	Wetzel et al. 2017
Pacific Sardine (*Sardinops sagax*)	SWFSC	Kuriyama et al. 2020
Pacific Spiny Dogfish (*Squalus suckleyi*)	NWFSC/SWFSC	Gertseva et al. 2021
Patagoian Toothfish (*Dissostichus eleginoides*)	Australia Federal	Hillary and Day 2018
Baltic Pelagic stocks	ICES	Nord et al. 2023
Red Emperor (*Lutjanus sebae*)	Australia Queensland	Sumpter et al. 2022
Red Grouper (*Epinephelus morio*)	SEFSC	SEDAR 2021
Red king crab (*Paralithodes camtschaticus*)	AFSC	Szuwalski 2019
Red Porgy (*Pagrus pagrus*)	SEFSC	SEDAR 2020
Red Snapper (*Lutjanus campechanus*)	SEFSC	SEDAR 2018; SEDAR 2021
Eastern Redfish (*Centroberyx affinis*)	Australia Federal	Bessel-Browne and Tuck 2020
Redthroat Emperor (*Lethrinus miniatus*)	Australia Queensland	Northrop and Campbell 2020
Northern Rock Lobster (*Jasus edwardsii*)	Australia South	Linnane et al. 2021a
Southern Rock Lobster (*Jasus edwardsii*)	Australia Tasmania	Hartmann et al. 2019
Southern Rock Lobster (*Jasus edwardsii*)	Australia South	Linnane et al. 2021b
Tropical Rock Lobster (*Panulirus ornatus*)	Australia Torres Strait	Plagányi et al. 2019
Southern Rock Lobster (*Jasus edwardsii*)	Australia Victoria	VFA 2019
Sablefish (*Anoplopoma fimbria*)	AFSC	Goethel et al. 2020
Sablefish (*Anoplopoma fimbria*)	NWFSC/SWFSC	Haltuch et al. 2019
Saddletail Snapper (*Lutjanus malabaricus*)	Australia Queensland	Campbell et al. 2021
San Whiting (*Sillago ciliata*)	Australia Queensland	Leigh et al. 2019
Ballot’s Saucer Scallops (*Ylistrum balloti*)	Australia Queensland	Wortmann 2022
School Whiting (*Sillago flindersi*)	Australia Federal	Day and Bessel-Browne 2021
Sea Mullet (*Mugil cephalus*)	Australia Queensland	Lovett and Prosser 2019
West Coast Demersal Scalefish Fishery	Australia Western	Fairclough et al. 2021
Scup (*Stenotomus chrysops*)	NEFSC	NEFSC 2022d

Sea scallops (*Placopecten magellanicus*)	NEFSC	NEFSC 2022b
Silver Warehou (*Seriolella punctata*)	Australia Federal	Burch and Castillo-Jordán 2018
Atlantic Sharpnose Shark (*Rhixoprionodon terraenovae*)	SEFSC	SEDAR 2013
Shortfin Mako Shark (*Isurus oxyrinchus*)	SWFSC/WCPFC	ISC Shark Working Group 2018
Silky Shark (*Carcharhinus falciformis*)	PIFSC/WCPFC	Clarke et al. 2018
Silver Hake (*Merluccius bilinearis*)	NEFSC	NEFSC 2006
Skate stock complex (Bering Seas and Aluetian Islands)	AFSC	Ormseth 2021
Skate stock complex (Gulf of Alaska)	AFSC	Ormseth 2019
Skate stock complex	NEFSC	NEFSC 2020a
Skipjack Tuna (*Katsuwonus pelamis*)	PIFSC/WCPFC	Vincent et al. 2019
Snapper (*Chrysophrys auratus*)	Australia Queensland	Wortmann et al. 2018
Snapper (*Chrysophrys auratus*)	Australia South	Fowler et al. 2020
Snow Crab (*Chionoecetes opilio*)	AFSC	Szuwalski 2021
Southern Red Hake (*Urophycis chuss*)	NEFSC	NEFSC 2022b
Spanish Mackerel (*Scomeromorus commerson*)	Australia Queensland	Bessell-Browne et al. 2020
Spanish Mackerel (*Scomeromorus commerson*)	Australia Queensland	Tanimoto et al. 2020
Spanish Mackerel (*Scomeromorus commerson*)	Australia Torres Strait	O’Neill et al. 2022
Sprat	ICES	Carpi et al. 2018
Spiny lobster (*Panulirus argus*)	SEFSC	SEDAR 2019
Stout Whiting (*Sillago robusta*)	Australia Queensland	Wortmann and Hall 2020
Summer Flounder (*Paralichthys dentatus*)	NEFSC	NEFSC 2022c
Tailor (*Pomatomus saltatrix*)	Australia Queensland	Lovett et al. 2020
Tiger Prawns (*Pegaeus esculentus* and *Penaeus semisulcatus*)	Australia Queensland	Helidoniotis 2020
Vermilion Snapper (*Rhomboplites aurorubens*)	SEFSC	SEDAR 2020
Vongole (*Katelysia* spp.)	Australia Southl	Heldt and Mayfield 2020

Tiger Flathead (*Neoplatycephalus richardsoni*)	Australia Federal	Day 2019
Walleye Pollock (*Gadus chalcogrammus*)	AFSC	Ianelli et al. 2021
White Marlin (*Kajikia albida*)	SEFSC/ICCAT	ICCAT 2020
Oceanic Whitetip Shark (*Carcharhinus longimanus*)	PIFSC/WCPFC	Tremblay-Boyer et al. 2019
Widow Rockfish (*Sebastes entomelas*)	NWFSC/SWFSC	Hicks and Wetzel 2015
Windowpane Flounder (*Scophthalmus aquosus*)	NEFSC	NEFSC 2022b
Winter Flounder (*Pseudopleuronectes americuanus*)	NEFSC	NEFSC 2022b
White Teatfish (*Holothuria fuscogilva*)	Australia Queensland	Helidoniotis 2021b
Yelloweye Rockfish (*Sebastes ruberrimus*)	NWFSC/SWFSC	Gertseva and Cope 2017
Yellowfin Bream (*Acanthopagrus australis*)	Australia Queensland	Leigh et al. 2019
Yellowfin Tuna (*Thunnus albacares*)	IATTC	Minte-Vera et al. 2019
Yellowtail Flounder (*Pleuronectes ferruginea*)	NEFSC	Legault and McCurdy 2018
Yellowtail Rockfish (*Sebastes flavidus*)	NWFSC/SWFSC	Stephens and Taylor 2017
Yellowtail Snapper (*Ocyurus chrysurus*)	SEFSC	SEDAR 2020

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