CHAPTER 5

Marine and Aquatic Sciences Information Literacy

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Abstract

Marine and aquatic sciences encompass the study of oceanic and freshwater environments. Research in this area is often multidisciplinary and is conducted worldwide by academia, industry, and government and nongovernment organizations. This chapter examines unique aspects to consider when searching for this information (e.g., by scientific name or geographical area) and the importance of publication types beyond journal literature. It highlights key information resources such as taxonomy tools and species databases, encyclopedias, field guides, journals, databases, repositories, government sites, intergovernmental organizations, data and map sources, and citizen science websites. It includes practical examples for teaching information literacy skills to undergraduate and graduate students, as well as advice for staying current in the field.

Keywords: Aquatic science; Citizen science; Data sources; Databases; Field guides; Information literacy; Marine science; Repositories; Search strategies; Taxonomy tools.

INTRODUCTION

Think for a moment about the importance of water. It covers 71% of the Earth's surface and is critical to life on our planet. The oceans contain about 96.5% of this water with the remaining volume found in ice caps and glaciers, groundwater, ground ice and permafrost, lakes, rivers and swamps, and the atmosphere (US Geological Survey, 2016).

Two-thirds of the world's population lives within 60 km (37 miles) of the coast, and we depend on water for food (e.g., agriculture, fisheries), transportation (e.g., shipping), energy (both nonrenewable sources such as oil and gas, and renewable ones such as tides and wind), biotechnology (e.g., pharmaceuticals), and recreation (e.g., ecotourism) (UN Atlas of the Oceans, 2016). Of course, humans are not the only inhabitants on this planet; nonhuman organisms from tiny microbes to the gigantic blue whale also rely on the aquatic environment for survival but unfortunately are threatened by problems such as climate change and pollution.

Given that water is fundamental to life, it is no wonder that aquatic research is carried out all over the world by academic institutions; federal, regional, and local governments; industry; and nongovernment organizations (NGOs). Although much of the research is interdisciplinary, it is still useful to define the major disciplines before introducing key resources and search strategies.

According to the Association for the Sciences of Limnology and Oceanography (2015), aquatic science is the study of oceanic and freshwater environments. It can be classified as oceanography, the study of the

biological, chemical, geological, optical, and physical characteristics of oceans and estuaries; and limnology, the study of these same traits in inland waters (e.g., lakes, rivers, wetlands, etc.). Marine science can be used interchangeably with oceanography but an alternate definition includes marine biology, fisheries, marine resources, and ocean and coastal zone management (Barnett, 2005). In addition to the broad disciplines, a few other useful terms are marine biology (study of organisms within the marine environment), ichthyology (study of fish), fisheries (industry devoted to catching, processing, and selling fish), aquaculture (rearing of aquatic animals or breeding of aquatic plants for food), phycology (study of seaweeds and other algae), and conservation (preservation, protection, or restoration of the natural environment, ecosystems, vegetation, or wildlife).

Since this book is about information literacy and resources in the life sciences, this chapter will place an emphasis on the biological aspect of marine and aquatic sciences, but it is important to recognize the connection with physical and chemical limnology and oceanography, climate change, conservation, and environmental science.

UNIQUE ASPECTS OF SEARCHING

Before diving into the resources, it is useful to examine the search strategies needed to find information in these fields. As in other disciplines, you will build searches using techniques such as quotation marks for phrases, Boolean logic (AND, OR, NOT), and truncation (*). You will also make use of thesauri to determine subject headings or descriptors; even if only for keyword (vs. subject) searching, it is important to incorporate the controlled vocabulary into the search. So, what are the unique aspects of searching for marine and aquatic information?

First, when teaching students to find information about a biological organism, I emphasize the importance of searching for both the common and scientific names. For example, the species *Oncorhynchus tshawytscha* is known as Chinook salmon, king salmon, Quinnat salmon, spring salmon, and Tyee salmon. The scientific name offers a standard search term that will typically retrieve more results. However, the common name(s) may be appropriate for certain types of literature or where the focus is less on the biology of the organism and more on its utility for humans. Finding common name variants and the scientific name can be accomplished relatively easily, often through a simple Google search.

For those students without a biology background, reviewing the taxonomic classification system used to name and group organisms is a good idea. The scientific name is composed of two parts, the genus and the species within that genus. This naming system, binomial nomenclature, was developed by the Swedish botanist Carl Linnaeus in the 18th century. The genus is always capitalized, and the genus and species name is always italicized, as in the blue whale, *Balaenoptera musculus*. A species may be further divided into subspecies as in the Southern blue whale, *Balaenoptera musculus intermedia*. A person's name and date sometimes follow the scientific name. This identifies the authority or scientist who first published the species name, i.e., *Balaenoptera musculus intermedia* Burmeister, 1871.

Since Linnaeus published his classification system, it has developed into a modern system based on evolutionary relationships, not just structural similarities between organisms. For a recent classification system, see that proposed by Ruggiero et al. (2015). The basic hierarchy is Kingdom– Phylum–Class–Order–Family–Genus–Species but between these can be Super, Sub, and Infra ranks. There are many mnemonics on the Web that can assist with remembering the hierarchy but one common one is: King Philip's Class Ordered the Family Genus to Speak (KFCOFGS). Taxonomy tools for identifying an organism, its scientific name, and the hierarchical classification are listed in the Discipline Resources section.

The second aspect to consider when searching for marine and aquatic science information is its geographical nature. A topic may be connected to a place from the searcher's perspective, but organisms and water bodies do not respect political boundaries. If you imagine the Chinook salmon reproducing in a freshwater stream in British Columbia, Canada, and then making its way to the Pacific Ocean, or the invasive zebra mussel that originated in the Caspian Sea in Eastern Europe but is now found in all five of the Great Lakes in North America (Tans, 2015), you can appreciate that brainstorming search terms will be required not only with regard to taxonomy but also geographical names. A comprehensive strategy should include the names of relevant rivers, lakes, oceans, etc., as well as locations such as islands, countries, regions, and so on. Moreover, when searching for historical information, it is important to know whether political boundaries or location names have changed over time.

The recent proliferation of databases created with geospatial interfaces that allow searching for reference citations or data sets associated with a location on Earth has been especially useful to the aquatic sciences. This exciting development involves indexing an object (e.g., citation, data set, image) with latitude and longitude coordinates to enable searching by points, lines, or polygons on a map. The map links to specific citations and to full text if available. For example, the Coos Bay Georeferenced Bibliography is a publication database maintained in EndNote, but each citation has been georeferenced to the site where the sample was collected (Oregon Institute of Marine Biology Library, 2014; Schmitt & Butler, 2012). Another example is a catalog of data sets hosted by the US government (US General Services Administration, 2017), where it is possible to filter a search to ocean data and then draw a boundary box defined by two latitudes and two longitudes to retrieve data that fall within an area of interest on the map.

Finally, it is worth noting the different publication types and the approaches used for finding information in these sources. All researchers will use journal articles, which are fairly straightforward to find using the commercial databases described below. But they may also require gray literature, which are documents produced outside the commercial realm, typically by academia, government, industry, and NGOs, and not widely distributed. Therefore, it is important to have a good understanding of the landscape of players who produce the information. This is articulated in the ACRL *Framework for Information Literacy for Higher Education*, Searching as Strategic Exploration frame, which states that a learner who is information literate will be able to "identify interested parties, such as scholars, organizations, governments, and industries, who might produce information about a topic and then determine how to access that information" (Association of College and Research Libraries [ACRL] Board, 2016).

When considering a topic or question, teach students to first identify who would conduct the research and disseminate the information. In the marine and aquatic sciences, these sources are most likely to be academic institutions (many of which have research institutes or field stations), government agencies and institutions, intergovernmental organizations, aquaria, museums, companies, and NGOs. In addition to the organizations that publish the information, libraries affiliated with them will likely catalog institutional publications or host them on their websites or in repositories. Librarians at those institutions or organizations can be a font of knowledge for students looking for hard-to-find sources.

DISCIPLINE RESOURCES

Taxonomy and Species Databases

Although reference sources for taxonomy can be purchased, many are now freely available on the Web. They include the following:

Integrated Taxonomic Information System (ITIS)

ITIS is a database of taxonomic information for plants, animals, fungi, and microbes of the world. For each scientific name, ITIS includes the authority (author and date), associated synonyms and common names, taxonomic hierarchy, and source publications. ITIS forms the taxonomic foundation for the Encyclopedia of Life (EOL).

https://www.itis.gov/info.html.

National Center for Biotechnology Information (NCBI) Taxonomy Browser

This is a curated database for all species represented in the NCBI genetic sequence databases, equal to about 10% of described species on Earth. Searching by common name (e.g., blue whale) or scientific name (e.g., *B. musculus*) will find the classification of a species, and hovering your mouse over the taxonomic information will indicate what rank it is (e.g., genus, family, etc.). The record links out to genetic sequence databases, articles in PubMed Central, and specialized tools such as the EOL and the Ocean Biographic Information System.

https://www.ncbi.nlm.nih.gov/taxonomy.

Encyclopedia of Life

Imagine an encyclopedia with a "webpage for every species." That was the goal in 2007 when the EOL was established. It is now an open database of more than one million pages containing text (e.g., species descriptions, ecology, conservation), data (e.g., physical traits, distribution), media (images, video, sound), and maps. Content is incorporated from existing databases and contributed by experts and nonexperts around the world.

http://eol.org/.

AlgaeBase

An aid to taxonomic studies begun in Galway, Ireland, in 1996, AlgaeBase contains information for more than 140,000 species and infraspecies of algae found in marine, aquatic, and terrestrial environments. Entries include taxonomic classification, description, distribution, images, and source publications. There is also a glossary of terms related to algae (e.g., unicellular, red tide, etc.).

http://www.algaebase.org/.

FishBase

FishBase is a global database of more than 30,000 fish species (specifically finfish) and has been available on the Web since 1996. Entries provide information on the taxonomy, distribution, habitat, morphology, ecology, and human uses of individual species. You can search by common or scientific name, but it is also possible to identify species that share characteristics, e.g., multiple species found in the Philippines that are used in aquaculture. There are a number of built-in search tools for finding topical information such as fish sounds, scientific expeditions, and even fish stamps and coins. While FishBase focuses on adult fish, a parallel database called LarvalBase contains information about fish eggs, larvae, and fry.

http://fishbase.org/.

Global Plants

This database is a bit different from other resources in this list in that it includes digitized plant type specimens, contributed by herbaria in more than 300 institutions in 70 countries, which are used to verify nomenclature and act as a record of changes in flora. Global Plants is not a free resource but is offered as a subscription through JSTOR. There are herbaria that provide free access to their specimens, notably the Marine Biological Laboratory of the Woods Hole Oceanographic Institution Library Herbarium and the Cambridge University Herbarium. The latter even includes digitized specimens from Darwin's *Voyage of the Beagle*.

http://plants.jstor.org/.

Ocean Biogeographic Information System (OBIS)

OBIS is a global information system focused on marine biodiversity. A species entry may include taxonomy, images, distribution, environmental conditions (e.g., temperature, depth, salinity), occurrences, and data sets. The database includes more than 45 million georeferenced observations for 120,000 marine species from 800 data sources. In addition to searching by species, data sets can be found by country, Marine World Heritage Sites (e.g., Komodo National Park), ABNJ (Areas Beyond National Jurisdiction; e.g., Indian Ocean), and EBSA (Ecologically and Biologically Significant Areas; e.g., Galapagos Islands). OBIS went online in 2002 and became the information system for the 10-year Census of Marine Life initiative. It is now a project of the Intergovernmental Oceanographic Commission of UNESCO's International Oceanographic Data and Information Exchange (IODE) program.

http://www.iobis.org/.

SeaLifeBase

A sister database to FishBase and created in 2006 due to a demand for information on aquatic species other than finfish, SeaLifeBase contains information on the taxonomy, distribution, and ecology for 74,000 marine species. SeaLifeBase links out from a species page to other websites such as Biodiversity Heritage Library and Google Scholar.

http://www.sealifebase.org/.

Encyclopedias

Encyclopedias exist on a wide range of topics. The first two listed here are large databases sold as online subscriptions, although individual volumes of the latter can be purchased outright.

Aquaculture Compendium

Produced by CABI, Aquaculture Compendium is an encyclopedic resource covering all aspects of aquaculture in marine, brackish, and freshwater environments. There are data sheets about fish, mollusks, crustacean, algae, and live feed species as well as diseases, production and environmental systems, and issues in aquaculture. Other features include a database, case studies, images, maps of species' wild and cultured distributions, and maps of disease distributions.

http://www.cabi.org/ac/.

Encyclopedia of Life Support Systems (EOLSS)

An integrated compendium of 21 encyclopedias with peer-reviewed content and arranged thematically, EOLSS includes both major core subjects as well as interdisciplinary articles to "help foster the transdisciplinary context required to fulfill the vision of sustainable development." Sample chapters

include *Aquatic habitats in Africa; Biological oceanography;* and *Mangroves of the reef domain: A case study in Belize*. EOLSS was developed under the auspices of UNESCO and EOLSS publishers.

http://www.eolss.net/.

To illustrate the breadth of topics covered, here are just a few examples of encyclopedia titles that can be purchased as ebooks or in print:

Hopley, D. (Ed.). (2011). *Encyclopedia of modern coral reefs: Structure, form and process*. Dordrecht, Netherlands: Springer.

Kornprobst, J. M. (Ed.). (2014). *Encyclopedia of marine natural products* (2nd ed.). Weinheim, Germany: Wiley.

Likens, G. E. (Ed.). (2009). *Encyclopedia of inland waters.* San Diego, CA: Elsevier.

Smith, H. D., Suarez de Vivero, J. L., & Agardy, T. S. (Eds.). (2015). *Routledge handbook of ocean resources and management.* London: Taylor & Francis.

Steele, J. H., Turekian, K. K., & Thorpe, S. A. (Eds.). (2009). *Encyclopedia of ocean sciences* (2nd ed.). San Diego, CA: Elsevier.

Field Guides and Other Identification Guides

A field guide is a book used to identify a species. It typically contains descriptions and illustrations, and often other information such as behavior, habitat, or geographic distribution that will help the reader to distinguish one species from another. One of the best resources devoted to identifying field guides is the International Field Guides database, hosted by the University of Illinois at Urbana–Champaign. It provides a searchable listing, including by classification and biogeographical regions, of field guides for animals and plants worldwide (Schmidt, 2014).

Field guides often have a local or regional relevance, as shown by the following examples:

Davis, R. B. (2016). *Bogs and fens: A guide to the peatland plants of the northeastern United States and adjacent Canada*. Hanover, NH: University Press of New England.

Druehl, L., & Clarkston, B. (2016). *Pacific seaweeds: A guide to common seaweeds on the Pacific west coast.* Madeira Park, BC: Harbour Publishing.

Kells, V. A., Rocha, L. A., & Allen, L. G. (2016). *Field guide to coastal fishes: From Alaska to California.* Baltimore, MD: Johns Hopkins University Press.

Markle, D. F., & Tomelleri, J. R. (2016). *Guide to freshwater fishes of Oregon.* Corvallis, OR: Oregon State University Press.

Reeber, S. (2015). *Waterfowl of North America, Europe, and Asia: An identification guide*. Princeton, NJ: Princeton University Press.

Scientists also use more advanced texts such as atlases, floras and faunas, handbooks, and keys for species identification. Here are a few examples of recently published titles:

Bielanska-Grajner, I., Ejsmont-Karabin, J., & Radwan, S. (2017). *Rotifers (Rotifera): Freshwater fauna of Poland.* Kraków, Poland: Jagiellonian University Press.

Hayward, P. J., & Ryland, J. S. (2017). *Handbook of the marine fauna of North-West Europe.* Oxford: Oxford University Press.

Heesen, H. J. L., Daan, N., & Ellis, J. R. (Eds.). (2015). *Fish atlas of the Celtic Sea, North Sea, and Baltic Sea: Based on international research-vessel surveys*. Wageningen: Wageningen Academic Publishers.

Sim-Smith, C., & Kelly, M. (2015). *Marine fauna of New Zealand: Sponges in the family Geodiidae (Demospongiae: Astrophorina).* Auckland, NZ: National Institute of Water and Atmospheric Research.

Journals

Marine and aquatic science journals are published by large and small commercial publishers, government, universities, and societies. Some are freely available as Open Access journals, but others range in subscription cost from a few hundred to several thousand dollars. It is difficult to estimate how many there are but in a series of publications, Barnett (1986, 1995, 2005) described more than 400 English-language journals and serials in the marine sciences. Core lists of marine journals are also available in multiple editions of *Magazines for Libraries* by Webster and Butler (2006, pp. 706–714, 2008, pp. 648–657, 2010, pp. 582–591, 2012, pp. 569–579). Finally, Journal Citation Reports (2015 ed.), a subscription-based resource that measures how often articles in a journal are cited (i.e., Impact Factor) lists 104 titles in Marine and Aquatic Biology and 19 titles in Limnology.

With so many journals and a finite budget, how does a library decide what to purchase for its researchers? In response to journal cancellations at their institutions, Butler and Webster (2011) questioned the notion of "core journals" and instead recommend analyzing where your researchers are publishing and what they are citing, as well as considering new ways to provide access to journals such as collaborative collection development. When making decisions to renew or cancel a journal, most institutions or libraries look at overall cost, cost per download, Impact Factor, the number of articles authored by their faculty, how often articles are cited from the journal, and local relevance.

Databases

For many researchers in the sciences, the key databases are Google Scholar, Web of Science, or Scopus. Yet, they should be encouraged to make use of specialized databases because of the unique content and powerful search functionality. The databases listed here contain abstracts only, but some will link out to free articles, full text in repositories, or Open URL link resolvers found in many libraries.

Aquatic Sciences and Fisheries Abstracts (ASFA)

ASFA includes international coverage of the world's literature on science, technology, management, and conservation of marine, brackish, and freshwater resources. Dates of coverage vary, and publication types include journal articles, books, conference proceedings, dissertations, films, maps, numerical data, patents, and reports. ASFA comprises five subfiles: (1) ASFA 1: Biological Sciences & Living Resources; (2) ASFA 2: Ocean Technology, Policy & Non-Living Resources; (3) ASFA 3: Aquatic Pollution & Environmental Quality; (4) Aquaculture Abstracts; and (5) Marine Biotechnology Abstracts; as well as complementary access to Oceanic Abstracts. ASFA is produced by the ASFA Partnership, a network of four United Nations agencies and more than 60 international and national partners, each responsible for indexing the aquatic literature in their region. ASFA is published under a cooperative agreement between ProQuest and the Food and Agriculture Organization of the United Nations (FAO).

http://proquest.libguides.com/asfa.

BIOSIS Previews

With international coverage of journal articles, conference proceedings, books, and patents for life sciences and biomedical research, this resource comprises the journal content from Biological Abstracts with supplemental, nonjournal coverage from Biological Abstracts/RRM (Reports, Reviews, Meetings). Coverage dates back to 1926. Published by Thomson Reuters.

http://thomsonreuters.com/en/products-services/scholarly-scientific-research/scholarly-search-and-discovery/biosis-previews.html.

CAB Direct

Comprised of two databases—CAB Abstracts and Global Health—CAB Direct includes international coverage of journal articles, proceedings, and books in the applied life sciences such as agriculture (including aquaculture), conservation, global health, and nutrition. Coverage dates back to 1973 with an archive available back to 1900. Published by CABI.

https://www.cabdirect.org/.

Environmental Sciences and Pollution Management (ESPM)

Areas of note in this resource include aquatic pollution, bacteriology, ecology, and water resource issues found in journal articles, conference proceedings, books, reports, and government publications in the environmental sciences. ESPM comprises 13 subdatabases, including ASFA 3: Aquatic Pollution & Environmental Quality as well as Water Resources Abstracts. Coverage extends back to 1967. Published by ProQuest.

http://proquest.libguides.com/espm.

Fish, Fisheries and Aquatic Diversity Worldwide

Dating back to the 1970s, this database has international coverage of journal articles, conference proceedings, books, reports, and theses in all areas of ichthyology, fisheries, aquatic and marine biology, and aquaculture. It comprises 19 databases, including the ceased database, Aquatic Biology, Aquaculture & Fisheries Resources. It also includes links to FishBase. Published by EBSCO.

https://www.ebscohost.com/academic/fish-fisheries-aquatic-biodiversity-worldwide.

GeoBase

This resource has international coverage of journal articles, conference proceedings, and book chapters in the areas of earth sciences, ecology, geology, human and physical geography, environmental sciences, oceanography, geomechanics, alternative energy sources, pollution, waste management, and nature conservation. Date coverage varies based on subset of records. Published by Elsevier.

https://www.elsevier.com/solutions/engineering-village/content/geobase.

GeoRef

GeoRef indexes journal articles, conference proceedings, books, maps, reports, and theses in the geosciences, including marine geology, oceanography, and hydrology. Published by the American Geosciences Institute and hosted on a variety of platforms, coverage of geology in North America is from 1666 and for the rest of the world it is from 1933.

http://www.americangeosciences.org/georef/about-georef-database.

MarinLit

Established in the 1970s at the University of Canterbury, New Zealand, and now published by the Royal Society of Chemistry, MarinLit indexes journal articles related to marine natural products, including new and revised compounds, synthesis, ecology, and biological activities.

http://pubs.rsc.org/marinlit/.

Oceanic Abstracts

With coverage going back to 1981, this database indexes journal articles related to the marine and brackish-water environment, including areas such as marine biology, physical oceanography, fisheries, and aquaculture. Published by ProQuest.

http://search.proquest.com/oceanic/productfulldescdetail.

Zoological Record

Zoological Record indexes journal articles, conference proceedings, and book chapters in zoology, including animal behavior, biodiversity, ecology, conservation, taxonomy, and wildlife management, and it serves as the unofficial register of animal names. When the back file is purchased, access is from 1864. Published by Thomson Reuters.

http://thomsonreuters.com/en/products-services/scholarly-scientific-research/scholarly-search-and-discovery/zoological-record.html.

Repositories

For more than a decade, libraries have been digitizing publications and making them available in repositories. Institutional publications, typically available in the past through library exchange programs or subscriptions, are now easily accessible online. Similarly, historical texts found in special collections at select libraries can now be consulted by researchers worldwide. Hundreds of institutional and governmental repositories contain documents relevant to the aquatic sciences. Here are a few key international repositories.

Aquatic Commons

Aquatic Commons is a thematic digital repository focusing on the natural marine, estuarine/brackish, and freshwater environments. It covers the science, technology, management, and conservation of these environments; the organisms and resources; and the economic, sociological, and legal aspects. The repository is directed by the International Association of Aquatic and Marine Science Libraries and Information Centers (IAMSLIC) and hosted by the UNESCO/IOC Project Office for the International Oceanographic Data and Information Exchange (IODE).

http://aquaticcommons.org/.

OceanDocs

OceanDocs is a repository of marine science publications originating from members of the ocean research and observation community around the world. Marine institutions in Africa and Latin America are especially active in contributing documents. OceanDocs is supported by the Intergovernmental Oceanographic Commission (IOC) and hosted by the UNESCO/IOC Project Office for IODE.

http://www.oceandocs.org/.

Biodiversity Heritage Library (BHL) Portal

The BHL Portal is a rich resource of historical literature that includes more than 100,000 titles related to 150 million species names. It is the achievement of an international consortium of natural history and botanical libraries, working in partnership with Internet Archive, to digitize literature held in their collections and make it freely available on the Web. BHL content is incorporated into the EOL.

http://www.biodiversitylibrary.org/.

Government Websites

Websites at all levels of government (e.g., local, regional, national) are useful for providing research publications, library catalogs, repositories (leading to more publications), statistics and data sets, and mapping tools. It is nearly impossible to cover all of the websites of potential use, so instead here is a description of one approach to take when looking for government information in Canada, followed by examples for two other countries.

In Canada, the following federal ministries would be of potential interest: Environment and Climate Change Canada, Fisheries and Oceans Canada, and Natural Resources Canada. Fortunately, the ministries are transitioning to one database for federal government publications (Government of Canada, 2017a) and one Federal Science Library catalog (Government of Canada, 2017b), but until that work is complete, it is also necessary to search the individual ministry sites for additional publications and statistical information. Depending on the topic, websites for the provincial government (e.g., Ministry of Agriculture; Ministry of Environment; Ministry of Forests, Lands and Natural Resource Operations) or even those at the municipal or local levels are good choices.

Always consider who the major players are in specific countries. For example, if you are interested in the United States, key federal agencies are the Environmental Protection Agency (EPA), Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA), all of which publish a wealth of information. In Kenya, information may be sourced from the Ministry of Environment and Natural Resources, Ministry of Agriculture, Livestock and Fisheries, and the Ministry of Water and Irrigation.

Intergovernmental Websites

Since water bodies and species cross national boundaries, a number of intergovernmental organizations have been created to inform management of these resources. Similar to government sites, they are a good source of publications, statistics and data, and maps.

Food and Agriculture Organization

The three main goals of FAO are eradication of hunger, food insecurity, and malnutrition; elimination of poverty and the driving forward of economic and social progress for all; and sustainable management and utilization of natural resources, including land, water, air, climate, and genetic resources for the benefit of present and future generations. FAO has a publications repository, statistics tools for fisheries and water, and a catalog of the holdings at the David Lubin Memorial Library, renowned for its resources on food, agriculture, and international development.

http://www.fao.org/home/en/.

http://www.fao.org/library/libraryhome/en/.

Inter-American Tropical Tuna Commission (IATTC)

Responsible for the conservation and management of tunas and other marine resources in the eastern Pacific Ocean, IATTC publishes monthly catch statistics and maintains a registry of vessels. Publications include its Bulletin, Stock Assessment Reports, Special Reports, and Data Reports.

https://www.iattc.org/HomeENG.htm.

International Commission for the Conservation of Atlantic Tunas (ICCAT)

Monitoring conservation of tunas and tunalike species in the Atlantic Ocean and adjacent seas, ICCAT compiles statistics for species in the Atlantic Ocean and offers other resources on its site, including a record of vessels, a record of bluefin tuna farming facilities, and a list of tagging programs. Series based on its work include Collective Volume of Scientific Papers, Statistical Bulletin, and Biennial Reports.

https://www.iccat.int/en/.

International Council for the Exploration of the Sea (ICES)

This global scientific organization facilitates research between its 20 member countries and advises decision makers on the sustainable use of the marine environment and ecosystems. ICES publications include its subscription-based *ICES Journal of Marine Science*, as well as Cooperative Research Reports synthesizing research conducted by expert groups, and Conference and Meeting documents. It also maintains a data portal covering such themes as biodiversity (seals and seabirds), fish egg and larvae (from ichthyoplankton surveys), and underwater noise.

http://www.ices.dk.

International Joint Commission (IJC)

The IJC is an example of an organization formed by two countries (Canada and the United States) to prevent and resolve disputes and to pursue the common good as it pertains to lake and river systems along their border. Guided by the Boundary Waters Treaty of 1909, its jurisdiction applies to a range of water uses including drinking water, shipping, hydroelectric power generation, agriculture, industry, and fishing. Its website includes technical reports, administrative documentation, and interactive maps.

http://www.ijc.org/.

International Pacific Halibut Commission (IPHC)

Established by Canada and the United States in 1923 to research and manage the stocks of the Pacific halibut, IPHC conducts standardized stock assessment fishing surveys and basic halibut biology projects. Annual survey data, scientific reports, technical reports, and information bulletins are found on the website.

http://www.iphc.int/.

International Whaling Commission (IWC)

IWC was established under the International Convention for the Regulation of Whaling in 1946 as the global organization charged with the conservation of whales and the management of whaling. Although a moratorium on commercial whaling was introduced in 1986, IWC continues to set catch limits for

aboriginal subsistence whaling. It also works to address issues such as entanglement, ship strike, marine debris, and climate change. IWC maintains a library of full-text publications and publishes the *Journal of Cetacean Research and Management.* Its website links to related research organizations and agencies in both Canada and the United States, as well as worldwide, including the United Nations Oceans & Laws of the Sea.

https://iwc.int/home.

Northwest Atlantic Fisheries Organization (NAFO)

NAFO is a multinational, intergovernmental body whose main objective is to aid in the optimum utilization, management, and conservation of fishery resources (excluding salmon, tunas/marlins, whales, and sedentary species) in the NAFO Convention Area. Charged with making fisheries research pertaining to the Northwest Atlantic available to the scientific community, its website provides access to catch statistics, the peer-reviewed *Journal of the Northwest Atlantic Fishery Science,* and other publications.

https://www.nafo.int/.

Pacific Salmon Commission (PSC)

PSC was formed to implement goals set out in the Pacific Salmon Treaty of 1985 between Canada and the United States to conserve and manage the shared key resource of Pacific salmon. PSC maintains a staffed research library, and its website links to fisheries maps, technical and annual reports, and many other publications including those of its predecessor, the International Pacific Salmon Fisheries Commission.

http://www.psc.org/.

Data and Map Sources

Many of the websites described above contain data or maps; this section highlights resources where these are the main focus.

AQUASTAT

AQUASTAT is FAO's global water information system, developed by its Land and Water Division. It provides reports, data sets, summary tables, maps, country profiles, and river basin profiles related to water resources, water uses, irrigation and drainage, dams, and climate.

http://www.fao.org/nr/water/aquastat/main/index.stm.

Dryad

This digital repository is an Open Access curated resource of data sets linked to specific scientific publications that can be searched by keyword and then filtered by author, subject, or journal.

http://datadryad.org/.

FAO Fisheries and Aquaculture Department

To promote responsible aquaculture and fisheries, FAO analyzes and disseminates global statistics on production (both capture and aquaculture), tuna catches, number of fishers, consumption of fish and fishery products, and fishery commodities and trade. It offers the data in three ways: a stand-alone application called FishStatJ for experts and scientists; online query panels for advanced users to extract

customized reports; and the FAO *Yearbook of Fishery and Aquaculture Statistics*, an annual summary with detailed tables.

http://www.fao.org/fishery/statistics/en.

Global Biodiversity Information Facility (GBIF)

GBIF is an international, open data initiative funded by governments and organizations around the world to allow anyone, from student to policy maker to researcher, to access and use data and information about all types of life on Earth. Underway in 2001, this resource can be explored in a myriad of ways, including species, country, and data publisher; results are georeferenced on a world map.

http://www.gbif.org/.

PANGAEA

PANGAEA is a repository of georeferenced data for earth and environmental sciences. While most data are freely available, some data sets for ongoing projects may be under embargo; if so, a description and the investigator's contact information are provided. PANGAEA can be searched by keyword and filtered by criteria such as author, year, theme (e.g., oceans), device, and location (e.g., Weddell Sea). Data sets can also be viewed using Google Maps or Google Earth.

https://www.pangaea.de/.

ReefBase

A global information repository for coral reefs, ReefBase comprises three main tools: a Global Database that provides data and information on the location, threats, monitoring, and management of coral reefs in more than 120 countries and territories; the ReefBase Online Library of nearly 30,000 publications; and ReefGIS, offering access to maps on themes such as coral disease, reef bleaching, and marine protected areas.

http://www.reefbase.org/.

Sea Around Us

A research initiative at the University of British Columbia to assess the impact of fisheries on the marine ecosystems of the world, this source includes catch data that can be searched by country or taxonomy. Results can be displayed at spatial scales with ecological and policy relevance, such Data are also available for fisheries economics, biodiversity, and mariculture. Graphed data are reconstructed based on official reported data (mainly from FAO) and reconstructed estimates of unreported data from the literature and consultations with local experts.

http://www.seaaroundus.org/.

Water Resources of the United States

This site serves as an example of the kind of data related to water that governments may disseminate. The US Geological Survey provides past and present data for such topics as streamflow, floods, droughts, surface water quality (e.g., temperature, pH), and groundwater.

https://www2.usgs.gov/water/.

World Database of Protected Areas (WDPA)

This global database of marine and terrestrial protected areas is presented through a mapping interface. Searches can be conducted for protected areas by individual names or via a map that identifies protected areas in a region. WDPA is a joint project between the United Nations Environment Programme (UNEP) and the International Union for Conservation of Nature (IUCN). It is managed by UNEP World Conservation Monitoring Centre (UNEP-WCMC).

https://www.protectedplanet.net/.

Citizen Science

The world is a big place. What if you could harness the energy of amateur naturalists to gather observations that scientists could use? Often using mobile apps, citizen scientists are doing just that. You may be familiar with eBird, but there is a raft of others, including many for the aquatic world. Here are a few global examples.

iNaturalist

iNaturalist covers the terrestrial and aquatic world. Participants record an observation by taking a photograph, share it with other naturalists, and discuss the findings to crowdsource a correct identification. iNaturalist shares its data with other data repositories like the GBIF described above.

http://www.inaturalist.org/.

iSeahorse

The goal of iSeahorse is to better understand seahorse behavior, species ranges, and threats to improve conservation around the world. Participants can submit a photo, description, coordinates, and even guess the species based on identification guides available on the website.

http://www.iseahorse.org/?q=home.

Reef Life Survey (RLS)

Recreational divers participate in the RLS to collect data at scales impossible for researchers to cover. Divers use standardized visual census methods to record fish and invertebrate species seen along underwater transects. In addition to being experienced and capable, divers have to be dedicated enough to identify species and enter the data after their dives.

http://reeflifesurvey.com/.

Secchi Disk: The Global Seafarer Study of the Phytoplankton

Phytoplankton produce 50% of the world's oxygen and are a key part of the aquatic food web, but scientists have observed a population decline in recent years. A Secchi disk provides a simple way to measure water clarity, and when measured away from estuaries and shallows, it is an indication of the amount of phytoplankton in the water column. Seafarers and boaters are asked to lower the disk vertically from a stationary boat and record their GPS coordinates and the Secchi depth, the point at which the disk disappears from sight. The disk and the results are available on the website.

http://www.secchidisk.org/.

DISCIPLINE INFORMATION LITERACY INSTRUCTION

Undergraduate Students

My main goals for undergraduate students are to make sure they know the resources available to them and how to conduct a basic search effectively. When demonstrating a database, I develop a research question that will enable me to illustrate the concepts of phrase searching, Boolean logic (AND, OR, NOT), and truncation, as well as how to search for the scientific name. In an upper-division class and certainly in a one-on-one consultation, it is appropriate to explain and demonstrate how using subject headings/descriptors can be an effective way to increase the relevancy of results. Depending on the database, it may be useful to discuss key features such as sorting, filtering/limiting, and saving/exporting records. The latter is particularly helpful if citation management software is available to the students.

As an example of the process, a sample research question that is drawn from real life and relates to the students' coursework might be: Migration of Chinook salmon from the river to the ocean is being impeded by hydroelectric dams along the route. What strategies are being tested to increase the survival rate of the smolts? I query the class for the two or three main ideas in the question, teaching them to identify the individual components and terms. Once the question is understood, we can examine how to choose an appropriate database, one that is likely to hold applicable content and what its authority is based on. This is often a good time for discussion about the differences between subscription databases, Google, and Google Scholar. As the search strategy is explained and developed within the structure of the chosen database, I demonstrate each step of the way through searching the database, showing the kind and number of retrieved results and asking the class what they would do next. This generally allows for instruction of all of the basic concepts. For this research question example, developing the search strategy might look like this:

• Identify main topic. Introduce phrase searching.

"Chinook salmon"

• Determine and include the scientific name. Demonstrate how the Boolean operator OR means more.

"Chinook salmon" OR "oncorhynchus tshawytscha"

• Include the second concept. Is there a synonym that should be used? Introduce the use of AND.

("Chinook salmon" OR "oncorhynchus tshawytscha") AND (dam or dams)

• Include the third concept. Introduce truncation.

("Chinook salmon" OR "oncorhynchus tshawytscha") AND (dam or dams) AND surviv*

A very basic introduction to Boolean operators for first- or second-year students in a large lecture hall is an exercise that my colleagues and I call "Stand-up Boolean." The students find it fun, and it can give them a visceral understanding of Boolean searching, or at least a good laugh. It works like this:

Please stand up if you had salad for lunch.

Please stand up if you had salad OR a sandwich for lunch.

Please stand up if you had salad OR a sandwich OR sushi for lunch.

Please stand up if you had salad OR a sandwich OR sushi for lunch AND a juice.

Then we debrief. When OR is used, more and more students stand up. When AND is included, only a few students are left standing.

The online format of information somewhat masks the purpose and quality of a resource, so it is important for undergraduate students to understand what they are looking at when they find an article or book or website. When teaching a conservation course, it works well to pick a hot topic or one that is more controversial (e.g., marine protected areas, invasive species, ocean acidification), provide a list of the types of information (e.g., media, books, journal articles, reports), and have the students discuss in pairs when they would use that type of information and how they would look for it. I would project this diagram on the screen (Fig. 5.1).

[Figure 5.1 inserted here]

The students contribute what they know, which can then be reinforced by repeating or paraphrasing, or clarifying or correcting if necessary. I also take this opportunity to explain peer review and distinguish it from review articles. This exercise works particularly well because it engages students who already know something about evaluating information and can share it with their peers. It also leads nicely into the searching component of the class.

Graduate Students

Sometimes graduate students may not know much more than undergraduate students with respect to searching. Perhaps they made it through their undergraduate degrees using only Google Scholar, or they have returned to university after time away, or they may have studied previously at an institution without specialized databases. One big difference is that they usually are already familiar with their area of research, so I typically ask them for an example of a research question or information need. Using the student's example is also more authentic, slows down the demonstration, and illustrates that searching is an iterative process.

Graduate students, of course, have greater information needs than undergraduates because their research is more comprehensive. The specialized databases that index gray literature are especially beneficial to them. Graduate students are the scholars of the future, so incorporating techniques for identifying key authors or journals in their fields and introducing them to the issues of scholarly publishing, Open Access, and research data management are valuable skills for them to learn. One-on-one or small group consultations can be the most rewarding because questions can be much more in-depth. An example of a more focused project used in the past is one where graduate students and other research assistants on the University of British Columbia's Sea Around Us project had to search for catch statistics beyond the reported FAO data. Strategies included searching for scientific publications using ASFA, tracking down government websites (often in other languages), and being cognizant of changing names of government bodies and even countries.

STAYING UP-TO-DATE

If you are passionate about the aquatic environment, it is relatively easy to stay current by following news from the media and aquatic organizations on Twitter or whatever your favorite social media tool may be. For information about new resources and trends in information management, library associations can be invaluable.

In this field, we are fortunate to have an entire library association devoted to the topic. The IAMSLIC brings together more than 300 members from around the world in academia, government, industry, and NGOs to explore ideas and issues of mutual concern. IAMSLIC began under the name East Coast Marine Science Librarians in 1975 with a meeting of 23 librarians from the United States, Canada, and Bermuda. Since then it has expanded geographically and encompasses all aquatic sciences, not just marine.

IAMSLIC has six regional groups, so members can forge connections closer to home. Like other associations, IAMSLIC has a blog and an email list, and hosts an annual conference with published proceedings.

Over the years, my friends and colleagues in IAMSLIC have taught me a lot about key areas such as digitization, repositories, Open Access, data management, and preservation. One of the things I appreciate most is the international perspective of the members, illustrated by the four resources below that were presented at recent IAMSLIC conferences.

Agriculture and Environmental Data Archive

A project managed by the UK Freshwater Biological Association in partnership with the Centre for e-Research at King's College London, this archive contains data sets, gray literature, images, video, and a variety of other information.

http://www.environmentdata.org/.

Gaia Antarctic Digital Repository

The purpose of this resource is to develop a single platform to collect, preserve, and disseminate information about Antarctic and polar topics. The repository is a partnership of the Universidad de Magallanes in Chile with academic and research institutions contributing content.

http://antarticarepositorio.umag.cl/.

Oregon Estuarine Invertebrates: Rudys' Illustrated Guide to Common Species (3rd ed.)

While most field guides are only available for purchase in print or occasionally as an ebook, *Oregon Estuarine Invertebrates* is freely available from the University of Oregon's institutional repository.

http://researchguides.uoregon.edu/oei.

SPC Coastal and Oceanic Fisheries Digital Library

The Secretariat of the Pacific Community (SPC) is the principal scientific and technical organization in the Pacific region owned and governed by 26 country and territory members. The Digital Library helps with the dissemination of fisheries and aquaculture-related documents produced by, for, or in collaboration with SPC to fisheries managers throughout the Pacific.

https://www.spc.int/DigitalLibrary/FAME.

FINAL THOUGHTS

I hope the selection of resources and examples has helped you to appreciate the importance of marine and aquatic sciences and the breadth of research that is available to students and researchers alike. While many resources have been covered here, many more are out there to be discovered. It is impossible to know them all, so remember to look at the context of the question (e.g., species, location, issue) and consider which organization(s) would be compelled to collect data and publish on the topic. Also check other library websites to see what resources they recommend, and if you join IAMSLIC, you will have an international network of colleagues with whom to consult.

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