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Specimens by the Millions: Managing Large, Specialized Collections at the University of Washington Burke Museum Fish Collection

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The University of Washington Fish Collection is a state-funded collection shared between the University of Washington School of Aquatic and Fishery Sciences and the Burke Museum of Natural History and Culture dating back to 1919. Early collecting followed the interests of curators and university class field trips, with a slow and steady growth rate up until the late 1970s. At that time, recognizing that state and federal agencies routinely collect specimens as part of their fishery and resource management efforts, we sought out partnerships with several local agencies, most notably the National Oceanographic and Atmospheric Administration Fisheries Department, to provide collections support for the natural history specimens collected through their survey work. The millions of specimens collected through these efforts, including adults, juveniles, eggs, larvae, skeletal materials, otoliths, and tissue samples, along with detailed locality data, are now freely available to researchers around the world. Vouchering specimens adds value to agency research by allowing for verification of results of work critical to the management of our resources, including supporting forensic vouchering for law enforcement. Our collection benefits not only from the huge number and diversity of specimens we can make available to researchers, but also through training opportunities for our students who help to curate the collections and often participate in survey fieldwork along with agency scientists. I outline these partnerships and the benefits to both parties as we curate these vast specialized collections.

THE University of Washington Fish Collection (UWFC) dates back to the formation of the College of Fisheries in 1919. It was originally a teaching collection developed by The Young Naturalists' Society of Seattle (Pietsch, 1997) as well as the early faculty of the college. There are specimens in the collection dating back to the 1880s, including some collected aboard the U.S. Fish Commission Steamer *Albatross*, but the majority of the early specimens were collected by early faculty members as part of their research or class field trips. The first officially named Curator of the collection, Leonard P. Schultz, was hired in 1928 to teach a course in ichthyology and to lend scientific credibility to a college that was heavily criticized as "only involved in the training of individuals for the canning industry" (Stickney, 1989). Schultz found the fish collection to be in "horrible condition" with many potential safety hazards including an open case of disintegrating dynamite (Stickney, 1989). Schultz built the collection into a valuable teaching and research collection by assigning catalog numbers and recording locality and specimen data in a large ledger book. Collection building mostly consisted of freshwater collecting trips around the Pacific Northwest as well as field trips with his College of Fisheries classes, adding, by Schultz's estimate, 100,000 specimens to the collection during his tenure. This number seems unlikely, given that the University of Washington (UW) Fish Collection records only show 4,216 lots accessioned between 1928 and 1937, when Schultz was hired away by the U.S. National Museum, where he remained for the duration of his career (Pietsch and Orr, 2019).

After Schultz were several Curators who were faculty members in the College of Fisheries, including Arthur Welander (1936–1948), Albert W. C. T. Herre (1948–1957), John Donald McPhail (1963–1966), and Donald Warren Hagen (1967–1972), all of whom slowly built the collection with class field trips and some of their own research (Stickney, 1989; Pietsch and Orr, 2019). However, curation of the collection lapsed in the early years, as one faculty member would leave and years would pass before a new faculty member was assigned responsibility for the collection. Arthur Welander was on the faculty from 1936 to 1978 and took charge of the fish collection during these gaps (Pietsch, 1982a; Stickney, 1989). A survey of fish collections in the United States and Canada in 1976 reported 102,000 specimens and no type material for the UWFC, giving it a ranking of 13 out of 20 among "Other Collections" that were not at the standing of the more substantial International, National, or Regional Centers (Collette and Lachner, 1976).

It was not until 1978 when Theodore W. Pietsch was hired by the now UW School of Aquatic and Fishery Sciences (SAFS) that a period of growth and care for the collection really flourished. During his time as curator, Pietsch secured four National Science Foundation (NSF) collection improvement grants, moved the collection to a brand new building with a collection facility he helped design, and created an archival storage facility holding one of the largest collections of early life history stages of fishes in the world, as well as one of the largest collections of fish otoliths. In 1982, just a few years after taking charge of the collection, Pietsch reported on the status of the collection after receiving his first NSF collection improvement grant. He reported approximately 207,750 specimens in 24,420 lots (Pietsch, 1982b). A second survey of fish collections in the United States and Canada in 1995 improved the status of the UWFC to a ranking of five out of eight Regional Centers, with 229,400 specimens and 14 type specimens reported (Poss and Collette, 1995). At the time of Pietsch's retirement in 2015, the UWFC housed over

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Table 1. Number of specimens and lots and percent received from NOAA Fisheries in the University of Washington Fish Collection in 2019. Totals do not include tissues because their vouchers are included in the Adult and Juvenile numbers. Otoliths and salmon scales are not kept in lots, and are not included in the total percent from NOAA Fisheries.

Collection	Specimens	Lots	Percent
Adults and juveniles	397,141	58,553	26
Tissues	17,257	8,321	49
Early life history	9,279,555	137,101	95
Otoliths	2,559,900		100
Dry skeletons	947	933	10
Salmon scales	800,000		0
Totals	13,037,543	196,587	74%

11 million specimens and would certainly be considered one of the top International Centers if there were a third survey.

Perhaps one of the most important contributions to the UWFC was Pietsch's partnership with the U.S. National Oceanic and Atmospheric Administration (NOAA) Fisheries Department. During his early years on the faculty at the UW, Pietsch recognized the close connection between the local NOAA Alaska and Northwest Fisheries Science Centers and the UW School of Aquatic and Fishery Sciences (SAFS). Many UW alumni worked at the NOAA centers, and there were many collaborations happening between NOAA scientists and UW faculty and students. Pietsch fostered these partnerships and secured what was the beginning of a continuous funding relationship between NOAA Fisheries and the UWFC as early as 1980.

The collaboration with NOAA Fisheries is a unique relationship. The U.S. National Museum of Natural History (USNM) has the first right of refusal for all federally collected specimens. Curators there agreed that keeping specimens on the west coast for west coast scientists was far more beneficial than sending them to the USNM. Early contracts were established for consulting services to identify the species of fishes caught on NOAA surveys both in Alaska and along the west coast of the United States, including specimens collected by observers contracted to work aboard commercial fishing vessels. These early contracts extended into a larger partnership creating an archival storage facility for the early life history stages of fishes collected by the Alaska Fisheries Science Center (AFSC) Fisheries–Oceanography Coordinated Investigations (FOCI) Program in 1992. The success of that partnership led to the archiving of the adult and juvenile specimens collected by the Groundfish Assessment Program in the AFSC Resource Assessment and Conservation Engineering (RACE) division in 1999. The last NSF Collections improvement grant in 2012 added the otolith collection from the AFSC containing over 2.5 million pairs of otoliths dating back into the mid-1970s.

The UW Fish Collection joined the Burke Museum of Natural History and Culture in 2007 and is now a shared resource between the Burke Museum and the UW School of Aquatic and Fishery Sciences. As of 2019, the collection has grown to over 13 million specimens. Our collection is broken into several management units, including the Adult and Juvenile Collection, the Early Life History Collection, the Skeleton Collection, the Tissue Collection, and the Otolith Collection (Table 1). I will highlight how the collaboration with NOAA Fisheries has benefited each of these collections, and how the collaboration has benefited NOAA Fisheries as well.

ADULT AND JUVENILE COLLECTION

In 2019, the Adult and Juvenile Collection consists of 397,141 specimens in 58,553 lots (Table 1). Specimens are housed in glass jars and stainless-steel containers on a mobile compactor shelving system. Over 4,100 species in 1,408 genera and 325 families are represented. The type material is restricted to those lots deposited since 1978 when Ted Pietsch took over as Curator. Prior to that, all types were sent to the USNM for safekeeping (Meldrim and Wadley, 1968). Current types include 28 holotypes and 267 lots of secondary type material. The oldest specimen in the collection dates to 1862 (*Gasterosteus aculeatus*, UW 015926), but the majority of the collection is from the mid-1920s onward. The entire collection is cataloged, databased, and searchable on the Burke Museum website (https://www.burkemuseum.org/collections-and-research/biology/ichthyology), as well as the many collections data aggregation online portals such as iDigBio.org, VertNet.org, FishNet2.net, OBIS.org, and GBIF.org.

Over 15,000 lots, or 26% of the adult collection (Table 1), were collected either by NOAA Fisheries scientists during resource assessment surveys or by fisheries observers aboard commercial fishing vessels. The majority of these collections date from 1980 forward. Figure 1 shows the collection pathway of specimens collected on a groundfish survey to their eventual deposition in the UW Fish Collection and their data being made available through our search engine.

There are many benefits to NOAA from this partnership. NOAA Fisheries resource surveys support annual stock assessments that are used to manage the resources of our oceans. The data gathered on the surveys are used to set quotas for the commercial fishing industry. Accurate species identification by NOAA scientists is critical to their mission. Specimens collected aboard the surveys and deposited in the UWFC provide vouchers to corroborate field identifications as well as training material for field biologists.

Over the decades of this collaboration, NOAA scientists have described dozens of new species. These include many commercially important species such as *Lepidopsetta polyxystra*, *Sebastes melanostictus* (resurrected by Orr and Hawkins, 2008), *Sebastes variabilis* (resurrected by Orr and Blackburn, 2004), *Bathyraja mariposa*, and *Bathyraja panthera*. There are many at different trophic levels as well, such as the eelpouts *Lycodes akuugun* and *Bothrocara nyx*, and many new species in the snailfish genera *Careproctus* (Orr and Maslenikov, 2007; Orr, 2012, 2016; Orr et al., 2015), *Allocareproctus* (Orr and Busby, 2006), and *Paraliparis* (Baldwin and Orr, 2010), as well as new genera of snailfishes to encompass the new species *Prognatholiparis ptychomandibularis* and *Lopholiparis flerxi*. Descriptions of new species are facilitated by having access to extensive comparative material in the UWFC, and type material deposited locally allows greater access for west coast scientists. Paratypes are sent to the USNM to ensure that federally collected specimens are deposited in the National Museum of Natural History.

One of the main benefits to both NOAA and the UW is training provided to students by this partnership. Both graduate and undergraduate students work closely with the collections, learning to identify species, as well as learning

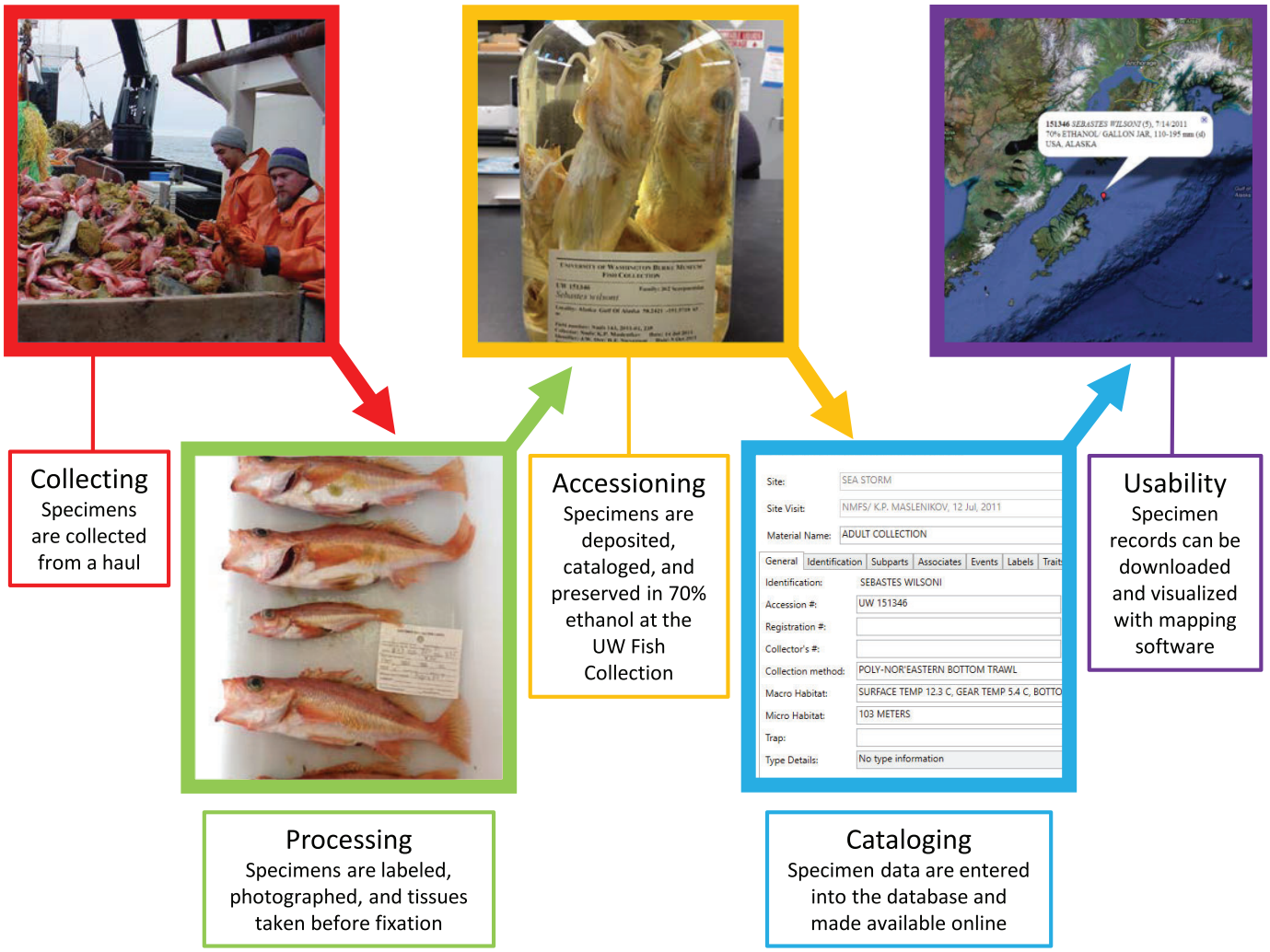

Fig. 1. Pathway of specimens collected aboard NOAA Fisheries AFSC groundfish trawl surveys. First, specimens are collected from a haul. Next, specimens are labeled and photographed, tissues are taken and placed in 95% ethanol, and specimens are placed in 10% formalin. Specimens are then deposited in the UW Fish Collection where they are cataloged and placed in jars of 70% ethanol. Specimen and locality data are entered in the collection database and uploaded to the online search engine at https://www.burkemuseum.org/collections-and-research/biology/ichthyology/collections-database/search.php. Finally, specimen records can be downloaded and visualized with publicly available mapping software. Record shown is for *Sebastes wilsoni*, UW 151346.

proper museum collection management skills. Many of our students have participated in the NOAA resource surveys alongside NOAA Fisheries scientists, gaining valuable fieldwork experience and networking opportunities. Many UWFC alumni have found jobs at the AFSC.

A particularly important collection associated with the adults and juveniles is our tissue collection. This resource has been growing since the 1990s and includes 17,257 tissue vials from 8,321 lots. Tissues are stored in a –86°C freezer and represent 857 species in 148 families. This collection is strongly tied to NOAA, with 49% of tissue lots hailing from NOAA material (Table 1). Tissues account for half of our yearly loan activity with other institutions and researchers, so the tissues collected aboard NOAA vessels have far-reaching impact.

EARLY LIFE HISTORY COLLECTION

The eggs, larvae, and juveniles caught through the NOAA AFSC Recruitment Processes Program (formerly called FOCI) surveys support the recruitment modeling for stock assessments. This is a huge dataset recording the occurrence of early life history stages in the eastern north Pacific and the Bering Sea dating back into the 1960s and supported by voucher specimens deposited at the UWFC.

As of 2019, the collection consists of over 9.2 million specimens in 137,101 lots, representing 404 species in 208 genera and 87 families (Table 1). Over 95% of this collection comes from NOAA Fisheries, with some additional material from the International Pacific Halibut Commission from the 1930s as well as local Salish Sea collections from UW classes at Friday Harbor Laboratories.

In the late 1980s, the Ichthyoplankton Laboratory of the AFSC FOCI Program (now the Recruitment Processes Program) found itself in a tough situation. They had been routinely collecting plankton samples for decades and had amassed a large collection. NOAA has mandated that science centers do not keep collections on site and that the USNM has the first right of refusal for collections. The USNM did not want this large collection, nor did the AFSC scientists want to

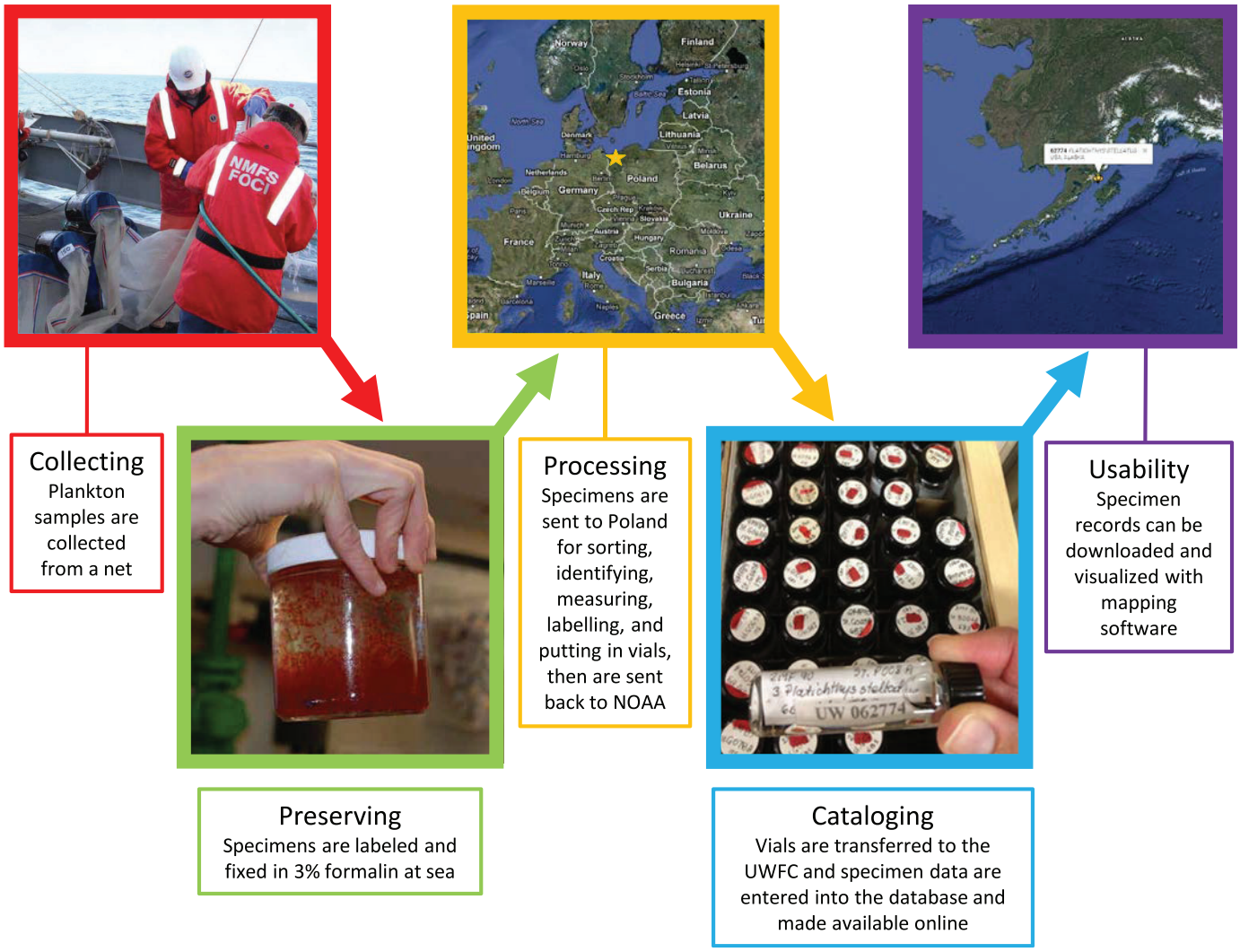

Fig. 2. Pathway of Early Life History collection specimens. First, plankton samples are collected by NOAA Fisheries AFSC FOCI (now the Recruitment Processes Program) scientists during annual surveys. Samples are then labeled and fixed in 3% formalin at sea. Next, samples are shipped to the Plankton Sorting and Identification Laboratory, Szczecin, Poland (ZSIOP), where they are sorted, identified, measured, and labeled. Larvae are placed in vials of 70% ethanol and eggs are placed in vials of 3% formalin. Labeled samples are then sent back to the AFSC for analysis. Quality control measures are in place to verify data and identifications. Samples are then transferred to the UW Fish Collection where they are cataloged and placed in cabinets. Specimen and locality data are entered in the collection database and uploaded to the online search engine at https://www.burkemuseum.org/collections-and-research/biology/ichthyology/collections-database/search.php. Specimen records can be downloaded and visualized with publicly available mapping software. Record shown is for *Platichthys stellatus*, UW 062774.

send it across the country. Knowing that contracts already existed between the AFSC RACE division and the UW Fish Collection to identify and archive adult specimens, FOCI scientists worked with Ted Pietsch to write an NSF grant proposal to create an archival center for early life history stages at the UW. This grant was awarded in 1991 allowing for the transfer of 48,000 lots collected between the late 1960s and mid-1980s. A reference collection of redundant material was sent to the USNM to fulfill the obligation of NOAA Fisheries collections being made available to the USNM.

The arrangement allowed for the yearly transfer of 3,000–5,000 vials into the foreseeable future. The journey of the specimens follows a complicated pathway (Fig. 2). Annual ichthyoplankton cruises sample the waters of the eastern north Pacific and Bering Sea. Those plankton samples are fixed in 3% formalin at sea and then shipped to the Plankton Sorting and Identification Laboratory in Sczcecin, Poland (ZSIOP). Polish scientists sort, identify, count, measure, and label vials from the NOAA surveys and then send them back to the AFSC in Seattle. AFSC scientists then perform their own quality control systems to confirm identifications and data accuracy. There is an eight-year lag between when the samples are collected and when they are transferred to the UWFC. AFSC scientists keep the most recent years of samples in their Ichthyoplankton Laboratory to have easy access to the samples most relevant for their distribution models. They also keep samples from the taxa they are working with for various research projects. Once the Ichthyoplankton Laboratory has all of the data confirmed and inventoried, the samples are ready to be transferred to the UWFC.

A graduate student at the UW works with AFSC scientists to pull the samples from one year and organizes them into boxes to transfer them to the UW. They inventory everything

against AFSC cruise records to check for discrepancies and fix any problems found by working directly with NOAA scientists. Databases are updated to reflect any changes. Once all data are confirmed to be accurate, the UW graduate student assigns UW catalog numbers to all of the vials. At this point the vials are transferred to the UW and organized into taxonomic order for placement in the larval and egg cabinets in the UWFC. Catalog numbers are printed and placed into all of the vials before shelving the vials into the collection. All data are then imported into the collection management software and subsequently uploaded to the Burke Museum website search engine as well as the many natural history collections data aggregation web portals listed previously. All records are georeferenced, allowing for easy visualization with mapping software.

NOAA scientists benefit from this partnership in many ways. The immediate problem of storing the many thousands of vials was solved by transferring them just four miles away into a new well-organized system at the UWFC. Samples are almost instantly retrievable when requested. As technology improves, new techniques allow old samples to be used in new ways. Recruitment Processes Program surveys are now routinely collecting some portion of the plankton sample into 95% ethanol to allow for genetic identification of specimens. There are many specimens in the archive that are only identified to the genus or family. Genetic identification of samples allows for the retroactive identification of voucher specimens. For instance, if larval specimens were consistently identifiable but it was not known what the adult form of that larvae was, AFSC scientists assigned a temporary name, such as *Lepidopsetta* type 2. With the growing international databases of known genetic sequences for fish species, that larval type can now be sequenced and identified. This allows all of the *Lepidopsetta* type 2 larvae in the collection to be updated to the correct identification and unleashes decades of distributional data for that species. Because all of the samples were vouchered and not just discarded, we can now go back to the specimens with the knowledge of the genetic identification and start to look for morphological characters that might help to distinguish species. These characters may then help to inform developmental studies or evolutionary studies of relationships.

AFSC scientists use the early life history specimens for a variety of research topics in addition to the stock assessment work so important to the management of our fisheries resources. Because the specimens are now available through the UWFC, researchers around the world have access to them. Countless management and recruitment (Lanksbury et al., 2005; Sohn et al., 2010), taxonomic (Busby, 1998; Busby et al., 2017), developmental (Busby et al., 2012; Deary et al., 2018), and ecological (Duffy-Anderson et al., 2010; Smart et al., 2012) studies have been published over the decades.

In addition to the research value of the collection, one of the main benefits of this partnership is the opportunity for student training. Dozens of graduate and undergraduate students have worked with the collection over the decades. Many of our graduate students have participated in survey cruises, gaining valuable field experience and working alongside NOAA scientists. The partnership between the federal collections and the university museum has far-reaching benefits and is a model that more federal science centers should explore.

OTOLITH COLLECTION

Scientists at the AFSC found themselves in another difficult situation in 2011 concerning their extensive collection of otoliths. Otoliths are the inner ear "stones" used by fishery biologists to determine the age of a fish, useful because they deposit yearly growth rings by accumulating minerals from their environment. Otoliths had been routinely collected on resource surveys and by observers on commercial fishing vessels since the mid-1970s and had grown into a massive collection housed in an old World War II aircraft hangar with no environmental controls or fire suppression capability. The Seattle Fire Department had issued repeated citations and had warned NOAA that in the event of a fire they would let the building burn and would not attempt to salvage anything inside.

Again, NOAA AFSC scientists partnered with Ted Pietsch to write an NSF CSBR (Collections in Support of Biological Research) grant proposal, which was awarded in 2012 (NSF DBI-1202709). Work began immediately to transfer the otolith vials from Styrofoam boxes into new archival-quality cardboard boxes. Eight UW undergraduates were hired to assist with this project, which took two years to complete. A complete inventory was taken and compared to NOAA's records. Figure 3 shows the transfer of otoliths from the AFSC to the new facility at UWFC.

The otolith collection consists of two parts: those collected by NOAA personnel during resource surveys, and those collected by observers aboard commercial fishing vessels. Both date back to the mid-1970s. All locality and specimen data are available for the survey otoliths, but the observer otoliths locality data fall under the auspices of the Magnuson-Stevens Fishery Conservation and Management Act, Public Law 94-265, Section 402b, which allows commercial fishing companies to keep precise locality data confidential. Data are available upon petition to the fishing company. Abbreviated locality data may be released publicly, such as the quarter of the year and the NOAA Fisheries management area where the specimen was caught.

The otolith collection consists of 83 species in 41 genera and 17 families and has a broad geographic coverage from southern California to Alaska, the Aleutian Islands, Bering Sea, and the Pacific sector of the Arctic Ocean. There are over 2.5 million pairs of otoliths in 18,285 boxes, with 200–300 new boxes transferred to the UW every year. Precise specimen data are available for every pair, including species, sex, length, and weight. In addition, the survey otoliths have locality data available including latitude, longitude, depth, date, time, etc. and are searchable through a dedicated search portal on the Burke Museum website (https://www.burkemuseum.org/collections-and-research/biology/ichthyology/otolith-database/search.php). About 700,000 pairs of otoliths have been aged by the AFSC Age and Growth Program and they routinely borrow the otoliths for ongoing ageing work.

Otoliths are critical to fishery management, allowing accurate estimates of the relationships among sex, length, weight, and age to be used in stock assessments. Management strategies vary widely based on these biological parameters, so accurate and testable data are important. By retaining the otoliths used in ageing the stocks, the vouchers can then serve as a verifiable data point, allowing researchers to go back and verify data in previous assessments. As

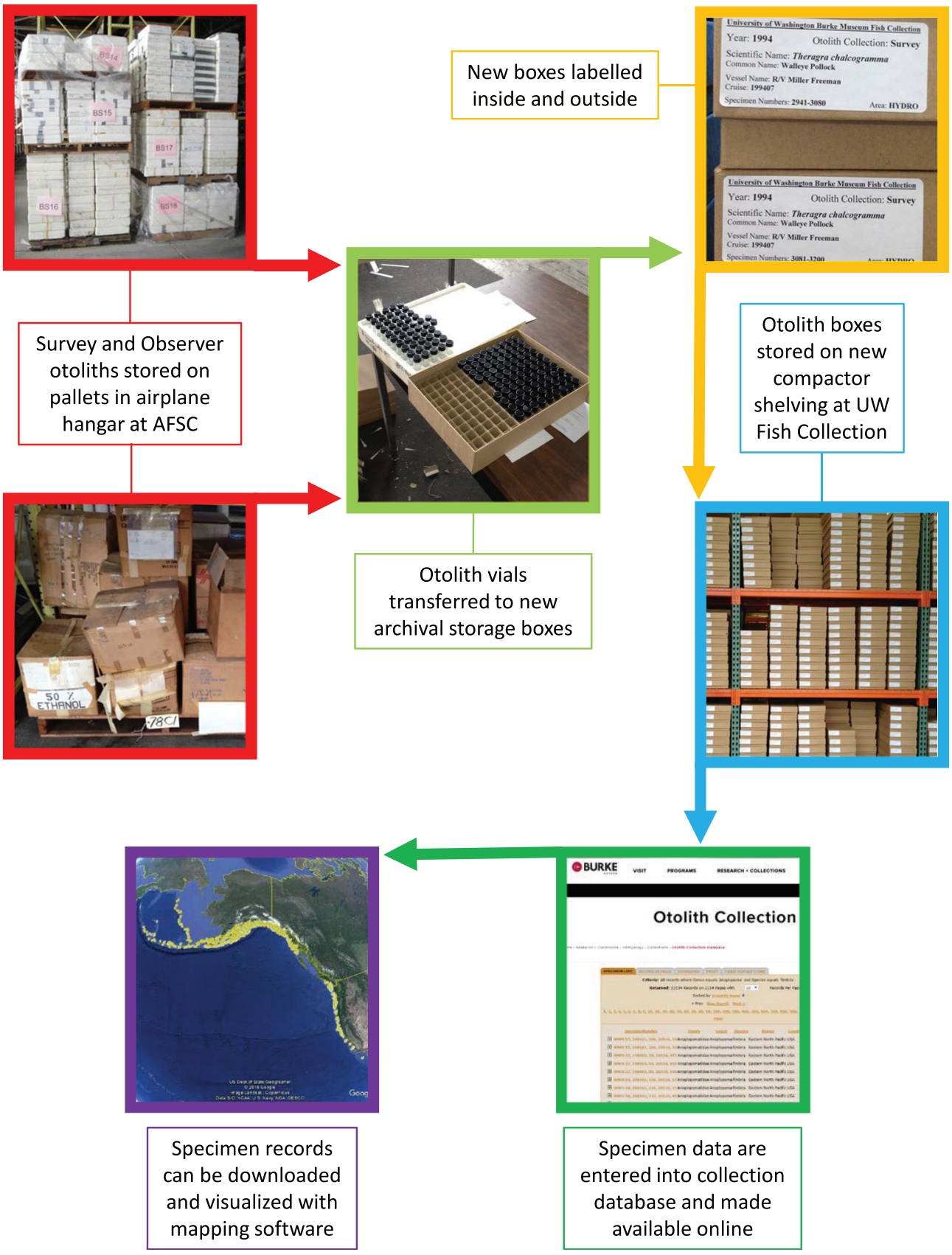

Fig. 3. Transfer of otoliths from the NOAA Fisheries AFSC to the UW Fish Collection. Survey-collected otoliths in Styrofoam boxes stacked 6 meters high (top left picture) and observer-collected otoliths in old cardboard boxes (center-left picture) stored in a World War II–era hangar at the AFSC. The otolith vials are transferred from Styrofoam boxes to new archival-quality cardboard boxes. Both boxes and lids are labeled to ensure no loss of data. Boxes are organized on new compactor shelves in a new storage facility at the UW. Specimen and locality data are entered in the collection database

technology improves, legacy otoliths can be used to test new techniques and possibly improve ageing accuracy and efficiency. New techniques also allow the otoliths to be used in new ways that were never imagined when they were first collected. We now know that otoliths are a time capsule of ocean chemistry and can be used to determine the chemical composition of the ocean in every year of a fish's life. They also provide information about the diet and movements of the individual fish, based on the stable isotopes absorbed from their food and environment. Scientists of the AFSC Age and Growth Program have published extensively on the utility of otoliths for more than age determination (Helser et al., 2018a, 2018b, 2019).

In addition to the value of the otoliths themselves, making the data associated with the otoliths available to the public provides an enormous dataset for a large number of species and their occurrence in time and space. Retaining all of these millions of otoliths over the decades has allowed for an extensive record of ocean chemistry that can be used by scientists to study climate change, ocean acidification, and a host of other topics yet to be identified as technology changes.

BENEFITS OF COLLABORATION

Both parties clearly benefit from the collaboration fostered since 1980. Student support has been a vital part of the relationship. Between 2009 and 2019, 25 undergraduate students worked with the adult, early life history, and otolith collections. Ten students, both graduate and undergraduate, participated in NOAA Fisheries surveys, gaining field experience and working directly with NOAA scientists. In the same period, 13 graduate students worked with the collections. In addition, we have a NOAA-funded graduate student position responsible for training fisheries observers in species identification. The student works closely with the observer program to train observers, curate and obtain specimens used in teaching, as well as to deposit into the fish collection rare or interesting specimens collected by observers at sea. In addition, several NOAA AFSC scientists have served as committee members for our graduate students over the years.

One benefit for NOAA scientists is the easy access to vouchered specimens. Both the Recruitment Processes Program Ichthyoplankton Laboratory and the RACE Groundfish Assessment Program Systematics Laboratory routinely borrow specimens for their research. The Age and Growth Program borrows dozens of boxes of otoliths multiple times per year for their ongoing ageing studies as well as for research they are conducting on new ageing methods and microchemistry analyses. The Resource Ecology Ecosystem Modeling (REEM) Program Food Habits Laboratory borrows specimens, skeletons, and radiographs to help them identify gut contents for their diet analyses used in ecological modeling. Similarly, the Marine Mammal Laboratory borrows specimens for diet analysis. In addition, specimens are used to fulfill the public outreach goals of the science center. AFSC scientists borrow specimens for NOAA-sponsored programs as well as for use in other public outreach events.

The training of so many students over the years has fostered an employment pathway, which is an important outcome of University programs. Many graduate and undergraduate alumni of the UWFC have found both temporary and permanent employment with NOAA Fisheries, both at the AFSC and elsewhere.

Research is an important outcome of the collaboration as well. Between 2014 and 2019, 193 loans of specimens and tissues were granted from the UWFC to AFSC scientists. Of the 218 known publications citing UWFC specimens between 2008 and 2018, 91 (42%) are authored by AFSC scientists.

Overall, there are many benefits to federal and state agencies of collaborating with a museum collection. The massive ongoing collections through agency survey work require far too much costly infrastructure for agencies to maintain. Donating the specimens to a collection ensures they are well cared for and widely available to the scientific and educational community. With no expectation of collection management expertise among agency personnel, partnering with collections trained in best practices decreases wasteful collecting and increases the value of the specimens. Citing vouchered specimens increases the value of agency publications, allowing examination and repeatability of results by other scientists.

Benefits to museum collections from partnerships include the student training mentioned here, but also allows access to specimens we would not otherwise have. State and federal agencies have the required collecting permits to conduct fieldwork, and these permits can be very difficult to obtain. For instance, in Washington State any fieldwork in freshwater habitats may require a federal permit because of the likelihood of encountering a federally listed species such as salmon or Bull Trout. This process is lengthy and cumbersome, especially if the threatened species is not the target of the collection. Agencies are routinely conducting fieldwork and are typically very happy to donate non-threatened species to a collection. In fact, the Washington State Scientific Collecting Permit application states, "14. Wildlife Salvage—Notify the WDFW immediately if any State or Federally listed Threatened or Endangered species are encountered or salvaged and any salvaged State or Federal Threatened or Endangered Species must go to a major research collection such as WSU Conner Museum, University of Puget Sound Slater Museum of Natural History, or UW Seattle Burke Museum, or as directed by the WDFW" (Washington Department of Fish and Wildlife [WDFW], https://wdfw.wa.gov/licenses/environmental/scientific-collection, accessed 30 September 2019). Thus, the state agency mandates that specimens must be deposited in a research collection such as the UW Burke Museum of Natural History and Culture.

Additionally, federal and state agencies have the resources to conduct fieldwork in remote areas. Acquiring specimens from the Aleutian Islands or the Chukchi Sea would be extremely cost prohibitive for a single researcher, but because NOAA routinely conducts surveys in those areas, collections

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and uploaded to the online search engine at https://www.burkemuseum.org/collections-and-research/biology/ichthyology/otolith-database/search.php. Search results are shown for Sablefish (*Anoplopoma fimbria*) otoliths. Specimen records can be downloaded and visualized with publicly available mapping software. Image shows a map of all holdings of Sablefish otoliths collected by the NOAA Fisheries AFSC surveys.

from those surveys deposited in a museum collection are now available to researchers around the world.

OTHER STATE AND FEDERAL AGENCIES

The partnership between NOAA Fisheries and the UW Fish Collection has clearly been successful for both parties. This prompted us to reach out to other state and federal agencies to see what partnerships might be possible. The most obvious place to start was within our own institution, the University of Washington. Classes at the UW had sporadically deposited specimens into the collection over the decades, but there was no formal arrangement for them to do so. I started reaching out to professors in the School of Aquatic and Fishery Sciences (SAFS) to deposit specimens from their field trips, and I started going on the field trips to Friday Harbor Laboratories with our Marine Biology course in order to help them learn to identify local species and ultimately deposit those collections into the UWFC. It is now class protocol that specimens are deposited in the UWFC, and this has allowed us to build a time series of collections from the same sites for more than ten years.

The WDFW had deposited rare specimens and range extensions over the years, but the agency was not making any routine collections for the UWFC. While trying to build up our tissue collection for Salish Sea species, I asked if WDFW scientists might collect for us on their annual surveys, and, to help build the relationship with them, I volunteered to participate in their surveys and collect the specimens myself. Making connections with agency scientists and showing a willingness to participate goes a long way towards building strong relationships. They are now routinely depositing specimens into the UWFC.

Seattle is fortunate to have two NOAA Fisheries science centers, the Alaska Fisheries Science Center (AFSC) and the Northwest Fisheries Science Center (NWFSC). Despite our long history working with the AFSC, there was no real connection to the NWFSC. In 2003, the NWFSC Forensic Voucher Program reached out to us. Their goal is to sequence DNA from museum-vouchered west coast fish specimens and deposit these sequences to the online genetic data repositories such as NCBI GenBank at https://www.ncbi.nlm.nih.gov/genbank/ and the Fish Barcode of Life Database, now part of the International Barcode of Life project at https://ibol.org. These sequences and vouchered specimens can then be used in forensic analysis in law enforcement cases, as well as contribute to the growing library of genetic sequences available to the public. Ted Pietsch started partnering with their group in 2003 as the expert who could confirm the identification of the voucher specimen if called upon to do so in court. All specimens from the project are deposited into the UWFC, with over 2,000 specimens to date. Fostering this partnership allowed other connections to form at the NWFSC, and we now have two other groups routinely collecting specimens for the UWFC during their survey work.

The Washington Department of Ecology (WADOE) contacted me in 2010 to "get rid" of their voucher specimens from survey work in Washington State. They were starting a new program of watershed health analysis across the state and needed to free up space. I took the old vouchers and also built a new relationship whereby we provide a specimen identification service in exchange for the deposition of their vouchers. Federal Endangered Species Act (ESA) listings of salmon and Bull Trout make freshwater collections extremely difficult, so taking advantage of WADOE permits to work in these areas allows us to take the accidental mortalities as well as specimens difficult to identify in the field. This relationship has been the only source of freshwater material deposited into the UWFC in the last ten years and has allowed us to build up our tissue collection of freshwater species by hundreds of specimens.

The last partnership is a bit unorthodox. The United States Fish and Wildlife Service (USFWS) Seattle office reached out to us in 2010 with specimens seized at the border. Although a protocol was in place for dealing with live specimens crossing the border, no plan existed for dried or preserved fish specimens. USFWS did not want to destroy them and was looking to donate them for research and education purposes. The most commonly donated specimens are dried seahorses, and we have accepted more than a dozen shipments amounting to several hundred specimens. These specimens have been used in a genetics course in SAFS as well as in Burke Museum exhibits. They are also included in every tour of the fish collection in order to teach the public about species listed in the Convention on the International Trade of Endangered Species (CITES) and about declaring animals when traveling internationally. In addition to the seahorses, we have accepted a shipment of dried sharks; several Asian Arowana, *Scleropages formosus*; a 2.5-meter White Sturgeon, *Acipenser transmontanus*; and an alcoholic beverage infused with seahorses, ginseng root, goji berries, and slivers of deer antlers. Getting to know your local USFWS inspectors is also very helpful because they can offer advice when dealing with tricky shipments of specimens.

THE FUTURE LOOKS BRIGHT

UWFC has continued to foster relationships with local federal and state agencies to build collections, teach students, and provide resources to the scientific and educational community. Ted Pietsch retired in 2015, but our new Curator, Luke Tornabene, is equally committed to maintaining a strong relationship with NOAA Fisheries as well as other local agencies. Two of his current graduate students are working closely with AFSC scientists, and five students, both graduates and undergraduates, have participated in NOAA surveys in the last two years. The AFSC has also seen some turnover in the last few years, with long-time partners in the Ichthyoplankton Laboratory retiring. New leadership and scientists at NOAA are committed to supporting the UWFC and our continued relationship.

The relationship between the AFSC and the UWFC provides many benefits and is a model that all NOAA Fisheries Science Centers should look to emulate. Partnering with a local museum, particularly a university museum, ensures that publicly funded collections obtained through survey efforts are ultimately deposited in collections available to the public and maintained for the long term. The burden of maintaining the infrastructure associated with collections is passed to the museum where the expertise in collections management is found. Specimens are easily available to agency researchers locally, facilitating research and collaboration with the university. Student training with the collections and the potential of participating in fieldwork alongside NOAA scientists contributes to the greater impacts

of the work and can create an employment pipeline into fisheries careers.

Natural history collections staff should look to their local federal and state agencies for potential partnerships. Wasteful collections practices can be curbed and specimens that would otherwise be discarded can be made available to the public. Partnerships allow for funding opportunities as well as showing the inherent value of museum collections to ongoing research and government-funded programs. These mutually beneficial relationships should be actively encouraged by leadership on both sides of the partnerships.

DATA ACCESSIBILITY

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