NMFS Southwest Fisheries Science Center

Agency Report to the Technical Subcommittee of the Canada-U.S. Groundfish Committee

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With contributions from Joe Bizzarro, E.J. Dick, John Field, Tom Laidig, Melissa Monk, Nick Wegner, William Watson

A. AGENCY OVERVIEW

The Southwest Fisheries Science Center (SWFSC) conducts fisheries and marine mammal research at three laboratories in California. Activities are primarily in support of the Pacific Fishery Management Council, the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), as well as a number of international fisheries commissions and conventions. The Science and Research Director is Kristen Koch and John Crofts is the Deputy Director. All SWFSC divisions support the essential needs of the NMFS and the Pacific Fishery Management Council (PFMC) for groundfish, including as active members of the PFMC's Scientific and Statistical Committee (SSC), the Groundfish Management Team, and other management teams and advisory bodies.

The Center is headquartered in La Jolla, which hosts the Marine Mammal and Turtle Division (led by Dr. David Weller) and the Fisheries Resources Division (led by Annie Yau). The Fisheries Resources Division (FRD) conducts research on groundfish, large pelagic fishes (tunas, billfish and sharks), and small coastal pelagic fishes (anchovy, sardine and mackerel), and is the only source of groundfish research at the La Jolla facility. FRD researchers maintain ichthyoplankton collections and conduct studies of species abundance and distribution (including responses to climate variability), systematics, and the application of early life history information to stock assessments. A reorganization effort began in 2023 to integrate existing ecosystem science programs into a new Ecosystem Science Division (ESD), comprising the Antarctic Ecosystem Science Division, many members of the former Environmental Research Division (ERD), the CalCOFI program, and members of the Fisheries Ecology Division located in Arcata. A new Information Technology and Data Services Division has also been established and includes data services members from the former ERD.

The Fisheries Ecology Division (FED) in Santa Cruz is directed by Dr. Steve Lindley, and three of the four research branches conduct studies focused on groundfish. Dr. Steve Lindley is currently the acting supervisor of the Fisheries Economics team. The Molecular Ecology team (led by Dr. Carlos Garza) studies the molecular ecology and phylogeny salmonids and groundfish. Dr. John Field oversees a larger Fisheries Assessment Group with three teams, Fisheries and Ecosystem Oceanography (led by Dr. John Field), Habitat and Groundfish Ecology (led by Dr. E.J. Dick) and Fisheries Assessment Modeling (led by Dr. Michael O'Farrell).

All of the teams within the Fisheries Assessment Group support the needs of NMFS and the Pacific Fishery Management Council, one of which is groundfish stock assessment. Specific objectives of the FED groundfish programs include: (1) collecting and developing information useful in assessing and managing groundfish stocks; (2) conducting stock assessments and improving upon stock assessment methods to provide a basis for harvest management decisions by the PFMC; (3) characterizing and mapping biotic and abiotic components of groundfish

habitats, including structure-forming invertebrates; (4) disseminating information, research findings and advice to the fishery management and scientific communities; and (5) providing professional services (many of which fall into the above categories) at all levels, including inter-agency, state, national and international working groups. Several scientists from the Fisheries Ecology Division in Santa Cruz currently serve on the Pacific Council's Scientific and Statistical Committee (Drs. Will Satterthwaite, Cameron Speir, and John Field) and Groundfish Management Team (Dr. Aaron Mamula).

There is also much collaboration among the three teams within the Fisheries Assessment Group. The Fisheries Assessment Modeling team primarily conducts stock assessments for both groundfish and salmon, focusing on research to advance fisheries assessment methods. The Habitat and Groundfish Ecology team also conducts groundfish stock assessments, and utilizes a number of survey tools, e.g., visual surveys conducted with remotely operated vehicles (ROV), autonomous underwater vehicles (AUV), scuba, hook-and-line fishing, and captive rearing, to study groundfish habitats, ecology, and life history. The Fisheries and Ecosystem Oceanography team within the group is responsible for leading the annual pelagic juvenile rockfish recruitment and California Current ecosystem assessment survey along the West Coast.

B. MULTISPECIES STUDIES

B1. FRD Research on larval rockfish

Contact: William Watson (William.Watson@noaa.gov)
Larval Rockfish Investigators: Andrew Thompson, William Watson

From 2013-2020 the ichthyoplankton and molecular ecology laboratories at the SWFSC, La Jolla, built species-specific larval rockfish time-series by genetically sequencing individual larvae from winter CalCOFI samples between 1998 and 2013. In 2023 and 2024, we are working on extending this time series. Our Scripps Institution of Oceanography (SIO) masters student, Lucy Bulkeley, is exploring how the larval rockfish assemblage reacted to the 2014-2016 Marine Heat Wave (MHW).

A recently published study based on otolith core width as a proxy for maternal investment demonstrated that when adult rockfishes were exposed to Pacific subarctic water during gestation they tended to spawn larger larvae that exhibited higher survival probability and tended to be more robust later in larval life (Fennie et al. 2023). A similar ongoing project is based on an evaluation of compound-specific stable isotope analysis on a subset of shortbelly rockfish (*Sebastes jordani*). Preliminary results show that larvae tend to be larger at age when consuming prey that are lower in the food chain. A manuscript has been submitted to Marine and Coastal Fisheries (Kwan et al. in review). A similar study to evaluate the implications of maternal effects and larval rockfish diet on larval condition was also conducted in 2023. SIO master's student Kamran Walsh sorted plankton samples cooled in a freezer prior to preservation to identify the prey field and remove larval rockfishes. He genetically identified the rockfish species, dissected

their guts to quantify prey and quantified otolith characteristics. He found that there is strong selection for calanoid copepods by rockfish larva (Walsh 2023). However, the effect of prey type on larval condition was age-dependent. Preflexion- and flexion-stage larvae were larger and grew faster when feeding on calanoid copepods, but postflexion-stage larvae were more robust when consuming euphausiids. In addition, maternal effects were also evident as larvae born with larger otolith cores survived longer and were larger when collected. We are submitting a manuscript describing this study to Marine Ecology Progress Series.

B2. FED Research on juvenile rockfish
Contact: John Field (John.Field@noaa.gov)

Since 1983 the SWFSC has conducted a Rockfish Recruitment and Ecosystem Assessment Survey in late Spring surveys for pelagic young-of-the-year (YOY) rockfish using a modified Cobb midwater trawl. The 2023 survey represented the 41st continuous year of sampling for this survey. To recognize the first 40 years of the survey, an online Story Map was previously developed to highlight the history, ecosystem insights, and management contributions of 40 years of this survey. Data through 2022 are currently served on the ERDDAP website hosted by the SFWSC, and a database publication is in preparation.

The survey supports the development of recruitment indices for stock assessments of many winter-spawning rockfish (e.g., chilipepper, bocaccio, canary, blue/deacon, black, shortbelly and widow rockfishes), and a suite of fisheries and ecosystem oceanography studies. In the 2023 stock assessment cycle, YOY indices were developed for canary rockfish (coastwide stock) and black rockfish (in Oregon and California), although due to the sparseness of black rockfish observations, they were ultimately not included in black rockfish stock assessments. A working group of both SWFSC and NWFSC biologists and assessment analysts have also been working to better evaluate best practices for using pelagic YOY indices of abundance in stock assessment models, and to objectively quantify the value of this information to managers. Preliminary results were presented at the 2023 PICES conference in Seattle, WA.

In recent years, the data have been used in a broad array of studies to better understand and predict recruitment, including an analysis that evaluates the relationship between a suite of ocean survey indicators and oceanographic variables relative to stock assessment recruitment estimates (Ward et al., in revision), an evaluation of juvenile growth rates based on a mix of empirical observations and ROMS model data (Morales et al. 2024) and several ongoing efforts related to the role of YOY groundfish in the pelagic ecosystem that are taking place as part of the Marine Biodiversity Observation Network (MBON) project.

Survey results and interpretations are reported in the California Current Integrated Ecosystem Assessment Status Report, as well as the "State of the California Current" report and other ecosystem status and trends reports. In 2023, survey effort was highly constrained due to ship issues, consequently data for many regions were sparse. Despite such challenges, trends were evaluated for the 2023 survey, the results of which suggest relative abundance shifts in the forage base within central California, as despite continued high abundance of northern anchovies, YOY rockfish were seen at greatest abundance level since the large marine heatwave of 2015-16. YOY

hake were also well above average in the core and southern areas, but very low in the north (NCC- OR/WA). YOY sanddabs were estimated to be slightly below long-term average in most areas, although YOY groundfish diversity – and diversity in general- seemed greater than usual (results in prep by MBON team). Pyrosomes continued to be very abundant in the core and southern areas, while krill catches declined after several years of low, but increasing, abundance. Anecdotal accounts of adult rockfish consuming large numbers of pyrosomes were widespread throughout 2023.

C. SPECIES STUDIES

C1. FED Stock assessments for black and copper rockfish

Contacts: E.J. Dick (Edward.Dick@noaa.gov) and Melissa Monk (Melissa.Monk@noaa.gov)

California stock assessments for black rockfish and copper rockfish were led by E.J. Dick and Melissa Monk, respectively. The 2023 assessment for black rockfish in California (Dick et al. 2023) consisted of two sub-area models for northern and central areas, in order to allow for spatial and temporal variation in size composition, exploitation history and other factors, but pooled the results statewide following the stock definition. The pooled results indicate that the stock was at 37.7% of unfished spawning output in 2023, below the 40% management target level but above the minimum stock size threshold (MSST). The relative spawning output trajectory was very similar to that estimated in the 2015 assessment, and suggests recent increases in both abundance and recruitment. Among the critical uncertainties in the model were movement rates between the two California area models, as well as from California to Oregon, as suggested by both historical and recent tagging data.

The 2023 benchmark assessment of copper rockfish in California included two sub-area models split at Point Conception, California (34°27′ N lat.), both of which were developed with a combination of SWFSC, NWFSC and California Department of Fish and Wildlife staff. Each of the two models had a similar structure, but additional data sources, relative to the two data-moderate assessments developed in 2021; the unexpected pessimistic results of the 2021 models were key drivers of the decision to re-assess the stock, and to include additional fishery independent information that was outside of the terms of reference for the data-moderate models. The results of the southern model (Wetzel et al. 2023) were considerably more pessimistic than the results of the northern model (Monk et al. 2023), but when the results of both models were combined (as per the adopted stock definition), the pooled abundance was estimated to represent a spawning output of 36.6% of the unfished level. This is below the 40% management target level, but above the minimum stock size threshold (MSST).

C2. FED Rockfish Reproductive Ecology Laboratory and Field Studies
Contact: John Field (John.Field@noaa.gov); Jessica Choi (Jessica.Choi@noaa.gov)

Ongoing studies at the SWFSC Fisheries Ecology Division in partnership with the University of California, Santa Cruz (UCSC) highlight spatiotemporal variability in reproductive output, including interannual variability in fecundity for four species of California Current rockfish, using data collected from the mid-1980s through 2020 (Beyer et al. in press). In this study, we found that after accounting for size-dependent influences on reproductive output, interannual variability in larval production was as high as 58% in large females for yellowtail and widow rockfish, but with lesser variation in chilipepper and bocaccio (known multiple brooding species, so variability may be more manifest in the number of broods), and with less variability for smaller individuals of all species. The results demonstrate that there are strong environmental and bioenergetic effects on reproduction, and provide a basis for evaluating impacts to the reproductive potential of commercially and recreationally important resources in response to climate change. In support of that and other research efforts, an imaging analysis method was developed, tested, and implemented for more rapid processing of unfertilized oocytes from all four species evaluated in the above study, as well as for rosy rockfish (*S. rosaceus*) and vermilion rockfish (*S. miniatus*). The autodiametric method, on average, was five times faster than the traditional gravimetric counting method for unfertilized stages in rockfishes and will increase the efficiency of processing fecundity samples (Mapes *et al.* 2023).

C3. FRD Cowcod and bocaccio rockfish barotrauma and release device research
Contact: Nick Wegner (Nick.Wegner@noaa.gov)
The Genetics, Physiology, and Aquaculture program at the SWFSC in La Jolla is actively studying the effects of capture and barotrauma on rockfishes (*Sebastes* spp.) following release in recreational fisheries. This work has largely focused on cowcod (*S. levis*) and bocaccio (*S. paucispinis*), two species historically important in management decisions, particularly in southern California. Findings reveal that dissolved oxygen levels at depth significantly influence post-release behavior in both species. For cowcod, low dissolved oxygen levels significantly reduce post-release survival. Consequently, ongoing laboratory-based studies are investigating the effects of hypoxia on cowcod and bocaccio behavior and physiology. Specifically, this work assesses cowcod and bocaccio behavioral avoidance to low oxygen using a custom-built shuttle-box system, and examines the effects of hypoxia on metabolism through respirometry trials at different temperatures. Enhancing our comprehension of how reduced dissolved oxygen levels contribute to mortality and rockfish behavior can help refine catch-and-release procedures and facilitate the implementation of release protocols to optimize survival rates. Additionally, this research sheds light on potential oxygen thresholds for suitable rockfish habitat, and can thus aid in abundance estimates.

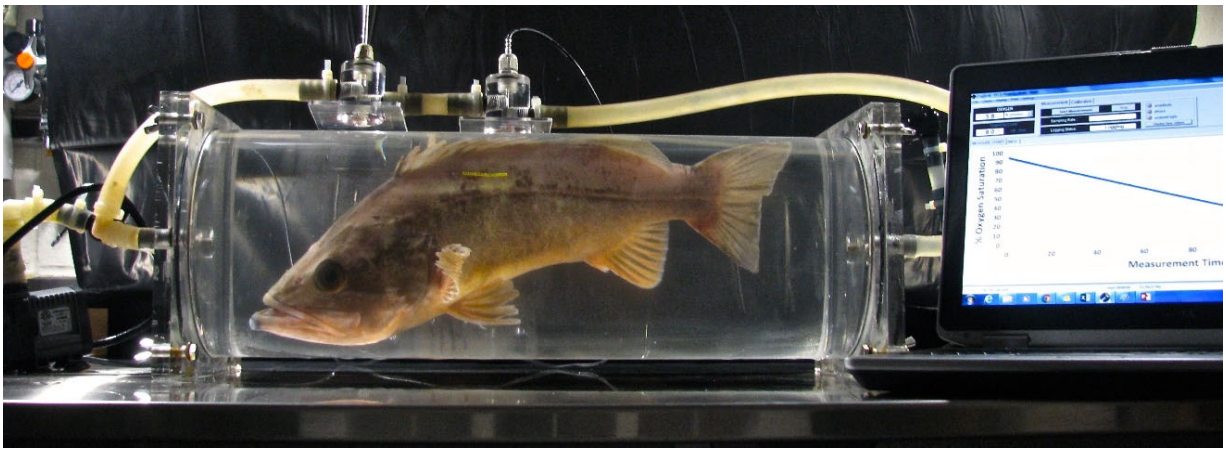

Figure 1: Bocaccio rockfish in a closed respirometry system used to determined rockfish sensitivity to hypoxia.

D. OTHER RELATED STUDIES

D1. FED Habitat and Groundfish Ecology Team 2023-24 Research on California Demersal Communities

Contact: E.J. Dick (Edward.Dick@noaa.gov)
FED HAGE Investigators: Joe Bizzarro, Tom Laidig, Melissa Monk, Diana Watters

The SWFSC/FED Habitat and Groundfish Ecology Team (HAGE) conducts stock assessments on groundfish species and research on deep-water California demersal communities. The objective of the deep-water component is to provide sound scientific information to ensure the sustainability of marine fisheries and the effective management of marine ecosystems, with objectives to: (1) improve stock assessments, especially of groundfish species in untrawlable habitats; (2) characterize fish and habitat associations to improve EFH identification and conservation; (3) contribute to MPA design & monitoring; and (4) understand the significance of deep-sea corals and sponges (DSCS) as groundfish habitat. The HAGE uses a variety of underwater vehicles to visually survey demersal fishes, DSCS, and associated seafloor habitats off northern, central, and southern California. These surveys have resulted in habitat-specific assemblage analyses on multiple spatial scales; fishery-independent stock assessments; baseline monitoring of MPAs; documentation of marine debris on the seafloor; and predictive models of the distribution and abundance of groundfishes and deep-sea corals. The following are a few examples of recent projects conducted by the HAGE and collaborators.

D1i. Expanding Pacific Research and Exploration of Submerged Systems Campaign

Contact: Tom Laidig (Tom.Laidig@noaa.gov)

The interagency EXpanding Pacific Research and Exploration of Submerged Systems (EXPRESS) research campaign targets deep-water areas off California, Oregon, and Washington. A core focus of campaign activities is to fill critical mapping gaps and to characterize seafloor habitats and faunal communities on the continental shelf, shelf edge, and

slope, to inform resource management decisions and geological hazard assessments. Partners include NOAA (NOS and NMFS), Bureau of Ocean Energy Management, U.S. Geological Survey, and Monterey Bay Aquarium Research Institute. The campaign has evolved into a major field program engaging scientists and marine resource managers spanning numerous disciplines. The 2022-23 EXPRESS:West Coast Exploration cruises aboard the Okeanos Explorer conducted: a sub-bottom survey at a recently discovered glass sponge reef south of the Channel Islands, targeted bathymetric mapping north of Mendocino Ridge, mapping and AUV dives in the proposed Chumash Heritage National Marine Sanctuary, and ROV dives on Mendocino Flats, Cascadia Margin, and in Astoria, Quinault, and Nitinat Canyons off Washington. In 2024, one EXPRESS cruise aboard NOAA Ship *Bell M. Shimada* is planned to conduct AUV visual surveys of fishes, corals, sponges, and habitats within the Oregon and northern California wind energy areas.

D1ii. The importance of corals and sponges as groundfish habitat off Central and Southern California

Contact: Tom Laidig (Tom.Laidig@noaa.gov)
FED HAGE Investigators: Joseph J. Bizzarro, Rebecca Miller, Tom Laidig, Diana Watters

This project investigates the utilization of corals and sponges as habitat by groundfishes, by analyzing extensive, long-term video data sets collected in central and southern California. Fish densities, sizes, diversity, and assemblage structure are being compared among similar seafloor habitat types with varying amounts and types of corals and sponges. Comparisons are being conducted within and between central and southern California study sites to assess the amount of spatial variability in fish-coral associations. Successful completion of this project will result in quantitative estimates of the relative importance of corals as habitat for a variety of commercially and ecologically significant groundfishes and the spatial consistency of these associations.

The project was initiated during 2020, with the first two years devoted to database standardization, video review, data editing, and new data collection. Using digital seafloor video data collected during human occupied submersible dives, we completed video review and data collection for 106 dive-transects among 85 dives from Central California at depths of 35–303, and 97 dive-transects among 72 dives from Southern California at depths of 22–360. Preliminary results indicate that rockfishes were the dominant fish taxa associated with deep-sea corals and sponges (DSCS) in both study regions and scales of < 1 body length (BL) and < 3 m. At a scale of < 1 BL, relatively abundant (> 50 documented individuals) fishes off central California had generally stronger DSCS associations; however, differences between regions were not substantial. Sponges were more strongly utilized than corals by the studied groundfish assemblages at the < 1 BL scale in both regions. In contrast to the 1 BL scale, relatively abundant fishes (> 50 individuals) in southern California exhibited stronger associations with DSCS at < 3 m distance than those off central California. Relative use of sponges and corals was similar at <3 m, and more overall associations and associations of both sponges and corals were noted. Analysis is nearing completion, with results presented at the 2023 Western Groundfish Conference in Juneau, Alaska (April 24-28), and a manuscript to be submitted spring or summer 2024.

D1iii. Serving Demersal Fish and Habitat Data and Associated Video from Quantitative Visual Surveys off California and Oregon
Contact: Diana Watters (Diana.Watters@noaa.gov)
FED HAGE contributors: E.J. Dick, Tom Laidig, Diana Watters

Since 1992, SWFSC's HAGE team has conducted visual surveys using submersibles to quantify demersal groundfish communities in deep seafloor habitats typically inaccessible to trawls. To date, our database contains 460,000 individual fishes and 201 taxa, including 242,000 rockfishes comprising 55 species (genus *Sebastes*), recorded from 2,000 transects at depths 25 – 1,200 meters primarily off California. This georeferenced dataset also provides estimated fish total lengths, associated habitat, and in situ depth and temperature. The data have applications for a variety of research topics, including ecology, distribution modeling, essential fish habitat, and stock assessment, and have supported more than 40 publications. To allow greater accessibility to these data, we are preparing data products with links to associated video files, all of which will be served via ERDAPP, with expected first release later in 2024.

D1iv. Cooperative Research in Support of Groundfish Stock Assessments
Contact: Melissa Monk (Melissa.Monk@noaa.gov)

The SWFSC Fisheries Ecology Division is working to fill data gaps for nearshore rockfish species that are critically needed for stock assessments and management. In partnership with the Sportfishing Association of California (SAC) and the charter boat fleet, deckhands on vessels from 4 ports were trained to measure and retain copper (*Sebastes caurinus*) and quillback rockfish (*S. maliger*) samples. Prior to filleting the fish for the customer, the deckhand measures and records the fish length. The samples are then labeled, organized, preserved, and shipped to FED Santa Cruz for further dissection and analysis. Over 800 copper rockfish otoliths were collected and used to inform the 2023 copper rockfish stock assessments. Over 100 quillback rockfish were also sampled in 2022 and will be aged in support of the potential 2025 stock assessment.

In 2023, the program expanded to cover the majority of the California coast and had over twenty charter vessels participating from Eureka to San Diego. The suite of species collected in 2023 also expanded beyond copper and quillback (which has since been declared overfish and is prohibited) to include all nearshore species encountered in the recreational fleet. Additional funding also allowed the project to partner with the six university partners within the California Collaborative Fisheries Research Program. This additional partnership provided increased throughput. Over 2,500 otoliths were collected across the California coast during the 2024 recreational fishing season.

D1v. California Current Trophic Database
Contact: Joe.Bizzarro@noaa.gov

The California Current Trophic Database (CCTD) was developed at NOAA Southwest Fisheries Science Center in collaboration with numerous diet data contributors and is publicly available through ERDAPP. We compiled the CCTD from twenty-four data sets, representing both systematic collections and directed trophic studies. Diet composition data, including stomach and scat samples, were obtained from 105,694 individual predators from 143 taxa collected throughout

the California Current Large Marine Ecosystem (CCLME) from 1967–2019. Predator taxa consist of squids (n=5), elasmobranchs (n=13), bony fishes (n=118), and marine mammals (n=7). Extensive time series are available for some predators (e.g., California sea lion, Pacific hake, Chinook salmon). The CCTD represents the largest compilation of raw trophic data within the CCLME, allowing for more refined analyses and modeling studies within this region.

A manuscript that describes the creation, content, and usage of the CCTD was published in 2023 (Bizzarro et al. 2023a), along with two other studies that leveraged the CCTD (Wells et al. 2023, Bizzarro et al. 2023b). At least a dozen additional studies have either been completed or are in progress using data from the CCTD. During FY24, we will update the CCTD with the addition of new datasets for long-term time series (e.g., Albacore, Pacific Hake, California Sea Lion) and the recovery of historical diet data (e.g., Wolf Eel, salmonids, pinnipeds, rockfishes).

E. SWFSC GROUNDFISH PUBLICATIONS OF THE SWFSC, 2023 to date

E1. Primary Literature Publications

Baetscher, D.S., H.M. Nuetzel, and J.C. Garza. 2023. Highly accurate species identification of Eastern Pacific rockfishes (Sebastes spp.) with high-throughput DNA sequencing. Conservation Genetics 24(5):563-574.

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McClure, Michelle M. et al. 2023. Vulnerability to climate change of managed stocks in the California Current large marine ecosystem. Front. Mar. Sci. 10:1103767. doi: 10.3389/fmars.2023.1103767

Morales, M.M., Fiechter, J., Field, J.C., Kashef, N.S., Hazen, E.L. and Carr, M.H., 2024. Development and application of a bioenergetics growth model for multiple early life stages of an ecologically important marine fish. Ecological Modelling, 488, p.110575.

Ward, E., M. Hunsicker, K. Marshall, K. Oken, B. Semmens, J. Field, M. Haltuch, K. Johnson, I. Taylor, A. Thompson and N. Tolimieri. In revision. Leveraging ecological indicators to improve short term forecasts of fish recruitment. Fish and Fisheries.

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E2. Other Publications

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Macpherson, M., J. Cope, P. Lynch, A. Furnish, M. Karp, J. Berkson, D. Lambert, L. Brooks, S. Sagarese, K. Siegfried, E. Dick, C. Tribuzio, and D. Kobayashi. 2022. National Standard 1

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