Wakefield Fisheries Symposium

April 16–18, 2024 | Sitka, Alaska

SHIFTING DISTRIBUTIONS AND PHENOLOGIES implications for fisheries

Abstracts

Sea Grant ALASKA

As we gather together for the Lowell Wakefield Fisheries Symposium in Sheet'ká K̲wáan on Lingít Aaní, also known as Sitka, Alaska, we acknowledge that Lingít peoples have been stewards of the land since time immemorial, and we are grateful for that stewardship and incredible care. We also recognize neighboring X̲aadas and Ts'msyen peoples. We honor the relationships that exist between Lingít, X̲aadas, and Ts'msyen peoples, and their sovereign relationships to their lands, their languages, their ancestors, and future generations.

WAKEFIELD FISHERIES SYMPOSIUM

Alaska Sea Grant has been sponsoring and coordinating the Lowell Wakefield Fisheries Symposium since 1982, in partnership with the Alaska Department of Fish and Game, NOAA Alaska Fisheries Science Center, North Pacific Fishery Management Council, and North Pacific Research Board.

These meetings are a forum for information exchange in biology, management, economics, and processing of various fish species and complexes, as well as an opportunity for scientists from high-latitude countries to meet informally and discuss their work.

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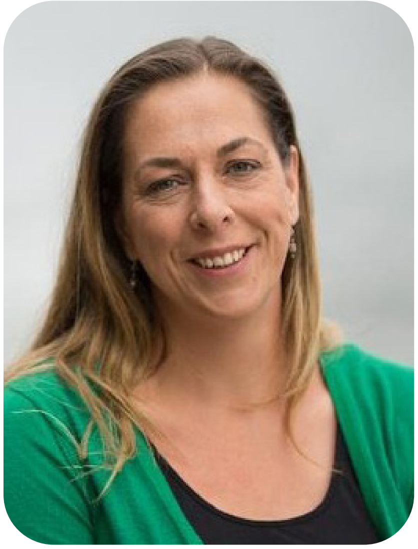
KEYNOTE SPEAKER



Gretta Pecl is a professor of marine ecology at the Institute for Marine and Antarctic Studies, and the Director of the Centre for Marine Socioecology at University of Tasmania. She has a diverse research background, but currently spends most of her time exploring the impact of climate change on natural systems and helping develop adaptation options for conservation, fisheries and aquaculture. Gretta has a specific interest in how climate change is resulting in a redistribution of life on earth, and she leads several national and international efforts to better understand climate-driven changes to species distributions, including the citizen science initiative Redmap Australia and the international Species on the Move collaboration. She is a lead author for the Intergovernmental Panel on Climate Change sixth assessment report, a recent Australian Research Council Future Fellow, and an associate editor for several leading international journals. Gretta has been prominent in UN Decade of Ocean Science programs, actions and working groups, including co-leading Future Seas 2030 and other major international initiatives. She has a strong passion for science communication and engagement with the public and is ranked in the top 200 most influential climate scientists in the world and the top 20 women.

ABSTRACT – KEYNOTE

Fish and fisheries in a shifting world and changing ocean: What's in store and what's needed to ensure a thriving future?

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Climate change is driving a pervasive global redistribution of the planet's species, with manifest implications from genes to ecosystems across multiple temporal and spatial scales. Species redistribution defies paradigms that focus on restoring systems to a baseline and challenges management strategies, which are often static and based on human-dictated boundaries drawn in the past. Changes in distribution of marine resources creates difficulties, particularly when species cross jurisdictional boundaries and where historical catch rates and assessment processes may no longer be appropriate. Moreover, we are still a long way from understanding the suite of mechanisms and processes underlying the high variation in rate and magnitude of shifts. Building on that uncertainty, we have even less understanding of how species redistribution will drive changes in ecological communities further complicating aspirations of ecosystem-based management. Climate-driven species redistribution therefore presents intriguing ecological challenges to unravel, as well as fundamental questions and urgent issues related to food security, Indigenous and local livelihoods, economic viability of fisheries and many other aspects related to human well-being. This presentation will highlight some of the key questions for climate-driven species redistribution in marine systems in the context of fisheries, ecology, natural resource management and social science. Understanding range shifts from ecological, physiological, genetic and biogeographical perspectives is essential for informing and designing natural resource management strategies for a changing future. However, for species redistribution research to support development of relevant adaptive strategies and policy decisions adequately, studies need to take an interdisciplinary approach and must recognise and value stakeholders.

SESSION 1
FISH AND SHELLFISH SPECIES SHIFTING DISTRIBUTIONS

Chair: Robert Foy

As high-latitude ecosystems respond to gradual and extreme shifts in environmental conditions, fish stocks also shift to accommodate physiological thresholds, prey availability, and in response to changes in other marine species. However, the environmental shifts are not linear or temporally consistent. The subsequent effects on fish stock movement or effects on stock production are not consistent. This session will highlight the current state of shifting stock distributions, resultant ecosystem changes, and the potential for predicting future shifts.

Spasming sablefish: Unraveling the quandary of a climate boon and socioeconomic swoon

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Perturbed biotic and abiotic marine environments resulting from climate change have led to species redistribution, altered habitat use, and rapidly fluctuating population demographics. In Alaska, more frequent marine heatwaves are a direct result of climate change and have negatively impacted many groundfish species. However, Alaskan sablefish (*Anoplopoma fimbria*) are unique in that productivity has increased concomitant with rapid alterations to the marine ecosystem. In addition to the recent production of multiple cohorts of unprecedented magnitude, sablefish appear to be expanding their distribution to reestablish historical population centers (e.g., the Bering Sea Shelf) that have been at low densities since the peak of international removals in the 1970s. Although sablefish are emerging as a climate success story in Alaska, increasing biomass has led to inversely proportional responses in socioeconomics. Based on results from recent studies, including analysis of productivity drivers, density-dependent growth, mark-recapture data, electronic tagging, and a spatially-explicit stock assessment, we summarize the existing state of knowledge regarding the ecosystem drivers of spatiotemporal dynamics. Moreover, we highlight how a changing climate may impact sablefish fisheries and discuss alternate harvest strategies that may help avoid market saturation and ensure age structure diversity for this long-lived species. We conclude with future research recommendations that could inform ontogenetic habitat utilization, while also apprising drivers of spasmodic recruitment. In the coming years, ensuring sustainability of the sablefish resource, fishery, and communities that rely on sablefish harvest will require increased collection and integration of high resolution spatiotemporal data related to biological, ecosystem, and socioeconomic drivers.

Status and challenges in addressing changes in species distribution—an IMR perspective

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Marine animal distributions are constantly shifting. Surveys have been the gold standard in data collection but there are increasing challenges in survey planning and execution (e.g. budget, inaccessible grounds, weather). Therefore, scientists are forced to improve/optimize data collection and/or develop methods that counteract "missing" data (ref WKUSER2). In this presentation, I give an overview of ongoing work at the Norwegian Institute of Marine Research to address the above points. One focus area is operationalizing unmanned drones to collect acoustic data and complement existing surveys. To evaluate possible survey designs for both survey vessels and drones, and estimation of indices, a 3D simulation model of fish distribution is being built. Additionally, a "new" estimation approach that couples acoustic and trawl data is being developed. A second focus area is the use of fishery data to inform species distribution models and assessment. In Norway, logbook data is currently only mandated for larger vessels in coastal fisheries and catch data from smaller vessels are only available at the trip level. Yet, many small vessels carry some tracking system (e.g., AIS, VMS) which can be used to detect fishing events. Thus, a new approach is being proposed to combine SDMs and survey data to improve the allocation of catch composition to each detected fishing event.

Projecting future shifts of Bering Sea groundfish spawning distributions

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Changing oceans may lead species to move toward more favorable conditions and spawn in new areas. In Alaska, adult groundfish population distributions are known to have shifted due to climate change, but less is known about how they may respond during their early life stages. Many fish species require specific spawning locations or time their reproduction with ocean conditions. Geographic constraints can promote local retention of offspring in nursery habitat while precise timing can facilitate transport of offspring to suitable locations through seasonal circulation patterns. To explore the effects of changing oceans on spawning, we used early life stage data and the Bering10K ROMS to predict next-century shifts in Bering Sea groundfish spawning distributions. We constructed species distribution models (SDMs) for eggs and larvae of six groundfish species, first using ROMS hindcasts to determine whether species exhibit flexible geography or phenology. The final SDMs were used to project changes in distribution, center of gravity, and thermal niche for each species and life stage. Our analyses found that most species exhibit flexible geography and thus, distributional patterns changed spatially over time. Centers of gravity for species abundance largely moved north but did not track future thermal niche. These results show the potential for combining early life history data with climate projections to predict spawning distribution changes. Understanding how eggs and larvae of commercially important species will be affected by climate change is crucial for the sustainability of the region's fisheries, as effects on these stages are connected to adult population responses.

Examining distributional shifts of spawning and feeding migrations of Pacific cod in Alaska with Satellite popup tags

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Pacific cod (*Gadus macrocephalus*) is a key component of the Eastern Bering Sea ecosystem. Warming in recent years has resulted in dramatic shifts in the distribution of Pacific cod in Alaskan waters. Particular concerns include a northward shift in distribution of Pacific cod from the Eastern Bering Sea to the Northern Bering Sea and seasonal movement between the Gulf of Alaska and Bering Sea management areas.

This study examines the changes in seasonal distribution patterns with Satellite popup tags. These tags provide popup locations as well as light, temperature, and depth data. We estimate movement paths with a hidden Markov model (HMM) that enables us to reconstruct the travel paths of individual fish and produce monthly maps of tagged cod distributions. Results from tags released in the Northern Bering Sea show that fish migrated south to spawn in the Eastern Bering Sea, suggesting that the Northern Bering Sea summer population is a northward expansion of Eastern Bering Sea and Gulf of Alaska Pacific cod stocks. Results from tags released in the winter in the Western Gulf of Alaska indicate that a high percentage may move north into the Bering Sea for the summer, with tagged fish migrating into the Northern Bering Sea, Russia, and the Chukchi Sea during the summer months. These northward shifts in Pacific cod distribution and the seasonal movement across management boundaries pose challenges for stock assessment and results from this study have provided valuable information for spatial management of Pacific cod stocks.

Bering Sea Pacific cod in a warming climate

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Pacific cod (*Gadus macrocephalus*) is widely distributed ranging from the Californian coast in the south to the Chukchi Sea in the north and westward from the Gulf of Anadyr to the Yellow Sea. In the eastern Pacific, reductions in population abundance at its southern extent has been coincident with warming in the region. A sequential latitudinal collapse of Pacific cod fisheries has been evident starting with the collapse of the Puget Sound stock in the 1980s, the collapse of the Canadian west coast stocks in the 1990s, and the recent collapse of the Gulf of Alaska stock and sharp reduction in abundance in the Aleutian Islands. These changes in population abundance coincident with warming have been tied to both reductions in recruitment due to degradation of habitat suitability for egg and larval survival and reductions in forage together with increased metabolism likely resulting in increased mortality across ages.

Temperatures in the Bering Sea have not reached the extremes observed in the south and impacts on abundance have not been evident. However, in a recent string of warmer than average years, the stock has shown a northerly shift in summer distribution in both the bottom trawl survey and the fishery. Climate projections indicate continued warming with temperatures in the southern Bering Sea eventually exceeding optimum conditions for Pacific cod. This presentation will discuss potential effects of warming on the Bering Sea Pacific cod population and fishery in the wider context of climate change impacts on this species throughout the eastern Pacific.

Modernizing fisheries-independent groundfish/ shellfish surveys in Alaska

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Fisheries-independent bottom trawl surveys (hereafter surveys) support the management of more than 50 fish and crab stocks in Alaska. The primary role of surveys is to provide consistent time series data for use in stock and ecosystem assessments. To assure this consistency, surveys to date concentrated on enhancing standardization of survey methodology. However, standardization is becoming more difficult because of the changes in fishing and monitoring technologies, regulations, and in the environment. For example, old trawls are becoming obsolete, new sampling tools are becoming available (e.g., new fishing gear, cameras, acoustics, and eDNA), and fish stock distributions are changing. This creates a need to modernize and adapt surveys to the new circumstances while assuring consistency of survey data products. This is a considerable challenge that can only be addressed with a broad range of actions. The planned actions for Alaska surveys include: revising sampling designs, designing and testing new survey trawls, modernizing survey protocols, survey calibrations, and planning for the transition from old to new survey methods and technologies. To date, we've redesigned the Gulf of Alaska survey to make it more efficient and more flexible to fluctuating survey effort over time while maintaining continuity in survey time-series. In the Bering Sea, we are currently working on a new sampling design that would increase sampling efficiency and merge three historically distinct surveys into one. We are also working with stakeholders to modernize survey trawls and fishing methods and are preparing for future survey calibrations. The end goal of these efforts is to create a more efficient and flexible survey that can adapt to changes in survey effort, the environment, technology, and data needs.

Pacific salmon in the Alaska Arctic: Old wine in new bottle?

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The poleward expansion of temperate species is a clear harbinger of global climate change. In the Alaska Arctic, Pacific salmon have been observed by Indigenous hunters and fishers for at least a century, and in the last decade appear to be more commonly encountered by northern residents. What remains unknown is whether Pacific salmon are in the process of establishing self-sustaining populations in rivers that flow to the Arctic Ocean. This talk presents work aimed to illuminate this question, and highlights recent fieldwork during the fall of 2023 that provides unequivocal evidence of spawning chum salmon (*Oncorhynchus keta*; Iñupiatun, iqalugruaq) in the Anaktuvuk and Itkillik Rivers, tributaries of the north-flowing Colville River that empties to the Beaufort Sea. Spawners were observed using off-channel groundwater/hyporheic sloughs, which is consistent habitat for fall spawning chum salmon throughout their native range. Dolly Varden (*Salvelinus malma*; Iñupiatun, iqalukpik) were observed in large quantities in other portions of the river, but were not observed in the same locations as spawning salmon, raising questions about the potential (or lack thereof) for interspecific interactions. Beyond documentation of spawning, otoliths and tissue samples were taken from 55 spawned-out individuals and recovered carcasses that will be invaluable to investigating questions of fish provenance and establishment. Temperature loggers were installed directly into nests, which will allow for calculation of hatching and emergence timing and will directly address whether incubation to the early life history was potentially successful if temperatures remained above freezing. Combined with previous opportunistic observations of Western scientists and deep-time knowledge by Indigenous residents, this work provides strong evidence that Pacific [chum; iqalugruaq] salmon are already established or well on their way to becoming established in Alaska's Arctic rivers.

Mapping suitable thermal habitat for Yukon chum salmon in the North Pacific Ocean

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Recent anomalous warming in the North Pacific Ocean has influenced distribution of fishes in marine habitats. We used information recently published on Pacific salmon sea temperature preferences developed from catch records (1953–2022) from salmon research surveys in the North Pacific Ocean to model chum salmon-suitable thermal habitat. The thermal habitat model was run from 2012 to 2022 to compare annual differences in suitable thermal habitat during periods of marine heat waves versus periods when conditions were closer to the mean. Our models indicate that chum salmon thermal habitat shifts north in the Gulf of Alaska in winter and shifts west from the Gulf of Alaska and into the Bering Sea in summer during years with marine heat waves. International Year of the Salmon surveys conducted during 2019, 2020, and 2022 confirm that during a warm winter (2019), chum salmon were distributed further north than the other years with near-mean sea surface temperatures. Genetic information on chum salmon bycatch from eastern Bering Sea summer groundfish fisheries indicates that a higher proportion of Gulf of Alaska and Pacific Northwest stocks were captured during marine heat wave years in the Gulf of Alaska. These fishery independent and dependent data tend to confirm the model output on how chum salmon distribution responds to rapid shifts in thermal habitat within the North Pacific Ocean.

Flow-phenology mismatches drive reduction of salmon near their southern edge

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Species range shifts have been widely documented in repeat surveys separated by multi-decadal intervals. While such surveys can determine whether observed shifts are in the expected direction (e.g., poleward or upslope due to global warming), they do not reveal the mechanisms or time scales of range shifts—whether shifts were gradual in response to trends or punctuated in response to disturbance events. Here we present a multi-site documentation of population reduction and range contraction of Pacific salmonids at their southern range edge due to a prolonged drought. Within the context of California's 2012–2016 extreme multi-year drought, the 2013–2014 winter stands apart because rainfall was both reduced and delayed. Extremely low river flows during the breeding season of salmonid fishes reduced and in some cases precluded access to breeding habitat. The impact of this flow-phenology mismatch differed among species due to differences in their breeding phenology. While O. tshawytscha experienced a down-river range contraction and distributional shift, O. mykiss and O. kisutch suffered cohort failure at multiple scales from individual tributaries (O. mykiss) to entire watersheds (O. kisutch). All of the reductions were temporary, and recovery at impacted sites was influenced by aspects of life history complexity that differed across species. Flow-phenology matches and mismatches will help determine winners and losers under climate change in riverine ecosystems; when there are only a few large storms, the timing of particular storms will play an outsized role in determining which species are able to access their typical breeding grounds at the typical time.

Arctic char thermal physiology in a rapidly warming north

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Rapid northern climate change is restructuring the thermal regimes of high-latitude cold-adapted species like the Arctic char (*Salvelinus alpinus*). The Arctic char is the most northerly distributed freshwater or anadromous fish on Earth and is essential to Inuit food security and culture. In North America, anadromous Arctic char migrate between freshwater and the Arctic Ocean many times throughout their lives, which can expose them to an already extreme range of temperatures (-1 to >21°C). We conducted a series of laboratory and field-based studies to determine the ability of Arctic char to physiologically cope with such thermal variation over acute to generational time scales. We used a mobile laboratory in the central Canadian Arctic to assess how acute temperature changes impact cardiac function and aerobic metabolism in migrating Arctic char. We conducted similar assessments on four more populations to determine if their thermal and cardiorespiratory physiology was suggestive of adaption to their local migratory environments. In the laboratory, we acclimated (>6 weeks) Arctic char to five temperatures spanning their natural thermal range and determined their potential to compensate their thermal tolerance and metabolism. Together this research indicates that Arctic char exhibit surprisingly broad thermal performance and plasticity that may help mitigate the negative impacts of rapid environmental warming. Nevertheless, we have shown that some Arctic char already encounter Arctic temperatures high enough to induce thermal stress, constrain growth, and limit metabolic performance, which will likely impact fish health and persistence in a population-specific manner.

Functional trait analysis reveals the hidden stability of multitrophic communities

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Although important for understanding how ecosystems will fare with increasing global change, the relationship between diversity and stability in multitrophic communities is still debated. Our best understanding comes from work within competitive guilds, where the relationship between stability and functional diversity is generally positive and also more direct and mechanistic than the relationship with species diversity. To expand our understanding, there is a need to examine empirically how functional trait identity relates to spatial and temporal stability relative to species identity within multitrophic communities. Here, we measured 13 functional traits of six coastal pond fish communities to examine temporal and spatial community stability through the lenses of functional trait diversity and species diversity. We found that solely considering species composition may underestimate stability, in our case, due to the level of functional redundancy in the system. Additionally, we found spatial convergence and temporal divergence in species and trait variability, and we link this variation to processes of deterministic community assembly. Lastly, we found that correlations of species with key functional traits allows us to make inferences about how trophic position of species relates to trait stability. Inferring community processes and making conservation decisions from species or trophic groups based on functional trait knowledge may be a viable strategy when resources are limited.

SESSION 2
MODELING SHIFTING DISTRIBUTIONS

Chair: Jim Thorson

The spatial distribution for populations is continually shifting on a variety of spatial and temporal scales. Similarly, researchers use a variety of data types and analytical techniques to study distribution shifts. This session invites case studies that illustrate analytic approaches used by researchers worldwide, ideally including correlative species distribution models and mechanistic models, fitted to both point-count and tagging data. We anticipate talks from multiple regions, including efforts to integrate multiple surveys and across jurisdictions.

Incorporating local responses to regional change into Bering Sea range projections

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Concurrent warming, sea ice loss, deoxygenation, and acidification of the global ocean under climate change is driving shifts in the abundance and distribution of marine fishes and invertebrates, but to date most studies projecting marine species distributions rely principally on temperature to characterize change. In the Bering Sea, recent warming has reduced the extent of winter and spring sea ice which has in turn resulted in the recession of a deep, cold pool of bottom water characteristic of the region. We use a model-averaging approach employing generalized additive models fitted to presence/absence and biomass data to assess the potential impacts of future changes in bottom temperature, oxygen, pH, and the cold pool on the distributions of several ecologically and economically important species of groundfish and crabs. We find that models which link spatiotemporal variation in presence/absence and biomass to the annual extent of the cold pool improve hindcast and forecast accuracy over other model parameterizations while projecting more extensive range shifts by end of century. We project declines in area occupied for red king crab and snow crab, as well as a substantial increase in the area occupied by arrowtooth flounder, a key predator of walleye pollock. For most species, projection uncertainty associated with model parameterizations rivaled or exceeded uncertainty due to emissions scenarios. These results demonstrate that models that account for dynamic covariates beyond temperature can result in more pronounced range shift projections, with potentially important implications for the dynamics of interacting species and the fisheries they support.

Considerations for spatial prediction and inference among candidate SDMs

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There exists an ever-expanding array of methods for quantifying the distribution of fish and aquatic organisms in space and time. Machine-learning methods including boosted regression trees, spline-based methods such as generalized additive models (GAMs) and vector-autoregressive spatiotemporal (VAST) models, are increasingly utilized for development of species distribution models (SDMs). However, individual SDM estimation methods offer tradeoffs in ease of interpretation for ecological inference, predictive performance, and sensitivity to spatial and temporal imbalance in abundance observations. Identifying the optimal estimation platform depends on the specific use case, including whether the objective is inferring past distributions, identifying core habitat areas and quantifying habitat associations, or for predicting future occurrence and distribution under novel conditions. Here we describe lessons learned about these tradeoffs among SDMs platforms using three case studies of Pacific herring (*Clupea pallasii*), and juvenile and subadult Pacific salmon (*Oncorhynchus* spp.), representing application to both survey and fishery-dependent observations.

Shifts in distribution and abundance of Alaskan pinnipeds

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Climate warming has potential to shift the spatial distribution of many Alaskan marine species, which may alter predation landscapes. Understanding how shifts in spatial distribution alter the magnitude of predator interactions is key for climate-informed fisheries management. Although rarely explicitly considered in fisheries management, Alaskan pinnipeds may impose large top-down effects on fish populations due to their abundance, large body size and endothermic nature that result in high energy requirements. In this talk, we explore current efforts to fill key data gaps needed to better understand the magnitude of top-down forcing on fish populations, including spatial distribution, diet and abundance. We use examples from pinnipeds co-managed by NMFS and Alaska Natives, including northern fur seals and several species of ice-associated seals that prey on commercially fished stocks, such as walleye pollock, Pacific cod, and Pacific herring. Current efforts include building integrated models to estimate current species density maps, forecasting future species distributions, and summarizing trophic roles at the population level. We highlight how inter- and intra-specific differences in reliance on land or sea ice for resting and during key life history functions (e.g., reproduction, molting) may influence adaptability to climate change, and the implications for such differences in altering predation landscapes.

Estimating physiological mechanisms from monitoring data reveal challenges and opportunities to forecasting distribution shifts

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To anticipate consequences of a warming ocean, species distribution models often identify statistical associations between distribution and temperature and oxygen. However, they rarely consider the mechanisms by which these environmental variables affect metabolism. Oxygen and temperature jointly govern the rate of oxygen supply to oxygen demand, and theory predicts thresholds in these rates below which species densities are diminished. Parameterizing models with this joint dependence is challenging because of the paucity of experimental work for most species, and the limited applicability of experimental findings in situ. Here we ask whether the joint effects of temperature and oxygen can be reliably inferred from species distribution data, using the U.S. Pacific coast as a model system.

Through simulation testing, we found that our statistical model—which adapted the metabolic index to jointly consider oxygen and temperature and linked to fish distribution with a non-linear threshold function—could not precisely estimate the parameters due to inherent features of the distribution data. However, it did reliably estimate an overall metabolic index threshold effect, and provided a better fit to sablefish (*Anoplopoma fimbria*) spatial distribution than previously used models. This mechanistic approach may improve predictions of species distribution, even in novel environmental conditions. Further efforts to combine insights from mechanistic responses and realized species distributions will continue to improve forecasts of species' responses to future environmental changes.

We will next apply this work to projecting distributional shifts of groundfishes from the Bering Sea through the California Current under future climate conditions to identify the threat of lost fishing opportunities at broad regional scales and in usual and accustomed tribal fishing areas. This work is done in consultation with an advisory panel, consisting of members from tribes, management agencies, and the non-tribal commercial fishing industry.

DFO-NOAA Climate and Fisheries Collaboration Initiative in the Northwest Atlantic

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The Northwest Atlantic DFO-NOAA Climate and Fisheries Collaboration (CAUSES pillar) is part of a larger bilateral working group (CAUSES). The climate pillar focuses on advancing bilateral research to detect, understand, project, and respond to climate-related changes.

Here, we describe efforts to jointly address monitoring, modelling, and science needed to adapt to climate change. Bit by bit, DFO, NOAA, and ICES working groups are improving data sharing, data and product accessibility, and integration between existing but separate long-term monitoring programs.

On modeling, members have used a spatio-temporal modeling framework to integrate U.S. and Canadian fisheries-independent survey data. Code and outputs are now available (Github_Species Distribution Modeling Workflow and Github VAST TargetsSDM). Future projections of species distributions are underway using CMIP-6, with plans to use other ocean models (e.g., MOM-6). An aspirational goal is to develop interactive visualization tools for model outputs, including projections (e.g., FishVis) similar to the NOAA's Distribution Mapping Portal.

Distribution shifts across borders remains an imminent challenge. Each country typically has separate assessments and national policies. Now, with model outputs that integrate disparate surveys, we plan to develop shift indicators, such as centre of biomass, area occupied, leading/trailing edges, and distance from centroid to jurisdictional border. We will present the challenges of developing indicators for spatially structured stocks that appear fragmented across the seascape, as well as measuring shifts at the scale of management units. Although we have a long way to go, bilateral collaboration can produce the science needed to ensure sustainability in an era of climate change.

Combining multiple datasets for spatial-temporal patterns of Alaska forage fish

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Forage fish are energy rich species that play a crucial role in the diets of seabirds, marine mammals, and commercially important fish in Alaska. Understanding the spatial and temporal variability of forage species would help explain complex predator-prey interactions and assess potential trophic vulnerabilities to climate change within Alaska marine ecosystems. However, forage fish exhibit diverse life history strategies and are often patchily distributed, making consistent spatial and temporal sampling of forage fish abundance challenging. Additionally, many forage fish are not targeted by direct fisheries, so resources for forage fish assessment are often limited. In this study we compiled data from multiple sources, including trawls, beach seines, and predator diets, in order to assess spatial and temporal variation in forage fish populations within Alaska. The expanded scope from the resulting combined forage fish dataset will inform occurrence and abundance trends across space and time. We describe and visualize current data compilation efforts on forage fish abundance and distribution in terms of spatial and temporal availability. We present spatio-temporal models of key forage species (Pacific sand lance, Pacific herring, and Pacific capelin) distributions in the Gulf of Alaska. Models fit to single and multiple datasets will be explored and used to assess the impacts of environmental variability on forage fish distribution across time. This first step towards a large-scale understanding of forage fish distribution in Alaska will facilitate greater understanding of forage fish dynamics, trophic processes in marine ecosystems, and risk analysis in areas of oil and gas development.

Leveraging multiple datasets to detect and address spatiotemporal population redistribution

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Climate change often leads to species redistribution, which can have important consequences for fisheries-independent surveys when historical survey footprints become misaligned with population distributions. Moreover, surveys may fail to detect fish movement outside of the survey area, thus, resulting indices may be unable to determine whether a fish population is truly declining. Additionally, fisheries-independent survey designs are rarely optimized for sampling species of low commercial value and infrequently encountered species, which can add to the potential for inaccurate survey trends. In the Gulf of Alaska, trawl surveys are not optimized to sample many rockfish species (e.g., due to untrawlable habitat), and changes in distribution due to climate change could further impede the ability to develop reliable indices. To help improve indices of abundance, we explore a spatiotemporal model that integrates both fisheries-independent and fisheries-dependent data. Several rockfish case studies are used to investigate how incorporating fisheries data from onboard observers combined with trawl survey data might improve abundance estimates. Preliminary results indicate that incorporating multiple data sources with varying spatiotemporal coverage may result in improved tracking of the population trends as well as provide better estimates of spatial abundance patterns, which can directly inform area-specific harvest levels (i.e. catch apportionment to management regions). Spatiotemporal models that can integrate multiple data sources will be important tools for balancing both slow and fast adapting collection platforms (i.e. fishery-independent vs. dependent), informing whether survey footprints adequately sample populations, and to improve tracking population fluctuations caused by climate change.

tinyVAST: user-friendly and expressive interface for multivariate spatio-temporal models

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Fisheries scientists worldwide use species distribution models (SDMs) to forecast distribution shifts, attribute population density to habitat features, and standardize spatially unbalanced sampling data. However, the majority of SDMs analyze a single variable in isolation (i.e. "univariate" SDMs), and therefore neglect consideration of species competition, predator-prey interactions, and size/age structured effects. Although multivariate SDMs can be fitted using the Vector Autoregressive Spatio-Temporal (VAST) model, I speculate that the user-interface is too dissimilar to alternative regression models to allow easy adoption by new users. To address this, I introduce a new R-package tinyVAST, which uses a regression interface to specify multivariate SDMs while incorporating lagged and simultaneous interactions among spatial variables. This expressive interface includes a wide range of hypothesized models, including empirical orthogonal functions that estimate dominant ecosystem patterns, and vector autoregressive models that estimate lagged species interactions. I briefly illustrate these options using survey data from bottom trawls and towed cameras that sample fishes and structure-forming invertebrates in the Gulf of Alaska and Aleutian Islands. I conclude by outlining other potential uses, including (1) expanding age-composition information for eastern Bering Sea pollock, (2) forecasting salmon returns for stocks across the north Pacific, and (3) estimating in-stream densities for freshwater surveys.

LIGHTNING PRESENTATIONS

ABSTRACT – LIGHTNING PRESENTATION

Stock-group level analysis of Yukon River Chinook smolt phenology

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Since 2014, Chinook salmon smolt have been captured at nine permanent stations in the lower Yukon River from ice-out through the end of July. This research has created a time series of data to better understand variations in migration phenology, diet, and energetic condition (health). After spending their first full year rearing, Yukon River juvenile Chinook salmon undertake one of the longest-known fish migrations, with some individuals traveling more than 3,000 km from the headwaters in Northwest Canada to the Bering Sea in Alaska. The long downstream migration and diversity of environmental conditions encountered differentiate Yukon River Chinook salmon from other Chinook salmon stocks in the U.S. and Canada. These factors may disproportionately influence production than is typical for other Chinook populations. This research effectively samples Yukon River mixed-stock juvenile Chinook at the three main river mouths as they prepare to move into marine waters. Until recently, genetic data for Yukon Chinook was confined to genetic stock compositions of intra-seasonal strata. In 2023, in collaboration with the Alaska Department of Fish & Game Gene Conservation Laboratory, Chinook salmon sampled for this research have been individually assigned to five fine-scale genetic stock groups in the Yukon River. This research provides an opportunity to evaluate stock-specific condition and timing prior to ocean entry and to identify characteristics of the natal and migratory habitats for investigating the influence of environmental heterogeneity on phenology and health. Here we present preliminary data on stock-specific size and phenology of outmigrating smolt.

ABSTRACT – LIGHTNING PRESENTATION

Char (*Salvelinus* spp.) diversity in the Coppermine River near Kugluktuk, Nunavut: Exploring species-level shifts over time

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In the Canadian Arctic, the Mackenzie River has long been thought to represent the eastern extent of northern form Dolly Varden (*Salvelinus malma malma*); char to the east of the Mackenzie River have conventionally been understood to be Arctic char (*Salvelinus alpinus*). Over the past decade, however, observations by subsistence fishers and limited mtDNA data have suggested that Dolly Varden may coexist with Arctic char in the Coppermine River in the central Canadian Arctic, hundreds of kilometers east of the purported Dolly Varden range. The presence of Dolly Varden east of the Mackenzie River would be significant as northern form Dolly Varden have been listed as a Species of Special Concern in Canada. Using the 87K Salvelinus SNP array and meristics, we assessed the diversity of chars in multiple river systems across the central Canadian Arctic. Genomic data confirm the presence of both Arctic char and Dolly Varden in the Coppermine River, and meristic data suggest that Dolly Varden have increased in frequency in the system over the past 50 years, though the exact drivers of such a shift remain unknown. This represents the first confirmation of contemporary Dolly Varden populations east of the Mackenzie River, and understanding species-level shifts over time will allow us to understand potential effects of climate change. In collaboration with subsistence fishers in the Canadian Arctic, these data will also help inform habitat restoration and management, thereby ensuring the viability of critical subsistence fisheries.

Using predators as samplers to predict prey distributions and densities

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Prey availability is an important factor influencing habitat quality for predator species. Distributions of groundfish predators are also known to respond to localized prey abundances. Currently, standardized surveys in the Gulf of Alaska (GOA) do not adequately sample prey species (e.g., euphausiids, forage fishes, benthic invertebrates) and the capacity to expand survey scope is limited. Therefore, we aim to use diet data from groundfish predators to quantify spatiotemporal variation in prey densities throughout the GOA. Joint species distribution models (JSDMs) will be used to model prey densities as a function of predator species and size, along with a suite of environmental covariates (e.g., depth, occurrence of structure-forming invertebrates). Groundfish predators with sufficient sample sizes include arrowtooth flounder (*Atheresthes stomias*), Pacific cod (*Gadus macrocephalus*), Pacific halibut (*Hippoglossus stenolepis*), Pacific ocean perch (*Sebastes alutus*), sablefish (*Anoplopoma fimbria*), and walleye pollock (*Gadus chalcogrammus*). JSDMs provide a multivariate context to quantify species correlations and improve model performance for more rare taxa. We will use regional modeling system (ROMS) products (e.g., zooplankton abundance, bottom temperature) from the GOA Climate Integrated Modeling (GOACLIM) project to identify potential climate drivers of prey availability. We will also include spatial, temporal, and spatiotemporal covariates to account for latent ecological processes using the tinyVAST R package (Thorson, in development). Prey predictions will then be used as ecological covariates for species distribution models used to describe essential fish habitat (EFH) for groundfish predators. The inclusion of ecological covariates supports ecosystem-based fisheries management initiatives to further refine EFH in the GOA.

Modeling the distribution of snow crab under a shifting climate

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Eastern Bering Sea (EBS) snow crab (*Chionoecetes opilio*) support one of the most valuable fisheries in Alaska and the United States, worth $132 million in 2020. Despite snow crab abundance reaching historical highs in 2018, abundance plummeted to historical lows alongside a northward contraction in 2021. Past studies on snow crab declines and distribution shifts linked increased Pacific cod (Gadus macrocephalus) predation and rising bottom temperatures to snow crab declines, whilst recent studies have identified increased snow crab density coupled with high bottom temperatures as the main drivers. Our objective for this study was to develop a spatially explicit framework to quantify the relationship between snow crab, predation, bottom temperature, and female biomass in the EBS through past abundance fluctuations and within the context of the recent collapse. Using the NOAA EBS summer bottom trawl survey dataset and the NOAA stomach contents database, generalized additive models (GAMs) were used to quantify relationships between snow crab, predation, female biomass, and bottom temperatures throughout the shelf. Spatially explicit GAMs were implemented using the sdmTMB package in R to assess how these factors have impacted snow crab abundances across size and sex classes. Preliminary results suggest that increases in bottom temperature were associated with declines in snow crab abundance, particularly in the southern areas of the EBS shelf. Furthering our understanding of how these factors influence the recruitment of snow crab across the EBS will be critical in the restoration of the fishery under a rapidly changing climate.

ABSTRACT – LIGHTNING PRESENTATION

Dynamic habitat use of Bristol Bay red king crab by sex and maturity stage

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As marine environments continue to change, there is a need to characterize species habitat usage under contrasting environmental regimes to ensure the proper management of fishery resource species and habitats under varying conditions. In Bristol Bay, Alaska, the red king crab population has undergone distribution shifts through time, often correlated with trends in bottom temperatures. In this study, we used dynamic species distribution models (SDMs) to identify processes driving shifts in the Bristol Bay red king crab habitat-related distribution and abundance. Specifically, generalized additive models were fit to species abundance data provided by Alaska Fisheries Science Center's summer bottom-trawl surveys with dynamic environmental covariates. Contrasting climate regimes were compared for differences in the predicted distributions and habitat drivers of Bristol Bay red king crab between 1982 and 2023. Preliminary results suggest potential drivers of habitat-related distribution and abundance differ by sex and maturity stage. These results advance understanding of habitat use and spatial-temporal stock structure and can inform fisheries management decisions for Bristol Bay red king crab.

Blood sampling from fish: A feasible technique in the field?

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Clinical pathology is a health discipline concerned with the diagnosis of disease based on the laboratory analysis of bodily fluids such as blood through varied approaches. Although it is comparatively underutilized in the study of aquatic animals such as fish, clinical pathology is a powerful tool in understanding the health of animals. As the veterinary medical field advances, there is an ever-increasing amount of baseline data and description of many novel biomarkers of animal health, all of which might be useful in the assessment of fish health. However, the scenarios in which blood sampling has been used to understand the health of wild populations is fairly limited at present.

We present an introduction to blood sampling from fish as an approach to obtaining samples for clinical pathology. Although blood sampling can theoretically be conducted in a non-lethal, minimally invasive manner from fish, just as it can from mammals, various factors must be considered in its application. Thus, in this lightening talk, we describe considerations and procedures for effectively obtaining blood from fish in a field setting to aid other researchers in use of this sampling approach.

SESSION 3
HUMAN DIMENSIONS

Chair: Davin Holen

Coastal communities in the North have economies dependent on a seasonal round of harvest that depends on specific resources for the subsistence way of life. These systems are not static and are adaptable to changing conditions. However, variability in ocean temperatures, ocean acidification, and other factors, as well as warming stream temperatures, are having profound ecosystem changes that are faster than communities and management regimes can cope with to ensure adequate food security. As resources shift and decline in some regions while moving into other regions, there is a disruption in fisheries for food security and local economies, as well as for the continuity of culture. This session will explore shifting resources and how communities cope. The session will also focus on collaborative research between communities and academic and agency researchers to ensure that research questions meet the needs of coastal communities. Finally, the session will explore how this collaborative research can build resilience and adaptability of the management regime and governance at multiple scales.

Disrupted diets: Seasonal and restorative perspectives on Nuxalk finfish-related food security

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Over the past decades, access to traditional marine foods in Nuxalk territory has been disrupted by myriad social-ecological changes, with important implications for health, wellness, and cultural continuity. Within rapidly evolving governance contexts that foreground Indigenous leadership and values, it is helpful to recognize historical losses that have occurred and how knowledge of this might also inform restoration of social-ecological systems. Here, we share the process and results of collaborative research conducted with the Nuxalk Nation (BC central coast), through which we have endeavoured to bring dietary and food security data into conversation with the context of marine management. In particular, focusing on anadromous finfish (including salmon), we consider (1) impacts of changes to seasonal harvest (phenology) on food security; (2) implications of measuring dietary changes based in pre-colonial (restorative) baselines; and (3) limitations to standard measures of food security in identifying the impacts of changing traditional food access. We then share how this collaborative research is informing and supporting local priorities and action on the ground, including through the development of a Nuxalk Food Office.

The Canadian Arctic, where Pacific salmon now roam

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Pacific salmon, responding to warming oceans, are expanding ranges northward and are being harvested in subsistence fisheries across the Canadian Arctic. While iconic in their Pacific distribution, salmon are not the preferred species in the Arctic. Communities with a longer history of salmon harvests link the increase in salmon to broader climate change issues. In other communities, salmon are considered invasive. There are widespread concerns about competition among salmon and Arctic species and also potential impacts of salmon on Arctic ecosystems. Here we discuss a community-led initiative to monitor changes in coastal fish biodiversity, called Arctic Salmon, and Canadian Arctic perspectives related to impacts and opportunities associated with shifting fish distributions.

Centering communities in fisheries: Co-producing research on Sitka Sound herring

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The Sheet'ká K̲wáan (People of Sitka) have stewarded yaaw (Pacific herring) for 8,000+ years and have deep knowledge of herring in the ecosystem. Amidst the collapse of Southeast Alaska herring populations, Sitka has remained home to the last major spawning population that can still support a traditional harvest of post-spawn herring roe on branches.

While fisheries research and management decisions have significant ramifications for communities, local communities are rarely included in shaping research and defining management priorities. Indigenous and local knowledge holders are fisheries experts that can provide valuable insight to improve research and management at all stages. We invite you to challenge current paradigms and imagine how we can transform research and management to better address contemporary fisheries issues by centering communities, respecting tribal sovereignty, and uplifting Indigenous knowledge holders as experts in holistic management.

Join us for a conversation on this topic through an emerging community-driven research project. Sitka's herring are currently managed under a single-species model based on annual biomass estimates; Indigenous knowledge points to additional indicators of herring population health that can inform ecosystem-based management. This project is being co-developed based on priorities identified by Indigenous knowledge holders and will combine multiple approaches to map ecosystem relationships and model spatio-temporal distribution of herring spawn in Sitka as a crucial metric in meeting the community's amount necessary for subsistence (ANS).

We will discuss what it takes to respect tribal sovereignty in fisheries research and management, center Indigenous knowledge, and co-produce fisheries research that tangibly benefits communities.

Understanding climate resilience pathways for Gulf of Alaska fishing communities

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With many adverse climate-driven impacts projected to continue, accelerate, and potentially synergize, the Gulf of Alaska faces substantial climate risk. Climate change is dramatically altering the marine ecosystem of the region with downturns in several valuable fisheries, decreasing fish sizes, changes in salmon run timing and strength, and algal and jellyfish blooms. Across the many geographically isolated and fishing-dependent communities within the Gulf of Alaska, such losses may be devastating for fishermen and their communities that lack economic diversity, make it difficult to maintain fishing-dependent food systems, and erase cultural fishing practices that cannot be replaced. This presentation discusses the multi-faceted, mixed-methods approach that is being used at the NOAA Alaska Fisheries Science Center to conduct social science research on climate-driven changes, vulnerabilities, and adaptation pathways in Gulf of Alaska fishing communities. Through the use of multivariate analysis, participatory approaches, vulnerability assessments, and content analysis, this research demonstrates how a diversified methodological portfolio can create a baseline understanding of climate attribution, resilience pathways, and adaptation planning in highly dependent but geographically isolated fishing communities. Furthermore, bridging knowledge gaps and information pathways between scientists and stakeholders is shown to be essential for correcting misattribution and preventing the entrenchment of polarized opinions among fisheries stakeholders.

Navigating uncharted waters: Graying of the fleet and unprecedented challenges

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This presentation provides perspectives on the graying of the commercial fishing fleet in Alaska, touches on divergent public perceptions and support for young farmers and young fishermen nationally, and discusses recent abrupt multifaceted challenges faced by Alaskan fishermen. High barriers to entry persist given the dominance of privatized access as a fisheries management tool. The precarity of the fishing industry was highlighted in 2023 with extreme global seafood market instability, rising interest rates and operating costs, destabilized geopolitical tensions, and hastening environmental change, most notably timing and migratory changes of key species. Coastal commercial fishing livelihoods, particularly for young people getting their start, have become increasingly precarious. Such livelihoods are critical to local and regional food security and provide pathways for young people to remain living in their home communities pursuing culturally appropriate careers. The combination of entrenched intergenerational inequities in management and current turmoil within the seafood world is likely to exacerbate barriers to entry and upward mobility for fishermen in Alaska. With a focus on the need for systemic flexibility and localized adaptation capability, this presentation explores a holistic understanding of fisheries sustainability and calls for solutions-focused proactive measures from communities, fishery management bodies, and state and federal governments to safeguard the future of Alaskan fishermen and wild American seafood.

SESSION 4

FISHERIES "SUSTAINABILITY" AND ADAPTING MANAGEMENT STRUCTURES IN A CHANGING CLIMATE

Chairs: Diana Stram and Chris Siddon

Fisheries, unlike fish populations, are defined by regional boundaries, but climate change and shifting boundaries are impacting fisheries as well as fish stocks. Static management measures need to adapt. Questions covered in this session include: How is a changing climate impacting the way fisheries themselves are managed? Should management move towards ecosystem-level goals that may conflict with managing to MSY of all stocks, and how best to accomplish this? This session will discuss how management of fish and shellfish stocks need to adapt and be modified to shifting baselines and stock- and policy-level benchmarks. This may include modified management structures, changes to fishery management plans and modified harvest control rules that are more adaptive to a shifting climate.

A model fishery in bad relations: Making Sitka herring history

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For the past fifty years, the commercial herring fishery in Sitka Sound has escalated, targeting older, fertile herring populations critical both for commercial fisheries and the traditional subsistence practices of local and indigenous communities. This practice, involving the capture of thousands of tons of herring annually through purse seining right before spawning, not only undermines the ecological fabric of Sitka Sound but also the subsistence harvest of herring roe on kelp and hemlock branches.

It is apparent that the discourse surrounding the fishery's sustainability, particularly between local narratives and the Alaska Department of Fish & Game (ADF&G) statistical forecasts, is profoundly disconnected. Observations of ADF&G reporting and Board of Fisheries deliberations reveal a systemic inclination towards low-quality scientifically derived data, often at the expense of local and indigenous knowledge, historical practices, and other rich sources of knowledge.

This presentation delves into the construction and representation of scientific knowledge regarding the Sitka herring fishery, examining how such representations are legitimized and operationalized by policymakers, often counter to local and indigenous perspectives. Through this lens, I explore the broader implications of privileging certain types of knowledge in environmental management and the urgent need for a more inclusive governance approach that respects and integrates traditional ecological knowledge, prioritizes subsistence use, and seeks tribal consent and co-management.

We can do better than, "They died from climate change"

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It is apparent that hypotheses of heat waves and starvation, along with "regime shift" and "borealization," are not holding up well when confronted with actual data. Studies show that snow crabs exhibit a high resilience to starvation and that their preferred temperatures are between 0 and 5°C, well within the present range of Bering Sea bottom temperatures in snow crab habitat. Red king crab have an even greater preferred temperature range, appearing in abundance at Barents Sea sites from -1.6 to 18°C.

Clearly it would be prudent to develop more realistic hypotheses than those promoted by NMFS since the post-1980 collapse of BBRKC. First, assuming we can learn from experience, the loss of the GOARKC stock should convince us of the folly of a core management assumption—that calling a halt to fishing will permit an overfished stock to recover from low abundance levels.

Second, the model's assumption that all mature male RKC mate at least once every year is inconsistent with reality and has resulted in decades of gross overestimates of Male Reproductive Potential, thus contributing to chronic poor recruitment.

Third, a major correction to the BBRKC database, resulting in the elimination of several hundred biased trawl samples collected during the 1970s and 1980s, has substantially changed our understanding of whether the BBRKC stock succumbed to a "regime shift" or whether it was simply overfished.

Working together to account for space as baselines, barometers, and best-guesses

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A major goal of contemporary ecology is to estimate population and community responses to changing environments. This already difficult task is especially challenging in marine ecosystems, which are characterized by spatially expansive, temporally variable, and highly complex habitats. In this talk, I will provide an overview of several projects that rely on field-, lab-, and model-based methods to quantify spatial and spatiotemporal dynamics of groundfishes in the North Pacific. Many of these species are widely distributed and require an understanding about how disparate habitats may impact key biological and ecological processes before we can effectively track changes through time.

The research highlighted in this presentation involves estimating spatially-resolved life history traits to inform stock assessments, developing indicators for ecosystem-based fisheries management, and refining species distribution models used to inform essential fish habitat. Specifically, we will explore how grass-roots efforts can help identify biogeography effects on growth, maturity, and mortality in the California Current. We will then discuss how survey-based estimates of predation and synchrony can be used to make inferences about food web stability in the Gulf of Alaska. Finally, we will explore how different treatments of ecological data can improve forecast skill for a variety of population metrics. Each of these projects underscore the value of transdisciplinary collaborations in maximizing the utility of scientific research and promoting a shared understanding of our natural resources.

Biomarkers of Ichthyophonus infection in migrating Yukon River Chinook salmon

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In recent years there has been a marked reduction in the number of returning Yukon River Chinook salmon. Recent evidence points to both marine and freshwater challenges to fish health that influence numbers of adults returning to successfully spawn. The infectious disease ichthyophoniasis specifically is considered an important challenge to Yukon River Chinook salmon during their freshwater spawning migration, with infection status of migrating adults proposed to be associated with in-river morality.

Ichthyophoniasis is caused by the pathogenic organism Ichthyophonus, a parasite that can infect many of the organs of fish including the heart. Current best-practice approaches in surveillance for this disease involve assessment of cardiac tissue either via histopathology or molecular screening. However, these approaches unfortunately necessitate lethal sampling from fish. Here we present a trial use of blood-based biomarkers as potential non-lethal alternatives to current ichthyophoniasis surveillance approaches. By contrasting levels of potential biomarkers from plasma and serum with results of best-practice surveillance conducted by management agencies, we present preliminary data regarding the usefulness of blood sampling in determining the Ichthyophonus infection status of Yukon River Chinook salmon.

Identifying needs, challenges, and opportunities for climate-informed fisheries management

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The Bering Sea in Alaska (USA) is one of the most productive marine ecosystems worldwide, supporting vibrant ecosystems, critical subsistence harvests, and some of the world's largest sustainable commercial fisheries. Food, protein, and macronutrients from these harvests are fundamental to food and nutritional security at regional to global scales and are a core component of food sovereignty, social cohesion, and personal identity for Alaska communities of practice and place. Yet, climate change and attendant climate shocks pose an unprecedented challenge to regional social-ecological connections and fisheries which are increasingly disrupted by ecological and human responses to altered conditions. Ecosystem-Based Management provides a framework to navigate some of the novel challenges of rapid change, but requires accelerated implementation of climate-informed management processes and advice. We present an overview of an approach to synthesize climate readiness as well as planning for operationalizing climate-informed advice including progress and plans to date and challenges for future efforts in the Bering Sea and the North Pacific. Our example highlights the work of the North Pacific Marine Fishery Council (Council) Climate Change Task Force Climate Readiness Synthesis (CRS) and plans for climate scenario planning efforts by the Council in the North Pacific. This work is informed by ongoing work from the Alaska Climate Integrated Modeling project.

THANK YOU FOR ATTENDING

Your feedback is important to us.

We have some questions for everyone who attended the conference, including your thoughts on the meeting schedule and ideas for future symposia. Alaska Sea Grant and the steering committee will read your answers to help decide next steps, and in consideration for future Wakefield Fisheries symposia.

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