Eulachon (*Thaleichthys pacificus*) 2014-2020

Bibliography

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Background & Scope

Eulachon (*Thaleichthys pacificus*) are small anadromous fish found along the Pacific coast of North America from northern California to Alaska. Also known as eulachon and candlefish, Eulachon have been historically important to indigenous communities on the Pacific coast and are threatened by climate change, bycatch losses, and predation. This bibliography focuses on eulachon literature (peer-reviewed, technical reports, biological opinions, etc.) since 2014. It is intended as a reference resource for ESA staff of the NOAA Fisheries Office of Protected Resources and the U.S. Fish and Wildlife Service when compiling and summarizing any relevant new (i.e. 2014-present) information for this fish species. It is organized into four sections: Biology, Ecology, Population Abundance and Trends, and Threats.

Section I – Biology

Section one is intended to provide an overview of the life history of eulachon. The research in this area includes a compilation of lifespan and habitat, migration patterns, and feeding, as well as any current literature on eulachon biology.

Section II – Ecology

Section two is intended to provide an overview of how eulachon interact with the environment. The research in this area includes a compilation of feeding ecology, food resources, prey composition and how climate change affects eulachon.

Section III – Population Abundance and Trends

Section three is intended to provide an overview of the latest population estimates and trends for eulachon, as well as bycatch reduction efforts.

Section IV – Threats

Section four is intended to provide an overview of any new and/or existing threats to eulachon (i.e. bycatch, predation, contaminants/pollutants, disturbance due to research, and any new threats that may be documented in the literature).

Sources Reviewed

The following databases were used to identify sources: Clarivate Analytics Web of Science: Science Citation Index Expanded and Social Science Index; Science.gov; ProQuest Science and Technology including Aquatic Science Fisheries Abstracts; Elsevier Science Direct; JSTOR; EBSCO Academic Search Complete and Environment Complete; EBSCO EconLit; the NOAA Institutional Repository; the Biodiversity Heritage Library; BioOne Complete; Congressional Research Service Reports; E&E News, Lexis Advance, and Wiley Online.

Section I: Biology

Benson, I. M., Kastelle, C. R., Helser, T. E., Short, J. A., & Anderl, D. M. (2019). Age interpretation in eulachon (Thaleichthys pacificus) as suggested by otolith microchemical signatures. Environmental Biology of Fishes, 102(4), 629-643 https://doi.org/10.1007/s10641-019-00858-7.

Eulachon (Thaleichthys pacificus) are forage fish that play an important role in the ecosystem as prey for many species. Given their continuing population decline, determining accurate ages is necessary for age-structured stock assessments. This study employed microchemistry analysis to identify group differences and help interpret growth zone patterns on otolith surfaces. Specimens were collected off the coast of Oregon, in the coastal areas of Southeast Alaska, and in the southeastern Bering Sea. Laser-ablation inductively-coupled plasma mass spectrometry (LA-ICP-MS) was used to measure elemental ratios in the otoliths along a continuous track from the core to the proximoventral margin. Ba:Ca, Sr:Ca, Zn:Ca, and Mg:Ca signatures suggested that eulachon specimens from three geographic regions are different based on their elemental profiles. For the Oregon specimens, fluctuations in Ba:Ca and Zn:Ca signatures appeared consistent with otolith growth zones and most likely were the result of seasonal coastal upwelling events. Variations in Ba:Ca and Zn:Ca were useful as annual markers for eulachon otoliths from the Bering Sea. For the Southeast Alaska specimens, analysis of the Ba:Ca and Zn:Ca oscillations was not straightforward. Further work is needed to understand the link between otolith microchemistry, fish physiology, and regional environmental factors.

Biological assessment for vegetation treatments using aminopyralid, fluroxypyr, and rimsulfuron on Bureau of Land Management lands in 17 Western states. (2015). Washington D.C.: U.S. Department of the Interior, Bureau of Land Management.

No abstract

Candy, J. R., Campbell, N. R., Grinnell, M. H., Beacham, T. D., Larson, W. A., & Narum, S. R. (2015). Population differentiation determined from putative neutral and divergent adaptive genetic markers in Eulachon (Thaleichthys pacificus, Osmeridae), an anadromous Pacific smelt. Molecular Ecology Resources, 15(6), 1421-1434 https://doi.org/10.1111/1755-0998.12400.

Twelve eulachon (Thaleichthys pacificus, Osmeridae) populations ranging from Cook Inlet, Alaska and along the west coast of North America to the Columbia River were examined by restriction-site-associated DNA (RAD) sequencing to elucidate patterns of neutral and adaptive variation in this high geneflow species. A total of 4104 single-nucleotide polymorphisms (SNPs) were discovered across the genome, with 193 putatively adaptive SNPs as determined by F-ST outlier tests. Estimates of population structure in eulachon with the putatively adaptive SNPs were similar, but provided greater resolution of stocks compared with a putatively neutral panel of 3911 SNPs or previous estimates with 14 microsatellites. A cline of increasing measures of genetic diversity from south to north was found in the adaptive panel, but not in the neutral markers (SNPs or microsatellites). This may indicate divergent selective pressures in differing freshwater and marine environments between regional eulachon populations and that these adaptive diversity patterns not seen with neutral markers could be a consideration when determining genetic boundaries for conservation purposes. Estimates of effective population size (N-e) were similar with the neutral SNP panel and microsatellites and may be utilized to monitor population status for eulachon where census sizes are difficult to obtain. Greater differentiation

with the panel of putatively adaptive SNPs provided higher individual assignment accuracy compared to the neutral panel or microsatellites for stock identification purposes. This study presents the first SNPs that have been developed for eulachon, and analyses with these markers highlighted the importance of integrating genome-wide neutral and adaptive genetic variation for the applications of conservation and management.

Kamikawa, D. J. (2017). Survey fishes : an illlustrated list of the fishes captured during the Northwest Fisheries Science Center's Fishery Resource Analysis and Monitoring Division's West Coast surveys. https://doi.org/10.7289/v5/tm-nwfsc-138.

The intention of this guide is to be a field reference to the fishes captured during the various FRAM Division West Coast surveys. Scientific and technical terms have been kept to a minimum and, when used, are defined within the text. Descriptions and distribution are confined to those species within the geographic (U.S.-Canada to U.S.-Mexico borders) and depth (30-1,680 m) parameters of the FRAM West Coast surveys. Many of the fishes described have geographic and/or depth ranges that extend outside of the survey parameters. Distributions include these areas and are described by political boundaries (e.g., state and/or country borders), bodies of water (i.e., the northeastern Pacific, the Strait of Juan de Fuca, the Columbia River, etc.), islands and/or major geographical features (i.e., the Hawaiian, Farallon, and Channel Islands, Cape Flattery, Point Conception, etc.). Conducted aboard small commercial vessels with limited personnel and space, the majority of the FRAM West Coast surveys do not have access to wet/dry lab facilities for detailed observations. Due to a variety of factors such as body size and specimen damage, internal meristic counts (i.e., vertebrae or pyloric caeca), and others that cannot be made with the naked eye, identification of some groups of fishes included in this text are treated only to the family or generic level. The species accounts are in scientific order as much as possible. The list of common and scientific names are in the List of Species. Photographs are provided when available. The family and species keys are for the families/species within the guide. However, some species not known from within the scope of this work may have been included to complete a couplet.

Li, Y.-H., & Wang, H.-P. (2017). Advances of genotyping-by-sequencing in fisheries and aquaculture. Reviews in Fish Biology and Fisheries, 27(3), 535-559 https://doi.org/10.1007/s11160-017-9473-2.

The use of genotyping has enabled the characterization and mapping of genes and the study of stock identification, population genetics, evolution, ecological speciation, and invasion, as well as genomic evaluation, sex control and sex determination, nutrition, biomarkers for disease, and quantitative trait loci mapping for marker-assisted selection in fisheries and aquaculture. High-throughput variant discovery has been made possible in multiple species by the recent advent of next-generation DNA sequencing technologies. New genotyping methods that are high-throughput, accurate, and inexpensive are urgently needed for gaining full access to the abundant genetic variation of organisms. This approach is known as genotyping-by-sequencing (GBS), which holds great promise as a research tool because of its ability to allow simultaneous marker discovery and genotyping at low cost and with a simple molecular biology workflow for fisheries and aquaculture studies. Since it was first developed for rice in 2009, GBS has been applied in over 50 species/studies by the end of 2014. It is also increasingly in use in fisheries and aquaculture and has been applied in nearly 40 species/studies from 2015 to present. This review summarizes the genotyping methodologies, recent advances in next-generation DNA sequencing technologies to achieve GBS, and the promises this approach holds as a genome-wide

genotyping application in fisheries and aquaculture. Additionally, we discuss the potential of whole-genome sequencing (WGS) in GBS and present the advances of WGS in fisheries and aquaculture.

National Marine Fisheries Service (2014). *Critical habitat for the southern Distinct Population Segment of eulachon (Thaleichthys pacificus).* Retrieved from https://www.govinfo.gov/app/details/CFR-2014-title50-vol10/CFR-2014-title50-vol10-sec226-222

No abstract

Oregon Dept. of Fish and Wildlife, National Oceanic and Atmospheric Administration, Washington Dept. of Fish and Wildlife (2014). *Studies of Eulachon Smelt in Oregon and Washington. Project Completion Report, July 2010-June 2013*. Retrieved from https://ntrl.ntis.gov/NTRL/dashboard/searchResults/titleDetail/PB2016103928.xhtml

In 2011, the Oregon Department of Fish and Wildlife and the Washington Department of Fish and Wildlife (WDFW) initiated a three-year monitoring program to assist in tracking coast-wide status and trends in abundance and distribution of the ESA listed southern eulachon smelt distinct population segment (DPS). One objective of this work was for WDFW to develop annual eulachon spawning stock biomass (SSB) estimates for the Columbia River population based on egg and larval production surveys. We developed survey protocols that estimated egg and larvae density (n/m3) at a transect comprised of six sampling stations crossing the Columbia River just upstream of the estuary. The transect was situated to capture eggs and larvae produced from all Columbia River spawning areas (mainstem and tributaries) except for the Grays River. Separate sampling stations were located on the Grays River. We combined mean weekly egg and larvae densities with estimated river discharge (m3/s) to estimate the total number of eulachon eggs and larvae produced for specific time periods over three years of eulachon returns to the Columbia River. We converted the estimates of total egg and larvae production into SSB using estimated relative fecundity, sex ratio, and fish weight. We used bootstrapping on the Columbia River data to develop confidence limits for those estimates. We estimated SSB for the Columbia River from January 9, 2011 through May 28, 2011; December 4, 2011 through May 26, 2012; and November 25, 2012 through June 22, 2013 and from the Grays River for January 16, 2011 through May 14, 2011; December 18, 2011 through May 19, 2012; and December 23, 2012 through May 11, 2013.

Programmatic Biological and Conference Opinion on the Towing of Inactive U.S. Navy Ships from their Existing Berths to Dismantling Facilities or other Inactive Ship Sites. (2017). https://doi.org/10.25923/sw62-zf21.

The Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.) establishes a national program for conserving threatened and endangered species of fish, wildlife, plants, and the habitat they depend on. Section 7(a)(2) of the ESA requires Federal agencies to insure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or adversely modify or destroy their designated critical habitat. Federal agencies must do so in consultation with National Marine Fisheries Service (NMFS) for threatened or endangered species (ESA-listed), or designated critical habitat that may be affected by the action that are under NMFS jurisdiction (50 C.F.R. §402.14(a)). If a Federal action agency determines that an action "may affect, but is not likely to adversely affect" endangered species, threatened species, or designated critical habitat and NMFS

concurs with that determination for species under NMFS jurisdiction, consultation concludes informally (50 C.F.R. §402.14(b)).

Section II: Ecology

Baker, M. R., & Hollowed, A. B. (2014). Delineating ecological regions in marine systems: Integrating physical structure and community composition to inform spatial management in the eastern Bering Sea. Deep Sea Research Part II: Topical Studies in Oceanography, 109, 215-240 https://doi.org/10.1016/j.dsr2.2014.03.001.

Characterizing spatial structure and delineating meaningful spatial boundaries have useful applications to understanding regional dynamics in marine systems, and are integral to ecosystem approaches to fisheries management .Physical structure and drivers combine with biological responses and interactions to organize marine systems in unique ways at multiple scales.We apply multivariate statistical methods to define spatially coherent ecological units or ecoregions in the eastern Bering Sea.We also illustrate a practical approach to integrate data on species distribution, habitat structure and physical forcing mechanisms to distinguish areas with distinct biogeography as one means to define management units in large marine ecosystems. We use random forests to quantify the relative importance of habitat and environmental variables to the distribution of individual species, and to quantify shifts in multispecies assemblages or community composition along environmental gradients.Threshold shifts community composition are used to identify regions with distinct physical and biological attributes, and to evaluate the relative importance of predictor variables to determining regional boundaries. Depth, bottom temperature and frontal boundaries were dominant factors delineating distinct biological communities in this system,with a latitudinal divide at approximately 601N. Our results indicate that distinct climatic periods will shift habitat gradients and that dynamic physical variables such as temperature and stratification are important to understanding temporal stability of ecoregion boundaries. We note distinct distribution patterns among functional guilds and also evidence for resource partitioning among individual species within each guild. By integrating physical and biological data to determine spatial patterns in community composition,we partition ecosystems along ecologically significant gradients. This may provide a basis for defining spatial management units or serve as a baseline index for analyses of structural shifts in the physical environment,species abundance and distribution, and community dynamics overtime.

Cheung, W. W., Brodeur, R. D., Okey, T. A., & Pauly, D. (2015). Projecting future changes in distributions of pelagic fish species of Northeast Pacific shelf seas. Progress in Oceanography, 130, 19-31 https://doi.org/10.1016/j.pocean.2014.09.003.

Marine life is being affected by changes in ocean conditions resulting from changes in climate and chemistry triggered by combustion of fossil fuels. Shifting spatial distributions of fish species is a major observed and predicted impact of these oceanographic changes, and such shifts may modify fish community structure considerably in particular locations and regions. We projected future range shifts of pelagic marine fishes of the Northeast Pacific shelf seas by 2050 relative to the present. We combined published data, expert knowledge, and pelagic fish survey data to predict current species distribution ranges of 28 fish species of the Northeast Pacific shelf seas that occur in the epipelagic zone and are well-represented in pelagic fish surveys. These represent a wide spectrum of sub-tropical to sub-polar species, with a wide range of life history characteristics. Using projected ocean condition changes from

three different Earth System Models, we simulated changes in the spatial distribution of each species. We show that Northeast Pacific shelf seas may undergo considerable changes in the structure of its pelagic marine communities by mid-21st century. Ensembles of model projections suggest that the distribution centroids of the studied species are expected to shift poleward at an average rate of 30.1 ± 2.34 (S.E.) km decade 1 under the SRES A2 scenario from 2000 to 2050. The projected species range shifts result in a high rate of range expansion of this group of species into the Gulf of Alaska and the Bering Sea. Rate of range contraction of these species is highest at the Aleutian Islands, and in the California Current Large Marine Ecosystem. We also predict increasing dominance of warmer water species in all regions. The projected changes in species assemblages may have large ecological and socio-economic implications through mismatches of co-evolved species, unexpected trophic effects, and shifts of fishing grounds. These results provide hypotheses of climate change impacts that can be tested using data collected by monitoring programmes in the region.

Csepp, D. J., Honeyfield, D. C., Vollenweider, J. J., & Womble, J. N. (2017). Estuarine distribution, nutritional and thiaminase content of eulachon (Thaleichthys pacificus) in southeast Alaska, with implications for Steller sea lions. https://doi.org/10.7289/V5/TM-AFSC-356.

Eulachon (Thaleichthys pacificus) are small, pelagic fish whose spawning habits and marine distribution are not well understood. Eulachon are a nutrient-rich, seasonally important source of food for predators, including Steller sea lions (Eumetopias jubatus) in southeast Alaska. Echo integrated-trawl surveys were conducted from 3 April to 6 May 2006 to estimate eulachon population structure and biomass, identify fish movement, location, and acoustic targets. The presence of Steller sea lions and other marine predators attracted to pre-spawning aggregations of eulachon were used to fine-tune the timing and location of our survey sites. We identified the distribution of pre-spawning adults, sub-adult, and juvenile eulachon in five estuaries of northern southeast Alaska during the 2006 spring spawning season and analyzed their nutritional and thiaminase content. Mean eulachon weight and nutritional energy varied between sites, from a low of 10.68 g body weight ± 2.93 g with a total energy of 94.4 kJ/fish in Berners Bay, to a high of 33.22 g body weight ± 5.99 g with a total energy of 291.9 kJ/fish in Lutak Inlet. Of the five estuaries surveyed, juvenile and sub-adult eulachon were found only in Taku Inlet, Berners Bay, and Chilkat Inlet and were concentrated at a distinct depth of 50-80 m throughout the estuaries. Adult eulachon were found in three of the five estuaries: Lutak Inlet, Taku Inlet, and Berners Bay with no fish identified with our fishing gear or acoustics in Taiya Inlet. Eulachon school biomass and the duration these schools spend in the estuaries correlated with sea lion abundance. Sea lion numbers were directly proportional to eulachon biomass. Spawning eulachon move quickly into their freshwater spawning river, with estuary size directly proportional to the time spent in the estuary. Thiaminase, a potentially harmful enzyme, was found in eulachon at all five sites, with a mean activity range of 5.0-7.0 umols·g^{-1} ·min^{-1} . The ingestion of thiaminase laced eulachon by Steller sea lions does not appear to affect the health of sea lions in our study area because they were not ingested long enough for the thiaminase to take effect. The role that thiaminase plays in the health of marine predators is not well understood and warrants further study and could play a role in the junk food theory that was used to explain Steller sea lion declines in other areas especially in populations with low dietary diversity.

Endangered Species Act (ESA) Section 7(a)(2) Biological Opinion Port of Anchorage Test Pile Project and Associated Proposed Issuance of Incidental Harassment Authorization and NWP Verification. (2016). Retrieved from https://repository.library.noaa.gov/view/noaa/17172.

This document represents NMFS's biological opinion on the effects of the proposed actions on the endangered Cook Inlet beluga whale (Delphinapterus leucas) and on the endangered Steller sea lion (Eumatopias jubatus). This opinion and incidental take statement were prepared by NMFS Alaska Region (AKR) in accordance with section 7(b) of the ESA and implementing regulations at 50 CFR 402. This opinion and Incidental Take Statement are in compliance with the Data Quality Act (44 U.S.C. 3504(d)(1) et seq.) and have undergone pre-dissemination review. A complete record of this consultation is on file at NMFS's Anchorage Alaska office.

Kaplan, I. C., Koehn, L. E., Hodgson, E. E., Marshall, K. N., & Essington, T. E. (2017). Modeling food web effects of low sardine and anchovy abundance in the California Current. Ecological modelling, 359, 1-24 https://doi.org/10.1016/j.ecolmodel.2017.05.007.

Populations of sardine, anchovy, and other forage species can fluctuate to low levels due to climate variability and fishing, leading to indirect effects on marine food webs. In the context of recent declines of sardine (Sardinops sagax) and anchovy (Engraulis mordax) in the California Current, we apply an end-to-end Atlantis ecosystem model that is spatially explicit, includes trophic interactions, and allows high and low recruitment regimes (production of juveniles). Our simulations suggest that depleted sardine populations, whether caused by fishing or natural cycles, may lead to declines in predator groups such as dolphins and large piscivorous flatfish (e.g. California halibut Paralichthys californicus). Birds exhibited more moderate declines, and California sea lions (Zalophus californianus) exhibited relatively weak declines. The Atlantis ecosystem model also predicted indirect positive effects of sardine depletion, primarily for prey species such as zooplankton. Overall our model predicted moderate declines in most predators during simulated severe declines in sardine and anchovy, illustrating the important buffering role provided by forage species other than sardine and anchovy. This 'buffered response' is weaker than what would be suggested by another ecosystem model (Ecosim), as predicted by diet information and a global synthesis of Ecosim models (the PREP equation). One limitation of the Atlantis model is that it did not include processes that might give rise to localized depletion of sardine at scales relevant to central place foragers, such as birds and pinnipeds. This analysis will contribute to a collaborative multi-model approach that evaluates the role of sardine in the California Current.

Lefebvre, K. A., Quakenbush, L., Frame, E., Huntington, K. B., Sheffield, G., Stimmelmayr, R., Goldstein, T. (2016). Prevalence of algal toxins in Alaskan marine mammals foraging in a changing arctic and subarctic environment. Harmful Algae, 55, 13-24 https://doi.org/10.1016/j.hal.2016.01.007.

Current climate trends resulting in rapid declines in sea ice and increasing water temperatures are likely to expand the northern geographic range and duration of favorable conditions for harmful algal blooms (HABs), making algal toxins a growing concern in Alaskan marine food webs. Two of the most common HAB toxins along the west coast of North America are the neurotoxins domoic acid (DA) and saxitoxin (STX). Over the last 20 years, DA toxicosis has caused significant illness and mortality in marine mammals along the west coast of the USA, but has not been reported to impact marine mammals foraging in Alaskan waters. Saxitoxin, the most potent of the paralytic shellfish poisoning toxins, has been well-documented in shellfish in the Aleutians and Gulf of Alaska for decades and associated with human illnesses and deaths due to consumption of toxic clams. There is little information regarding exposure of Alaskan marine mammals. Here, the spatial patterns and prevalence of DA and STX exposure in Alaskan marine mammals are documented in order to assess health risks to northern

populations including those species that are important to the nutritional, cultural, and economic well-being of Alaskan coastal communities. In this study, 905 marine mammals from 13 species were sampled including; humpback whales, bowhead whales, beluga whales, harbor porpoises, northern fur seals, Steller sea lions, harbor seals, ringed seals, bearded seals, spotted seals, ribbon seals, Pacific walruses, and northern sea otters. Domoic acid was detected in all 13 species examined and had the greatest prevalence in bowhead whales (68%) and harbor seals (67%). Saxitoxin was detected in 10 of the 13 species, with the highest prevalence in humpback whales (50%) and bowhead whales (32%). Pacific walruses contained the highest concentrations of both STX and DA, with DA concentrations similar to those detected in California sea lions exhibiting clinical signs of DA toxicosis (seizures) off the coast of Central California, USA. Forty-six individual marine mammals contained detectable concentrations of both toxins emphasizing the potential for combined exposure risks. Additionally, fetuses from a beluga whale, a harbor porpoise and a Steller sea lion contained detectable concentrations of DA documenting maternal toxin transfer in these species. These results provide evidence that HAB toxins are present throughout Alaska waters at levels high enough to be detected in marine mammals and have the potential to impact marine mammal health in the Arctic marine environment.

Limpinsel, D. E., Eagleton, M. P., & Hanson, J. L. (2017). Impacts to essential fish habitat from non-fishing activities in Alaska : EFH 5 year review : 2010 through 2015. https://doi.org/10.7289/V5/TM-F/AKR-14

The Magnuson-Stevens Fishery Conservation and Management Act (MSA) is the primary law governing marine fisheries management in United States (U.S.) federal waters. First passed in 1976, the MSA fosters long-term biological and economic sustainability of our nation's marine fisheries out to 200 nautical miles (nm) from shore. In 1996, the U.S. Congress added new habitat conservation provisions to assist the fishery management councils (FMCs) in the description and identification of Essential Fish Habitat (EFH) in fishery management plans (FMPs); including adverse impacts on such habitat, and in the consideration of actions to ensure the conservation and enhancement of such habitat. The MSA also requires federal agencies to consult with the National Marine Fisheries Service (NMFS) on all actions or proposed actions that are permitted, funded, or undertaken by the agency that may adversely affect EFH. To specifically meet national standards, EFH descriptions and any conservation and management measures shall be based on the best scientific information available and allow for variations among, and contingencies in, fisheries, fishery resources, and catches. Previous iterations of this report Impacts to Essential Fish Habitat from Non-fishing Activities in Alaska addressed non-fishing activities requiring EFH consultations and activities that may adversely affect EFH and offered example conservation measures for a wide variety of non-fishing activities. In this recent update these activities are grouped into four broad environmental categories to which impacts usually occur: (1) wetlands and woodlands; (2) headwaters, streams, rivers, and lakes; (3) marine estuaries and nearshore zones; and (4) open water marine and offshore zones. Alaska extends over Arctic, subarctic, and temperate climate zones. Four recognized Large Marine Ecosystems (LMEs) exist in these climate zones (NMFS 2010, NOAA 2012). A total of seventeen coastal zones are identified within the nearshore and coastal zones (Piatt and Springer 2007), eight terrestrial ecoregions are defined above the high tide line to interior Alaska (Nowacki et al. 2001). Water, the most important EFH feature, moves through all of these ecoregions and habitat types. This 2016 report introduces an ecosystem-based approach to this key feature, and presents the current understanding of the existing ecosystem processes within these regions and habitats that support EFH attributes necessary for fish and invertebrate survival at different life stages. A new section also summaries our current understanding of climate change and ocean acidification;

presents potential effects on marine EFH, discusses potential cumulative impacts in light of current projections, and includes recommendations for improving our understanding and monitoring of climate change. The exact reason why climate change maybe occurring is not fully understood. However, climate scientists, oceanographers, and fisheries biologists have identified significant change in our atmosphere, oceans, and regional weather patterns. An indicator in Alaska is the decline in the extent and duration of sea ice. Scientists at NMFS's Alaska Fisheries Science Center (AFSC) have suggested that changes to marine conditions have altered trophic dynamics and influenced the distribution and abundance of some commercial fish species in the Eastern Bering Sea (EBS). Furthermore, increasing sea surface temperatures (SSTs) in the Gulf of Alaska (GOA) may have a similar influence on fisheries distribution and abundance. The NMFS Alaska Region Habitat Conservation Division offers this report to inform decision makers and the public on activities that may affect EFH and possible EFH Conservation Recommendations to conserve healthy fish stocks and their habitat.

Marsh, J. M., Foy, R. J., Hillgruber, N., & Kruse, G. H. (2015). Variability in trophic positions of four commercially important groundfish species in the Gulf of Alaska. Fisheries Research, 165, 100-114 https://doi.org/10.1016/j.fishres.2015.01.003.

We examined trends in nitrogen stable isotope data as a proxy for trophic position (mean trophic level, TL) of commercial and survey catches as an ecosystem-based indicator of sustainability of four groundfish species in the Gulf of Alaska. From 2000 to 2004, walleye pollock (Gadus chalcogrammus), Pacific cod (Gadus macrocephalus), arrowtooth flounder (Atheresthes stomias), and Pacific halibut (Hippoglossus stenolepis) were collected from the waters surrounding Kodiak Island, Alaska. Several analyses of covariance (ANCOVA) models were tested to detect variations in mean TL among years with fish length as a covariate. Best-fit models were selected using the Akaiki Information Criterion to estimate trends in mean TL of commercial catch using length-frequency data from onboard fishery observers for each target species. Then, linear regression models were used to estimate mean TL of commercial catch over 1990–2009 and the mean TL of population biomass over 1984–2007 based on length-frequency data and biomass estimates from trawl surveys conducted by National Marine Fisheries Service and from historical catch data. The TL of catch for each species except walleye pollock remained stable over the time frame of the study. Walleye pollock TLs became increasingly variable after 1999. Similar trends in mean TL were observed for the survey biomass of walleye pollock. Additionally, there was an observed decrease of the occurrence of higher TL Pacific halibut over time. While the decline had no impact on overall TL estimates during 1990–2009, a continued decline may affect mean TL in the future. Overall, length seems to be the most important factor in estimating a species' TL. Therefore, including relationships between length of catch and TL estimates could lead to an early detection of TL declines that may be associated with unsustainable fishing mortality.

Paquin, M. M., Buckley, T. W., Hibpshman, R. E., & Canino, M. F. (2014). DNA-based identification methods of prey fish from stomach contents of 12 species of eastern North Pacific groundfish. Deep Sea Research Part I: Oceanographic Research Papers, 85, 110-117 https://doi.org/10.1016/j.dsr.2013.12.002.

Stomach content analysis of eastern NorthPacific groundfish has been conducted routinely by researchers interested in understanding trophic interactions between key predator species and their prey. Identification of prey by traditional morphological methods has limitations however, due to the loss of identifiable characters from digestion and morphological similarities between taxa. Furthermore,

some forage fish (e.g., osmerids ,ammodytids, and juvenile gadids), common prey of Bering Sea and Gulf of Alaska groundfish, are difficult to distinguish because of their slender or fusiform shape, disarticulating easily during digestion. DNA-based identification methods were developed to differentiate among 18 fish species, some that are found at depths greater than 200m, from four taxonomic families: Ammodytidae and Osmeridae(forage fish), Pleuronectidae(flatfish), andGadidae(gadid fish). Polymerase chain reaction (PCR) amplification of 739 base pair section of mitochondrial DNA cytochrome c oxidase I and an 862 base pair section of mitochondrial DNAcytochrome b was followed by restriction digest assays and resulted in species level resolution for 16 of 18 species of interest. PCR restriction digest assays applied to fish prey from stomach contents of ground fish indicated presence several target species, eulachon (Thaleichthyspacificus), walleye pollock (Gadus chalcogrammus), searcher (Bathymaster signatus), rocksole (Lepidopsetta bilineata), yellowfin sole (Limanda aspera) and eitherBering flounder (Hippoglossoides robustus) or flathead sole(H. elassodon). The PCR restriction digest protocol improved the identification rate predated fish from stomach content compared to identification by conventional taxonomic methods alone, and DNA sequence analysis further resolved identification of unknown prey fish samples.

Patton, A. K., Martindale, A., Orchard, T. J., Vanier, S., & Coupland, G. (2019). Finding eulachon: The use and cultural importance of Thaleichthys pacificus on the northern Northwest Coast of North America. Journal of Archaeological Science: Reports, 23, 687-699 https://doi.org/https://doi.org/10.1016/j.jasrep.2018.11.033.

This paper examines the pre-contact history of the eulachon fishery on the northern Northwest Coast of North America through multiple lines of evidence: zooarchaeological, ethnographic, and oral historical. The eulachon fishery and eulachon oil production was central to Northern Tsimshian socio-political relations, systems of ownership, and trade during the contact-and-post-contact period in the region. We bring together the results of an analysis of 15 fine-screened faunal assemblages collected from village sites in Prince Rupert Harbour and compare these with published northern coast village and camp fine-screened faunal assemblages. Our results show that eulachon and other smelt taxa are present in these assemblages, suggesting a deep history to the eulachon fishery. We suggest also that the paucity of eulachon remains at some sites could be explained by eulachon oil production and consider what lines of evidence are needed to explore the limitations of zooarchaeological data and the history of eulachon oil production in the future.

Plagányi, É. E., & Essington, T. E. (2014). When the SURFs up, forage fish are key. Fisheries Research, 159, 68-74 https://doi.org/10.1016/j.fishres.2014.05.011.

A novel method for identifying “key” prey species such as forage fish, upon which upper trophic level predators depend, is proposed. Forage fish fisheries collectively constitute 30% of global fishery landings and are important prey for other fished species as well as marine mammals and seabirds. The SURF index(SUpportive Role to Fishery ecosystems) for each prey species weights food web connectance by the importance of trophic connections, so that higher scores indicate a greater potential for indirect food web effects of forage fish fisheries. We show that the SURF index is less sensitive to choices on degree of taxonomic aggregation of analysis than typical connectance measures. Moreover, we show that SURFprovides more robust predictions of which species have greatest effects on other food web components.This rapid and empirically based method has utility in ensuring that management plans for these species take into account the broader ecosystem impacts of different harvest levels.

National Marine FIsheries Service (2020). *Endangered Species Act Section 7(a)(2) Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for the Jordan Cove LNG Export Terminal and Pacific Connector Pipeline Project, Southwest Oregon (FERC Docket Nos. CP17-494-000 and CP07-495-000)*. Retrieved from https://repository.library.noaa.gov/view/noaa/22990

No abstract

Shaffer, J. A., Munsch, S., & Juanes, F. (2018). Functional diversity responses of a nearshore fish community to restoration driven by large-scale dam removal. Estuarine, Coastal and Shelf Science, 213, 245-252 https://doi.org/10.1016/j.ecss.2018.08.030.

Large scale dams have numerous significant impacts on river and nearshore components of watersheds. Large scale dam removal is therefore an increasingly useful restoration tool that reestablishes physical processes and habitats that form nearshore ecosystems. Removing large scale dams will likely affect the functional ecology of nearshore ecosystems, but this concept has yet to be explored. Here we use data from a decade long study to define how the functional ecology of fish responded to large scale dam removal. Dam removal resulted in shifts in the nearshore through the reconnection of riverine and marine hydrodynamic system, large-scale and rapid creation of nearshore habitats, and a shift in nearshore habitats from tidally influenced to non-tidally influenced habitats. The functional diversity of the fish community within the system restored by dam removal was volatile during and after dam removal. Dam removal released sediment that formed new lower river and estuary. These new nearshore habitats supported a fish community of significantly greater functional dispersion and entropy relative to previously present beaches within and outside the new delta. That is, species unique in their diet, habitat use, morphology, and size were abundant relative to less functionally unique fish in newly formed beaches. These trends were temporary as there were no significant differences in functional diversity or entropy of fishes among sites after the restoration. Newly formed habitats proved to be more diverse but had lower resiliency after dam removal. Newly establishing nearshore sites appear more vulnerable to non-native and nuisance species that could disrupt the establishment of the watershed and shoreline. While functional richness at the original estuary sites dropped dramatically after dam removal, resiliency was higher after dam removal corresponding to a shift from estuary to lower river side channel habitat, indicating a more stable nearshore zone than new sites. We anticipate that functional diversity at the newly formed nearshore areas will stabilize as the habitats are vegetated and mature.

Stocking, J., Bishop, M. A., & Arab, A. (2018). Spatio-temporal distributions of piscivorous birds in a subarctic sound during the nonbreeding season. Deep Sea Research Part II: Topical Studies in Oceanography, 147, 138-147 https://doi.org/10.1016/j.dsr2.2017.07.017.

Understanding bird distributions outside of the breeding season may help to identify important criteria for winter refuge. We surveyed marine birds in Prince William Sound, Alaska, USA over nine winters from 2007 to 2016. Our objectives were twofold: to examine the seasonal patterns of piscivorous species overwintering in Prince William Sound, and to explore the relationships between spatial covariates and bird distributions, accounting for inherent spatial structure. We used hurdle models to

examine nine species groups of piscivorous seabirds: loons, grebes, cormorants, mergansers, large gulls, small gulls, kittiwakes, Brachyramphus murrelets, and murres. Seven groups showed pronounced seasonal patterns. The models with the most support identified water depth and distance to shore as key environmental covariates, while habitat type, wave exposure, sea surface temperature and seafloor slope had less support. Environmental associations are consistent with the available knowledge of forage fish distribution during this time, but studies that address habitat associations of prey fish in winter could strengthen our understanding of processes in Prince William Sound.

Talloni-Álvarez, N. E., Sumaila, R. U., Le Billon, P., & Cheung, W. W. (2019). Climate change impact on Canada's Pacific marine ecosystem: The current state of knowledge. Marine Policy, 104, 163-176 https://doi.org/10.1016/j.marpol.2019.02.035.

Global warming is already affecting the oceans through changes in water temperature, acidification, oxygen content and sea level rise, amongst many others. These changes are having multiple effects on marine species worldwide, with subsequent impacts on marine fisheries, peoples' livelihoods and food security. This work presents a review of the recent literature on the current and projected impacts of climate change on Canada's Pacific marine ecosystem. We find that there is an increasing number of studies in British Columbia focusing on changes in ocean conditions and marine species responses under climate change, including an emerging literature on the socio-economic impacts of these changes considered to be a knowledge gap. According to the literature, it is well established that ocean temperatures are increasing over the long-term, especially, in southern areas of British Columbia. Warming trends are increasing in the spring and are strongest in summer. However, there are important uncertainties regarding other climate drivers, such as oxygen concentration and acidification, stemming mainly from the insufficiency of data. Pacific salmon, elasmobranchs, invertebrates and rockfishes are amongst the most vulnerable species groups to climate change in British Columbia. Also, shifts in stock distribution and fish abundance under climate change may have a significant impact on fish supply affecting the livelihoods and food security of some British Columbians. The magnitude of these impacts is likely to vary according to a latitudinal gradient, with southern coastal areas being more affected than northern and central areas; challenging multiple areas of governance, such as equity and fishing access amongst First Nations; and institutional arrangements for transboundary stocks between the U.S. and Canada.

Ward, E. J., Jannot, J. E., Lee, Y. W., Ono, K., Shelton, A. O., & Thorson, J. T. (2015). Using spatiotemporal species distribution models to identify temporally evolving hotspots of species co-occurrence. Ecological Applications, 25(8), 2198-2209 https://doi.org/10.1890/15-0051.1.sm.

Identifying spatiotemporal hotspots is important for understanding basic ecological processes, but is particularly important for species at risk. A number of terrestrial and aquatic species are indirectly affected by anthropogenic impacts, simply because they tend to be associated with species that are targeted for removals. Using newly developed statistical models that allow for the inclusion of time-varying spatial effects, we examine how the co-occurrence of a targeted and nontargeted species can be modeled as a function of environmental covariates (temperature, depth) and interannual variability. The nontarget species in our case study (eulachon) is listed under the U.S. Endangered Species Act, and is encountered by fisheries off the U.S. West Coast that target pink shrimp. Results from our spatiotemporal model indicated that eulachon bycatch risk decreases with depth and has a convex relationship with sea surface temperature. Additionally, we found that over the 2007 2012 period, there

was support for an increase in eulachon density from both a fishery data set (+40%) and a fishery-independent data set (+55%). Eulachon bycatch has increased in recent years, but the agreement between these two data sets implies that increases in bycatch are not due to an increase in incidental targeting of eulachon by fishing vessels, but because of an increasing population size of eulachon. Based on our results, the application of spatiotemporal models to species that are of conservation concern appears promising in identifying the spatial distribution of environmental and anthropogenic risks to the population.

Welch, L. (2018). Early Cook Inlet fisheries near; ballot initiative draws big bucks. Alaska Journal of Commerce, 42(17), 4-5. Retrieved from https://www.alaskajournal.com/2018-04-25/fish-factor-early-cook-inlet-fisheries-near-ballot-initiative-draws-big-bucks.

Two commercial fisheries open each spring at Upper Cook Inlet that attract little notice and few participants, but each pays big bucks to fishermen.

Wolf, N., Harris, B. P., Richard, N., Sethi, S. A., Lomac-MacNair, K., & Parker, L. (2018). High-frequency aerial surveys inform the seasonal distribution of Cook Inlet beluga whales. Wildlife Society Bulletin, 42(4), 577-586 https://doi.org/10.1002/wsb.922.

Management options to mitigate potential effects from the overlap of anthropogenic and marine mammal activities require understanding of species' habitat use and movement patterns. We analyzed high temporal frequency industrial marine mammal monitoring program aerial surveys conducted over a protracted period from April to October of 2013 and 2014 to examine beluga whale (Delphinapterus leucas) ecology in the Cook Inlet, Alaska, USA. Our objectives were to characterize the spatiotemporal whale distributions, determine the utility of these patterns to inform management practices, and assess industrial survey data as a supplement to agency population monitoring programs. Cook Inlet beluga whale densities peaked in late June to early July, with some activity observed in all survey months. Consistent trends in spatial persistence were identified and found to be associated with the seasonal sequence of prey field distributions including eulachon (Thaleichthys pacificus), Pacific salmon (Oncorhynchus spp.), and gadids (Gadidae spp.). Seasonal beluga whale distributions were stable across both study years, indicating hotspots of habitat use with predictable seasonal timing. The regular temporal and spatial distribution of beluga whale activity suggests potential to inform management efforts to mitigate disturbance of whales from anthropogenic activities in the Inlet. We found high-frequency surveys conducted as part of industrial marine mammal monitoring programs provided a useful additional data source for population monitoring; however, improvements in survey design and efforts to control for observer detection biases may further increase the utility of these surveys to complement ongoing standardized scientific surveys.

Section III: Population Abundance and Trends

de Blois, S. (2020). The 2019 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic-Trawl Survey : Cruise Report SH-19-06. https://doi.org/10.25923/p55a-1a22.

The results presented here are from the 2019 Joint U.S.–Canada Integrated Ecosystem and Pacific Hake Acoustic-Trawl Survey. This report provides a brief description of the methods used in the survey and

summarizes the distribution, biological composition, and biomass of hake in U.S. and Canadian waters off the Pacific coast. It also summarizes results of acoustic system calibrations and secondary survey objectives.

Ess, C. (2015). Shrimp fleet on a roll with big landings, higher prices and major bycatch victory. National Fisherman, 95(10), 20. Retrieved from https://www.nationalfisherman.com/uncategorized/market-reports-58/

"It was a little difficult to believe what we were seeing," says Bob Hannah, the Oregon Department of Fish and Wildlife's pink shrimp project leader. "The level of bycatch reduction was so large; we all instantly knew that if this held up through the rest of the experimental tows, it was going to be huge for the fishery, and for eulachon."

Guan, L., Dower, J. F., McKinnell, S. M., Pepin, P., Pakhomov, E. A., & Hunt, B. P. (2015). A comparison of spring larval fish assemblages in the Strait of Georgia (British Columbia, Canada) between the early 1980s and late 2000s. Progress in oceanography, 138, 45-57 https://doi.org/10.1016/j.pocean.2015.09.006.

The concentration and composition of the larval fish assemblage in the Strait of Georgia (British Columbia, Canada) has changed between the early 1980s (1980 and 1981) and the late 2000s (2007, 2009 and 2010). During both periods, the spring larval fish assemblages were dominated by pelagic species: Clupea pallasi (Pacific herring), Merluccius productus (Pacific hake), Leuroglossus schmidti (northern smooth tongue) and Theragra chalcogramma (walleye Pollock). The average concentration of Merluccius productus, Theragra chalcogramma, Leuroglossus schmidti, and Sebastes spp. declined between the early 1980s and the late 2000s; in contrast, the absolute concentration and proportion of Pleuronectidae and several demersal fish taxa increased in the spring larval assemblage. Examination of the associations between larval fish assemblages and environmental fluctuations suggests that large-scale climate processes are potential contributors to variations in overall larval concentrations of the dominant taxa and assemblage composition in the Strait of Georgia.

Hannah, R. W., Lomeli, M. J. M., & Jones, S. A. (2015). Tests of artificial light for bycatch reduction in an ocean shrimp (Pandalus jordani) trawl: Strong but opposite effects at the footrope and near the bycatch reduction device. Fisheries Research, 170, 60-67 https://doi.org/10.1016/j.fishres.2015.05.010.

We investigated how the addition of artificial light in the vicinity of the rigid-grate bycatch reduction device (BRD) and along the fishing line of an ocean shrimp (Pandalus jordani) trawl altered fish bycatch and ocean shrimp catch. In separate trials using double-rigged shrimp nets, with one net incorporating artificial lights and the other serving as a control, we 1) attached one to four Lindgren-Pitman Electralume (R) LED lights (colors green or blue) in locations around the rigid-grate BRD, and 2) attached 10 green lights along the trawl fishing line. Both experiments were conducted with rigid-grate BRDs with 19.1 mm bar spacing installed in each net. Contrary to expectations, in 12 paired hauls the addition of artificial light around the rigid-grate increased the bycatch of eulachon (Thaleichthys pacificus), a threatened anadromous smelt species, by 104% (all by weight, $P = 0.0005$) and slender sole (Lyopsetta exilis) by 77% ($P = 0.0082$), with no effect on ocean shrimp catch or bycatch of other fishes ($P > 0.05$). In

42 paired hauls, the addition of 10 LED lights along the fishing line dramatically reduced the bycatch of a wide variety of fishes with no effect on ocean shrimp catch ($P > 0.05$). Bycatch of eulachon was reduced by 91% ($P = 0.0001$). Bycatch of slender sole and other small flatfishes were each reduced by 69% ($P < 0.0005$). Bycatch of darkblotched rockfish (Sebastes crameri), a commercially important but depressed rockfish species, was reduced by 82% ($P = 0.0001$) while the bycatch of other juvenile rockfish (Sebastes spp.) was reduced by 56% ($P = 0.0001$). How the addition of artificial light is causing these changes in fish behavior and bycatch reduction is not known. However, in both experiments the addition of artificial light appears to have greatly increased the passage of fishes through restricted spaces (between BRD bars and the open space between trawl fishing line and groundline) that they typically would not pass through as readily under normal seafloor ambient light conditions.

Larsen, R. B., Herrmann, B., Sistiaga, M., Brčić, J., Brinkhof, J., & Tatone, I. (2018). Could green artificial light reduce bycatch during Barents Sea Deep-water shrimp trawling? Fisheries Research, 204, 441-447 https://doi.org/10.1016/j.fishres.2018.03.023.

The Nordmøre grid is widely used in shrimp trawls to reduce the bycatch of fish species. However, small-sized fish species and juveniles still pass through the grid and enter the codend, along with the targeted shrimp. This bycatch of small fish has a negative impact on the ecosystem due to increased fish mortality, and leads to additional sorting work onboard. Some small-sized fish that enter the trawl avoid entering the codend by escaping through the outlet above the grid, without making contact with the grid itself. Design changes that promote this behavior could potentially reduce bycatch in shrimp trawl fisheries. Light-emitting diodes (LEDs) mounted around the escape outlet have previously been found to have either a negative effect, or no effect at all, on fish bycatch species. This study investigates the effect of mounting green LEDs on the lower part of a Nordmøre grid, to determine if their presence would encourage bycatch fish to rise towards the escape outlet prior to contacting the grid. Experimental fishing trials were conducted to assess the size selective properties of a 19mmbar spaced Nordmøre grid with and without LEDs, mounted on a bottom trawl targeting Deep-water shrimp (Pandalus borealis). For the four bycatch species investigated, 51–100% of small fish passed through the Nordmøre grid. The addition of green LEDs to the Nordmøre grid did not significantly affect the escape probability or the size selectivity of any of the investigated species. Very few Deep-water shrimp were found to escape through the escape outlet independent of the presence of the LEDs mounted on the grid.

Lauth, R. R., Dawson, E. J., & Conner, J. (2019). Results of the 2017 eastern and northern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate fauna. https://doi.org/10.25923/h118-nw41.

In 2017, the National Marine Fisheries Service's (NMFS) Resource Assessment and Conservation Engineering (RACE) Division of the Alaska Fisheries Science Center (AFSC) conducted two contiguous bottom trawl surveys on the Bering Sea continental shelf: the 2017 "Eastern Bering Sea" (EBS) survey was the 36th in an annual time series that began in 1982 (Conner and Lauth 2017), and the 2017 "Northern Bering Sea" (NBS) survey was conducted for only the second time since 2010 (Lauth 2011). Both bottom trawl surveys are mission critical to the AFSC because the results are critical to managing fisheries resources, monitoring the ecosystem, and providing a valuable data time-series for doing basic fisheries research. Fishery-independent abundance estimates and other biological and oceanographic information from Bering Sea bottom trawl surveys are used by the AFSC, North Pacific Fishery

Management Council (NPFMC) and the Alaska Department of Fish and Game (ADF&G) to manage groundfish and crab stocks and to do ecosystem forecast modeling that are requirements of the Bering Sea and Aleutian Island (BSAI) Fishery Management Plan (FMP) established under the Magnuson-Stevens Fishery Conservation and Management Act.

Lomeli, M. J. M., Groth, S. D., Blume, M. T. O., Herrmann, B., & Wakefield, W. W. (2018). Effects on the bycatch of eulachon and juvenile groundfish by altering the level of artificial illumination along an ocean shrimp trawl fishing line. Ices Journal of Marine Science, 75(6), 2224-2234 https://doi.org/10.1093/icesjms/fsy105.

We examined how catches of ocean shrimp (Pandalus jordani), eulachon (Thaleichthys pacificus), and juvenile groundfish could be affected by altering the level of artificial illumination along the fishing line of an ocean shrimp trawl. In the ocean shrimp trawl fishery, catches of eulachon are of special concern, as the species' southern Distinct Population Segment is listed as "threatened" under the US Endangered Species Act. Using a double-rigged trawl vessel, with one trawl illuminated and the other unilluminated, we compared the catch efficiencies for ocean shrimp, eulachon, and juvenile groundfish between an unilluminated trawl and trawls illuminated with 5, 10, and 20 LED fishing lights along their fishing line. The addition of artificial illumination along the trawl fishing line significantly affected the average catch efficiency for eulachon, rockfish (Sebastes spp.), and flatfish, with the three LED configurations each catching significantly fewer individuals than the unilluminated trawl without impacting ocean shrimp catches. For Pacific hake (Merluccius productus), the ten LED-configured trawl caught significantly more fish than the unilluminated trawl. For the five and 20 LED configurations, mean Pacific hake catches did not differ from the unilluminated trawl. This study contributes new data on how artificial illumination can affect eulachon catches (and other fish) and contribute to their conservation.

Lomeli, M. J. M., Groth, S. D., Blume, M. T. O., Herrmann, B., & Wakefield, W. W. (2020). The efficacy of illumination to reduce bycatch of eulachon and groundfishes before trawl capture in the eastern North Pacific ocean shrimp fishery. Canadian Journal of Fisheries and Aquatic Sciences, 77(1), 44-54 https://doi.org/10.1139/cjfas-2018-0497.

This study examined the extent that eulachon (Thaleichthys pacificus) and groundfishes escape trawl entrainment in response to artificial illumination along an ocean shrimp (Pandalus jordani) trawl fishing line. Using a double-rigged trawler, we compared the catch efficiencies for ocean shrimp, eulachon, and groundfishes between an unilluminated trawl and a trawl illuminated with five green LEDs along its fishing line. Results showed a significant reduction in the bycatch of eulachon and yellowtail rockfish (Sebastes flavidus) in the presence of illumination. As eulachon are a species listed in the Endangered Species Act, this finding provides valuable information for fishery managers implementing recovery plans and evaluating potential fishery impacts on their recovery and conservation. For other rockfishes (Sebastes spp.) and flatfishes, however, we did not see the same effect as the illuminated trawl caught similarly or significantly more fishes than did the unilluminated trawl. Prior to this research, the extent that eulachon and groundfishes escape trawl capture in response to illumination along an ocean shrimp trawl fishing line was unclear. Our study has provided results to fill that data gap.

McGowan, D. W., Horne, J. K., & Parker-Stetter, S. L. (2019). Variability in species composition and distribution of forage fish in the Gulf of Alaska. Deep Sea Research Part II: Topical Studies in Oceanography, 165, 221-237 https://doi.org/10.1016/j.dsr2.2016.11.019.

In the Gulf of Alaska (GOA), forage fish species, such as age-0 walleye pollock (Gadus chalcogrammus), capelin (Mallotus villosus), Pacific herring (Clupea pallasii), and mesopelagic fishes (e.g. Myctophidae), are ecologically important as both consumers of zooplankton, and as prey for fish, seabirds, and marine mammals. As part of the Gulf of Alaska Integrated Ecosystem Research Program, an acoustic-trawl survey was conducted in the summer and fall of 2011 and 2013 to quantify variability in species composition, density, and distributions of forage fish over the continental shelf and slope in the central and eastern regions of the GOA. The forage fish community in 2011 was characterized by the absence of age-0 pollock and lower densities of capelin, herring, and mesopelagics compared to observations in 2013. Age-0 pollock were abundant across both regions in summer 2013, but were rarely observed in fall. In contrast, summer observations of herring were rare, while aggregations of herring were observed over the eastern GOA shelf in fall of both years. Seasonal changes in community composition are attributed to the transport of age-0 pollock from offshore waters in summer to nearshore waters in fall, and to immigration of herring to the eastern GOA shelf in fall. Forage fish spatial patterns varied within and between regions due to intra- and interspecific differences in horizontal and vertical distributions that were correlated with bottom depth. Observed spatial and temporal variability in community composition and distributions of forage fish species may potentially impact predator foraging in the GOA, as well as the effectiveness of monitoring to detect changes in forage fish biomass.

National Marine Fisheries Service (2018). *FEMA Disaster, Mitigation, and Preparedness Programs in California*. Retrieved from https://repository.library.noaa.gov/view/noaa/22006

No abstract

Ormseth, O., Moss, J., McGowan, D. (2016). *Forage species report for the Gulf of Alaska*. Retrieved from https://repository.library.noaa.gov/view/noaa/19402

The format of this report varies according to new developments in forage fish research and data availability. The 2014 report contains extensive information regarding the distribution of different forage species in the GOA, which is not repeated in this report. The 2016 report focuses on three areas of interest regarding GOA forage species: 1) Data regarding incidental catches of forage fishes in federal groundfish fisheries in Alaska 2) Data from the GOA Assessment Survey conducted in the eastern GOA during 2011-2013 3) A summary of GOAIERP research regarding forage fishes The overview section of the report is similar to the 2014 report and is included here to provide an introduction to forage species and management in the GOA.

Ormseth, O. A. (2018). Status of forage species in the Gulf of Alaska region. Retrieved from https://repository.library.noaa.gov/view/noaa/20248.

A report on the status of forage species in the Gulf of Alaska (GOA) region is prepared on a biennial basis and presented to the GOA Plan Team and the North Pacific Fishery Management Council (NPFMC) in even years. This report is not intended as a formal stock assessment, although forage populations are

analyzed if data are available. The two main objectives of the report are to 1) investigate trends in the abundance and distribution of forage populations, and 2) describe interactions between federal fisheries and species that make up the forage base (i.e. to monitor potential impacts of bycatch).

Osgood, G. J., Kennedy, L. A., Holden, J. J., Hertz, E., McKinnell, S., & Juanes, F. (2016). Historical Diets of Forage Fish and Juvenile Pacific Salmon in the Strait of Georgia, 1966-1968. Marine and Coastal Fisheries, 8(1), 580-594 https://doi.org/10.1080/19425120.2016.1223231.

The Strait of Georgia, British Columbia, provides important feeding and rearing habitat for forage fish, such as Pacific Herring Clupea pallasii and Eulachon Thaleichthys pacificus as well as all species of North American Pacific salmon Oncorhynchus spp. during their juvenile out-migration. In recent decades, this region has undergone large-scale physical and biological changes. Pacific Herring and Pacific salmon populations have experienced dramatic population fluctuations, while Eulachon have failed to recover from precipitous declines in the 1990s. Archival records of stomach content data from the 1960s, collected primarily from juvenile Pacific salmon, Pacific Herring, and Eulachon, allowed us to investigate diet variability in these species 60 years ago. Consistent with contemporary reports, we found that all species except Eulachon had generalist diets. In contrast to recent studies finding that Pacific Herring are the most important fish prey, Eulachon were the most frequently consumed fish, occurring in 28% of all piscivorous fish stomachs. This suggests that Pacific Herring are an important component of some Pacific salmon diets now, but only because lipid-rich Eulachon are no longer available. Chinook Salmon O. tshawytscha and Coho Salmon O. kisutch had the most similar diets, in part because of their greater piscivory. Species, length, and month and year of capture showed some explanatory power in differentiating the diets of the fish, although they explained less than 10% of total diet variation. Historical data, such as those presented here, offer a unique opportunity to investigate temporal differences in foraging ecology, informing management on how changes in the Strait of Georgia ecosystem may impact the trophic interactions between species.

Pochardt, M., Allen, J. M., Hart, T., Miller, S. D. L., Yu, D. W., & Levi, T. (2020). Environmental DNA facilitates accurate, inexpensive, and multiyear population estimates of millions of anadromous fish. Molecular Ecology Resources, 20(2), 457-467 https://doi.org/10.1111/1755-0998.13123.

Although environmental DNA shed from an organism is now widely used for species detection in a wide variety of contexts, mobilizing environmental DNA for management requires estimation of population size and trends in addition to assessing presence or absence. However, the efficacy of environmental-DNA-based indices of abundance for long-term population monitoring have not yet been assessed. Here we report on the relationship between six years of mark-recapture population estimates for eulachon (Thaleichthys pacificus) and "eDNA rates" which are calculated from the product of stream flow and DNA concentration. Eulachon are a culturally and biologically important anadromous fish that have significantly declined in the southern part of their range but were historically rendered into oil and traded. Both the peak eDNA rate and the area under the curve of the daily eDNA rate were highly predictive of the mark-recapture population estimate, explaining 84.96% and 92.53% of the deviance, respectively. Even in the absence of flow correction, the peak of the daily eDNA concentration explained an astonishing 89.53% while the area under the curve explained 90.74% of the deviance. These results support the use of eDNA to monitor eulachon population trends and represent a >80% cost savings over mark-recapture, which could be further increased with automated water sampling, reduced replication,

and focused temporal sampling. Due to its logistical ease and affordability, eDNA sampling can facilitate monitoring a larger number of rivers and in remote locations where mark-recapture is infeasible.

Shaffer, J. A., Juanes, F., Quinn, T. P., Parks, D., McBride, T., Michel, J., . . . Byrnes, C. (2017). Nearshore fish community responses to large scale dam removal: implications for watershed restoration and fish management. Aquatic Sciences, 79(3), 643-660 https://doi.org/10.1007/s00027-017-0526-3.

The nearshore is a critical zone for northeast Pacific Ocean fish communities, including ecologically and culturally important salmon species. The largest dam removal in the world was recently completed on the Elwha River, with the goal of restoring fisheries and ecosystems to the watershed. The nearshore Elwha fish community was monitored monthly from January 2008 to November 2015 before, during and after dam removal. As of September 2015, approximately 2.6 million m(3) of sediment material had increased the area of the Elwha delta to over 150 ha. Newly formed nearshore habitats were quickly colonized by fish communities during the dam removal period but the communities were similar in total species richness and Shannon diversity before and after dam removal, and were similar to a nearby reference site (Salt Creek estuary). Select fish species, including ESA-listed Pacific salmon and trout Oncorhynchus spp., and eulachon Thaleichthys pacificus, and non-native, American shad (Alosa sapidissima), appeared quickly in these new habitats. Hatchery releases of Chinook, O. tshawytscha, coho, O. kisutch, and steel-head, O. mykiss (over 3 million total fish annually to the lower river), dominated the Elwha estuary catch from April through August of each year before, during, and after dam removal. Chum salmon catch rate, size, and duration of estuary occupancy declined during and after dam removal. Overall catches of chum salmon fry prior to, during, and after dam removal were significantly negatively correlated with Chinook salmon catches but significantly, and positively, correlated with coho salmon. When assessed at the Elwha estuary separately, chum abundance was significantly positively correlated with Chinook, coho, and steelhead abundance. These patterns indicate overlap, and likely interaction between these respective groups of hatchery and wild fish. Continued hatchery releases may therefore further challenge chum salmon recovery and should be considered when planning for watershed recovery.

Von Szalay, P. G., & Raring, N. W. (2016). Data report : 2015 Gulf of Alaska bottom trawl survey. https://doi.org/10.7289/V5/TM-AFSC-325.

This report presents data from the 2015 Gulf of Alaska groundfish survey conducted by the Alaska Fisheries Science Center of the National Marine Fisheries Service. It contains detailed descriptions of the survey planning and operations, species distribution and abundance charts, length frequency plots, tables of estimated biomass, catch per unit effort, average weight and length estimates, length frequency plots, length-weight regression parameters, lists of identified species, survey strata specifications and charts, and trawl descriptions and diagrams.

Von Szalay, P. G., & Raring, N. W. (2018). Data Report : 2017 Gulf of Alaska bottom trawl survey. https://doi.org/10.7289/V5/TM-AFSC-374.

Scientists of the Groundfish Assessment Program of Alaska Fisheries Science Center's Resource Assessment and Conservation Engineering (RACE) Division conducted the tenth Gulf of Alaska Biennial

Bottom Trawl Survey during the summer of 2017. This survey extends to 15 the series of surveys, previously conducted every 3 years between 1984 and 1999, which constitute the time series used in stock assessments of Gulf of Alaska groundfish resources. The survey area covered the continental shelf and upper continental slope to 700 m in the Gulf of Alaska from Islands of Four Mountains (170°W long.) and approximately 2,800 km across the Gulf of Alaska to Dixon Entrance (133°25'W long.). The survey was conducted aboard two chartered commercial trawlers, the FV Ocean Explorer and FV Sea Storm. Trawl haul samples were successfully collected at 536 survey stations using standard RACE Division Poly Nor'Eastern high-opening bottom trawl nets with rubber bobbin roller gear. The primary survey objectives were to define the distribution and estimate the relative abundance of the principal groundfish species within the survey area, and to collect data to estimate biological parameters useful to groundfish researchers and managers including growth, length-weight relationships, feeding habits, and size, sex, and age composition. The survey also collected ancillary data requested by other research groups. A total of 161 fish and 364 invertebrate species were captured in the survey. Species with the highest total catch abundance (by weight) over the entire survey area were Pacific ocean perch (Sebastes alutus), arrowtooth flounder (Atheresthes stomias), walleye pollock (Gadus chalcogrammus), Pacific halibut (Hippoglossus stenolepis), flathead sole (Hippoglossoides elassodon), giant grenadier (Coryphaenoides pectoralis), northern rockfish (Sebastes polyspinis), and sablefish (Anoplopoma fimbria). Survey results presented here include estimates of catch per unit of effort, biomass, population size composition, and length-weight relationships, as well as charts depicting the distribution of catch for commercially important species encountered during the survey.

Williams, S., Thom, B. A., Hanshew, G., & Harley, A. (2016). Amendment 27 to the Pacific coast groundfish fishery management plan and 2017-2018 harvest specifications and management measures : final environmental assessment. Retrieved from https://repository.library.noaa.gov/view/noaa/16384.

In accordance with the Magnuson-Stevens Fishery Conservation and Management Act (MSA), NMFS' proposed actions consist of the following: The adoption of 2017-2018 harvest specifications and new management measures (Section 1.4) and (2) a decision on the proposed Pacific Coast Groundfish Fishery Management Plan (Groundfish FMP) Amendment 27 to change a stock classification and implement other management measures (Section 1.5). These two actions are designed to prevent overfishing, to rebuild overfished stocks, to ensure conservation, to facilitate long-term protection of essential fish habitat (EFH), and to realize the full potential of the nation's fishery resources. These actions are needed to respond to new scientific information and information about the needs of fishing communities, to provide additional tools to ensure that annual catch limits (ACLs) and other federal harvest guidelines are not exceeded and to afford additional fishing opportunities where warranted.

Section IV: Threats

Biological and Conference Opinion on the issuance of Permit No. 18786-01 to the Marine Mammal Health and Stranding Response Program pursuant to Sections 109(h), 112(c), 104(c) and Title IV of the Marine Mammal Protection Act and Section 10(a)(l)(A) of the Endangered Species Act, and implementation of the Marine Mammal Health and Stranding Response Program. (2016). http://doi.org/10.7289/V5WQ01V1.

The action agency for this consultation is the NMFS Office of Protected Resources (NMFS OPR) Permits and Conservation Division (hereafter referred to as 'the Permits Division') for its issuance of a scientific research and enhancement of propagation or survival permit pursuant to section 10(a)(1)(A) of the ESA and the NMFS OPR Marine Mammal Health and Stranding Response Program (hereafter referred to as 'the MMHSRP' or 'the Program') pursuant to sections 104c, 109(h), 112(c) and Title IV of the Marine Mammal Protection Act (MMPA). Consultation in accordance with section 7(a)(2) of the statute (16 USC 1536 (a)(2)), associated implementing regulations (50 CFR. '402), and agency policy and guidance (USFWS and NMFS 1998a) was conducted by the NMFS OPR's ESA Interagency Cooperation Division (hereafter referred to as 'we'). This biological opinion (opinion) and incidental take statement were prepared by the NMFS OPR's ESA Interagency Cooperation Division in accordance with section 7(b) of the ESA and implementing regulations at 50 CFR '402. This document represents the NMFS' opinion on the effects of these actions on endangered and threatened species and designated critical habitat for those species.

Biological Opinion on EPA pesticides general permit for discharge of pollutants into U.S. waters. (2016). Retrieved from https://repository.library.noaa.gov/view/noaa/14798

This document represents NMFS' opinion on the U.S. Environmental Protection Agency's (EPA's) reissuance of its Pesticides General Permit (PGP) authorizing discharges of biological pesticides and residues from chemical pesticides (together, pesticide pollutants) to waters of the U.S. and the implications of these discharges for threatened and endangered species and their designated critical habitat under NMFS' jurisdiction. The EPA uses general permits issued under section 402, the National Discharge Elimination System (NPDES) of the Clean Water Act (33 U.S.C. 1342 et seq.; CWA), to authorize routine discharges by multiple dischargers. Coverage for discharges under a general permit is granted to applicants after they submit a notice of intent to discharge (NOI1). Once the NOI is submitted and any review period specified under the PGP has closed, the applicant is authorized to discharge under the terms of the general permit. Under the PGP, however, some dischargers are automatically covered without submitting an NOI. The PGP authorizes discharges only of pesticide pollutants from pesticides that EPA has registered for use under the Federal Insecticide Fungicide and Rodenticide Act (FIFRA), 7 U.S.C. 136136y. The opinion and incidental take statement were prepared by NMFS' Endangered Species Act Interagency Cooperation Division in accordance with section 7(b) of the ESA and implementing regulations at 50 CFR '402. This document represents NMFS' opinion on the effects of these actions on endangered and threatened species and designated critical habitat that has been designated for those species. A complete record of this consultation is on file at NMFS' Office of Protected Resources in Silver Spring, Maryland.

Endangered Species Act Recovery Plan for the Southern Distinct Population Segment of Eulachon (Thaleichthys pacificus). (2017). Retrieved from https://repository.library.noaa.gov/view/noaa/15989

This Recovery Plan serves as a blueprint for the protection and recovery of the southern Distinct Population Segment (DPS) of eulachon (Thaleichthys pacificus) using the best available science per the requirements of the Endangered Species Act (ESA). The Recovery Plan links threats and management actions to an active research program to fill data gaps, and a monitoring program to assess these actions' effectiveness. Research and monitoring results will provide information to refine ongoing

actions and prioritize new actions to achieve the Plan's goal: to restore the listed species to the point where it no longer requires the protections of the ESA.

Federal Register (2016). *Endangered and Threatened Species; Take of Anadromous Fish, Rockfish, and Eulachon*. Retrieved from https://www.govinfo.gov/app/details/FR-2016-05-20/2016-11999

Notice is hereby given that NMFS has received seven scientific research permit application requests relating to Pacific salmon, steelhead, rockfish, sturgeon, and eulachon. The proposed research is intended to increase knowledge of species listed under the Endangered Species Act (ESA) and to help guide management and conservation efforts.

Matson, S. E., & Erickson, D. L. (2018). Analysis of West Coast Groundfish Fisheries for the 2017 Biological Opinion on Endangered Species Act-listed Salmon. Retrieved from https://repository.library.noaa.gov/view/noaa/20939.

This analysis addresses the groundfish trawl and non-trawl sectors and their impacts on salmon bycatch, in support of the Endangered Species Act (ESA) salmon consultation for the groundfish fishery. While effects on Chinook salmon bycatch by the non-whiting trawl sector are emphasized, impacts on salmon (e.g., coho salmon and Chinook salmon) are also analyzed for the non-trawl groundfish sectors (both recreational and commercial) and the whiting trawl sector.

National Marine Fisheries Service (2017). *2016 5-Year Review: Summary & Evaluation of Eulachon*. Retrieved from https://repository.library.noaa.gov/view/noaa/17807

On 18 March 2010, the National Marine Fisheries Service (NMFS) published a final rule in the Federal Register (75 FR 13012) to list the southern distinct population segment (DPS) of eulachon (Thaleichthys pacificus) as threatened under the U.S. Endangered Species Act (ESA) (NMFS 2010). This listing encompassed all subpopulations of eulachon within the states of Washington, Oregon, and California and extended from the Skeena River in British Columbia south to the Mad River in Northern California (Figure 1). The Biological Review Team (BRT) concluded that the major threats to the of eulachon, included climate change impacts on ocean conditions and freshwater habitat, bycatch in offshore shrimp trawl fisheries, changes in downstream flow-timing and intensity due to dams or water diversions, and predation. These threats, together with large declines in abundance, indicated to the BRT that the southern DPS of eulachon was at moderate risk of extinction throughout all of its range (Gustafson et al. 2010, 2012). These factors collectively led the NMFS listing of the southern DPS of eulachon as a threatened species under the Federal ESA.

Sigler, M. F., Gende, S. M., & Csepp, D. J. (2017). Association of foraging Steller sea lions with persistent prey hot spots in southeast Alaska. Marine Ecology Progress Series, 571, 233-243 https://doi.org/10.3354/meps12145.

Understanding how air-breathing marine vertebrates find and utilize prey provides insight into their foraging mechanisms and ultimately their population productivity and trends. Utilization depends on their ability to locate areas where productive foraging conditions exist. We quantified the abundance of

forage fish in southeast Alaska during acoustic surveys between October and April to improve our understanding of Steller sea lion Eumetopias jubatus foraging behavior. Energy densities (millions kJ km(-2)) of forage fish were orders of magnitude greater between November and February due to the presence of large schools of Pacific herring Clupea pallasi. Herring schools were highly aggregated, although the location of these aggregations shifted southward from November to April. Thus, a productive foraging area in one month did not necessarily equate to a productive area in the next month. However, by surveying on successive days and weeks, we found that herring aggregations persisted at shorter time scales. When the study area was partitioned into 1 x 1 km blocks, the day-to-day abundance of prey within a block was highly correlated with prey abundance the following day (correlation coefficient, $r = 0.75$, $p < 0.001$) and with prey abundance for the following week ($r = 0.55$, $p < 0.001$). More importantly, the persistence of these prey hot spots was an important characteristic in determining whether foraging sea lions utilized them. The odds of observing a foraging sea lion were about 1 in 3 for locations where prey hot spots were persistent. The persistence of these hot spots allowed predators to predict their locations and concentrate search efforts accordingly.

United States Bureau of Land Management (2016). *Record of decision : vegetation treatments using aminopyralid, fluroxypyr, and rimsulfuron on Bureau of Land Management lands in 17 western states programmatic environmental impact statement*. Retrieved from https://www.biodiversitylibrary.org/item/245930

This Final Programmatic Environmental Impact Statement (PEIS) analyzes the potential direct, indirect, and cumulative impacts associated with the Bureau of Land Management's (BLM's) use of the herbicides aminopyralid, fluroxypyr, and rimsulfuron on the human and natural environment. These three herbicides would be added to the BLM's list of approved active ingredients and integrated into the vegetation management program that was analyzed in an earlier PEIS released in 2007.