## Data gaps and research priorities from 2019 individual SAFE report chapters

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The sections below refer to individual chapters submitted in 2019. NOTE that this is intended as a sample summary document and includes only the “Full” assessments done in 2019.

## Sablefish

There is little information on early life history of sablefish and recruitment processes. A better understanding of juvenile distribution, habitat utilization, and species interactions would improve understanding of the processes that determine the productivity of the stock. Better estimation of recruitment and year class strength would improve assessment and management of the sablefish population. Future sablefish research is going to focus on several directions:

1. Refine fishery abundance index to utilize a core fleet, and identify covariates that affect catch rates.
2. Consider new strategies for incorporating annual growth data.
3. Re-examine selectivity assumptions, particularly the fishery and GOA trawl survey
4. Continue to explore the use of environmental data to aid in determining recruitment.
5. We have developed a spatially explicit research assessment model that includes movement, which examines smaller-scale population dynamics while retaining a single stock hypothesis Alaska-wide sablefish model.
6. Evaluate differences in condition (weight at length and energetic storage) among management areas and years to evaluate if they relate to spawning, recruitment, and environmental conditions.

# GOA FMP

## GOA Pollock

Based on the 2017 CIE review of the Gulf of Alaska pollock assessment, the following research priorities are identified:

* Consider to explore alternative modeling platforms in parallel to the ADMB assessment.
* Continue to develop spatial GLMM models for survey indices of GOA pollock
* Evaluate pollock population dynamics in a multi-species context using the CEATTLE model.
* Develop an Ecosystem and Socioeconomic Profile (ESP) for GOA pollock.
* Explore implications of non-constant natural mortality on pollock assessment and management.

This year we initiated the GOA pollock ESP during an internal AFSC workshop that was held in May 2019 to discuss and develop the ESP process and products. A working group was formed to complete and present the draft GOA pollock ESP document for review during the 2019 September Plan Team. The GOA Groundfish Plan Team looked forward to seeing the updated and completed ESP in November, recommended including the conceptual model, and suggested the authors consider alternative community engagement indicators in the future. Additionally, the GOA Groundfish Plan Team encouraged the authors to consider potential avenues for updating ESPs rather than producing full ESPs in the future. We provide the completed GOA pollock ESP with this assessment in Appendix 1A. During the next ESP workshop planned for March 2020, we will discuss more standardized avenues for providing a summary of the ESP recommendations for use in the main SAFE document and for producing partial ESPs when there are only updates to the indicators and limited model evaluation.

## GOA Pacific cod

Understanding of the above ecosystem considerations would be improved if future research were directed toward closing certain data gaps. Such research would have several foci, including the following:

1. ecology of the Pacific cod stock, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment;
2. behavior of the Pacific cod fishery, including spatial dynamics;
3. determinants of trawl survey catchability and selectivity and relationship with environmental covariates;
4. age determination and effects of aging error and bias on model parameters including natural mortality;
5. ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and
6. ecology of species that interact with Pacific cod, including estimation of biomass, carrying capacity, and resilience.

## GOA ATF

Analysis of the herding and escapement studies for arrowtooth would result in improved estimates of selectivities and catchability. Otoliths have been aged through the 2017 survey, but continued aging will allow monitoring of growth trends. A correlation between bottom temperatures and catchability has been observed in Arrowtooth Flounder and other flatfish; whether a similar relationship exists for GOA ATF would provide helpful information for the estimation of catchability. In addition, an examination of catchability may benefit the model. Examination of genetic stock structure of Arrowtooth Flounder throughout its range is important to delineate stock boundaries and may lead to insight on the migratory behavior and skewed sex ratio of this species.

## GOA Deepwater flatfish

There is time-varying cohort-specific pattern in the maximum size of Dover sole that is not currently taken into account in the model. This appears as a spatial pattern as well because Dover sole move ontogenetically. Resolving the uncertainty in growth in the assessment could lead to better-fitting models, much lower CVs in length-at-age, and improved selectivity estimates. Appendix B explores several two-area models meant to explicitly take into account the ontogenetic movement patterns and spatial growth patterns, but lead to some confounding among selectivity, growth, and movement parameters. In addition, it appears that males and females may have different movement patterns. Fish in the Eastern GOA appear to not grow as large as fish in the Western-Central GOA, and fewer old fish are found in the Eastern GOA. Genetic stock structure is unknown for Dover sole, so it is not known whether the fish in the Eastern GOA are a separate sub-population, if they don’t grow as old, or if older Eastern GOA Dover sole migrate offshore and west to deeper water. Further study of genetic stock structure of Dover sole would be interesting, though it may be difficult to obtain the funding that would be necessary to explore this. However, exploration of how these growth and movement patterns and our uncertainty about growth and movement may influence the performance of stock assessment models would be useful.

For GOA rex sole, resolving the spatial uncertainty in growth dramatically changed the fishery selectivity curve and fishery reference points, and the appropriateness of the new fishery reference points was confirmed by the addition of newly-aged historical fishery ages to the model. GOA Dover sole currently depends only on fishery length composition data, as there are no fishery otoliths or ages available. Changing the observer sampling protocol to obtain even one year of fishery ages could lead to improved estimates of fishery selectivity.

A contributing factor to the uncertainty in the relationship between length and age is the large amount of ageing error for older Dover sole. The stock assessment incorporated ageing error by using an existing ageing error matrix for West Coast Dover sole. A priority for future assessments is to analyze ageing error data for GOA Dover sole using methods described in Punt et al. (2008) and to incorporate a resulting ageing error matrix that is specific to GOA Dover sole into the assessment.

## GOA POP

There is little information on early life history of POP and recruitment processes. A better understanding of juvenile distribution, habitat utilization, and species interactions would improve understanding of the processes that determine the productivity of the stock. In addition, modeling investigations into the potential relationships between recruitment or natural mortality and environmental indices should be conducted to enable the model to better describe the increase in biomass observed by the bottom trawl survey. Better estimation of recruitment and year class strength would improve assessment and management of the POP population. Studies to improve our understanding of POP density between trawlable and untrawlable grounds and other habitat associations would help in our determination of catchability parameters. Further investigations of spatial population dynamics of POP across the GOA may enable improved assessment as well, given the closed area in the Eastern GOA and the recent increases in biomass in this area and the potential differences in population dynamics among the regions of the GOA. Incorporation of acoustics information that have been collected by the Mid-water Assessment and Conservation Engineering (MACE) group would also aid the assessment and would allow increased understanding of the changes to POP distribution in conjunction with the recent increases in biomass. Interaction with other species in the fishery, such as Walleye Pollock, should also be evaluated to determine the influence of POP population expansion. This research could potentially be done in a Management Strategy Evaluation (MSE) framework as well as Maximum Economic Yield (MEY) framework.

## GOA Shortraker rockfish

Currently, validation of aging methods for shortraker rockfish is the most important research priority so that an age-structured model can be used for assessment. Also, much additional research is needed on other aspects of shortraker rockfish biology and assessment. There is little to no information on larval, post-larval, or early stage juveniles of shortraker rockfish. In particular, information is lacking on juvenile shortraker rockfish, which are very seldom caught in any sampling gear. Habitat requirements for larval, post-larval, and early stages are mostly unknown. Habitat requirements for later stage juvenile and adult fish are mostly anecdotal or conjectural. While recent work has improved our understanding greatly (Du Preez and Tunnicliffe 2011, Laman *et al.* 2015), further research needs to be done on the bottom habitat

of the fishing grounds, on what HAPC biota are found on these grounds, and on what impact bottom trawling has on the grounds. Investigation is needed on the distribution and abundance of shortraker rockfish in areas of rough bottom that cannot be sampled by trawl surveys.

## GOA Rougheye/blackspotted

Future assessment priorities include 1) assessment of RE/BS rockfish density between trawlable and untrawlable grounds, 2) analyses of different fishery fleet spatial patterns and behavior given the Rockfish Program and observer restructuring, and 3) examining potential age and growth differences between RE/BS rockfish to consider the utility of developing species-specific life history parameters for this two-species complex.

There is little information on early life history of rougheye and blackspotted rockfish. Recruitment processes influencing the early life stages or habitat requirements for all stages are mostly unknown. A better understanding of early life stage distribution, habitat utilization, and species interactions would improve understanding of the processes that determine the productivity of the stock. Better estimation of recruitment and year class strength would improve assessment and management of the RE/BS population.

We also hope to collect and age subsamples of rougheye otoliths from the longline survey for future use in the stock assessment model. Additional analyses may then include implications of sampling methodology and comparisons between trawl and longline survey age and length compositions.

A newly revamped stock ecosystem-socioeconomic profile (ESP) report framework is also planned to be introduced over the next several years. The ESPs may replace the Ecosystem Consideration section of the single-species assessment reports in some manner. The new reports can be considered a companion to the main SAFE chapter and will likely include several standardized products that review the ecosystem and socioeconomic pressures on a given stock and provide a subsequent evaluation of relevant indicators for monitoring shifts in stock productivity. The intention of the ESP report is to improve the process of integrating ecosystem information into the stock assessments and facilitate the ecosystem approach to fishery management. In the future, we may consider conducting and ESP for rougheye and blackspotted rockfish if this becomes a priority for this stock complex.

## GOA Other rockfish

Data limitations are severe for OR in the GOA, and it is extremely difficult to determine whether current management is appropriate with the limited information available. Gaps include imprecise biomass estimates, limited and unvalidated ageing, and lack of life history information (including movement, distribution, and reproductive parameters). Regardless of future management decisions regarding the OR complex management category, improving biological sampling of OR in fisheries and surveys is essential. Areas of research that would utilize existing fishery or survey data include: body condition, horizontal and/or vertical changes in fishery capture depth, and alternative modelling approaches that would incorporate other data sources where appropriate for each species.

## GOA Atka mackerel

Regional and seasonal food habits data for GOA Atka mackerel is very limited. Studies to determine the impacts of environmental indicators such as temperature regime, on Atka mackerel are needed. More information on Atka mackerel habitat preferences would be useful to improve our understanding of Essential Fish Habitat (EFH), and improve our assessment of the impacts to habitat due to fishing. Better habitat mapping of the GOA would provide information for survey stratification and the extent of trawlable and untrawlable habitat.

## GOA skates

Because fishing mortality appears to be a larger proportion of skate mortality in the GOA than predation mortality, highest priority research should continue to focus on direct fishing effects on skate populations. The most important component of this research is to fully evaluate the catch and discards in all fisheries capturing skates. It is also vital to continue research on the productive capacity of skate populations, including information on age and growth, maturity, fecundity, and habitat associations.

Although predation appears less important than fishing mortality on adult skates, juvenile skates and skate egg cases are likely much more vulnerable to predation. This effect has not been evaluated in population or ecosystem models. We expect to learn more about the effects of predation on skates, especially as juveniles, with the completion of Jerry Hoff’s (AFSC, RACE) research on skate nursery areas in the Bering Sea.

Skate habitat is only beginning to be described in detail. Adults appear capable of significant mobility in response to general habitat changes. However, eggs are limited to isolated nursery grounds and juveniles use different habitats than adults. Disturbance to these habitats could have disproportionate population effects. Changes in these habitats have not been monitored historically, so assessments of habitat quality and its trends are not currently available. We recommend continued study on skate nursery areas to evaluate importance to population production.

## GOA Octopus

A volume on cephalopod taxonomy and identification in Alaska has been published (Jorgensen 2009). Efforts to improve octopus identification during AFSC trawl surveys will continue, but because of seasonal differences between the survey and most fisheries, questions of species composition of octopus incidental catch may still be difficult to resolve. Genetic analysis of tissue samples could be used to identify octopus species.

Because octopuses are semelparous, a better understanding of reproductive seasons and habits is needed to determine the best strategies for protecting reproductive output. *Enteroctopus dofleini* in Japan and off the US west coast reportedly undergo seasonal movements, but the timing and extent of migrations in Alaska is unknown. The distribution of octopus biomass and extent of movement between federal and state waters is unknown and could become important if a directed state fishery develops.

Fishery-independent methods for assessing biomass of the harvested size group of octopus are feasible, but would be species-specific and could not be carried out as part of existing multi-species surveys. Pot surveys are effective both for collecting biological and distribution data and as an index of abundance; mark-recapture methods have been used with octopus both to document seasonal movements and to estimate biomass and mortality rates. These methods are currently being researched; priorities for funding and staffing for a dedicated octopus survey needs to be addressed.

Tagging studies are needed to obtain a complete understanding of the migratory patterns of *Enteroctopus dofleini*. Additional genetic and/or tagging studies are needed to clarify the stock structure of this species in Alaska waters.

# BSAI FMP

## EBS Pollock

The available data for EBS pollock are extensive yet many processes behind the observed patterns continue to be poorly understood.

The recent patterns of abundance observed in the northern Bering Sea provide an example. As such, we recommend the following research priorities:

* Continue to investigate using spatial processes for estimation purposes (e.g., combining acous- tic and bottom trawl survey data). The application of the geostatistical methods (presented for comparative purposes in this assessment) seems like a reasonable approach to statistically model disparate data sources for generating better abundance indices. Also, examine the po- tential to use pelagic samples from the BASIS survey to inform recruitment and subsequent spatial patterns.
* Develop methods to use spatio-temporal models to estimate composition information (i.e., length and age).
* Study the relationship between climate and recruitment and trophic interactions of pollock within the ecosystem would be useful for improving ways to evaluate the current and alterna- tive fishery management system. In particular, studies investigating the processes affecting recruitment of pollock in the different regions of the EBS (including potential for influx from the GOA) should be pursued.
* Apply new technologies (e.g., bottom-moored echosounders) to evaluate pollock movement between regions.
* Expand genetic sample collections for pollock (and process available samples) and apply high resolution genetic tools for stock structure analyses.

## EBS Pacific cod

Significant improvements in the quality of this assessment could be made if future research were directed toward closing certain data gaps. At this point, the most critical needs pertain to the effects of the large and potentially unprecedented movements of Pacific cod from the EBS and NBS that appear to have taken place in the last few years, including:

1. to understand the factors determining these movements,
2. to understand whether/how these movements change over time,
3. to obtain accurate estimates of these movements,
4. to understand the extent to which reciprocal movements occur, and
5. to understand the spawning contribution of NBS fish to the overall stock.

Additional surveys of the NBS are strongly encouraged, as are genetic analyses and tagging studies. Ageing also continues to be an issue, as the assessment models consistently estimate a positive ageing bias, at least for otoliths read prior to 2008. Longer-term research needs include improved understanding of:

1. the ecology of Pacific cod in the EBS, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment;
2. ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and
3. ecology of species that interact with Pacific cod, including estimation of interaction strengths, biomass, carrying capacity, and resilience.

## AI Pacific cod

Significant improvements in the quality of this assessment could be made if future research were directed toward closing certain data gaps. At this point, the most critical needs pertain to trawl survey catchability and selectivity, specifically: 1) to understand the factors determining these characteristics, 2) to understand whether/how these characteristics change over time, and 3) to obtain accurate estimates of these characteristics. Ageing also continues to be an issue, as assessment models of the EBS stock since 2009 have estimated a positive ageing bias, at least for otoliths aged prior to 2008. Longer-term research needs include improved understanding of: 1) the ecology of Pacific cod in the AI, including spatial dynamics, trophic and other interspecific relationships, and the relationship between climate and recruitment; 2) ecology of species taken as bycatch in the Pacific cod fisheries, including estimation of biomass, carrying capacity, and resilience; and 3) ecology of species that interact with Pacific cod, including estimation of interaction strengths, biomass, carrying capacity, and resilience.

## BSAI Yellowfin sole

Genetic studies are needed to confirm the assumption that Yellowfin Sole consist of a single stock throughout the Bering Sea. Additional studies of maturity at age throughout the range of Yellowfin Sole (including the northern Bering Sea) are also warranted.

In addition, research is needed to study the spatial variation in juvenile flatfish growth and condition in relation to habitat quality in the Bering Sea. The bottom trawl used in the Bering Sea surveys is not efficient in retaining animals of size ≤ 14 cm (Kotwicki et al, 2017). In recent studies where the 83-112 bottom trawl and the 3-m plumb staff beam trawl were fished consecutively at a survey station, the catch per unit effort (CPUE, number/hectare) of juvenile Yellowfin Sole (≤ 16 cm) estimated from the bottom trawl can be lower than the CPUE from the beam trawl by as high as an order of magnitude, or erroneously indicate absence (Yeung, unpubl. data). As a result of the low catch of small fish in the surveys, there is high uncertainty at the left tail of the age-length curve. The age-at-length from otolith analysis of juveniles collected with the beam trawl (n=84) was consistently older by 1-3 years than the estimated age using the survey-derived age-length key (Matta and Yeung, unpubl. data), suggesting that currently the age of juveniles may have been underestimated. Juvenile Yellowfin Sole are known historically to be concentrated in shallow, nearshore habitats near Kuskokwim and Togiak Bays in the EBS that are out of bottom-trawl survey range, just as the NBS surveys now showed them in high abundance in habitat of such type in Norton Sound in the NBS. Long-term, systematic survey of the nearshore with appropriate sampling gear will improve the assessment of the density and distribution of juvenile Yellowfin Sole, and the understanding of the linkages between environmental drivers, habitat quality and usage, and biomass production. Norton Sound and Kuskokwim-Togiak Bays should be focal areas of investigation for their potential importance as nurseries. These coastal areas are of high anthropogenic and environmental sensitivity, and are experiencing anomalously high water temperatures because of climate change that are likely to impact fish growth and condition. To fully assess Yellowfin Sole stock production, the level of connectivity between the EBS and NBS populations will need to be addressed with tools such as tagging, genomics, biomarkers and otolith microchemistry.

## BSAI AK Plaice

Authors suggest a genetic study on Alaska plaice stock structure throughout their range in the Bering Sea and AI.

## BSAI Northern rockfish

Little information is known regarding most aspects of the biology of northern rockfish, particularly in the Aleutian Islands. Recent genetic data suggests that the spatial movement of northern rockfish, per generation, may be much smaller that the currently-used BSAI management area. More generally, little is known regarding the reproductive biology and the distribution, duration, and habitat requirements of various life-history stages. Given the relatively unusual reproductive biology of rockfish and its importance in establishing management reference points, data on reproductive capacity should be collected on a periodic basis.

Further research on survey selectivity functional form should be investigated, with the aim of achieving estimates of survey selectivity with the use of a prior distribution. Previous assessments have consideration alternative fishery selectivity formulations (i.e., dome-shaped and/or time-varying), and this procedure could be applied to the survey as well. The aging error matrix should be investigated, as it is derived from GOA data but the slower growth in the AI may result in increased aging error if the otolith age marks are more closely grouped together. Studies on the distribution of fish in trawlable and untrawlable grounds may help refine our prior distribution of survey catchability.

## BSAI Atka mackerel

More information on Atka mackerel habitat preferences would be useful to improve our understanding of Essential Fish Habitat (EFH), and improve our assessment of the impacts to habitat due to fishing. Better habitat mapping of the Aleutian Islands would provide information for survey stratification and the extent of trawlable and untrawlable habitat.

The high variability in survey abundance and trend estimates is a major source of uncertainty in the assessment. Other approaches for analyzing the survey data such as spatial models, incorporating spatial covariates, especially those that are habitat related, into predictive estimates are research priorities. Changes in survey tow duration starting in 2002 may have resulted in a higher encounter rate for this species and may have resulted in an inconsistency in estimating the biomass over the complete time series. An evaluation of the survey data in terms of tow duration changes, survey design and the development of alternate estimation approaches possibly incorporating habitat information are research priorities.

Studies to determine the impacts of environmental indicators such as temperature regime on Atka mackerel are needed. Further studies to determine whether there have been any changes in life history parameters over time (e.g. fecundity, and weight- and length-at-age) would be informative.

## BSAI Forage

Information regarding BSAI forage fishes is very limited, so any increase in research activity would be beneficial. Areas of particular interest are:

1. Absolute abundance of capelin, eulachon, and rainbow smelt: In the GOA, the summer acoustic survey provides a reasonable estimate of capelin abundance. Unfortunately the corresponding survey in the EBS occurs outside of the main capelin distribution. Acoustic data collected during the EMA survey may provide useful information. Estimates exist from the ecosystem models but these are highly uncertain.
2. Spawning areas of BSAI eulachon: Eulachon spawning runs have been researched in the GOA but are not well known in the BSAI. Information on where eulachon spawn would be very useful for understanding the relationship of EBS eulachon to eulachon in other areas.
3. Stock structure of federally captured herring: Genetic studies to determine population structure, similar to those conducted for BSAI chinook and chum salmon, could be conducted and should include a comparison of the genetic composition of herring on overwintering grounds versus those on the spawning grounds.
4. Enhanced knowledge regarding seasonal migrations of herring: What is the reason for the high EMA survey CPUE in Norton Sound during September? A possible approach would be to use recent observer estimates of herring catches in the groundfish trawl fishery to continue the analysis of Tojo et al. (2007) and explore the seasonal migration of herring in relation to variability in climate and oceanographic conditions.
5. Enhanced knowledge of survey selectivity and catchability for capelin, eulachon, etc.; Knowledge of the effectiveness of the surveys at sampling forage species would allow us to make the most accurate calculations using the existing survey data.
6. Continued studies of how climate variability influences the abundance, distribution, and energy content of forage species in the BSAI.

Sample table summarizing categories of research priorities identified in individual 2019 SAFE report chapters.

