# Question 1.1

***What factors associated with reproduction could be studied to develop meaningful indices of reproductive potential?***

For Alaska sablefish, many unknowns with respect to reproduction and how different factors may impact the reproductive potential of the stock remains. One often hypothesized factor that impacts the reproductive potential of a given species is ***the age-diversity*** present in the population, where some studies have found including such metrics in a stock-recruitment analysis can aid in predictions of future recruitment (Marteinsdottir and Thorarinsson 1998). The impact of age-diversity is particularly important to understand because different ages may contribute disproportionately to recruitment through a variety of mechanisms, and understand these mechanisms are important for an accurate representation of reproductive potential. Some of these mechanisms can include a more protracted spawning season (e.g., Arnold et al. 2018) and more overlap in spawning among different age groups, which may better allow for recruitment processes to be hedged against variable environmental conditions or patchily distributed resources for juveniles (i.e., more likely that individuals encounter favorable conditions if spawning is protracted). Furthermore, different age-classes may exhibit alternative reproductive behaviors that may expand the spatial variability of the stock (e.g., different ages inhabit different habitats), and could facilitate a more diverse reproductive portfolio to buffer against unfavorable oceanic conditions. The factors described above can be investigated in a variety of ways, which could include electronic tagging studies for a variety of age-classes to understand how different age-classes utilize the available habitat, as well as to investigate whether they exhibit alternative reproductive strategies or spawning behaviors (Seitz et al. 2005). Other approaches could also include the incorporation of age-diversity in a stock recruitment analysis to understand whether it results in improved model performance and predictions, although this approach is unlikely to provide inference on what specific aspects of age-diversity (e.g., protracted spawning season) contributes to recruitment success.

In addition to the value of having a diverse age-structure and how that may improve reproductive potential, and hence, recruitment success, there has been recent interest in Alaska sablefish for maintain ***a more protracted age-structure, with a larger proportion of old individuals in the population***. While such interest is partially driven by socio-economic considerations, there are also some biological considerations for allowing for more older individuals in the population (i.e., maternal or paternal age effects), that could potentially benefit the reproductive potential of the stock. However, many of these factors remain unknown or sparsely studied (i.e., limited geographic scope and sampling). The value of understanding the presence of maternal age effects, its ability to impact reproductive potential and hence recruitment success, and its impact on management reference point has previously been noted (i.e., viable larvae, egg size, Murawski et al. 2001). There is generally evidence across a variety of fish species that larger and older individuals can increase provisioning to offspring, with the potential to result in increased survival rates (Arnold et al. 2018). While increased provisioning through increased egg sizes for older sablefish have been noted, these studies are limited in geographic scope and the number of samples collected (Rodgveller et al. 2016). Further studies with increased geographic sampling and number of samples collected would allow us to better understand how well this relationship holds. Laboratory studies investigating whether increased egg sizes result in larvae that are more viable (i.e., increased survival rates) are also warranted. In addition to increased egg survival rates and viable larvae, some studies have hypothesized and found that migratory pathways towards spawning grounds can be learned from following old individuals (i.e., the entrainment theory; Olsen et al. 2023). The loss of these older individuals could potentially reduce reproductive potential of the stock through a breakdown of social and migratory structures, difficulty in finding mates, stock contraction, which may subsequently reduce larval advection and impair recruitment success. However, it is currently unclear whether these effects are present within the sablefish population, and tagging studies understanding movement behaviors in conjunction with younger conspecifics are needed. Relatedly, the presence of first- and multi-time spawners could also have an impact on reproductive potential (Murphy et al. 2017), but the prevalence of this phenomenon in sablefish remains unclear. It is suggested that first-time spawners exhibit decreased success because they breed for shorter periods, are less fecund, and produce eggs that are less likely to be fertilized, coupled with lower hatch success (i.e., related to maternal age effects; Murawski et al. 2001). Laboratory experiments to validate these factors are of consequence in determining the reproductive potential of sablefish, which current methods fail to consider given a lack of information. Thus, investigations into the potential and prevalence for maternal age-effects in sablefish are crucial for understanding the impacts of having larger older individuals in the population may impact the subsequent reproductive potential of the stock.

Currently, the reproductive potential of Alaska sablefish stock is assessed using metrics of spawning biomass (sum of maturity, number of females-at-age, and female weight-at-age multiplied). However, this is a simple proxy for egg production/reproductive potential and assumes that egg production scales proportionally to spawning biomass (i.e., such that relative fecundity is constant across ages; isometry). In Beverton-Holt’s initial formulation of their stock-recruitment function, ***egg-production*** was utilized for reproductive potential instead of spawning biomass, which assumes that density-dependence occurs at young ages. Thus, the formulation of spawning biomass as reproductive potential is not consistent with their original formulation/theory and metrics that include egg production to characterize reproductive potential should instead be used. This is particularly important because egg production might not scale proportionally to spawning biomass (i.e., hyperallometry; Marshall et al. 2021). In particular, some studies have found for sablefish that relative fecundity decreases with age, and further studies with increased sampling efforts and geographic scope are needed to further confirm these findings (Rodgveller 2018a). The assuming of constant relative egg production as a proxy for reproductive potential could be problematic if relative egg production declines with age, because it could result in an overestimate of the reproductive potential of the stock.

Another key aspect of reproduction that needs to be better understood in Alaska sablefish is in regards to the prevalence of ***skipped spawning***, which can commonly occur in many marine species (Rideout and Tomkiewicz 2011). Skipped spawning appears to be a plastic trait in marine teleost fish and is likely a plastic trait in Alaska sablefish as well. In particular, variation in skipped spawning rates between 2011 and 2015 has previously been detected (Rodgveller 2018a), which is likely associated with prevailing environmental conditions, often linked to food availability (poor feeding conditions), coupled with energetic demands and costs associated with reproduction. Thus, the decision to skip-spawn is likely a trade-off between lifetime reproductive potential, natural mortality, and energetic costs associated with spawning activities (e.g., migration, development of oocytes, energetic demands associated with courting behaviors). However, additional histological studies with expanded sampling effort and geographic scope (recognizing that this requires a substantial resources) are needed to better understand the frequency of skipped-spawning across the entire population, the factors influencing skipped-spawning (i.e., oceanographic features), and how skipped spawning relates to age. In particular, there is conflicting evidence as to whether skipped spawning increases or decreases with age in Alaska sablefish (Rodgveller et al. 2016; Rodgveller 2018a). Increased histological samples that are representative for the entire population will be consequential for the assessment of reproductive potential of the stock, where current metrics will likely overestimate reproductive potential if they fail to account for dynamics associated with skipped spawning (Rodgveller et al. 2016).

Lastly, the reproductive potential (simplifying to discuss ***age or size-at-maturity*** here) of sablefish likely ***varies over time***. Size-at-maturity has been shown to vary for Baltic Sea Cod, which was related to spawning biomass and number of recruits entering the population (i.e., intra-specific competition), and environmental conditions (i.e., impacts food availability and metabolic conditions) (Cardinale and Modin 1999). With consideration of recent high recruitment events occurring in the fishery, we would *a priori* expect a larger size-at-maturity at increasing population sizes due to increased intra-specific competition, likely because individuals have insufficient energy to allocate energy towards reproduction, while simultaneously allocating energy towards somatic growth and maintenance. These factors are likely to also play a potential role in the prevalence of skipped spawning. Nevertheless, targeted modelling studies are needed to better understand how and why maturity-at-age or sizes vary over time (i.e., linking environmental and population-related covariates to predicting maturity over time), although such studies could potentially be confounded by genetic selection of earlier or later maturing individuals. Assuming time-invariant maturity will lead to a mischaracterization of the reproductive potential of the stock.

# Question 1.2

***What are some of the highest priority data that should be collected and evaluated?***

Considering the different important factors influencing reproductive potential, I believe that the following data sources should be collected and evaluated, which is in order of importance: 1) skipped spawning histological information, 2) accurate annual maturity information, and 3) fecundity and egg production dynamics.

As discussed above, skipped-spawning has been observed to occur in Alaska sablefish. However, there are still many unknowns with respect to their underlying dynamics and previous studies have been limited to small sample sizes collected near Kodiak Island (Rodgveller et al. 2016; Rodgveller 2018a). As such, ***increased frequency (ideally annual) of histological samples of sablefish gonads*** (generally detected through a thicker ovarian wall) would be of high priority, to understand the prevalence of skipped spawning, how it varies across ages, time, and spatial regions, and environmental drivers that may impact an individual’s decision to skip-spawn. However, recognizing that collecting histological information can be time-consuming and expensive (Rodgveller 2018b), it would perhaps be beneficial to develop other more cost-effective methods for assessing the prevalence of skipped-spawning. In particular, studies have utilized alternative metrics such as 17 estradiol to assess the prevalence of skipped spawning (Rideout and Tomkiewicz 2011). Formulating predictive relationships (if they are present) between concentrations of 17 estradiol and other factors (e.g., size, age, other reproductive indices) along with histological samples of skipped-spawning could potentially prove to be a cost-effective method for evaluating the presence and prevalence of skipped spawning in the long term. Other metrics such as water-soluble proteins to infer skipped spawning has also been used (lower water soluble proteins can be inferred to be a result of mass atresia; Rideout and Tomkiewicz 2011), although the collection of these data are unlikely to be of utility for sablefish, given that they exhibit the “resting” type of skipped spawning.

Additionally, it is fairly well understood that macroscopic maturity examination of gonads for sablefish and many other species is an imperfect method and can result in inaccurate maturity classifications. In particular, studies have found that when comparing macroscopic examinations to those collected from histological samples, macroscopic methods will often underestimate the age-at-50% maturity, which will result in an overestimation in reproductive potential if these data are utilized in a stock assessment context. Consequently, some high priority data that should be ***annually*** collected are ***accurate maturity classifications***. The collection of these data will not only allow for the estimation of maturity that is accurate but provides us with the available data that allow us to accurately characterize whether maturity varies as a function of time and factors influencing time-varying maturity, providing a more accurate index of annual reproductive potential, and information as to whether extra precaution for harvest recommendations is required under certain environmental conditions. Accurate maturity classifications can be collected through a variety of methods, which are discussed below following the order of most to least time-consuming and expensive, with further considerations also discussed. Firstly, as noted above, histological samples are the most straightforward method to accurately determining maturity classifications but can be quite time-intensive and expensive. Thus, alternative practical methods are needed for this endeavor. Another potential fruitful avenue that could be explored is the collection of auxiliary information that could help complement traditional macroscopic maturity classifications that could be used to formulate predictive relationships. Such information could include hepatosomatic indices (HSI; liver condition), condition indices (weight/length^beta), gonadosomatic indices (GSI), and % dry weight of either muscles or livers. These metrics have been shown to be useful in inferring the reproductive status of a given individual (Guzmán et al. 2017; Wuenschel et al. 2019), and has also been shown to result in predictions of maturity that can correspond closely to classifications made from histological samples (Rodgveller 2019). Lastly, obtaining accurate maturity classifications can include utilizing standardized macroscopic methods, where a single scientist with experience in sablefish maturity classifications determines maturity status using photographs of sablefish gonads (Rodgveller 2018b). However, while the standardized macroscopic method is more accurate and cost-effective, it places burden on a single person/group, where the knowledge of determining maturity classifications can be lost if these groups get dissolved, or the person retires (i.e., similar problems to an aging program). Of the alternative approaches discussed here, the last method would likely be the most preferable (standardized macroscopic), but I do note that all of these alternative methods are more expensive than the current methods for collecting maturity information (which are not even utilized in the assessment!).

Finally, Beverton and Holt’s initial formulation of a stock-recruitment relationship and metrics associated with reproductive potential utilized egg production and assumed that all eggs had an equal chance of surviving. Furthermore, current practice is to utilize spawning biomass as a proxy for egg production, given that fecundity (number of eggs produced) data are seldom available. However, several aspects of these assumptions can potentially be inappropriate. In particular, the assumption that all eggs have an equal chance of surviving is likely inappropriate, because larger eggs are generally thought to result in higher hatching success and survival rates of larvae. However, information regarding the size of eggs in relation to size or age for sablefish (collected through traditional gravimetric methods) is generally sparse and collected at small spatial scales (thought to be larger for larger individuals; Rodgveller et al. 2016) and further expansion of sampling effort is needed to understand the representativeness of these studies. Additionally, egg to larvae survival studies for sablefish are lacking, which is quite surprising given that some regions utilize sablefish for aquaculture purposes. Information regarding how maternal age effects may be conferred to eggs and larvae (i.e., larger egg sizes) may impact subsequent recruitment success are necessary to better understand the potential for the disproportionate contribution of different age-classes to the reproductive potential of the stock. In addition, the current practice of utilizing spawning biomass as a proxy for reproductive potential assumes that relative fecundity remains constant across ages. Although studies for other species have shown that the use of spawning biomass or fecundity as an index of reproductive potential does not result in substantial differences in resultant management advice (Murawski et al. 2001), there still remains conflicting evidence as to whether this relationship is appropriate for sablefish. Current evidence is conflicting given low samples and limited geographic scope of targeted studies (Rodgveller 2018a). Obtaining a fecundity-age or fecundity-size relationship that is representative of the entire sablefish population is necessary to accurately characterize the reproductive potential of the stock, particularly if the fecundity-spawning biomass relationship does not scale proportionally, which could lead to over or underestimation of reproductive potential. For example, if relative fecundity increases with age and the age-structure of the population shifts towards young individuals, reproductive potential will likely be overestimated (Witthames and Marshall 2008).

# Question 2

***Utilizing different study platforms: no-cost, specially-designed field sampling, and lab studies, design one approach per platform that could be used to initiate the development of potentially meaningful indices of reproductive potential. The positives and limitations of each platform should be considered. Include your preferred sampling season(s) given the reproductive cycle of sablefish in Alaska, the sampling frequency needed to start and continue the index, and the ideal and practical spatial distribution of sampling for each. Studies can be combined if more than one platform should be utilized for a single goal.***

In line with my recommendations above, the sampling designs and platforms utilized to collect meaningful indices of reproductive potential will focus on the study of ***skipped spawning, accurate maturity classifications, and fecundity/egg-production dynamics*** ***to develop meaningful an aggregate and comprehensive index of reproductive potential.*** Below, I will detail sample collections from 3 different study platforms (i.e., justifications when and where collections occur), assuming that cost is no object. ***These include: 1) fishery-dependent data from at-sea observers, 2) a fishery-independent survey, and 3) a charter vessel.***

I will first describe the initiation of spawning and the reproductive cycle before detailing why certain platforms sample during particular months. In general, sablefish will begin oocyte development during March to April, where development is initiated as a cohort (i.e., determinate fecundity). From May to July, vitellogenesis begins and yolk proteins recruit into oocytes (i.e., they get larger), and from July – September, ovarian follicles begin to increase in diameter due to continued vitellogenesis. From about September to December, sablefish will initiate late-vitellogenesis where their gonads are relatively enlarged. Spawning tends to occur approximately from Janurary to March (late winter to early spring) where eggs are released over a short period in batches (Guzmán et al. 2017; Rodgveller 2018b). Given the reproductive cycle of sablefish, the assessment of macroscopic and microscopic maturity states has been shown to be the most accurate periods after late August (Rodgveller 2018b), because most individuals would have oocytes recruited and in large sizes (i.e., most oocytes are in the mid-vitellogenesis stage). By contrast, macroscopic methods to determining maturity states are least accurate during summer months (i.e., June – July) because oocytes in individuals may still be in the initial developing stages such that gonads are markedly distended or that oocyte development could be delayed. Detection of skipped spawning via histological samples is also most likely to be accurate during periods after late August, which is typically characterized with the presence of a thick ovarian wall but a lack of vitellogenic oocytes (Rodgveller 2018a). Furthermore, the determination of fecundity and egg diameter of individuals are most likely to accurate and representative during the months of November to December, considering that egg sizes have likely reached their maxima (i.e., in late stage vitellogenesis) and that sampling occurs prior to peak spawning, such that most eggs are still retained within the body cavity of individuals and have yet to be released (Mason et al. 1983; Guzmán et al. 2017).

Considering that the assessment of maturity using standardized macroscopic methods is most accurate following the months of late August, and the constraints of the fishing season (mid-March to mid-November), ***I would begin the collection of standardized macroscopic maturity samples (i.e., photographs classified by an expert) during the months of late August to mid-November via fishery-dependent data with at-sea observers. Ideally, sample collections would occur on an annual basis because maturity ogives can vary as a function of population size and environmental conditions. Furthermore, it would also be ideal to sample across the entire fished distribution of sablefish following the sampling design of the observer program (i.e., from Southeast to Bering Sea; although preferably with more samples in Bering Sea and Aleutian Islands compared to the current deployment effort)*** to ensure that maturity samples are representative of the fished population and to allow for the accurate characterization of changes in sablefish maturity. Additionally, standardized maturity samples would be collected for individuals that are subsampled for otolith extraction, such that the necessary age, size, weight, and maturity information (as well as geospatial information; more on how I will use this information later) are collected and allow for the estimation of maturity ogives. Given that sample collections here result from fishery-dependent data, there are ***several caveats***. In particular, sampling of biological information is ***not collected in a systematic manner***, where harvesters may ***preferentially sample larger individuals, target known spawning areas***, ***or utilize different sampling methods*** that could potentially bias the estimation of maturity. Furthermore, ***harvest patterns are unlikely to encompass the entire distribution of sablefish*** given constrains with weather, distances to port, and *a priori* knowledge of where sablefish abundance, which could result in maturity samples that are not necessarily representative of the entire population of sablefish. However, there are several benefits for collecting maturity information via a fishery-dependent platform. In particular, samples from fishery-dependent data generally outnumber those collected from fishery-independent surveys and are considered to be more inexpensive***. Developed products resulting from these samples will include an accurate characterization of maturity-at-age and time***, which can be utilized to provide a more representative index of reproductive potential in the current stock assessment framework. However, as I note above, these samples suffer from issues pertaining to fishery-dependent data, which I will address in the in a later section (2 sections from here).

To complement the collection of standardized macroscopic maturity samples from fishery-dependent data, I would also collect information related to maturity and reproductive potential via a ***fishery-independent platform.*** ***Specifically, I would conduct a fishery-independent survey during the months of late August to December for the purpose of classifying skipped-spawning individuals using histological methods***. Sampling during these months to characterize skipped-spawning has been shown to be ideal because it is closer to the spawning season, where the presence of a thick ovarian wall coupled with absent vitellogenic oocytes are most likely indicative of an individual that is skipped-spawning. Similar to the collection of fishery-dependent data, it would be ***ideal for samples to be collected on an annual basis*** ***considering that skipped-spawning is most likely a plastic trait that varies as a function of the environment. Additionally, it would be ideal to be able to sample across the entire distribution occupied*** by sablefish (i.e., following the current survey design, but expanding to include annual samples from the Bering Sea and Aleutian Islands) to ensure that the characterization of skipped spawning is representative of the entire population. Similarly, histological samples would be collected for individuals that are subsampled for ageing, such that the necessary age, size, weight, and geospatial information are collected. The annual samples of skipped-spawning information across the geographic range occupied by Alaska sablefish would allow for a characterization of population-level skipped-spawning responses and how that may vary under prevailing conditions, which could be used to provide an index of reproductive potential within an assessment context. In particular, skipped spawning as a function of age and time could be modelled using functional forms. This could then be multiplied by an index of maturity-at-age and time to obtain “functional maturity”, which will likely provide a more representative depiction of reproductive potential when compared to the approach currently utilized in the assessment (i.e., spawning biomass with time-invariant maturity and no skipped-spawning). ***As an added bonus, the determination of skipped spawning would simultaneously allow for an accurate determination of maturity states as well.*** While data collection utilizing a fishery-independent platform allows for ***standardized sampling*** (i.e., same sampling protocol) to minimize biases in data collection and is generally designed such that areas that are not generally fished are indexed (i.e***., sampling is more representative of the entire population***, compared to fishery-dependent data), these sampling platforms are quite ***expensive*** and require substantial financial overhead. Furthermore, the number of ***samples collected are still comparatively fewer*** than those collected from fishery-dependent sampling. However, these increased costs could potentially be supplemented by chartering a fishing vessel and conducting a cost-recovery program, although the effectiveness of these programs could be inhibited by socio-economic conditions of the fishery (i.e., fish market conditions). In addition, to the cost of sampling and surveying a fish population, additional time and monetary costs are required for analyzing histological samples, which can be substantially higher than utilizing standardized macroscopic maturity methods. However, such methods do not allow for the determination of skipped spawning. ***Nevertheless, developed products from this sampling platform include an accurate index of skipped spawning by age and time, which can be utilized as an index for reproductive potential. Furthermore, an accurate index of maturity classifications by age can also be obtained from these histological samples under the fishery-independent platform (although see the following section).***

As detailed above, fishery-dependent data for maturity classifications can provide large sample sizes but suffer from potential issues regarding preferential sampling as well as the potential for not indexing the entire population (i.e., only fishing in abundant fishing grounds). By contrast, fishery-independent data for maturity classifications through histological samples suffer from comparatively smaller sample sizes, but standardized sampling methods are utilized from year-to-year, and indexes the entire range occupied by the species. Given that both platforms collect the same information on maturity, it would be beneficial to develop maturity ogives that simultaneously utilize information from both platforms, as opposed to developing platform-specific maturity ogives. Consequently, a single product of maturity-at-age/size that varies across time can potentially be developed by combining data from both platforms. This will allow for a broader spatiotemporal coverage of maturity classifications, where common fishing grounds and areas that are seldom targeted by the fishery but are targeted annually by the survey are encompassed, as well as increased sample sizes. However, I note that there are several complications that need to be addressed. In particular, there is: 1) uneven sampling effort from the fishery and survey, 2) potential differences in average maturity across spatial regions, 3) different gears utilized between the two platforms and within the fishery-dependent platform, and 4) different methods for characterizing maturity (standardized macroscopic vs. histological). One potential method to address these concerns could be to control for spatial and spatio-temporal differences in effort and maturity, different maturity classification methods, and gear differences through a spatio-temporal model (e.g., similar to methods of Williams et al. 2016).

Although the fishery-dependent and independent sampling platforms seek to provide accurate and representative depictions of maturity-at-age and skipped spawning-at-age, they are constrained by the use of spawning biomass as a proxy for reproductive potential/egg production. As such, it assumes that spawning biomass is proportional to the number of eggs produced, and that all eggs have an equal probability of survival. However, if egg production is not proportional to spawning biomass and if eggs have unequal probability of survival depending on size, utilizing spawning biomass as a metric of reproductive output/potential will result in bias. More generally, the total number of eggs produced from the population is more representative of reproductive potential/output than spawning biomass. ***Thus, the aims of this sampling platform are twofold: 1) develop a fecundity-at-age or size relationship for sablefish, and 2) utilizing eggs collected from this platform, conduct a laboratory experiment on the relationship of egg sizes on survival rates.*** Considering that the main objective of this sampling platform is related to egg production, sampling will take place from ***November to December***, which represent periods where egg sizes are likely to have reached their maximum diameter and that most eggs are still retained within individuals. Additionally, given that most spawning for Alaska sablefish is hypothesized to take place in the ***central and eastern Gulf of Alaska*** (Shotwell et al. 2014; Gibson et al. 2019), sampling will similarly take place in these regions ***along the continental slope***, at depths deeper than 300m (Mason et al. 1983). ***I*** ***believe that the collection of fecundity data should be conducted on an annual basis***, particularly because studies have demonstrated that the relationship of relative fecundity can potentially vary over time, in relation to food availability (Kraus et al. 2002). For this platform, I am envisioning chartering a fishing vessel and subsampling a wide-range of size-classes (given that ages are not known upon sampling), to ensure that fecundity data are available for most age-classes ***to develop a representative annual fecundity-age relationship***. Ages will then be collected for these subsampled individuals. In addition, ***a one-time laboratory experiment will also be planned***, which utilizes the fecundity data collected. Assuming that the relationship of larger/older sablefish producing larger eggs holds (Rodgveller et al. 2016), eggs will be separated by age groups (and hence egg size) and incubated in their natural temperature regimes. ***Hatch success as a function of maternal age/egg size (i.e., the percentage of viable larvae***) can then be calculated after the incubation period ends. However, collecting annual-fecundity data is likely extremely expensive and it is unclear how representative incubation conditions within the laboratory would translate *in situ*. ***Nonetheless, utilizing annual fecundity-age data and a one-time relationship with maternal age/egg size and hatch success, an index of functional/effective egg output can be produced from these experiments, which likely better characterizes the reproductive output of sablefish. Furthermore, with the information collected from the studies and platforms discussed above, an aggregate and comprehensive reproductive index can be formulated. Here, reproductive potential, which is a function of time (t) and age (a) can be written as:***

where *fec* is the fecundity at age and time relationship, *HS* denotes hatch success as a function of maternal age (and hence egg size), *SS* denotes skipped spawning, *Mat* denotes maturity and *N* is the number of females in the population, estimated by the operational stock assessment. If data were to be calculated and utilized on a platform-specific basis, several aspects of reproductive potential could be overlooked. For example, if we only utilized maturity information from fishery-dependent data, we would not have information on skipped spawning, nor would we have a comprehensive and representative index of how maturity ogives vary over time, due to sampling complications from fishery-dependent data. However, by collecting these disparate data sources across specific periods of the sablefish reproductive cycle, and combining them into a single index of reproductive potential, we are able to develop a metric that comprehensively monitors the annual reproductive status of the population.

I fully recognize that the studies designed above primarily focus on the use of reproductive indices and collection of biological information coupled with a traditional stock assessment. I believe the methods described above are best suited for sablefish, which utilizes a stock assessment to integrate all available information (e.g., age structure, fishery removals) to inform the reproductive potential of the stock. However, it is also possible to monitor reproductive potential without the use of a stock assessment. In particular, fishery-independent surveys designed to operate in a systematic manner can sample eggs in a given area. When the number of eggs sampled in a given area is divided by the average fecundity of an individual, estimates of effective spawners within this given area can be estimated. Several areas can then be sampled, and calculations can be summed to get an index of total effective spawners, and hence an index of reproductive potential. However, there are several caveats with this method, such as the fact that age-structure and differences in fecundity at age are ignored or the impact of oceanic currents to influence the distribution of eggs.

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