EVOSTC FY17-FY21 INVITATION FOR PROPOSALS
FY18 CONTINUING PROJECT PROPOSAL SUMMARY PAGE

Proposals requesting FY18 funding are due to shiway.wang@alaska.gov and elise.hsieh@alaska.gov by August 23, 2017. Please note that the information in your proposal and budget form will be used for funding review. Late proposals, revisions or corrections may not be accepted.

Project Number and Title

Project Number: 18170111-D

Title: Studies of Reproductive Maturity among Age Cohorts of Pacific Herring (*Clupea pallasii*) in Prince William Sound, Alaska

Primary Investigator(s) and Affiliation(s)

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Project Abstract

To address the lack of recovery of Pacific herring (*Clupea pallasii*, hereafter herring) in Prince William Sound (PWS), Alaska, research by the Herring Research and Monitoring (HRM) Program has been focused on improving predictive models of PWS herring stocks through observations and research. To this end, the goal of the project described here is ***to test the PWS herring Bayesian Age-Structured Assessment model's age at maturity function with empirical data***. The main objectives of the study originally proposed in FY17 are fourfold: 1) Assess the seasonal timing (spring, summer, fall, and winter) that allows for accurate determination of both previously spawned and maturing female herring, and maturing male herring, based on direct measures of gonad development to determine maturation states and the proportion of immature and mature herring per age cohort of interest (ages two through five) in PWS; 2) Assess inter-annual variability in the proportion of immature and mature herring per age cohort of interest in PWS collected at the optimal seasonal time as determined by Objective 1; 3) Couple histology results with annual scale growth information at the individual level, within specific age cohorts of interest, to understand if scale growth patterns reflect reproductive investment; and 4) Assess annual variation in herring age at maturity schedules before and after 1997 using ADF&G's PWS herring scale library. The work to be conducted in FY18 is focused only on Objective 1, namely the direct measure of reproductive maturation among PWS herring to determine the proportion of immature and mature herring for age cohorts of interest to the Bayesian Age-Structured-Assessment model (ages two through five).

EVOSTC Funding Requested* *(must include 9% GA)*

FY17	FY18	FY19	FY20	FY21	TOTAL
170.0	$172.0	165.1	169.6	173.3	850.0

Non-EVOSTC Funds to be used, please include source and amount per source:

FY17	FY18	FY19	FY20	FY21	TOTAL
0	0	0	0	0	0

**If the amount requested here does not match the amount on the budget form, the request on the budget form will considered to be correct.*

1. EXECUTIVE SUMMARY
Please provide a summary of the project including key hypotheses and overall goals, as submitted in your original proposal. If there are highlights that you would like to include from your FY17 work, please include them here. Also, please list any publications that have been submitted and/or accepted since you submitted your last proposal.

The information below is a complete description of the proposed project, which contains more information than requested by the continuing project proposal format (i.e., Procedural and Scientific Methods). The additional information is provided to ensure that all changes to the project requested by the EVOS Science Panel during the FY18 review process are outlined and contained within the body of the proposal.

Project Background
Forage fishes, known as abundant and schooling species, are critical marine ecosystem components for their role in energy transfer from lower to higher trophic levels including larger fishes, seabirds and marine mammals (Springer and Speckman 1997). Where one or a few forage fish species tend to be the principal conveyors of energy through an ecosystem, often termed *wasp-waist* (Rice 1995, Cury et al. 2000, Hunt and McKinnell 2006), these populations can often fluctuate greatly in size and even stabilize at higher or lower abundance depending on the form of ecological interactions at play - from bottom-up and top-down forcing, to interspecific and density-dependent competition (Bakun 2006).

Pacific herring (*Clupea pallasii*, hereafter herring) of Prince William Sound (PWS), Alaska are a regional example of a *wasp-waist* forage fish system that has undergone dramatic changes in population size over the last 35 years. During the 1980's, the PWS herring population sustained a commercial fishery with important subsistence and economic benefit to regional communities. Based on Alaska Department of Fish & Game's (ADF&G) Age-Structured Assessment (ASA) model at this time, biomass of PWS herring was ~60,000-110,000 metric tons (mt). Following the *Exxon Valdez* oil spill in March 1989, the PWS herring fishery remained active, but the population began a precipitous decline falling to ~20,000 mt by 1993. Herring of PWS rebounded, but then collapsed again below ~20,000 mt in 1998 following a short period of commercial harvest. Biomass of PWS herring has remained at ~20,000 mt since 1998, which is below a level that would allow a commercial catch (Pegau et al. 2013, Pegau et al. 2014, Muradian et al. 2017).

Factors underlying the initial decline in PWS herring biomass during the early 1990's and the continued lack of recovery are not well understood (e.g., Norcross et al. 2001, Thorne and Thomas 2008, Pearson et al. 2012). To enhance our understanding of the demography, ecology, and population dynamics of PWS herring, the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) supported an integrated herring restoration plan between 2009-2011 initially known as the Prince William Sound Herring Survey, which was focused on 1) identification of juvenile rearing bays, 2) understanding factors limiting herring recruitment such as abiotic and biotic environmental conditions, disease and predation, and 3) enhancing knowledge on spatial and temporal monitoring for future studies (Pegau et al. 2013). This initial program continued over five years (2012-2016) as the PWS Herring Research and Monitoring (HRM) Program with the overall goal focused on improving predictive models of herring stocks through monitoring and research with the following objectives: 1) provide information to improve input to, or test assumptions within, ADF&G's Age-Structure-Analysis (ASA) model, 2) inform the required synthesis effort, 3) address assumptions in current measurements, and 4) develop new approaches to monitoring (Pegau et al. 2014).

For the current PWS HRM program (2017-2021), the overall goal remains unchanged in that investigators plan to build off previous studies and continue to *improve predictive models of herring stocks through observations and research*. During the last five-year program, the ASA model was updated in a Bayesian framework, which can more objectively weight different datasets and provide estimates of uncertainty in model parameters and output (Pegau et al. 2014, Muradian et al. 2017). Key ASA model parameter estimates include an age at reproductive maturity function, i.e., the age at which herring spawn for the first time, which is used to estimate the total population biomass based on the age composition of the spawning population. Validating the estimated proportions of immature and mature individuals in each age class is the key objective of the study proposed here as the former and current ASA models' age at maturity function (Table 1) is not currently based on empirical data, but estimates values that allow the model to best fit the data (Hulson et al. 2008, Muradian et al. 2017).

Table 1. Age at maturity function used in former and current (Bayesian) ASA models for Pacific herring in Prince William Sound, Alaska. Values for Muradian et al. (2017) are median percent spawning and associated credible intervals.

Age	*% Spawning*	*% Spawning*	*Reference*
	1980-1996	*1997-2004*	
3	27	48	Hulson et al. 2008
4	89	75	Hulson et al. 2008
5	100	100	Hulson et al. 2008
	1980-1996	*1997-2012*	
3	39 (28, 56)	49 (37, 66)	Muradian et al. 2017
4	80 (62, 97)	90	Muradian et al. 2017
5	100 (assumed)	100 (assumed)	Muradian et al. 2017

Age at reproductive maturity is a key demographic parameter, which explains its inclusion in stock assessment models such as the ASA. At the individual level, age at maturity can shape overall lifetime reproductive success (Stearns 1992, Bernardo 1993), and therefore, contribute to stock productivity. There is some evidence that age at maturity might vary with population size. For example, Engelhard and Heino (2004a) showed that at 50% maturity Norwegian spring-spawning herring age was reduced and length increased during a period of low stock abundance in comparison with periods of higher stock abundance. The selective factors that likely contributed to this phenomenon include 1) reduced intraspecific competition for food during low abundance that resulted in enhanced growth and early onset of maturity or 2) early reproducing fish were selected for by fishing pressure - the former appears to be a more likely explanation (Engelhard and Heino 2004b).

Within the context of Pacific herring, it is generally understood that age at maturity increases with latitude from about age two off California, to age four-five in the Bering Sea, western Alaska (Barton and Wespestad 1980, Hay 1985). Given this regional variability in age at maturity, it is unclear whether the proportions of fish spawning for the first time estimated by PWS ASA models are valid (Table 1). Vollenweider and coworkers (NOAA-Auke Bay Labs) conducted preliminary studies of age at maturity among PWS herring during the previous HRM program (2012-2016) focusing on the validity of using scale growth to assess age at maturation and skipped spawning among PWS herring. There is considerable debate regarding the use of scale growth measurements as an accurate proxy of reproductive investment by herring (e.g., Kennedy et al. 2011). For example, Engelhard et al. (2003) employed this technique for Norwegian spring-spawn herring (*Clupea harengus*), which have been shown to undergo changes in the width and microstructure of annual scale growth layers in relation to the formation of gonads (see Lea 1928 and Runnstrom 1936 in Engelhard et al. 2003). Engelhard et al. (2003) demonstrated high classification success using two different techniques. However, other researchers have noted that reading errors of scales in age at maturity studies of Norwegian spring-spawn herring may have contributed to over estimation of skipped spawning by second time spawners (Kennedy et al. 2011). Similar approaches have been tested in Pacific herring. Vollenweider et al. (2017 EVOS Final Report 13120111-J) examined the scale growth technique commonly used for Norwegian spring-spawn herring in discriminating spawners from non-spawners and concluded that the approach may be extended to Pacific herring in PWS. However, aspects of the work by Vollenweider et al. (2017) was based on relatively small sample sizes.

Research by Vollenweider and coworkers included a lab study of southeast Alaska herring to determine the seasonal timing where spawned female herring could be identified using histological characteristics of ovaries. Studies confirmed that histology is an accurate method for discerning previously spawned females within three months after spawning (Vollenweider et al. 2017). Vollenweider et al. (2017) also conducted a summer only field study (2012) of female PWS herring coupling ovary maturation indices with scale growth patterns following the understanding that high energetic provisioning of gonads before the first reproductive effort results in reduced growth that is reflected in the width of scale annuli (Roff 1983, Scott and Heikkonen 2012). Vollenweider et al. (2017) found that during July 2012, immature three-year-old PWS herring not developing for spawning based on gonad maturation and ovary histology had significantly elevated scale growth relative to three-year-old herring preparing to spawn for the first time (n = 17 for age three fish, n = 166 for ages three through 11). Finally, Vollenweider et al. (2017) also examined ADF&G's long-term (1986-2013) herring scale library regarding bi-modal variability in annuli widths for specific age cohorts. With over 1,700 scale samples, analyses revealed that male and female PWS herring ages one and two showed unimodal scale growth, indicating that these fish were non-spawning, immature fish. However, male and female PWS herring ages three through six showed differentiation in scale growth patterns, which was interpreted as evidence of spawning activity.

Several aspects of the work reported by Vollenweider et al. (2017) warrant further investigation by new studies:

- First, results by Vollenweider and coworkers never reported estimates of the proportion of immature and mature PWS herring for age cohorts of interest to the ASA models, namely ages two through five (ages that bracket those that are estimated).
- Secondly, inter-annual variability in the proportion of immature and mature PWS herring for age cohorts of interest to the ASA model was not addressed.
- Finally, although Vollenweider and coworkers demonstrated that scale growth patterns reflect gonad maturation, for three year-old PWS herring and using the ADF&G PWS herring scale library (1986-2013), analyses were unable to retrospectively assess age at maturity before and after 1997, the year Hulson et al. (2008) determined maturity schedules changed for PWS herring, as all data were pooled for their analyses.

Here, proposed studies aim to build from previous research reported by Vollenweider et al. (2017). Studies are designed to test the estimated age at maturity function in the ASA models primarily using direct estimates of gonad maturity of PWS adult herring, and secondarily through the continued validation of the scale growth technique examined by Vollenweider et al. (2017). Importantly, if the scale growth technique is feasible, it would allow for the determination of age at maturity for the entire population once individuals have recruited.

Overall HRM Program and Project-Specific Goals

The overall goal of the proposed Herring Research and Monitoring Program (2017-2021) is *to improve predictive models of PWS herring stocks through observations and research*. To this end, the goal of the project described here is ***to test the PWS herring Bayesian Age-Structured Assessment model's age at maturity function with empirical data.***

First, proposed research will focus on adult female and male herring caught in PWS to provide annual estimates of the proportion of immature and mature herring for age cohorts of interest to the ASA model (ages two through five) using simple and direct measures of gonad maturation such as a gonadosomatic index (GSI) following Hay and Outram (1981), the Hjort criteria as outlined by Hay (1985), and ovary histology of females (Brown-Peterson et al. 2011). As a secondary effort, studies will continue to validate the use of scale growth measures as a technique for discerning age at maturation for both female and male herring in PWS. The advantage of using scale growth as a measure of age at maturity for herring, if accurate, is that it allows for sampling the entire population after individuals have recruited, as opposed to direct measures of gonad maturity that require sampling of younger fish that may be located differently in time or space from the spawning population.

Key Hypotheses

H1 (NULL). There is no seasonal variability (spring, summer, fall, and winter) in the determination of both previously spawned and maturing female herring, and maturing male herring, (ages two through five) based on direct measures of gonad maturation (GSI and Hjort indices, ovary histology).

H2 (NULL). For herring collected at the optimal seasonal sampling time (based on H1), there is no inter-annual variability in the proportion of immature and mature individuals. Mature female and male herring will have higher GSI and Hjort indices, and be heavier and longer than immature herring for a given age cohort.

H3. Maturation status, within a given age cohort (ages two through five), will correspond to scale growth patterns where spawned females and males based on direct maturation criteria (GSI and Hjort indices, ovary histology) will show a corresponding reduction in the width of the annual scale growth layer for that year as more energy is invested into reproduction and away from somatic growth.

H4. Age at maturity at the individual level (following H3) can be used to assess annual variation in maturity schedules before and after 1997 using ADF&G's PWS herring scale library.

Importantly, the key aspect of the scale growth technique, if validated as a measure of reproductive investment, is that by assessing scale growth of older, recruited fish, a complete past history of spawning effort can be understood. Such histories are especially critical during ages 2 through 4 when fish are maturing for the first time and might be more difficult to capture to assess direct measures of gonad maturation due to possibly being located outside the spawning population in little known areas. Thus, although development of the scale technique as a proxy of reproductive investment might be considered a risky research endeavor, should it prove valid (as preliminary work by Vollenweider et al. (2017) suggests), the technique offers a more powerful approach for sampling the entire population, unlike the capture of fish at distinct ages to assess direct measures of gonad investment.

Objectives
The objectives of the proposed research follow:

1) Assess the seasonal timing (spring, summer, fall, and winter) that allows for accurate determination of both previously spawned and maturing female herring, and maturing male herring, based on direct measures of gonad development to determine maturation states and the proportion of immature and mature herring among ages cohorts of interest (ages two through five) in PWS (FY17-18).

Although a laboratory study by Vollenweider et al. (2017) of post-spawn female herring collected in Southeast Alaska indicated that the presence of post-ovulatory follicles were a reliable indicator of past spawning activity within 3 months, I continue to test the null hypothesis so that these relationships can be established specifically for PWS herring. This proposal assumes that age 6+ fish are 100% mature and therefore are not considered in the sampling design. The proposal also assumes that evidence of gonad maturation indicates that an adult herring will in fact spawn in the spring. It is understood that for some herring systems (i.e., Norwegian Spring-Spawn herring) there is evidence that females may not abandon ovary development until very close to the spawning event (Kennedy et al. 2011). Since there is no indication late abandonment of gonad development is true for PWS herring, this proposal assumes that gonad maturation indicates that spawning will be attempted in the spring. Once the optimal seasonal sampling time is determined that best identifies past and future spawning effort (Objective 1), subsequent years (through FY21) will continue to sample at this time only to address inter-annual variability in the proportion of immature and mature herring per age cohort (see Objective 2).

2) Assess inter-annual variability (FY19-21) in the proportion of immature and mature herring in PWS collected at the optimal seasonal time as determined by Objective 1 per age cohort of interest.

3) Couple histology results with annual scale growth information at the individual level, within specific age cohorts, to understand if scale growth patterns reflect reproductive investment (FY19-21).

4) Assess annual variation in herring age at maturity schedules before and after 1997 using ADF&G's PWS herring scale library given results from Objectives 1 through 3.

The data produced by these studies will test the former and current (Bayesian) ASA models' age at maturity schedule. The proposed work builds on previous work by HRM investigators regarding age at maturity of PWS herring (Vollenweider et al. 2017). However, there are some clear differences from the past work supported by EVOSTC. First, the proposed research will primarily focus on direct measures of gonad maturation to produce annual estimates of the proportion of immature and mature herring in PWS for age cohorts of interest. The proposed research will cautiously continue to validate scale growth as a technique for discerning age at reproductive maturity among Pacific herring by increasing sample sizes of fish processed for both gonad maturation and scale growth patterns within age cohorts. Finally, should the scale growth technique prove to be reliable, future work will aim to use the approach to assign an age at maturity schedule for fish sampled before and after 1997 as part of the ADF&G scale library. The anticipated final products from this work will be a series of papers that address each of the main hypotheses outlined above, in addition to validating the age at maturity function estimated by PWS herring ASA models (Hulson et al. 2008, Muradian et al. 2017).

Procedural and Scientific Methods

Objective 1. This study will be conducted during the first two years of the five-year program. The main focus is to resolve the time of year female fish can be collected where post-ovulatory follicles (POFs) are still visible from an earlier spawning event, in addition to evidence of newly developing follicles in preparation for the next spawning event using direct measures such as histology, as well as GSI and Hjort criteria. Males will be examined for gonad maturity using GSI and Hjort criteria only. It is important to note that there is no diagnostic criteria for determining past spawning in males given the differing biology of gamete production between the sexes.

Female and male herring will be collected at four times during the year. a) During spring (March/April) collections for age, sex and length (S. Moffitt/S. Haught, ADF&G) and adult herring acoustics (P. Rand, PWSSC). These collections will take advantage of existing ship time to complete fieldwork. Specific effort will be made to temporally sample the spawning population in order to obtain representative samples from younger fish that might spawn later. b) During summer (late June/early July). c) During fall (September/October) in association with Gulf Watch Alaska (GWA) forage fish surveys (J. Moran, NOAA; M. Arimitsu and J. Piatt, USGS). And d) in in November/December as part of an independent effort by PWSSC and/or the GWA whale/forage fish survey (R. Heintz and J. Moran, NOAA). Thus, it is anticipated that there will be four collection periods including spring, summer, fall, and early winter. Examination of ADF&G's PWS herring bio-sampling database (1973-2014) will be used as a reference for locations and times of year to sample for herring. Females and males ages two through five will be targeted for collection mainly using jig and gill net gear, however a purse seine is used by ADF&G during spring spawning age, sex, and length surveys. Target sample sizes follow: age 2+ (n = 115/fish per sex, 230 fish/seasonal collection, total 920/year), age 3+ (n = 115/fish per sex, 230 fish/seasonal collection, total 920/year), age 4+ (n = 115/fish per sex, 230 fish/seasonal collection, total 920/year), and age 5+ (n = 60/fish per sex, 120 fish/collection, 480/year) resulting in a total of 3240 fish collected in each of the first two years of the study. It is important to note that in PWS, herring are considered a year older as of April 1 each year. Thus, fish collected during spring spawning (April) as age 4 fish would be the same cohort (age 4) as fish collected in the summer, fall and winter of that same year (S. Haught, ADF&G, pers. comm.).

Once collected, herring will either be flown immediately to the PWSSC laboratory for processing or be processed aboard charter vessels. First, multiple scales (4-5) per fish will be removed and mounted on slides for aging. Guidelines developed by ADF&G will direct the area scales are collected from on each fish, namely the lateral line just behind the gills (Moffitt 2017 EVOS Final Report 13120111-N). Individual fish with lengths between the ages of 2+ through 5+ as defined by ADF&G's 2008-2016 age, sex, length data (courtesy S. Moffitt ADF&G) will be further processed (Table 2).

Table 2. Length at age for male and female PWS herring following AD&G's long-term age, sex, length database.

Age	2+	3+	4+	5+
Ave. length	139.1	167.5	186.3	197.5
CI range	138.6 - 139.6	167.2 - 167.9	186.0 - 186.7	197.2 - 197.9

All herring within these ages will be measured for length (mm) and wet weight (g). Gonads will be examined and dissected from the body. Gonad maturation will be scored using the Hjort criteria following Hay (1985). A gonadosomatic index (GSI) will be developed by weighing the gonad separately where GSI = (ovary weight/whole wet weight)*100 (Hay and Outram 1981). For female herring, a small mid-section of ovary will be dissected and preserved in formalin for slide mounting and pathology analysis (H. Snyder, President and CEO, and J. Kramer, DVM, Histologistics, Worcester, MA) for discerning maturity states following criteria outlined by Brown-Peterson et al. (2011). Scales will be used to age fish using a microfiche reader. It is entirely possible that it will be difficult to meet targeted sample sizes as we do not know in advance what the age structure of fish schools are ahead of sampling. Further, spawning stocks of PWS herring have been among the lowest recorded in recent years, thus finding schools to sample may be challenging.

It is expected that females collected during the spring spawn surveys will have evidence of developed follicles as part of the current spawning event. It is unclear whether POFs will be evident at this time or not. Some proportion of females collected during summer should have evidence of POFs from the prior spring spawning event, while others may not, particularly for age 3 fish based on data by Vollenweider et al. (2017). Whether developing follicles among females, or gonads among males, for the next spring's spawning event will be evident at this time is not known. Females collected during the early fall may have the greatest potential to show both evidence of POFs from previous spawning the spring prior as well as developing follicles for the next spawning event. These collections are expected to help resolve the seasonal timing most optimal for understanding both the immediate spring season's spawning history for females and the future spring's spawning decisions of both females and males.

Objective 2. Once the optimal seasonal timing of sampling is determined by the previous studies during the first two years of the project, the following three years will focus collections on this one time period and increase the sample sizes for age 2+ through 5+ fish. Therefore, for years 3-5, samples sizes for age 2+ through 5+ fish during one collection period only will be n = 460 each for a total of 1840/year. Data will be collected in the field and at the PWSSC lab following procedures outlined above, gonad maturation will be determined by GSI and Hjort indices, and a professional pathologist will determine female maturation states based on ovary histology.

Objective 3. This study will build from the first two years of data collected where gonad maturation characteristics based on GSI and Hjort criteria, as well as histology, will be compared with annual scale growth data at the individual level within age cohorts. Fish will be processed in the field and lab as outlined above, and the individual scale annuli of both females and males will be measured using ADF&G imaging software. The key to the success of this part of the project is to be able to compare scale growth patterns from individuals of the same age cohort that have differing gonad characteristics. For example, scale growth patterns of age 3+ females that have evidence of POFs and developing follicles will be compared with other age 3+ females that have no evidence of POFs and either developing or non-developing ovaries in preparation for the following spring spawning event. The prediction is that age 3+ females with POFs would have a smaller year 3 summer growth layer in comparison with age 3+ females with no POFs. This would determine if scale growth patterns could help resolve age at reproductive maturity. This analysis will also be applied to herring age 2+ through 5+ females and males. Importantly, previous work funded by EVOSTC examined the precision of herring scale measurements demonstrating that 91-96% of the variation in scale growth was detected by second reads of scales (Moffitt 2017). This project will also conduct similar precision tests of scales collected from fish by either multiple reads of the same scales or measures of multiple scales from the same fish.

Objective 4. If it appears that ovary maturation does relate to scale growth (Objectives 1 and 3), this information will be used to assess age at maturity at the individual level for fish collected as part of ADF&G's long-term herring scale library. Specifically, the work will aim to determine if there is empirical evidence for a shift in age at maturity schedules before and after 1997, as this year is identified as a demarcation in maturity schedules in the ASA models (Hulson et al. 2008, Muradian et al. 2017).

Statistical analyses will use traditional statistics such as regression or ANOVA in an information-theoretic context (AIC, Burnham and Anderson 2002) to explore questions of interest related to age, ovary characteristics, scale growth and year. This approach would allow for determination of most parsimonious models and weighted parameter estimation, which is particularly well suited for observational studies such as the work described here.

Highlights from 2017

This project began in February 2017 with initial fieldwork conducted in April, June, and September 2017. Thus, at the time the proposal renewal was submitted (originally August 2017) the project had been underway less than six months. Therefore, since one full season of fieldwork has yet to be completed, no publications have been submitted for the current project. However, in October 2017, a publication from previously funded EVOS work regarding juvenile Pacific herring condition monitoring in PWS was accepted in the Gulf Watch Alaska/Herring Research and Monitoring Deep-Sea Research II special edition:

Gorman, K.B., T.C. Kline Jr., M.E. Roberts, F.F. Sewall, R.A. Heintz, and W.S. Pegau. 2017. Spatial and temporal variation in winter condition of juvenile Pacific herring (*Clupea pallasii*) in Prince William Sound, Alaska: oceanographic exchange with the Gulf of Alaska. *Deep-Sea Research II, http://dx.doi.org/10.1016/j.dsr2.2017.10.010.*

During spring 2017 (April), we were able to successfully collect herring from the spawning population. Specifically, we processed 937 herring ranging in age from 1 to 10 years old (only 1 fish was collected that was age 1). Because the FY17 proposal focused only on females, we only collected data for GSI and Hjort criteria on females in spring 2017. The histology results for this collection have not yet been received. Final age assignments, based on scale readings, have been determined.

During summer 2017 (June), I was unable to collect adult herring at many locations scouted throughout PWS.

During fall 2017 (September), we were able to collect 22 adult herring (approximately ages 2-5 based on length information from the field) near Port Gravina during the EVOS Integrated Predator/Prey Project. These fish were caught by jigging methods in over 100 m of water. The two schools we collected from were identified using hydro-acoustic methods led by M. Arimitsu (USGS). No other adult schools of herring were identified in PWS during this week-long cruise that conducted acoustic transects in the Bainbridge, Montague Entrance and Gravina regions.

One of the main issues for the lack of fish collected in summer and fall 2017 was simply the low density of adult herring schools currently in PWS (M. Arimitsu, pers. comm.). It was clear after the fall 2017 cruise, that coupling acoustic assessment and jigging is likely the best method for catching adult herring outside the spawning season. See further details in Changes to Project Design.

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2. COORDINATION AND COLLABORATION

A. Within an EVOTC-Funded Program
Provide a list and clearly describe the functional and operational relationships with any EVOSTC-funded Program (Herring Research and Monitoring, Long-Term Research and Monitoring or Data Management Programs). This includes any coordination that has taken or will take place and what form the coordination will take (shared field sites or researchers, research platforms, sample collection, data management, equipment purchases, etc.).

B. With Other EVOSTC-funded Projects
Indicate how your proposed project relates to, complements or includes collaborative efforts with other proposed or existing projects funded by the EVOSTC that are not part of a EVOSTC-funded program.

C. With Trustee or Management Agencies
Please discuss if there are any areas which may support EVOSTC trust or other agency work or which have received EVOSTC trust or other agency feedback or direction, including the contact name of the agency staff. Please include specific information as to how the subject area may assist EVOSTC trust or other agency work. If the proposed project requires or includes collaboration with other agencies, organizations or scientists to accomplish the work, such arrangements should be fully explained and the names of agency or organization representatives involved in the project should be provided. If your proposal is in conflict with another project, note this and explain why.

Coordination within the program

The proposed work will couple sampling during the first two years of the study with another HRM investigator leading adult herring acoustics (P. Rand, PWSSC). Further, the data will be used to validate the ASA model maturity schedule estimates (T. Branch, UW).

Coordination with other EVOSTC-funded programs

The work described here plans to build off relationships established with GWA including maximizing the forage fish (M. Arimitsu and J. Piatt, USGS) and whale survey (J. Moran and R. Heintz, NOAA) efforts to collect samples for this study.

Coordination with Management Agencies

The scale aging and growth measurement work is collaborative with ADF&G (S. Haught, ADF&G Cordova).

3. PROJECT DESIGN – PLAN FOR FY18

A. Objectives for FY18

Identify the primary objectives for your project for FY18 as submitted in your original proposal.

B. Changes to Project Design

If the project design has changed from your original proposal, please identify any substantive changes and the reason for the changes. Include any information on problems encountered with the research or methods, if any. This may include logistic or weather challenges, budget problems, personnel issues, etc. Please also include information as to how any problem has been or will be resolved. This may also include new insights or hypotheses that develop and prompt adjustment to the project.

FY18 Objectives

As identified in the original proposal, FY17 and FY18 objectives will be the same and focus on the seasonal timing of collections. Specifically, Objective 1 will be addressed in FY18:

1) Assess the seasonal timing (spring, summer, fall, and winter) that allows for accurate determination of both previously spawned and maturing female herring, and maturing male herring, based on direct measures of gonad development to determine maturation states and the proportion of immature and mature herring among ages cohorts of interest (ages two through five) in PWS (FY17-18).

Changes to Project Design

Proposal re-write

This proposal received substantial feedback from the EVOS Science Panel in September and October 2017 and the current proposal addresses issues raised during this review process. Important changes to the proposal for FY18 include the consideration of female and male herring in all aspects of the study, as opposed to the strict focus on females that was described in the FY17 proposal. Further, the FY18 proposal makes clear that the focus of the proposal is on generating direct estimates of gonad maturity of PWS adult herring to determine the proportions of immature and mature fish per age cohort of interest, and secondarily the continued validation of the scale growth technique considered by previous EVOSTC funded studies (Vollenweider et al. 2017).

Other changes to the proposal include a reorganizing of the main objectives of the study. Objective 1 now includes a winter sampling event and is explicitly focused on direct measures of gonad maturation. Objective 2 changed to consider inter-annual variation in the proportion of immature and mature fish per age cohort of interest, again using direct measures of gonad maturation. Objective 3 changed to reflect what was originally stated in Objective 2, and is focused on coupled measurements of gonad maturation and scale growth. Objective 4 changed to address possible retrospective analyses using ADF&G's scale library. Project milestones and measureable project tasks have also been updated.

Importantly, it should be recognized that several final reports for previously funded EVOS projects relevant to this proposal were not available at the time the FY17 proposal was written, namely reports by Vollenweider et al. (2017) and Moffitt (2017). However, results by both of these studies further support the work described in the original FY17 proposal, which focused primarily on coupled histology and scale growth measurements of female herring. In response to comments by the Science Panel regarding the FY18 proposal, the focus of the FY18 has now shifted to employing direct estimates of gonad maturity of both female and male herring to determine the proportion of immature and mature individuals per age cohort. In addition, consideration of existing databases will be used to help direct the timing and location of sampling efforts.

2017 fieldwork issues and proposed resolutions

Regarding fieldwork success in FY17, I was able to successfully collect herring from the spawning population during spring 2017 in adequate sample sizes across all age cohorts of interest. However, I was unable to collect herring from the non-spawning population during spring due to limited logistics, i.e., ship time or flights in regions of PWS where fish in non-spawning populations might occur. I expect to better address temporal sampling during spawning (early and late) in FY18 now that I have conducted one season of successful field collections and laboratory processing in FY17.

Although we had adequate ship time and aerial survey support during the mid-June 2017 summer sampling event, I was unable to collect adult herring at many locations scouted throughout PWS. I plan to revisit my knowledge of adult herring distribution during this time period to better direct sampling activities in order to be successful, i.e., particularly focusing on the entrances of Prince William Sound and Gravina regions based on Mary Anne Bishop's telemetry data and consideration of ADF&G's bio-sampling database for PWS herring.

After conducting the fall 2017 collections, it appears the use of hydro-acoustic methods, jigging and gillnet capture to collect herring outside of the spawning season is likely the best approach for catching non-spawning adults. These adults appear to remain at depth, unlike adults during the spawning period or juveniles that use shallow bays where cast- and gill-net techniques can catch fish.

The project will aim to collect fish during the winter, particularly leveraging field opportunities in November conducted by NOAA researchers (R. Heintz and J. Moran) and consider additional field excursions later in the winter.

4. SCHEDULE

A. Program Milestones for FY18

For each project objective listed, specify when critical project tasks will be completed, as submitted in your original proposal. Please identify any substantive changes and the reason for the changes.

B. Measurable Project Tasks for FY18

Specify, by each quarter of each fiscal year, when critical project tasks (for example, sample collection, data analysis, manuscript submittal, etc.) will be completed, as submitted in your original proposal. Please identify any substantive changes and the reason for the changes.

Project Milestones FY18

Objective 1

1) Assess the seasonal timing (spring, summer, fall, and winter) that allows for accurate determination of both previously spawned and maturing female herring, and maturing male herring, based on direct measures of gonad development to determine maturation states and the proportion of immature and mature herring among ages cohorts of interest (ages two through five) in PWS.

- March/April 2018. Collect adult herring during early and late spawning. Complete laboratory processing and send samples for histological analysis. Once data are available, including histology results, determine the proportion of immature and mature herring per age cohort of interest. Submit field and laboratory data to the AOOS data portal.
- June/July 2018. Collect non-spawning adult herring during early summer. Complete laboratory processing and send samples for histological analysis. Once data are available, including histology results, determine the proportion of immature and mature herring per age cohort of interest. Submit field and laboratory data to the AOOS data portal.
- September/October 2018. Collect non-spawning adult herring during early fall. Complete laboratory processing and send samples for histological analysis. Once data are available, including histology results, determine the proportion of immature and mature herring per age cohort of interest. Submit field and laboratory data to the AOOS data portal.
- November/December 2018. Collect non-spawning adult herring during early fall. Complete laboratory processing and send samples for histological analysis. Once data are available, including histology results, determine the proportion of immature and mature herring per age cohort of interest. Submit field and laboratory data to the AOOS data portal.
- January 2019. Begin writing a manuscript on the seasonal timing of collections and results concerning the proportions of immature and mature herring.

Measureable Project Tasks

2018	
1nd Quarter (Jan – March)	-Feb: 2017 Annual report completed and 2017 data submitted to AOOS portal. -Mar/Apr: Spring field collections, histology samples sent. -Determine the spring proportions of immature and mature herring per age cohort of interest. -Submit spring field and laboratory data to the AOOS data portal.
2rd Quarter (Apr – Jun)	-Mar/Apr: Spring field collections, histology samples sent (as noted above). -Jun/Jul: Summer field collections, histology samples sent. -Determine the summer proportions of immature and mature herring per age cohort of interest. -Submit summer field and laboratory data to the AOOS data portal.
3th Quarter (Jul – Sept)	-Aug: Renewal proposal for 2019 submitted. -Jun/Jul: Summer field collections, histology samples sent (as noted above). -Sept/Oct: Fall field collections, histology samples sent. -Determine the fall proportions of immature and mature herring per age cohort of interest. -Submit fall field and laboratory data to the AOOS data portal. -Submit abstract for 2019 AMSS meeting.
4th Quarter (Oct – Dec)	-Sept/Oct: Fall field collections, histology samples sent (as noted above). -Nov: PI meeting. -Nov/Dec: Winter field collections, histology samples sent. -Analysis for AMSS meeting presentation.

5. PROJECT PERSONNEL – CHANGES AND UPDATES

If there are any staffing changes to Primary Investigators or other senior personnel please provide CV's for any new personnel and describe their role on the project.

No changes to the Primary Investigator or other senior personnel.

6. Budget

A. Budget Forms (Attached)

Provide completed budget forms.

B. Changes from Original Proposal

If your FY18 funding request differs from your original proposal, provide a detailed list of the changes and discuss the reason for each change.

C. Sources of Additional Funding
Identify non-EVOSTC funds or in-kind contributions used as cost-share for the work in this proposal. List the amount of funds, the source of funds, and the purpose for which the funds will be used. Do not include funds that are not directly and specifically related to the work being proposed in this proposal.

A. Budget Forms

See attached for detail.

Budget Category:	Proposed FY 17	Proposed FY 18	Proposed FY 19	Proposed FY 20	Proposed FY 21	TOTAL PROPOSED	ACTUAL CUMULATIVE
Personnel	$71.5	$74.3	$79.4	$82.6	$85.2	$393.0	$ 14.6
Travel	$1.1	$1.1	$1.1	$1.1	$1.1	$5.5	$ -
Contractual	$45.0	$44.2	$34.2	$34.2	$34.2	$191.8	$ 17.6
Commodities	$2.4	$1.8	$1.8	$1.8	$1.8	$9.6	$ -
Equipment	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	$ -
Indirect Costs (*will vary by proposer*)	$36.0	$36.4	$35.0	$35.9	$36.7	$180.0	$ 9.7
SUBTOTAL	$156.0	$157.8	$151.5	$155.6	$159.0	$779.8	$41.9
General Administration (9% of	$14.0	$14.2	$13.6	$14.0	$14.3	$70.2	N/A
PROJECT TOTAL	$170.0	$172.0	$165.1	$169.6	$173.3	$850.0	
Other Resources (Cost Share Funds)	$0.0	$0.0	$0.0	$0.0	$0.0	$0.0	

B. Changes from Original Proposal

No changes in budget are requested.

C. Sources of Additional Funding

No additional sources of funding.