Statement of Work
National Oceanic and Atmospheric Administration (NOAA) Fisheries
Northeast Fisheries Science Center (NEFSC)
Population Biology Branch (PBB)
Development and Validation of Epigenetic Aging Models (DNA Methylation) for Northwest Atlantic Fish Species

1. Background

Accurate age data is critical for assessing fish stock health and determining sustainable catch limits. Traditional aging methods, which rely on counting visible growth rings on otoliths (earstones), are ineffective or unvalidated for several key species in the Northwest Atlantic Ocean. In a specific example, goosefish, the most profitable finfish fishery in the northeast United States marine region, cannot be aged by traditional means. Various alternative methods have been pursued but failed, leading to a perennial complaint by the fishing industry that rightly points out -- without sampling ages to build a demographic assessment, catch advice of goosefish is too conservative, based on the precautionary principle. The NOAA Fisheries Science Board has prioritized the development of alternative aging methods to more accurately advise policy. Recent innovations in epigenetic aging, such as measuring the accumulation of methyl groups on DNA, offer a promising alternative ageing method, which is the focus of this requirement.

2. Objective

The objective of this contract is to develop an epigenetic ageing model (an epigenetic clock) based on DNA methylation rates in a regional fish species (step 1), validate the ageing model with two (2) other regional fish species (step 2), and apply the model to a regional fish species that cannot be aged reliably (step 3). These steps follow a sequence to evaluate the proof of concept that epigenetic ageing is a solution worth pursuing, especially for species that are difficult or not possible to age using traditional methods. The contractor shall analyze tissue samples provided by the NOAA Fisheries, identify age-correlated methylation sites, and deliver predictive algorithms that can be seamlessly integrated into NOAA Fisheries' routine stock assessment workflows.

3. Scope of Work

The Contractor shall provide all personnel, equipment, materials, laboratory facilities, and bioinformatics infrastructure necessary to extract high-quality DNA, perform methylation sequencing, and develop computational age-prediction models. The final results of this requirement are for these prediction models to work with three (3) regional species which can be aged with high accuracy and precision by the NEFSC. Haddock (*Melanogrammus aeglefinus*) is prioritized for development of the initial ageing model, and Atlantic cod (*Gadus morhua*), and black sea bass (*Centropristic striata*) are prioritized for the validation step using the haddock epigenetic ageing model. Goosefish (*Lophius americanus*) is prioritized as the proof-of-concept species: impossible to age with any known accuracy using traditional methods.

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4. Tasks

The Contractor shall provide all labor, materials, equipment, supervision, training to do the following.

Task 1: Project Kickoff & Sample Coordination

Participate in a virtual kickoff meeting with NOAA Fisheries scientists to finalize the sampling protocol, data sharing plans, and project milestones.

Receive and catalog up approximately 250-350 fin clip samples for each of the species: haddock, Atlantic cod, black sea bass. Additionally, receive and catalog approximately 20-40 goosefish fin clips. Samples will be delivered in person by the NEFSC, representing a full demographic and age spectrum of the target species. An ability to develop, test, and apply using regional species is necessary for the NEFSC to contribute high-quality demographic data and samples to the vendor.

Develop project plan and timeline for lab and computational work at kickoff meeting.

- Advance haddock model and test the haddock model with Atlantic cod and blacksea bass (~July-December, 2026)
- Age a small set of monkfish (~January-June, 2027)

Task 2: DNA Extraction and Quality Control

- Extract genomic DNA from provided tissue samples using industry-standard protocols.
- Submit a Quality Assurance/Quality Control (QA/QC) plan for approval and perform rigorous QA/QC to ensure DNA integrity and sufficient concentration for downstream methylation analysis.

Task 3: DNA Methylation Sequencing

- Utilize appropriate next-generation sequencing techniques (e.g., Reduced Representation Bisulfite Sequencing, Whole Genome Bisulfite Sequencing, or custom targeted arrays) to quantify DNA methylation levels across the genome. Access to a sequencing platform with sufficient sequencing depth is necessary to develop the epigenetic aging model (e.g., NovaSeq).

Task 4: Bioinformatics and Model Development

- Process raw sequencing data to identify differentially methylated regions (DMRs) highly correlated with chronological age.
- Develop machine learning or penalized regression models (e.g., elastic net) to construct a highly accurate epigenetic clock for each target species.

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Task 5: Validation and Comparative Analysis

- Cross-validate the new epigenetic models against known-age samples or samples aged using standard, validated NOAA Fisheries otolith methods.
- Calculate error rates (e.g., Mean Absolute Error) and provide statistical confidence intervals for the models.
- Submit a draft report of these results within the context of related peer-review publications.

Task 6: Final Report & Presentation

- Finalized methodology, validated models, user guide, and a presentation to the NOAA Fisheries Science Board

Task 7 (Optional): Additional Experiments and Sampling

Option Period 1, if additional funding and additional, relevant samples are available, Option Period 1 shall be for increasing sample size and reporting on the results and discussing their implication to ageing goosefish for stock assessments. This period may also be used to incorporate complementary methods and additional species to address more refined questions. For example, this period will allow for the ability to be able to work closely with the NEFSC and other regional partners to grow live goosefish in an experimental marine culturing system. If successful, NEFSC will direct these samples to be aged with the new method developed in the base year (i.e. Fin clips will be taken repeatedly from individuals and estimated age will be evaluated against the time in the culturing system. Focus will be on collecting and growing out individuals from the middle Atlantic seaboard in the option period 1. Other than to age the monkfish held in experimental conditions, another priority species to apply the haddock, reduced-loci model is windowpane (Scophthalmus aquosus). Windowpane is a priority species because it cannot be aged reliably, and demographic data for this species is highly crucial to improve its stock assessment model. Specifically, Windowpane is a low-value, incidental catch species with their own catch limit, which when reached can shut down fishing for other species of much higher economic value. The specific number of samples will be based on what was processed in the base year. Based on current processing rates, the number of samples processed will be between 500 and 1,000 samples.

Task 8 (Optional): Additional Experiments and Sampling

Option Period 2, if funding is available, and may evolve based on the results of Option Period 1, NOAA Fisheries will continue the experimental culturing of individual goosefish, sampling fin clips at known intervals, and to validate the known age intervals against the actual sampling frequency. Effort will be made to sample and culture additional goosefish from the Gulf of Maine, as the goosefish assessment recognizes both middle Atlantic and Gulf of Maine stocks. In addition to ageing goosefish from the Sandy Hook Laboratory experiments, and the Gulf of Maine Stock, additional individuals of Windowpane also be aged (specifically to fill out older age classes that have not been sampled to date). The specific number of samples will be based on what was processed in the base year. Based on current processing rates, the number of samples processed will be between 500 and 1,000 samples.

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During this Option Period, an in-person (with virtual option) meeting on epigenetic aging will be convened to consider stock assessments implications for the new epigenetic aging method for the species that were successfully aged by this species.

Task 9 (Optional): Additional Species
Option Period 2: This will focus on developing preliminary data for a new proposal for additional species, such as sharks, which cannot be aged reliably for any species. Sampling methods in the field and laboratory would be more or less similar to previous tasks for goosefish and windowpane, scaled to account for lessons learned with those species. The goal would be to provide between 500 and 1,000 samples for processing.

5. Deliverables & Schedule

Deliverable	**Description**	**Due Date**
Project Plan **Reference section: Task 1**	Detailed methodology and timeline for lab and computational work.	30 days
Sequencing Data **Reference sections: Tasks 2-5**	Delivery of raw and quality-filtered sequencing data (FASTQ/BAM files).	6 months
Draft Report & Algorithm **Reference section: Task 5**	Initial epigenetic aging models, source code, and comparative analysis draft.	9 months
Final Report & Presentation **Reference section: Task 6**	Finalized methodology, validated models, user guide, and a presentation to the NOAA Fisheries Science Board.	12 Months

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6. Government Furnished Property (GFP)

NOAA Fisheries will provide the Contractor with biological tissue samples securely delivered in appropriate preservation buffers. The Government will also provide paired metadata for these samples, including estimated age (if known), length, sex, and catch location.

7. Place of Performance

The primary place of performance will be the Contractor's facilities for laboratory processing and bioinformatics analysis. Progress meetings and the final presentation will be conducted virtually.

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