**Fisheries and Oceans Canada (DFO)**

**Data Use Agreement for Data Collected through Joint Partnerships**

The undersigned acknowledges receiving the following data from Fisheries and Oceans Canada (DFO) and the indicated Joint Partner and agrees to the following terms and conditions governing the use of these data. The undersigned further acknowledges that the indicated Joint Partner may be made aware of this request.

Citation:

Dataset Creators:

Dataset Title:

Dataset Release Date:

Dataset Expiry Date:

Data Set Release Place:

Project Description Attached? **Yes** / No

1. The above citation shall be used in all references to these data;
2. The data may only be used for the following intended purpose;
3. The data will not be used deliberately to damage the natural environment (e.g., in cases where poaching is a concern);
4. The Dataset Creators shall be invited to review draft publications to ensure that business confidentiality is maintained and to allow for incorporation of comments from the Dataset Creators;
5. Any proposed publication shall be provided to the Dataset Creators prior to public dissemination to allow for incorporation of comments from the Dataset Creators;
6. Permission is required from the Dataset Creators for any other use;
7. Copyright and ownership of the data remains with DFO and the Joint Partner(s) as per applicable collaborative agreements;
8. The data shall not be copied, digitized, scanned, sold, licensed, leased, assigned or given to a third party without the prior approval of the Dataset Creators;
9. The data shall not be included in whole or in part in any commercial products without a licensing agreement with the Dataset Creators;
10. You recognize the limitations of the data and understand that the Dataset Creators do not warrant or guarantee the accuracy, completeness or currency of the data for any specific use;
11. Feedback on obvious mistakes in the dataset must be provided to the Dataset Creators; and
12. Use of the data provided is prohibited after the indicated expiry date.

Expected Products and Benefits to DFO:

1. Documentation of analysis in the form of a School of Resource and Environmental Management PhD Thesis by Client;
2. Copy of all software source code developed for the analysis and permission granted to DFO from the Client for use of the software;
3. Draft of primary publication(s) co-authored by Client, Client academic supervisor, Joint Partner, and DFO Personnel who contribute to the data and analyses as per accepted academic protocol.

DFO Personnel Name:

Joint Partner Personnel Name:

Client Name(s):

Address: School of Resource and Environmental Management, Simon Fraser University

8888 University Drive, Burnaby, B.C. V5A 1S6

Telephone: \_\_\_\_\_\_\_\_\_\_\_\_ Fax: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Client Signature: \_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Client Signature: \_\_\_\_\_\_\_\_\_\_\_\_ Date: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

File Number: N/A Date: \_\_\_\_\_\_\_\_SQL statement for data extraction attached? Yes / **No**

**Addendum – Data Request and Project Description**

May 15, 2017

To:

Mr. A.R. Kronlund (Rob)

Fisheries and Oceans Canada

Pacific Biological Station

Nanaimo, British Columbia V9T 6N7

RE: Pacific herring data request for REM 699 Project entitled “*Spatial Variation of Pacific Herring Productivity*”

Mr. Rob Kronlund

My name is Jessica Gill, I am a Master’s student at the School of Resource and Environmental Management (REM) at Simon Fraser University. Currently, I am developing my research on the Pacific herring spawning stocks. My research focuses on environmental variables that are affecting Pacific herring recruitment and spawning throughout the Pacific coast. Ideally, this analysis will pinpoint some of the driving forces for successful herring production.

**Research background**

There is a growing understanding among fishery scientists and fisheries managers that it may be impossible to sustainably manage fisheries without accounting for environmental effects on natural productivity (Mueter et al. 2007; Walters and Martell 2002). With increasing evidence that large-scale climate regime shifts can reorganize marine ecosystems, more research has focused on better understanding relationships between climate indices and marine fish productivity. For example, a reversal of the Pacific Decadal Oscillation during the winter of 1976-1977, which increased sea-surface temperatures in much of coastal northeastern Pacific Ocean, resulted in specifically through bottom-up forcing affecting early-life stages and subsequent recruitment of pelagic species (Francis et al. 1998; Mueter et al. 2007).

Commercial fisheries exert top-down control on the abundance of small pelagic schooling fish, and from past experience, it has been shown that this effect can be detrimental on fish stocks (Hutchings and Myers 1994). Schooling fish are often more susceptible to overfishing because their aggregating behaviour makes them vulnerable to fishing nets and this same behaviour makes it difficult to detect a decline in abundance until the stock is already depressed (Walters and Martell 2002). These characteristics can also make it challenging to distinguish natural population fluctuations from those caused by overfishing (Walters and Martell 2002).

Most current stock assessment models do not explicitly account for the effects of environmental variability, which could result in overestimating or underestimating future abundance under known productivity trends (Mueter et al. 2007). Modelling ecosystem responses to a specific climate variation is difficult to achieve due to mismatches of scale and nonlinearities (Francis et al. 1998). In addition, overfishing and anthropogenic climate change might alter the response of fish populations to the natural environmental cycles (Chavez et al. 2003; Essington et al. 2015).

Pacific herring (*Clupea pallasii*), a small pelagic schooling fish, are commercially important for the coastal communities of the northeast Pacific Ocean, have cultural importance for First Nations and Alaska Natives, and are vital components of marine ecosystems (Cox and Benson 2016; Thornton et al. 2010). Herring inhabit small bays as juveniles and pelagic habitat as adults, ranging from San Francisco Bay, California (CA) to Norton Sound, Alaska (AK). Often called forage fish, because of their important role as mediators of energy transfer from lower to upper trophic levels (Rosa et al. 2010), these species exhibit large natural fluctuations in population size that are thought to be linked to climate (Pikitch et al. 2014; Mantua and Hare 2002).

Pacific herring are managed by the nation whose territorial waters they spawn in (United States manages fish in their Exclusive Economic Zone (EEZ), Canada manages fish in their EEZ). Each U.S. state manages their commercial fisheries through their state fish and wildlife agency and British Columbia (BC) manages their commercial fisheries through the federal government, the Fisheries and Oceans Canada. This allows for flexible management of individual spawning stocks but also results in a complicated patchwork of fisheries management coast-wide. Each management authority manages their herring according to different management objectives and fishery practices. Current management policies have existed in most regions in a formal capacity since 1970, though commercial fishing of herring has been documented coast-wide since the 1860s. Herring are fished commercially in San Francisco Bay, Puget Sound, and intermittently from British Columbia to Norton Sound. Spawning stock designation occurs in three areas in California, one area in Oregon (OR), four in Washington (WA), five in BC, and six in AK (AK; Table 1). There are numerous smaller stocks in each area, with the exception of California and Oregon (Table 1). Commercial herring fisheries target both mature herring and herring roe. The majority of commercial fisheries supply adult herring and roe for human consumption or bait, though commercial spawn-on-kelp fisheries exist as well. In addition, several small scale recreational and indigenous fisheries also target adult herring and roe for traditional roe-on-kelp and roe-on-hemlock collection, providing important revenue, recreational, and cultural opportunities to coastal communities in British Columbia and Alaska.

Each state or province manages their own fisheries leading to a wide variation in harvest rates and biomass abundances throughout the Pacific coast (Figure 2). Harvest rates range from 10% to 20% of estimated spawning biomass. Some stocks are harvested consistently at 20% of estimated spawning stock biomass, in particular, the Strait of Georgia stock (DFO 2015) and the Sitka stock, with the exception of 2013 (Thynes et al. 2017). Other stocks are managed through harvest control rules where harvesting only occurs when the spawning stock biomass exceeds a set threshold level (Coonradt et al. 2017).

Despite these fairly strict harvest control rules, there are some populations that have not exceeded their threshold level for multiple years. This is the case for the Lynn Canal herring stock in Southeast Alaska, which has not been commercially fished since 1982 (Thynes et al. 2017). Similarly, the West Coast Vancouver Island (WCVI) stock was not commercially fished from 2006-2014, due to both limited spawning stock biomass and First Nations court injunctions (DFO 2015). In other regions, such as Prince William Sound, Alaska, herring stocks have had depressed biomass levels for decades and a viable spawning biomass for commercial harvest has not been observed since 1992 (Ward et al. 2017).

Environmental variability and climatic regime shifts might be causing the depressed stock size of some stocks, such as in Prince William Sound. For instance, evidence indicates that high Copper River discharge is associated with low herring recruitment, indicating a strong negative relationship between freshwater flows and recruitment (Ward et al. 2017). Timing of the spring bloom and primary productivity has also been shown to be an important link in productivity (Ward et al. 2017). Environmental variation might also be playing a role in depressed populations in Lynn Canal and the WCVI stocks. Chavez et al. (2003) found that other species of forage fish, i.e., sardines and anchovies, exhibit large population fluctuations in response to changes in the Pacific Decadal Oscillation Index. Some studies have identified sea surface temperature as the strongest influence on herring recruitment in British Columbia (Schweigert 1995) but major oceanographic changes could be detrimental or favourable to herring survival. Additionally, herring recruitment in Sitka Sound, Alaska was higher following warm, wet winters, with sea surface temperatures explaining about 40% of recruitment variation (Zebdi and Collie 1995). Recruitment of other pelagic fish species has been shown to be affected by other factors such as wind movement, thermal forcing by the atmosphere (Myers et al. 1997), upwelling (Hsieh et al. 2005), the Pacific Decadal Oscillation, and the North Pacific Gyre Oscillation (Malick et al. 2015).

**Research objectives**

My research will proceed in four work units as follows:

1. Use estimates of herring recruitment and productivity along with spatial covariation analysis to identify the spatial extent of covariation among herring populations in the northeast Pacific.
2. Use estimates of spawn timing and extent of spawn along with spatial covariation analysis to identify the spatial extent of covariation among spawning herring populations in the northeast Pacific.
3. Use hierarchical modelling to estimate the effects of several hypothesized environmental drivers of herring recruitment and spawning.

**Project members**

Supervisor:

- Dr. Sean Cox, Resource and Environmental Management, Simon Fraser University

- Dr. Mike Malick, Post-doc, Northwest Fisheries Science Center

- Dr. Ashleen Benson, Landmark Fisheries Research

**Data request:**

I would like to request the following data from the Department of Fisheries and Oceans Canada:

Research surveys:

1. The biological data from research surveys for Pacific herring, including spawning stock biomass and recruitment, for all managed herring stocks, including:
   * 1. West Coast Vancouver Island
     2. Haida Gwaii
     3. Strait of Georgia
     4. Prince Rupert District
     5. Central Coast
     6. Area 27
     7. Area 2W
2. Genetic data from research surveys, indicating the number of Rougheye, Blackspotted, hybrids (F1 and F2), and fails. Also, the fishing event data for these surveys indicating: year, month, day, management area, start latitude, start longitude, end latitude, end longitude and median depth, if that information is available.
3. Survey indices of abundance for the RE/BS rockfish complex: Hecate Strait (HS) assemblage survey, Queen Charlotte Sound (QCS) synoptic survey, QCS shrimp survey, west coast of Vancouver Island (WCVI) shrimp survey, until the most recent complete year.
4. Fishing event data for survey indices of abundance for the RE/BS rockfish complex indicating: year, month, day, management area, start latitude, start longitude, end latitude, end longitude and median depth, if that information is available.
5. Surveys age and/or length composition for the RE/BS rockfish complex, and for each species separately if it has been resolved by genetics, for all the available years.

Commercial data

1. Commercial catches for the RE/BS rockfish complex aggregated spatial and temporally, indicating: year and fishing gear for all the available years.
2. Commercial catches fishing events indicating: year, month, day, management area, latitude, longitude, and median depth of catches *subject to Privacy Act considerations*.
3. Fishery age and/or length composition for the RE/BS rockfish complex for all the available years.
4. Annual time-series of the commercial trawl CPUE (kg/h) for the RE/BS rockfish complex. If this information is not available by year, I would like to request catch (kg), effort data (h), distance travelled (km), and net opening (km) for stratum, year and tow, average vessel speed (km/h), average net width (m), area of stratum (km2), date of capture, management area and the depth and location of capture (latitude and longitude).

Additional data

1. Species compositions which are caught in research surveys (Hecate Strait (HS) assemblage survey, Queen Charlotte Sound (QCS) synoptic survey, QCS shrimp survey, west coast of Vancouver Island (WCVI) shrimp survey) and in commercial catches with the RE/BS rockfish complex; indicating year and fishing gear for the available years.

**Data purpose:**

The following describes how each of the data sources requested in the above section will be used.

**Purpose of (1):** GFBio biological data to estimate life-history parameters for the RE/BS rockfish complex, and/or for each species separately or life-history parameters estimates for the RE/BS rockfish complex, and/or for each species separately.

GFBio biological data, such as length-at-age data, maturity-at-length and weight-at-length data will be used to estimate key life-history parameters, such as von Bertalanffy growth parameters, length-weight relationship parameters, age-at-50% maturity, age-at-95% maturity, and instantaneous rate of natural mortality. These life-history parameters will be used to parametrize an operating model. The operating model will be used to simulate the population dynamic for the RE/BS rockfish complex and for each species separately. In addition, this biological information will be used to parametrize stock assessment models for data-poor fisheries (Carruthers et al., 2014; Dick and MacCall, 2011), such as the Stock Reduction Analysis (SRA), state-space surplus production models (SSPM), and delay-difference (DDM) models. These data-limited models will be tested using a simulation-estimation approach. Then, the models will be fitted to the current information for both species combined, as well as separated into discrete species/populations where possible.

**Purpose of (2):** Genetic data from research surveys, indicating the number of Rougheye, Blackspotted, hybrids (F1 and F2), and fails. Also, fishing event of these surveys indicating: year, month, day, management area, start latitude, start longitude, end latitude, end longitude, and median depth.

Genetic data for RE/BS rockfish from research surveys will be used to continue the work performed by Creamer (2015). In that study genetics-based species identifications were used to estimate proportions of Blackspotted Rockfish (out of the total RE/BS rockfish catch per set) from research survey catches. Using a linear regression analysis, the author explored the relationship of spatial and bathymetric variables to estimated proportions of Blackspotted Rockfish. In addition, Creamer (2015) investigated whether physical variables associated with the geographic locations of the catches could be used to predict the relative frequencies of RE/BS rockfish in fishery-independent abundance surveys. My study will replicate these analyses in order to estimate the proportion of RE/BS rockfish in catches and survey data, back and forward in time compared with the Creamer (2015) study. A more complete time-series of catches and survey indices by species could be obtained, and it will be used to perform a stock assessment and to obtain an updated representation of the current population status.

**Purpose of (3):** Survey indices of abundance for the RE/BS rockfish complex: Hecate Strait (HS) assemblage survey, Queen Charlotte Sound (QCS) synoptic survey, QCS shrimp survey, west coast of Vancouver Island (WCVI) shrimp survey, until the most recent complete year.

Abundance indices from surveys will be used by the assessment models to evaluate population status, estimate abundance, and BRPs for the RE/BS rockfish complex. These data will be used to fit a SRA, SSPM, and DDM models. In this study, the survey information will be analyzed to evaluate if some of these indices can be helpful as an abundance index to perform stock assessments. Haigh *et al*. (2005) pointed out that survey indices of abundance have not been used for assessing rougheye rockfish population trends, because most of them do not cover the entire depth or spatial range or the time-series are too short. However, since 2005 the survey series have been extended and their utility for stock assessment purpose will be re-evaluated..

**Purpose of (4):** Fishing event data of survey indices of abundance for the RE/BS rockfish complex indicating: year, month, day, management area, start latitude, start longitude, end latitude, end longitude, and median depth.

These data will be integrated with genetics-based species identifications to estimate proportions of Blackspotted Rockfish (out of the total RE/BS rockfish) from research survey catches. The relationship between the spatial/bathymetric variables and the proportion of Blackspotted Rockfish will be explored following the methodology by Creamer (2015) using a GLM approach.

**Purpose of (5):** Surveys age and/or length composition for the RE/BS rockfish complex, and for each species separately if it has been resolved by genetics for all the available years.

Age and/or length compositions will be used to estimate population parameters relevant for the population dynamics of the RE/BS rockfish complex. This information is used to understand the population structure and to estimate recruitment, fishing selectivity and fishing mortality (Maunder and Punt, 2013). The age or length information could contribute to improve the performance of stock assessment models. For example, if the age or length composition data are available, they could be incorporated in the SRA model or a catch-at-length (age) model could be performed.

**Purpose of (6):** Commercial catches for the RE/BS rockfish complex aggregated spatial and temporally, indicating: year and fishing gear for all the available years.

Commercial catches will be used by the assessment models to evaluate population status, estimate abundance, and biological reference points for the RE/BS rockfish complex. These data will be used to fit the SRA, SSPM, and DDM models.

**Purpose of (7):** Commercial catches fishing events indicating: year, month, day, management area, latitude, longitude, and median depth of catches *subject to Privacy Act considerations.*

This information will be integrated with genetic data and it will be used for partitioning commercial catch weight by species using the median polish algorithm, following the approach implemented by Creamer (2015).

**Purpose of (8):** Fishery age and/or length composition for the RE/BS rockfish complex, and for each species separately if it has been resolved by genetics for all the available years.

Age and/or length compositions from the fishery will be used to estimate population parameters relevant for the population dynamics of the RE/BS rockfish complex. This information is used to understand the population structure and to estimate recruitment, fishing selectivity and fishing mortality (Maunder and Punt, 2013).

**Purpose of (9):** Annual time-series of the commercial trawl CPUE (kg/h) for the RE/BS rockfish complex. If this information is not available by year, I would like to request catch (kg), effort data (h), distance travelled (km), and net opening (km) for stratum, year and tow, average vessel speed (km/h), average net width (m), area of stratum (km2), date of capture, management area and the depth and location of capture (latitude and longitude).

Catch and effort data for stratum, year and tow can be used to calculate the observed catch per unit effort (CPUE), which can be converted to CPUE densities (kg/km2) if average vessel speed (km/h), average net width (m), distance traveled (km), and net opening (km) are integrated (Haigh *et al*., 2005). CPUE densities multiplied by area of stratum (km2) can generate estimates of the annual biomass across strata. A GLM with a lognormal distribution (Quinn and Deriso, 1999) can be implemented to obtain a “Standardized” annual CPUE index. This model can include as predictor variables: date of capture, management area, and the depth and location of capture (Haigh *et al*., 2005).

**Purpose of (9):** Species compositions which are caught in research surveys and commercial catches with the RE/BS rockfish complex; indicating year and fishing gear for the available years.

One of the requirements of the third MSC principle is to maintain the integrity of the ecosystem (MSC, 2010). Therefore, it is important to account for the non-target species captured and landed in association with, or as a consequence of, the target species. A multivariate analysis will be performed to evaluate the RE/BS rockfish composition and other species caught with this species complex.

**Anticipated Outcomes of this Research:**

1. Estimates of population status and biological reference points for for the RE/BS rockfish complex (by species and combined);
2. Identify fishing objectives and performance metrics delineated by consultation with fishery industry and DFO fishery managers;
3. Simulation-tested management procedure options for the RE/BS rockfish complex and outputs that illustrate the trade-offs between conservation, economic and social objectives identified in 2;
4. Scientific publications and technical reports based on the results of the simulation-estimation analysis and the MSE for the RE/BS rockfish complex;
5. Establish the first steps toward the eco-labelling certification granted by Marine Stewardship Council (MSC);
6. Documentation of analysis in the form of a School of Resource and Environmental Management Thesis;
7. Copy of all software source code developed for the analysis and permission granted to DFO from the Client for use of the software;
8. Draft of primary publication co-authored by Client, Client academic supervisor, and DFO Personnel who contribute to the data and analyses as per accepted academic protocols.

Thank you for considering my request.

Sincerely,

Vania Henriquez

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