**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: Assessment models for cryptic rockfish species

Dataset Creators: DFO and the Joint Partner(s) as per applicable collaborative agreements

Dataset Title: Stock and fishery monitoring data for Rougheye and Blackspotted Rockfish

Dataset Release Date: May 15, 2017

Dataset Expiry Date: May 15, 2020

Data Set Release Place: Pacific Biological Station, Nanaimo, British Columbia

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.

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Vania Henriquez

April 24, 2017

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

April 24, 2017

Sean P. Cox

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

**Addendum – Data Request and Project Description**

April 24, 2017

To:

Mr. A.R. Kronlund (Rob)

Fisheries and Oceans Canada

Pacific Biological Station

Nanaimo, British Columbia V9T 6N7

RE: Rougheye and Blackspotted Rockfish data request for Mitacs Industrial Partnership Project entitled “*Fisheries stock assessment and management models for British Columbia's multispecies integrated groundfish fishery*”

Mr. Rob Kronlund

My name is Vania Henriquez, I am a PhD student at the School of Resource and Environmental Management (REM) at Simon Fraser University. Currently, I am developing my research on the Rougheye (*Sebastes melanostictus)* and Blackspotted (*S. aleutianus)* (RE/BS) Rockfish fishery. My research focuses on developing stock assessments and harvest strategies for the cryptic RE/BS rockfish sibling species complex. Stock assessment models for RE/BS require a novel approach to estimating population dynamics parameters for cryptic species based on catch and survey data for which species identification is uncertain. My work will adapt conventional assessment methods to deal with this challenge and then test the resulting methods using simulation-estimation procedures.

My research is a component of the Mitacs Industrial Partnership Project entitled “Fisheries stock assessment and management models for British Columbia's multispecies integrated groundfish fishery”. Project participants include Simon Fraser University, Wild Canadian Sablefish Ltd, the Pacific Halibut Management Association, and the Canadian Groundfish Research and Conservation Society.

**Research background**

Rougheye and Blackspotted rockfish are species with great longevity, estimated to approach 200 years (DFO, 2012). These species exhibit slow growth, low fecundity, and late maturity (McDermott, 1994). The RE/BS sibling species complex is managed as a single stock in British Columbia and until 2008 was considered to be a single species (Rougheye Rockfish). Genetic studies have demonstrated that they are two distinct species (Orr and Hawkins, 2008), although hybridization does occur (Hawkins *et al*., 2005; Gharrett *et al*., 2005). As genetics is the only method that can distinguish them accurately, data collected from commercial catches and abundance surveys represent the complex. This lack of species-specific information and their life-history traits make these species vulnerable to overfishing and population declines as a result of direct and indirect biological resource use (COSEWIC 2007; Shotwell *et al*., 2015).

This species complex was designated as species of “special concern” by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2007. Furthermore, in 2012, DFO developed a management plan establishing that the management goal for RE/BS rockfish is to maintain “sustainable population levels” within each species’ distribution range in Canadian Pacific waters (DFO, 2012). Therefore, it is necessary to address the requirements of the management plan based on stock assessment models. However, no formal stock assessment of either species has been undertaken to date and the abundance, population status, and whether or not current fishing levels are sustainable are unknown. Management actions should be considered to reduce the risk of population-level threats and these should be required at the species level because cryptic species may increase the risk of losing biological diversity (DFO, 2012). Cryptic species are typically assessed and managed as a species complex, (e.g., Rougheye and Blackspotted rockfish complex in the U.S. West Coast, South African hake, *Merluccius capensis* and *M. Paradoxus*, and Redfish complex *Sebastes mentella* and *Sebastes fasciatus* in the Canadian East Coast) but this situation can be problematic when populations exhibit differences in productivity, fishing mortality, or fishing effort (Shotwell *et al*., 2015; Rademeyer *et al*., 2008; COSEWIC, 2010).

The lack of knowledge and lack of species identification makes it necessary to develop assessment models to estimate biological reference points (BRPs) and to determine the population status, and historical exploitation rates. A simulation-estimation approach will be used to evaluate the estimation properties of alternative assessment models, and feedback simulations will be conducted to evaluate the relative performance of candidate management procedures which will include assessment models and harvest control rules. In this approach, operating models will be used to mimic the population and fishery dynamics and the interaction between the two. This will allow me to evaluate the robustness of assessment models to different assumptions (e.g., single species vs. species complex), choices of input data, and the misspecification of model components (DFO, 2009; Wetzel and Punt, 2011; Deroba and Schueller, 2013; Henriquez *et al*., 2016).

Simulation-estimation models are the first step towards the development of management strategy evaluation (MSE) for the RE/BS fishery. MSE is a robust process for evaluating expected performance of different candidate management procedures (MPs) against conservation, economic and socio-cultural objectives (Smith, 1993). This process is widely considered to be the best practice for evaluating the trade-offs of achieving the management goals given uncertainty (Punt, *et al*., 2016).

In short, MSE involves the following: (1) building an operating model and using it to simulate data of the fish population, assumptions about the stock and the fishery, and the data gathering of the fishery; (2) evaluating the stock status using an assessment model; (3) applying a harvest control rule (HCR) to determine catch limits (e.g., TAC or allowable fishing effort) based on the stock assessment; and (4) comparing different MPs to determine which one meets the desired (sometimes conflicting) objectives. In this process, industry and fishery managers will be involved in articulating goals that may balance conservation and economic interests and that may be translated into measurable objectives.

Through the simulation testing of MPs, the likelihood of identifying those that provide an adequate trade-off of management outcomes is increased. As a result, the conservation of exploited stocks can be benefited, the economic resilience of fisheries can be strengthened, and the economic value of the fishery can be enhanced. This outcome can help open the fishery to foreign markets and assist obtaining the eco-certification granted by agencies such as the Marine Stewardship Council (MSC), which is one of the objectives that the Groundfish fishery industry wants to achieve in the medium-short term. MSC certification establishes specific standards called the “Principles and Criteria for Sustainable Fishing”. These standards are used to recognize a sustainable fishery and are structured around three principles: (1) a fishery must be conducted in a manner that does not lead to overfishing or depletion of the exploited populations and, for those populations that are depleted, the fishery must be conducted in a manner that demonstrably leads to their recovery; (2) fishing operations should allow for the maintenance of the structure, productivity, function and diversity of the ecosystem (including habitat and associated dependent and ecologically related species) on which the fishery depends, and (3) the fishery is subject to an effective management system that respects local, national and international laws and standards and that incorporates institutional and operational frameworks requiring a responsible and sustainable use of the resource (MSC, 2010).

**Research objectives**

The complete Mitacs project proposal is attached with this data request. However in this project, I will develop the objective 1.3 called “*Assessment models for cryptic rockfish species*”. My research will proceed in four work units as follows:

1. Develop stock assessment models for the RE/BS rockfish fishery: assessing the RE/BS complex given uncertain species identificatlion in catch and survey data.
2. Evaluate the performance of stock assessment models for the cryptic groundfish species using simulation-estimation procedures: evaluation the effects of data lumping and splitting species on bias and precision.
3. Evaluate long-term conservation and yield outcomes for the RE/BS rockfish fishery using closed-loop simuation: simulating the long-term consequences of lumping and splitting data in the OM and testing different hypotheses about historical catch of the species complex.
4. Implement a decision-analytic approach to ranking the performance of management procedures.

**Project members**

Supervisor:

- Dr. Sean Cox, Resource and Environmental Management, Simon Fraser University and other research/academic supervisors to be determined.

Contacts at Mitacs project partner organizations:

* Mr. Chris Acheson, Executive Director, Wild Canadian Sablefish;
* Mr. Chris Sporer, President, Pacific Halibut Management Association;
* Mr. Bruce Turris, Director, Pacific Fishery Management, Canadian Groundfish Research and Conservation Society.

**Data request:**

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

Research surveys:

1. The GFBio biological data from research surveys for the RE/BS rockfish complex and/or for each species separately to estimate 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 estimations will require:
   * + - 1. Length-at-age data
         2. Maturity-at-length data
         3. Weight-at-length data
         4. Sex
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

**Literature Cited**

Carruthers, T., Punt, A., Walters, C., MacCall, A., McAllister, M., Dick, E., and Cope, J. 2014. Evaluating methods for setting catch limits in data-limited fisheries. Fisheries Research, 153:48-68.

COSEWIC. 2007. COSEWIC assessment and status report on the rougheye rockfish Sebastes sp. type I and Sebastes sp. type II in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. viii + 36 pp. ([www.sararegistry.gc.ca/status/status\_e.cfm](http://www.sararegistry.gc.ca/status/status_e.cfm)).

Carruthers, T., Punt, A., Walters, C., MacCall, A., McAllister, M., Dick, E., and Cope, J. 2014. Evaluating methods for setting catch limits in data-limited fisheries. Fisheries Research, 153:48-68.

COSEWIC. 2010. COSEWIC assessment and status report on the Deepwater Redfish/Acadian Redfish complex Sebastes mentella and Sebastes fasciatus, in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 80 pp. ([www.sararegistry.gc.ca/status/status\_e.cfm](http://www.sararegistry.gc.ca/status/status_e.cfm)).

Creamer, J. 2015. Using genetic species identification and environmental data to distinguish historical catches of cryptic Blackspotted Rockfish (Sebastes melanostictus) and Rougheye Rockfish (Sebastes aleutianus) in British Columbia. Master thesis, School of Resource and Environmental Management Faculty of Environment, Simon Fraser University.

Deroba, J. J., and Schueller, A. M. 2013. Performance of stock assessments with misspecified age- and time-varying natural mortality. Fisheries Research, 146: 27 – 40.

Dick, E. J., and MacCall, A. D. 2011. Depletion-based stock reduction analysis: a catch-based method for determining sustainable yields for data-poor fish stocks. Fisheries Research, 110: 331–341.

Fisheries and Oceans Canada. 2009. A Fishery Decision-Making Framework Incorporating the Precautionary Approach. http://www.dfo-mpo.gc.ca/reports-rapports/regs/sff-cpd/precaution-eng.htm

Fisheries and Oceans Canada. 2012. Management Plan for the Rougheye/Blackspotted Rockfish Complex (Sebastes aleutianus and S. melanostictus) and Longspine Thornyhead (Sebastolobus altivelis) in Canada [Final]. Species at Risk Act Management Plan Series. Fisheries and Oceans Canada, Ottawa. vi+ 49 pp.

Gharrett A.J., Matala A.P., Peterson E.L., Gray A.K., Li Z. & Heifetz J. 2005. Two genetically distinct forms of rougheye rockfish are different species. Transactions of the American Fisheries Society 134: 242-260.

Haigh, R., Olsen, N., and Starr, P. 2005b. A review of Longspine Thornyhead Sebastolobus altivelis along the Pacific coast of Canada: biology, distribution, and abundance trends. Canadian Science Advisory Secretariat, Research Document 2005/097, iv + 38 pp.

Hawkins S.L., Heifetz J., Kondzela C.M., Pohl J.E., Wilmot R.L., Katugin O.N. and Tuponogov V.N. 2005. Genetic variation of rougheye rockfish (Sebastes aleutianus) and shortraker rockfish (S. borealis) inferred from allozymes. Fishery Bulletin 103: 524-535.

Henrı́quez, V., Licandeo, R., Cubillos, L. A., and S. P. Cox. 2016. Interactions between ageing error and selectivity in statistical catch-at-age models: simulations and implications for assessment of the Chilean Patagonian toothfish fishery. ICES Journal of Marine Science 73 (4): 1074-1090.

Maunder, M. N., and Punt, A. E. 2013. A review of integrated analysis in fisheries stock assessment. Fisheries Research, 142: 61 – 74.

McDermott, S.F. 1994. Reproductive biology of rougheye and shortraker rockfish, *Sebastes aleutianus* and *Sebastes borealis*. Masters Thesis, School of Fisheries, University of Washington. 81 p.

MSC. 2010. MSC Fishery Standard Principles and Criteria for Sustainable Fishing. <https://www.msc.org/documents/scheme-documents/msc> [standards/MSC\_environmental\_standard\_for\_sustainable\_fishing.pdf](https://www.msc.org/documents/scheme-documents/msc-standards/MSC_environmental_standard_for_sustainable_fishing.pdf)

Orr J.W. & Hawkins S. 2008. Species of the rougheye rockfish complex: resurrection of Sebastes melanostictus (Matsubara, 1934) and a redescription of Sebastes aleutianus (Jordan and Evermann, 1898)(Teleostei: Scorpaeniformes). Fishery Bulletin 106: 111-134.

Punt, A. E., Butterworth, D. S, de Moor, C. L., De Oliveira, J. A., and M. Haddon. 2016. Fish and Fisheries. 17, 303–334.

Quinn and Deriso, 1999Quinn, T.R. and Deriso, R.B. 1999. Quantitative Fish Dynamics. Oxford University Press. 542 pp.

Rademeyer R.A., Butterworth D.S. & Plagányi É.E. 2008. Assessment of the South African hake resource taking its two-species nature into account. African Journal of Marine Science 30: 263-290.

Shotwell S.K., Hanselman D.H., Heifetz J. & Hulson P.F. 2015. Assessment of the Rougheye and Blackspotted Rockfish stock complex in the Gulf of Alaska. In Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Gulf of Alaska (pp.1103-1218). North Pacific Fishery Management Council, Anchorage, Alaska.

Smith, A. 1993. Risks of over- and under-fishing new resources. In Risk Evaluation and Biological Reference Points for Fisheries Management, pp. 261 – 267. Ed. by S. Smith, J. Hunt, and D. Rivard. Canadian Special Publication of Fisheries and Aquatic Sciences 120. 442 pp.

Wetzel, C. R., and Punt, A. E. 2011. Performance of a fisheries catch-at-age model (Stock Synthesis) in data-limited situations. Marine and Freshwater Research, 62: 927 – 936.