Estimation of fork length using cranial measurements of sablefish (*Anoplopoma fimbria*) in British Columbia

Kathryn x. Temple, Lisa C. Lacko and Kendra R. Holt and MGL person

Pacific Biological Station
Fisheries and Oceans Canada, 3190 Hammond Bay Road
Nanaimo, British Columbia, V9T 6N7, Canada

2022

Canadian Technical Report of Fisheries and Aquatic Sciences

Fisheries and Oceans Canada Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contributes to existing knowledge but which is not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter and the series reflects the broad interests and policies of Fisheries and Oceans Canada, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in the data base *Aquatic Sciences and Fisheries Abstracts*.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Rapport technique canadien des sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. II n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques de Pêches et Océans Canada, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications à part entière. Le titre exact figure au-dessus du résumé de chaque rapport. Les rapports techniques sont résumés dans la base de données *Résumés des sciences aquatiques et halieutiques.*

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre.

Les numéros 1 à 456 de cette série ont été publiés à titre de Rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de Rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de Rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Canadian Technical Report of
Fisheries and Aquatic Sciences nnn

2022

ESTIMATION OF FORK LENGTH USING CRANIAL MEASUREMENTS OF SABLEFISH (*ANOPLOPOMA FIMBRIA*) IN BRITISH COLUMBIA

by

Kathryn x. Temple and Lisa C. Lacko and Kendra R. Holt and MGL person

Pacific Biological Station
Fisheries and Oceans Canada, 3190 Hammond Bay Road
Nanaimo, British Columbia, V9T 6N7, Canada

Cat. No. Fs97-6/nnnE-PDF ISBN ISSN 1488-5379

Correct citation for this publication:

Kathryn x. Temple, L.C. Lacko and Holt K.R. and MGL person 2022. Estimation of fork length using cranial measurements of sablefish (*Anoplopoma fimbria*) in British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. nnn: v + 14 p.

CONTENTS

ABSTRACT

Kathryn x. Temple, L.C. Lacko and Holt K.R. and MGL person 2022. Estimation of fork length using cranial measurements of sablefish (*Anoplopoma fimbria*) in British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. nnn: v + 14 p.

Routine biological sampling of whole round sablefish from commercial fishing operations in British Columbia began the early 1990's. Historically, specimens were obtained through the voluntary fishery catch sampling and tag recovery programs. We investigate the potential for obtaining sex and length information using heads, rather than the entire fish. In 2016, 438 sablefish (240-1080 mm) were sampled at sea and six different fish head measurements were collected. Genetic samples (137) were obtained to develop methods of DNA-based sex identification. A pilot study occurred in 2017 with 360 head-only samples collected and sexed by a commercial vessel, followed by scientific sampling on shore. Regression analysis results reveal that all six cranial dimensions can be used to accurately predict length. However, interorbital distance was not only a good predictor of length, but samplers ranked it the most efficient to measure and easily repeatable. Genomic DNA were successfully processed for 130 of the 137 samples. Fisher sex determination was accurate xx% of the time. Given the results, the 2018 sampling collection program was modified so that returns of whole round sablefish were replaced by head-only samples with knife cuts on the operculum to indicate sex.

RÉSUMÉ

Kathryn x. Temple, L.C. Lacko and Holt K.R. and MGL person 2022. Estimation of fork length using cranial measurements of sablefish (*Anoplopoma fimbria*) in British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. nnn: v + 14 p.

1 Introduction

Biological samples of British Columbia (BC) Sablefish (*Anoplopoma fimbria*) from trap and hook & line fisheries have been collected from a fishery-based voluntary catch sampling program since 1995 (Haist and Wyeth 2001). Prior to 2018, catch samples were collected dockside from whole fish by Fisheries and Oceans Canada (DFO) port samplers and/or contracted service providers via the dockside monitoring program (DMP). In addition, tagged fish were collected whole from commercial fisheries (trap, trawl, hook & line) at the point of landing also by the dockside monioting program. Biological data collected during catch sampling included fork length and sex. In addition, otoliths were collected and archived for future ageing analyses. These data provide a fishery-dependent source of age and size composition data for the two-sex age structured operating model used as part of the BC Management Strategy Evaluation (MSE) (Cox et al. 2019, DFO 2020).

Between 2016 and 2017, DFO undertook research to evaluate the potential to switch to a 'head only' catch sampling program for Sablefish trap and hook & line fisheries. Head-only sampling allows commercial crew to collect samples directly while at sea, thereby eliminating the need to rely on port samplers for dockside data collection as well as the need for fishing vessels to store whole fish. Instead, commercial crew J-cut the fish at-sea as per commercial practice, view the gonads to determine sex, mark the sex with knife cuts on the operculum, and store the frozen head (and/or floy tag) for later sampling by science personal. The key motivation for switching to a head-only sampling programs was to increase the number and spatial distribution of fishery samples, while simultaneously maintaining the quality of biological data.

Length data from commercial fishery catch is a key input to the BC Sablefish operating model (Kendra to add citation), so switching to a head-only sampling program requires the development of methods for obtaining length information using heads, rather than the entire fish. Previous research on other fish species has shown that lengths can be accurately estimated from head dimensions (Serafy et al. 1996; Park et al. 2007), head and mandible lengths (Isermann and Vandergoot 2005), and head height to eye diameter ratio (Richardson et al. 2015). As part of the 2016 and 2017 studies, we explored relationships between Sablefish fork length and various head morphometric measurements to determine if fork length could be reliably estimated from head measurements.

In this technical report, we describe methods and results for two research investigations conducted in 2016 and 2017 as part of the evaluation of head-only catch sampling for Sablefish. Based on favourable results from these studies, the Sablefish catch sampling program switched to a head-only protocol in 2018 (Appendix xx?). A brief overview of these two studies is as follows:

1) **Experimental Study 2016** The 2016 experimental study focused on method development for head-only Sablefish sampling using fishery independent survey samples. Six different cranial measurement options were considered and evaluated as part of this study. Specific objectives were to:

    - Identify which of six different cranial measurements are reliable predictors of fork length based on logistic regression model fits.

- Evaluate each of the six cranial measurement methods based on ease of use and repeatability for science technicians.
- Assess the accuracy of sex identification by aquatic science technicians using DNA analysis

2) **Fishery Pilot Study 2017** Following promising preliminary results from the 2016 experimental study, a fishery pilot study was undertaken in 2017 to test the logistics of implementing a head-only sampling program for the commercial fishery. The pilot study involved commercial fishers collecting head samples while at-sea and recording a sex ID for each sample, followed by scientific sampling of heads on shore. Two of the cranial measurement options considered in the experimental study were dropped from the pilot study due to challenges identified at that stage. Specific objectives for the fishery pilot study were to:

- Assess ease of sample collection for commercial fishers as well as the condition of collected heads received for at-shore sampling.
- Quantify among-sampler precision for the four different cranial measurements considered using measurements from three different aquatic science technicians.

Biological samples of British Columbia (BC) Sablefish (*Anoplopoma fimbria*) have been collected from a fishery-based voluntary catch sampling program since 1995 (Haist and Wyeth 2001). Catch samples were processed by the Department of Fisheries and Oceans (DFO) port samplers and/or contracted service providers. In addition, whole tagged fish were recovered in commercial fisheries (trap, trawl, hook and line) at the point of landing via the dockside monitoring program (DMP) and sampled by Archipelago Marine Research (AMR) since the early 1990's.

These data provide a fishery dependent source of age and size composition data for the two-sex structured operating model of the coastal Management Strategy Evaluation (MSE) (Cox et al. 2019).

The sablefish head-only catch sampling and tagging program began in 2018 in an effort to improve the number of returns from fishers, maintain the quality of the biological data and expand the spatial distribution of samples. Instead of returning whole fish, commercial crew J-cut the fish at-sea as per commercial practice, view the gonads to determine sex, mark the sex with knife cuts on the operculum, and store the frozen head (and/or floy tag) for later sampling by science personal at shore.

Previous research on other fish species has accurately estimated lengths from head dimensions (Serafy et al. 1996; Park et al. 2007), head and mandible lengths (Isermann and Vandergoot 2005), and head height to eye diameter ratio (Richardson et al. 2015). In this technical report we expand on previous research and describe the results of 1) the 2016 experimental study of cranial dimensions regressed against fork length; 2) the sampler defined ease of head measurement; 3) DNA sex detection methods; and 4) the compared consistency of the 2017 pilot study head measurements.

2 Methods

2.1 Experimental Study 2016

Sablefish were randomly selected for sampling during the 2016 biennial DFO Groundfish Synoptic Bottom Trawl surveys, following a length stratified protocol. A tally of 212 fish were sampled on the West Coast Vancouver Island survey (Williams et al. 2018) and 219 fish were sampled on the West Coast Haida Gwaii survey (Nottingham et al. 2018). In addition, seven small sablefish were collected during the 2016 salmon survey (put reference here) (Figure 1).

For each selected fish, fork length, round weight, sex and maturity were recorded at sea. The heads were removed, labelled and frozen. On shore, the cranial dimensions of upper jaw (L_{UJ}), eye diameter (L_{ED}), interorbital distance (L_{ID}), snout length (L_{SL}), post orbital to preoperculum distance (L_{PP}) and post orbital head length (L_{PO}) were measured using Mitutoyo Absolute® 500-762-20 coolant proof digimatic calipers (Table 1, Appendix A). Sagittal otoliths were collected for future ageing. Fork lengths (L_{FL}) were estimated by a simple linear regression model, using the cranial measurements as a predictor variables.

At the time of sampling, each cranial dimension was evaluated by experienced samplers on a five point rating scale in terms of two distinct criteria: 1. ease of use and 2. repeatability. The ease of use metric focused on three key attributes of the measurement learn-ability (task understanding), efficiency (task-completion time) and degree of difficulty (task performance ease). The repeatability metric focused on ranking each measurement under repeated caliper placement, taking into consideration the soft and hard head tissues.

Operculum clips (DNA) were collected from the first 137 fish measured (79 male and 58 female) and forwarded to the Molecular Genetics Laboratory (MGL) for analysis and gender test development.

2.1.1 Molecular Genetics Laboratory (MGL) genetic sex-determination

DNA multiplex polymerase chain reactions (PCRs) were conducted using fluorescently labelled forward primers. X-insert and Y-insert specific primers developed by Rondeau et al. (2013) were used, but the X-insert forward and Y-nested reverse were redesigned to produce slightly smaller PCR products (Table 2). Sex specific alleles were size fractionated in an ABI 3730 capillary DNA analyzer and were scored with ABI GeneMapper using an internal lane sizing standard.

2.2 Pilot study 2017

In 2017, a pilot study was conducted with the commercial sector returning sablefish head-only samples. A total of 360 heads were collected from J-cut sablefish on a limited-entry fishery trip to the Cobb and Eickelberg seamounts (Figure 1). Each operculum was marked by commercial fishers with either one knife cut (male) or two knife cuts (female) (Appendix B).

Scientific sampling occurred on shore, with the first 99 heads of the pilot study measured by three samplers for L_{ID}, L_{SL}, L_{UJ} and L_{PP}. Given that three highly experienced technicians were used to conduct the same measurements of the each head morphometric, the Index of Average Error (IAE) (Beamish 1981) was calculated to find the most consistent cranial measurement. It is defined as:

$$IAE = \frac{1}{N}\sum_{j=1}^{N}\left[\frac{1}{R}\sum_{i=1}^{R}\frac{-X_j|}{X_j}\right]$$

where N is the number of sablefish measured for each cranial measurement, R is the number of times each cranial measurement was taken, X_{ij} is the average cranial length for the jth sablefish, and X_{ij} is the ith cranial measurement of the jth sablefish.

Fin clips (95 of 99) were forwarded to the molecular genetics lab for an audit of fisher sex determination.

3 Results

3.1 Experimental Study 2016

A total of 438 specimens comprising 222 males and 216 females were evaluated for this study. The smallest fork length of the collected specimens was 240 mm, the largest was 1080 mm, and the average was 573.3 mm (Table 3). The post orbital head length (L_{PO}) measurement was abandoned after testing 130 sablefish due to low sample quality and technical issues.

Table 4 lists the statistics of the cranial dimensions (L_{UJ}, L_{ED}, L_{ID}, L_{SL}, L_{PP}, L_{PO}) as predictors of the response variable fork length (L_{FL}). All cranial dimensions were highly correlated with fork length (Figure 2 and Figure 3). The correlation coefficient (r) was highest for female measurements of snout length (0.983) and interorbital distance (0.98) and male measurements of upper jaw length (0.974) and snout length (0.972).

The aquatic science research technicians scored interorbital distance (L_{ID}) as the highest on the five point scale for ease of use and repeatable criteria, and eye diameter (L_{ED}) and postorbital head length (L_{PO}) were scored as the lowest (Table 5). L_{ID} (narrowest distance between the eye sockets) proved the easiest measurement as the tissue could be easily compressed with the caliper jaws to obtain bone measurements. L_{ED} (anterior-posterior diameter of eye socket) proved hard to repeat on soft tissue and L_{PO} (posterior inner edge of orbit to dorsal insertion of opercle) was difficult to measure since many opercula were damaged during head removal by J-cut.

3.1.1 Molecular Genetics Laboratory (MGL) genetic sex-determinations

Genomic DNA (130 of 137 fin clips) were successfully PCR amplified to determine sex. The accuracy of sex detection by the science technicians was 92% (119/130).

3.2 Pilot study 2017

The 360 heads received from the commercial vessel were in good condition and operculum cuts worked well to indicate sex. The first 99 heads (60 from Cobb Seamount, 39 from Eikelberg seamount) were measured once by three expert science technicians for each cranial dimension of L_{UJ}, L_{ID}, L_{SL} and L_{PP} (Table 6). The cranial dimensions of L_{ED} and L_{PO} were eliminated after the results from the 2016 experimental study. The cranial measurements that produced the lowest mean error were upper jaw (L_{UJ}) and interorbial distance (L_{ID}) with IAE values of 1 % and 1.1 %, respectively (Table 6). The accuracy of the commercial fisher sex detection from the DNA gender analysis was xx% (x/95).

4 Discussion

All the cranial dimensions emerged as good predictors of fork length for sablefish. The head lengths of L_{UJ} and L_{ID} were determined to have the lowest average error when measured by three highly experienced technicians using a standardized protocol. Given that the L_{ID} measurement could also be performed accurately, repeatedly, and quickly by experienced samplers, we determined that interorbital distance (L_{ID}) should be used to predict sablefish fork lengths. As a result, in 2018, routine biological sampling procedures were modified so that commercial fisheries are now only returning head samples, rather than entire fish.

These changes have greatly reduced the burden on fishers and maintained our length composition sampling for sablefish. However, our overall goals were also intended to expand spatial distribution of samples and increase the number of samples. Unfortunately, these goals were not met given sampling challenges caused by COVID restrictions that began in early 2020. Now that travel restrictions are being lifted we are hopeful that our sampling coverage will expand improving our overall data confidence.

5 Acknowledgments

We thank Schon Acheson and Kristina Castle for lending their skilled technical expertise for this report. We also thank the crew of the Pacific Viking for participating in the pilot project.

6 Tables

Table 1. List of head dimensions for upper jaw length (L_{UJ}), eye diameter (L_{ED}), interorbital distance (L_{ID}), snout length (L_{SL}), post orbital to preoperculum distance (L_{PP}) and post orbital head length (L_{PO}) measurement descriptions and specification of caliper jaw placement. Many follow the morphological measurements described in (Shaw and McFarlane 1997). The matching images are found in Appendix A.

Head dimension	**Head description**	**Caliper jaw position**
L_{UJ}	Tip of snout to the posterior edge of the maxilla.	Outside caliper jaw measurement from forward point and centre of snout to back of maxilla.
L_{ED}	Anterior-posterior diameter of eye socket.	Inside caliper jaw measurement firmly stretched against eye socket at vertical midpoint of eye.
L_{ID}	Narrowest distance between eye sockets, measured on dorsal surface.	Outside caliper jaw measurement of the horizontal midpoint of eyes on dorsal surface.
L_{SL}	Tip of snout to anterior inner edge of eye socket.	Outside caliper jaw measurement from forward point and centre of snout to horizontal midpoint of anterior edge of eye socket.
L_{PP}	Posterior inner edge of orbit to visual insertion point of preopercle.	Outside caliper jaw measurement from back of eye socket to preopercle bone insertion point. Preopercle must be lifted to expose preopercle bone underneath.
L_{PO}	Posterior inner edge of orbit to dorsal insertion of opercle.	Outside caliper jaw measurement from back of eye socket to bone underneath gill cover notch at dorsal insertion of the opercle. The operculum must be held taut.

Table 2. Primers used in the development of a genetic test for determining sablefish sex, developed by the Pacific Biological Station (PBS) Molecular Genetics Laboratory (MGL).

Locus	**Sequence**	**Fragment Size**
X-insert-DFO_F1	6FAM-CACCGCTCATGTACACTTTG	321
X-insert-2R	TGCTGCACTGTACCATCAAA	
Y-nested-1F	NED-GTCAGAAGGCAGTGGTGTAGT	234
Y-nested-MGL_2R	CGCTTGCAGATACTACTGAATG	

Table 3. Summary of sablefish biological data collected during the 2016 experimental study. Tally of fork lengths (L_{FL}), round weights (RW), upper jaw lengths (L_{UJ}), eye diameters (L_{ED}), interorbital distances (L_{ID}), snout lengths (L_{SL}), post orbital to preoperculum distances (L_{PP}), post orbital head lengths (L_{PO}), females (F), males (M), sagittal otoliths and operculum clips (DNA) listed by survey.

Survey	**L_{FL}**	**RW**	**L_{UJ}**	**L_{ED}**	**L_{ID}**	**L_{SL}**	**L_{PP}**	**L_{PO}**	**F**	**M**	**Otoliths**	**DNA**	**Total**
2016 WCHG	219	219	219	219	218	219	207	52	111	108	219	59	219
2016 WCVI	212	212	211	212	212	211	212	78	105	107	212	78	212
Salmon	7	0	7	7	7	7	7	0	0	7	0	0	7
Total	**438**	**431**	**437**	**438**	**437**	**437**	**426**	**130**	**216**	**222**	**431**	**137**	**438**

Table 4. Statistics associated with simple linear regressions using measurements (mm) of cranial lengths: upper jaw length (L_{UJ}), eye diameter (L_{ED}), interorbital distance (L_{ID}), snout length (L_{SL}), post orbital to preoperculum length (L_{PP}) and post orbital head length (L_{PO}) as predictors of the fork length (L_{FL}) of 438 sablefish collected from research surveys in 2016. All models were significant at $P < 0.001$.

							Predictor		**Response L_{FL}**	
Cranial Measurement	**Sex**	**N**	**Slope**	**SE**	**R^2**	**r**	**Mean**	**SD**	**Mean**	**SD**
L_{UJ}	female	215	7.4	0.12	0.945	0.972	59.8	16.93	586.7	129.71
	male	222	8.1	0.13	0.949	0.974	56.2	13.16	560.3	109.45
L_{ED}	female	216	23.9	0.5	0.914	0.956	25.9	5.19	586.7	129.41
	male	222	20.1	0.51	0.877	0.936	25.9	5.09	560.3	109.45
L_{ID}	female	215	11.3	0.15	0.96	0.98	41.6	11.27	586.9	129.68
	male	222	12.2	0.25	0.916	0.957	39.2	8.59	560.3	109.45
L_{SL}	female	215	10.9	0.14	0.966	0.983	46.6	11.7	586.7	129.71
	male	222	11.9	0.19	0.945	0.972	43.1	8.93	560.3	109.45
L_{PP}	female	211	13.8	0.23	0.945	0.972	32.6	9.03	583	127.89
	male	215	15.7	0.31	0.921	0.96	30.4	6.73	559.9	109.84
L_{PO}	female	73	6.6	0.23	0.923	0.961	62.1	22.51	574.9	154.35
	male	57	7.8	0.34	0.904	0.951	59.2	12.81	555.6	104.97

Table 5. Ease of use and repeatable five point ranking scale recorded by experienced samplers for each cranial measurement for the 2016 experimental study, where 5 = Great; 4 = Good; 3 = Moderate; 2 = Questionable; 1 = Poor.

	5 Point Rank		Measurement			
Head Dimension	Ease of use	Repeatable	Caliper limitation	Bilateral	Bone	Considerations
L_{UJ}	3	4	x	x	x	End of the maxilla difficult to define. Caliper jaw position must be in center of snout.
L_{ED}	3	2		x		Caliper outside jaw position on soft tissue in eye socket may result in measurement differences.
L_{ID}	5	5			x	Tissue is compressed to obtain bone measurement. Easy to determine caliper jaw position.
L_{SL}	4	5		x	x	Caliper jaw position must be in center of snout.
L_{PP}	4	5		x	x	Caliper position on pre-operculum may result in measurement differences.
L_{PO}	3	2	x	x		Operculum damage from handling was observed on several fish.

Table 6. Summary of sablefish biological data collected from the 2017 pilot study to Cobb (n=60) and Eickelberg (n=39) seamounts, measured by three expert technicians using a standardized protocol for the 2017 pilot study. Index of Average Error (IAE) % values are reported for each of the cranial lengths.

	Sampler A	Sampler B	Sampler C	Sex		
Head Dimension	Min - Max (mm)	Min - Max (mm)	Min - Max (mm)	Males	Females	IAE
L_{UJ}	51.65 - 91.02	52.64 - 91.53	53.82 - 92.55	60	39	1
L_{ID}	35.43 - 61.18	35.91 - 60.81	34.94 - 60.72	60	39	1.1
L_{SL}	39.67 - 69.27	40.38 - 70.37	41.03 - 70.32	60	39	1.2
L_{PP}	27.69 - 49.88	26.83 - 52.51	27.25 - 52.15	60	39	2.3

7 Figures

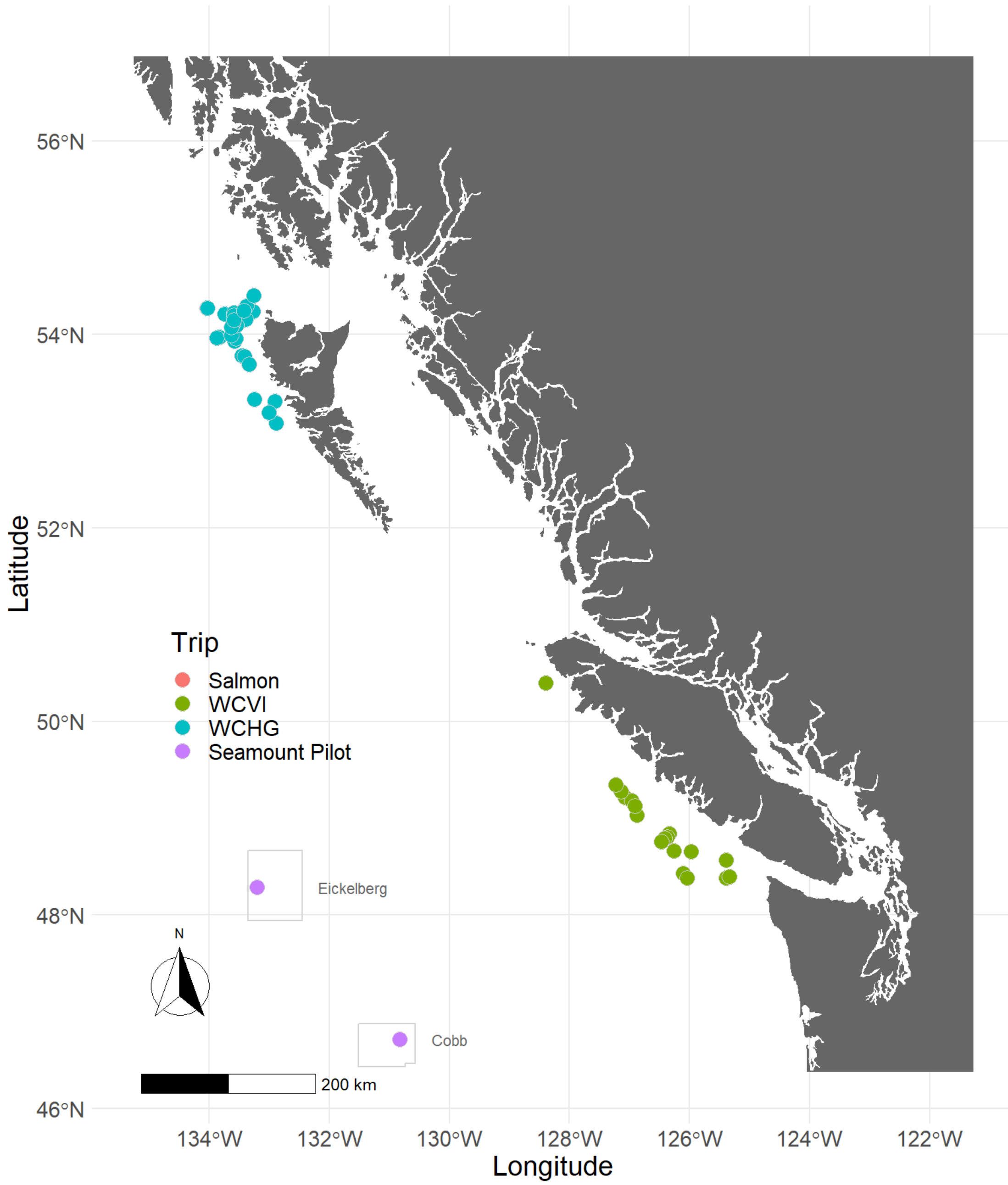


Figure 1. Sample locations from the 2016 WCVI, WCHG and salmon research surveys and 2017 pilot study.

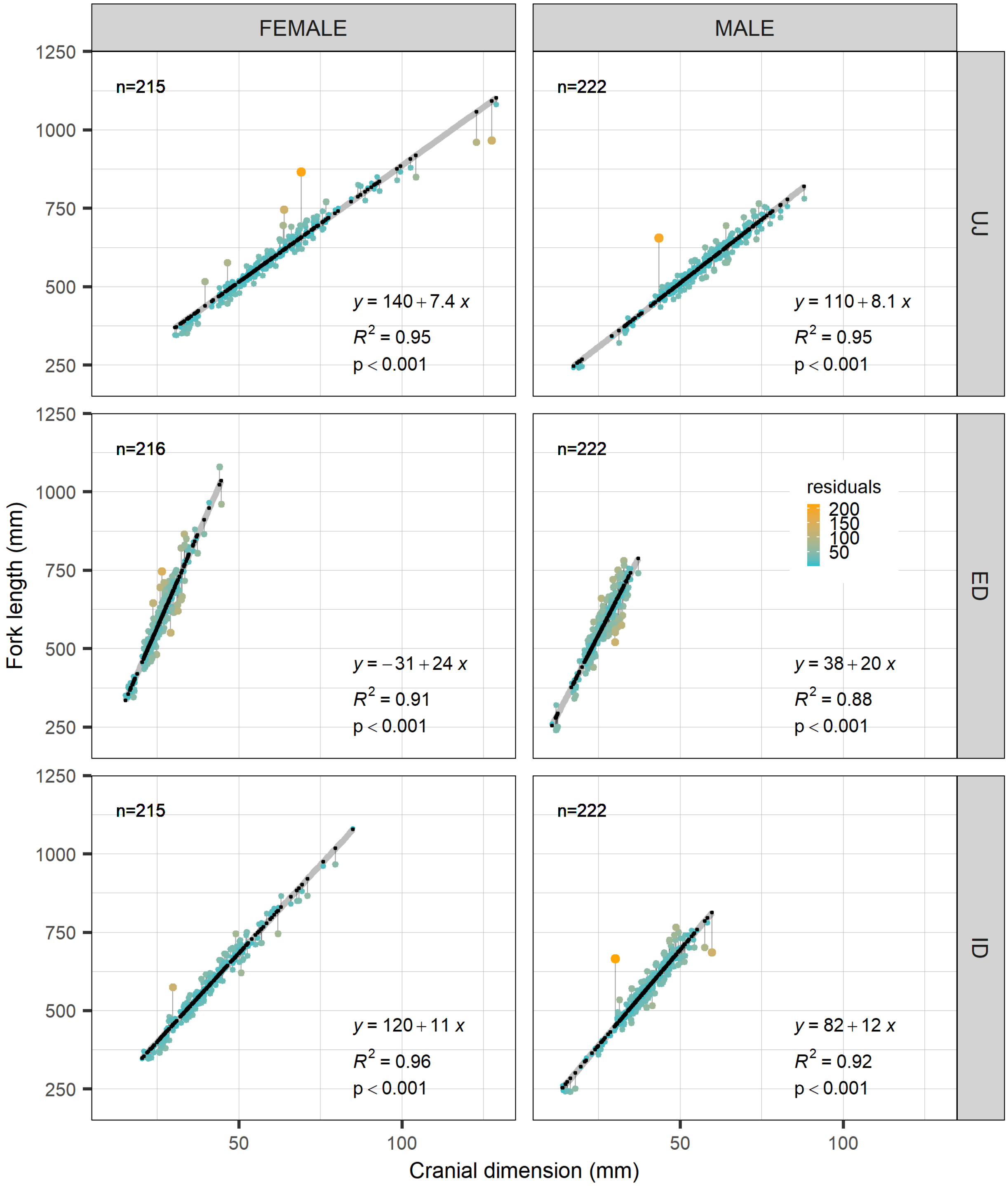


Figure 2. Relationship between cranial lengths (UJ, ED, ID) vs fork length in millimeters. Predicted points represented by black circles, measured values colored by residual scale.

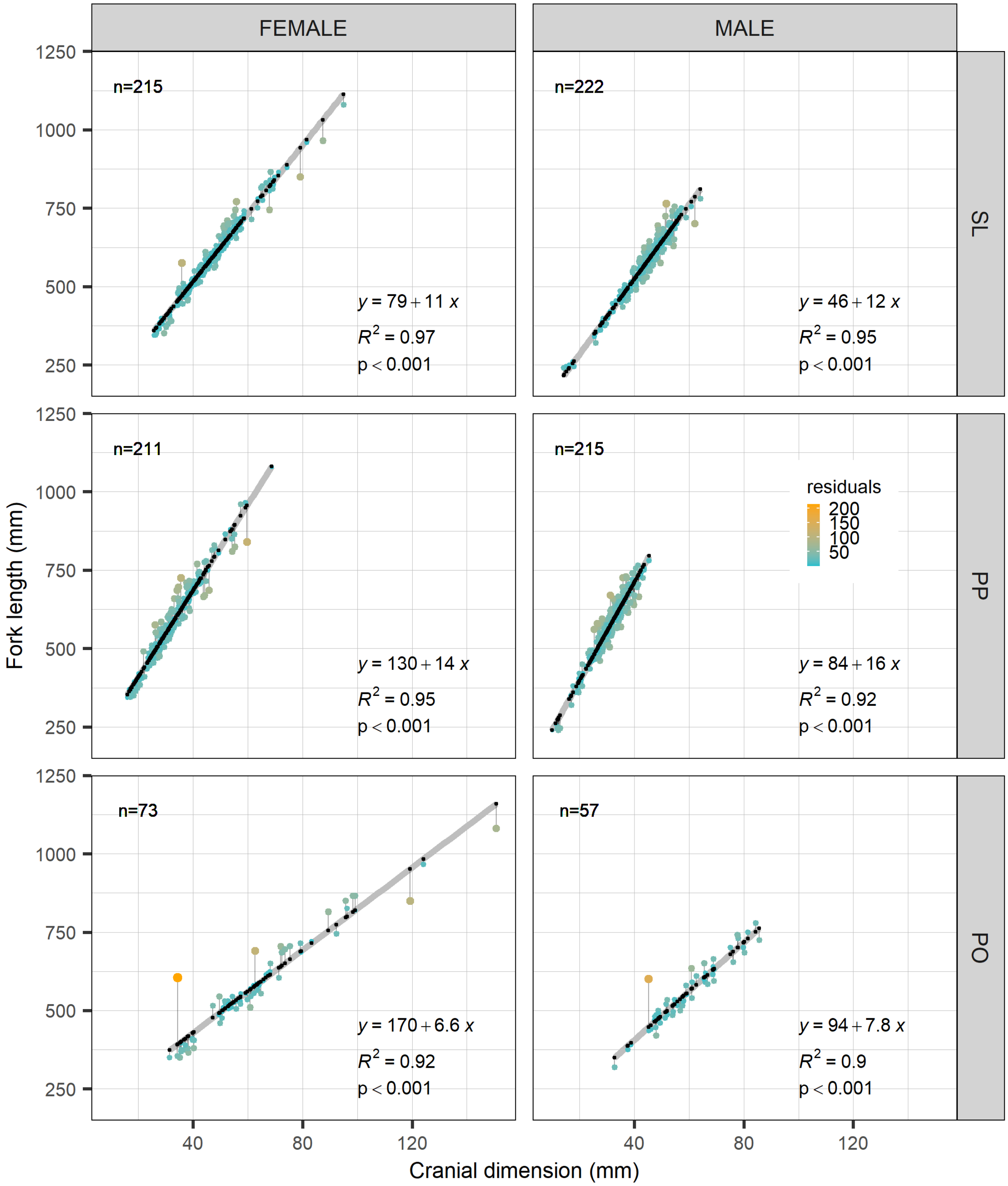
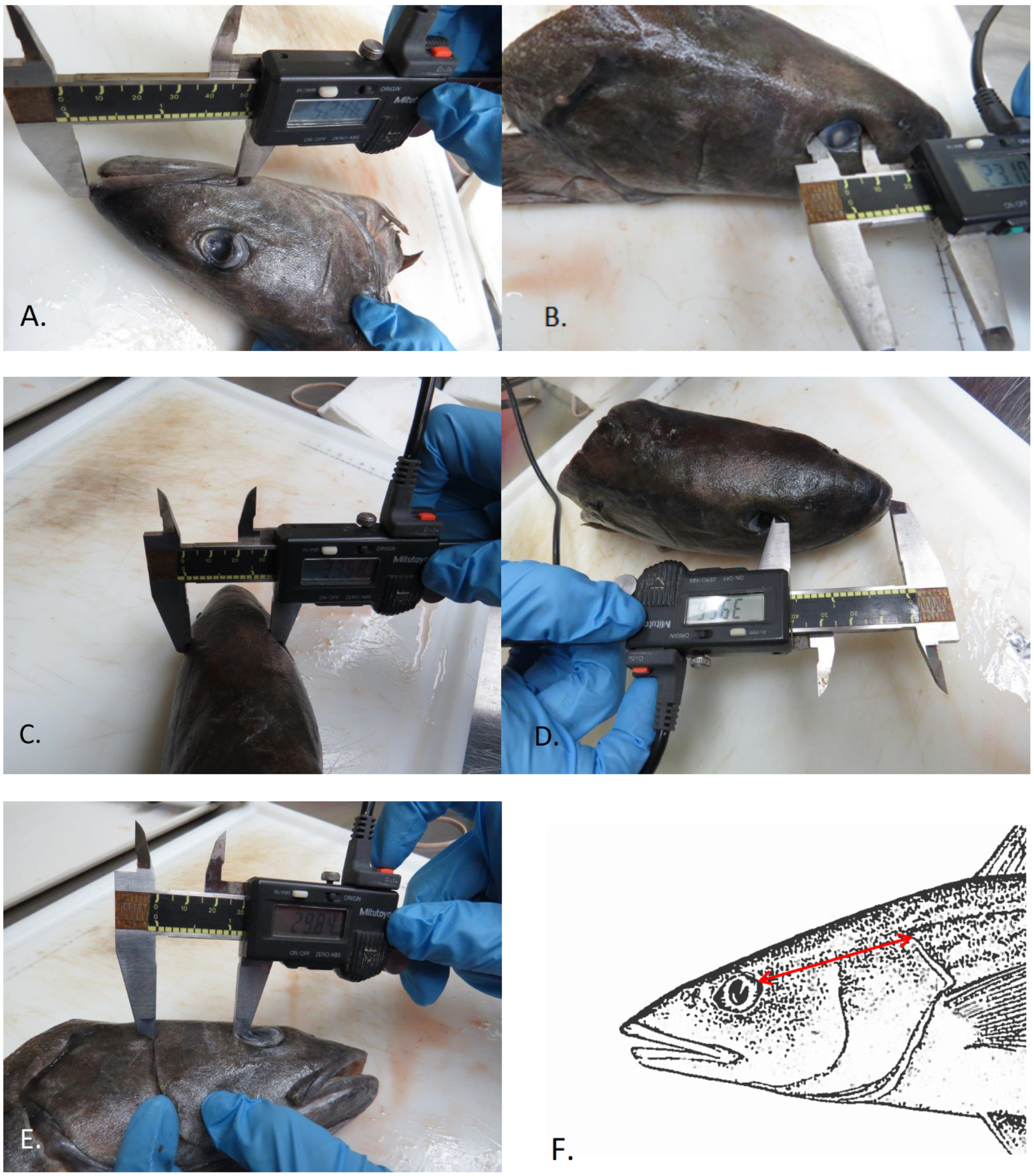


Figure 3. Relationship between cranial lengths (SL, PP, PO) vs fork length in millimeters. Predicted points represented by black circles, measured values colored by residual scale.

APPENDIX A IMAGES OF THE SIX CRANIAL DIMENSION MEASUREMENTS.

A. Upper jaw measurement (UJ); B. Eye diameter measurement (ED); C. Interorbital distance (ID); D. Snout length (SL); E. Post orbital to preoperculum length measurement (PP); F. Post orbital head length (PO).



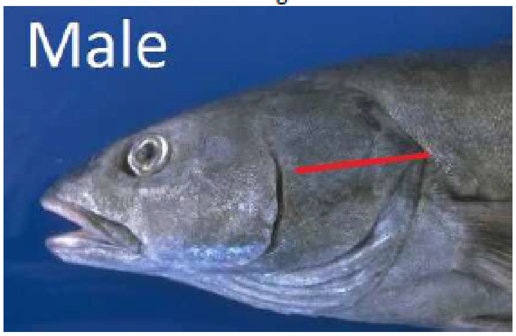
APPENDIX B SEX DETERMINATION BY OPERCULUM MARKING

Instructions for sex determinations and operculum knife cuts for sablefish males and females.

MALES

Look for **lobes that have an 'edge' to them.** Due to the 'edge', they will not 'roll' easily in your fingers. The lobes are fused together at the end closest to the head.

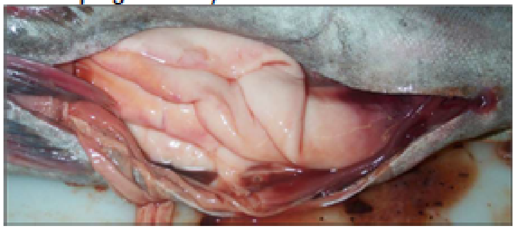
Mark with **one** cut on the gill cover



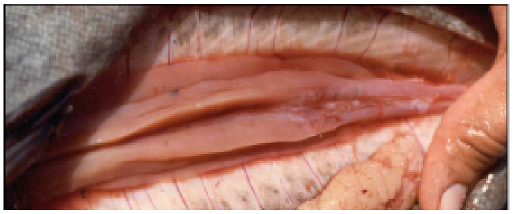
Sample photos for *color* and *shape reference*:

Juvenile: translucent-white

Developing: creamy-white



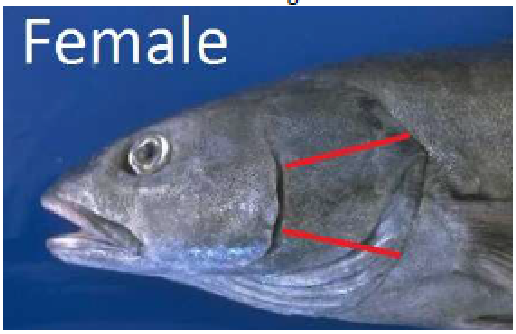
Post Spawning: brown or tan



FEMALES

Look for **tubes that are oval in cross section** and will 'roll' in your fingers.

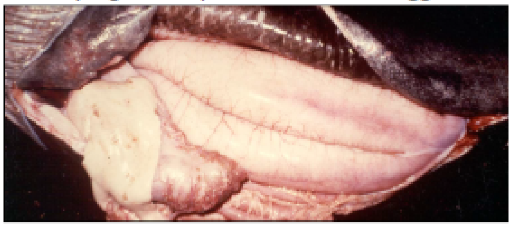
Mark with **two** cuts on the gill cover



Sample photos for *color* and *shape reference*:

Juvenile: translucent pinky purple

Developing: creamy white, filled with eggs



Post Spawning: reddish- purple- brown, whitish sheen to the exterior surface

8 References

Cox, S.P., Holt, K., and Johnson, S. 2019. Evaluating the robustness of management procedures for the Sablefish (*anoplopoma fimbria*) fishery in British Columbia, Canada for 2017-18. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/032. vi + 79 p.

Haist, R.H., V., and Wyeth, M. 2001. Sablefish Stock Assessment for 2001 and Advice to Managers for 2002. DFO Can. Sci. Advis. Sec. Res. Doc. 2001/135.

Isermann, D.A., and Vandergoot, C.S. 2005. Predicting walleye total length from head and mandible measurements. North American Journal of Fisheries Management 25(1): 316–321. Taylor & Francis.

Nottingham, M.K., Williams, D.C., Wyeth, M.R., and Olsen, N. 2018. Summary of the west coast haida gwaii synoptic bottom trawl survey, august 25 - september 26, 2016. Can. Manuscr. Rep. Fish. Aquat. Sci. 3151: viii: 51 p.

Park, I.S., Kim, Y.J., Choi, H.J., Oh, S.Y., Noh, C.H., and Lee, S.H. 2007. Total length estimation from head dimensions of artificially propagated brown croaker miichthys miiuy. Korean J. Ichthyol. 19: 128–131.

Richardson, J., Shears, N., and Taylor, R. 2015. Using relative eye size to estimate the length of fish from a single camera image. Marine Ecology Progress Series 538.

Rondeau, E.B., Messmer, A.M., Sanderson, D.S., Jantzen, S.G., Schalburg, K.R. von, Minkley, D.R., Leong, J.S., Macdonald, G.M., Davidsen, A.E., Parker, W.A., Mazzola, R.S.A., Campbell, B., and Koop, B.F. 2013. Genomics of sablefish (anoplopoma fimbria): Expressed genes, mitochondrial phylogeny, linkage map and identification of a putative sex gene. BMC Genomics 14(1): 452. Journal Article.

Serafy, J.E., Schmitz, C.M., Capo, T.R., Clarke, M.E., and Ault, J.S. 1996. Total length estimation of red drum from head dimensions. The Progressive Fish-Culturist 58(4): 289–290. Taylor & Francis.

Shaw, W., and McFarlane, G. 1997. Development of sablefish, anoplopoma fimbira larvae off the west coast of british columbia and transformation in the juvenile stage. NOAA Tech. Rep. NMFS 130: 3–12.

Williams, D.C., Nottingham, M.K., Olsen, N., and Wyeth, M.R. 2018. Summary of the west coast vancouver island synoptic bottom trawl survey, may 24 - june 15, 2016. Can. Manuscr. Rep. Fish. Aquat. Sci. 3137: viii: 54 p.