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

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Canadian Technical Report of Fisheries and Aquatic Sciences

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

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CONTENTS

ABSTRACT

Kathryn x. Temple, L.C. Lacko and Holt K.R. 2022. Estimation of fork length using cranial measurements of sablefish (*Anoplopoma fimbria*) in British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. nnn: v + 13 p.

Routine biological sampling of whole round sablefish from commercial fishing operations in British Columbia have occurred since the early 1990’s. Historically, specimens have been obtained through a voluntary catch sampling program and tagged sablefish recovery program. In order to improve the range of samples received, we investigated the potential for obtaining biological 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 assessed to see if they could predict fork length. Genetic samples (137) were collected to develop methods for DNA-based sex identification. A pilot study was conducted in 2017 with 360 head-only samples with sex markings provided by a commercial vessel, followed by scientific sampling on shore. Regression analysis results reveal that the interorbital distance measurement was a good predictor of sablefish fork length, while samplers ranked it the most efficient and easily repeatable. Initial genomic DNA (130 of 137) were successfully PCR amplified and results indicate 92% accuracy in sampler sex detection. DNA audit of fisher sex determination was xx%. Subsequently, 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. 2022. Estimation of fork length using cranial measurements of sablefish (*Anoplopoma fimbria*) in British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. nnn: v + 13 p.

1 Introduction

Biological samples of British Columbia (BC) sablefish (*Anoplopoma fimbria*) have been collected from a voluntary catch sampling program since 1995 (Haist and Wyeth 2001) and processed by the Department of Fisheries and Oceans (DFO) port samplers and contracted service providers. In addition, whole tagged fish recovered in commercial fisheries (trap, trawl, hook and line) have been received 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).

In recent years, a sablefish head only catch sampling and tagging program was developed in order to improve the number of returns, maintain the quality of the biological data and increase the range of fish sizes. Instead of returning the whole fish, commercial crew J-cut the fish as per commercial practice, view the gonads to determine sex, mark the sex with knife cuts on the operculum and store the head (and/or floy tag) for later sampling by the department and AMR.

Previous research has accurately estimated fish lengths from i) various head dimensions (Serafy et al. 1996; Park et al. 2007), ii) head and mandible lengths (Isermann and Vandergoot 2005) and iii) ratio of head height to eye diameter (Richardson et al. 2015). In our research, six unique sablefish head dimensions including 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 regressed against fork length (L_{FL}). In addition, a task performance ranking system was developed to reveal the most accurate and efficient cranial measurement.

In 2016, standard biological data including operculum clips (DNA) were obtained on several research surveys from 216 female and 222 male sablefish, followed by cranial measurements at the Pacific Biological Station (PBS). Methods for DNA-based sex identification were developed by the PBS Molecular Genetics Laboratory (MGL). In 2017, a pilot study was conducted on a commercial vessel. Head-only samples with sex markings were collected at sea, followed by scientific sampling on shore. DNA analysis measured the commercial fisher sex accuracy.

In this technical report we describe the results of 1) the relationship between the 2016 cranial dimensions and fork length; 2) the feasibility of each head measurement; 3) the test developed for DNA sex detection; and 4) the most consistent measurement from the 2017 pilot study. Successful application of this research has resulted in program revisions in the catch sampling programs and shore-side sampling of sablefish in 2018.

2 Methods

2.1 Experimental Study 2016

Sablefish were 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 (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 ((L_{UJ}, L_{ED}, L_{SL}, L_{PP},L_{PO}) were measured using Mitutoyo Absolute® 500-762-20 coolant proof digimatic calipers and sagittal otoliths were collected for future ageing.

Morphological measurements described in (Shaw and McFarlane 1997)

A number of fish head dimensions were considered as possible candidates for estimating fork length: 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 (L_{PO}) head length (Table 1, Appendix A). 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 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 used for the study. The smallest fork length of the collected specimens was 240 mm, the highest was 1080 mm, and the average was 573.3 mm (Table 3). The post orbital head length (L_{PO}) measurement was abandoned after 130 sablefish due to sample quality and technical complications.

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. The accuracy of sex detection by the science technicians from the 2016 experimental study was 92% (119/130).

3.2 Pilot study 2017

The 360 heads were received from the commercial vessel 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 experimental study. The cranial measurements that produced the lower average 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 L_{ID} 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 to the PBS science division, rather than entire fish.

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. Matching images 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_{LF}**	
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

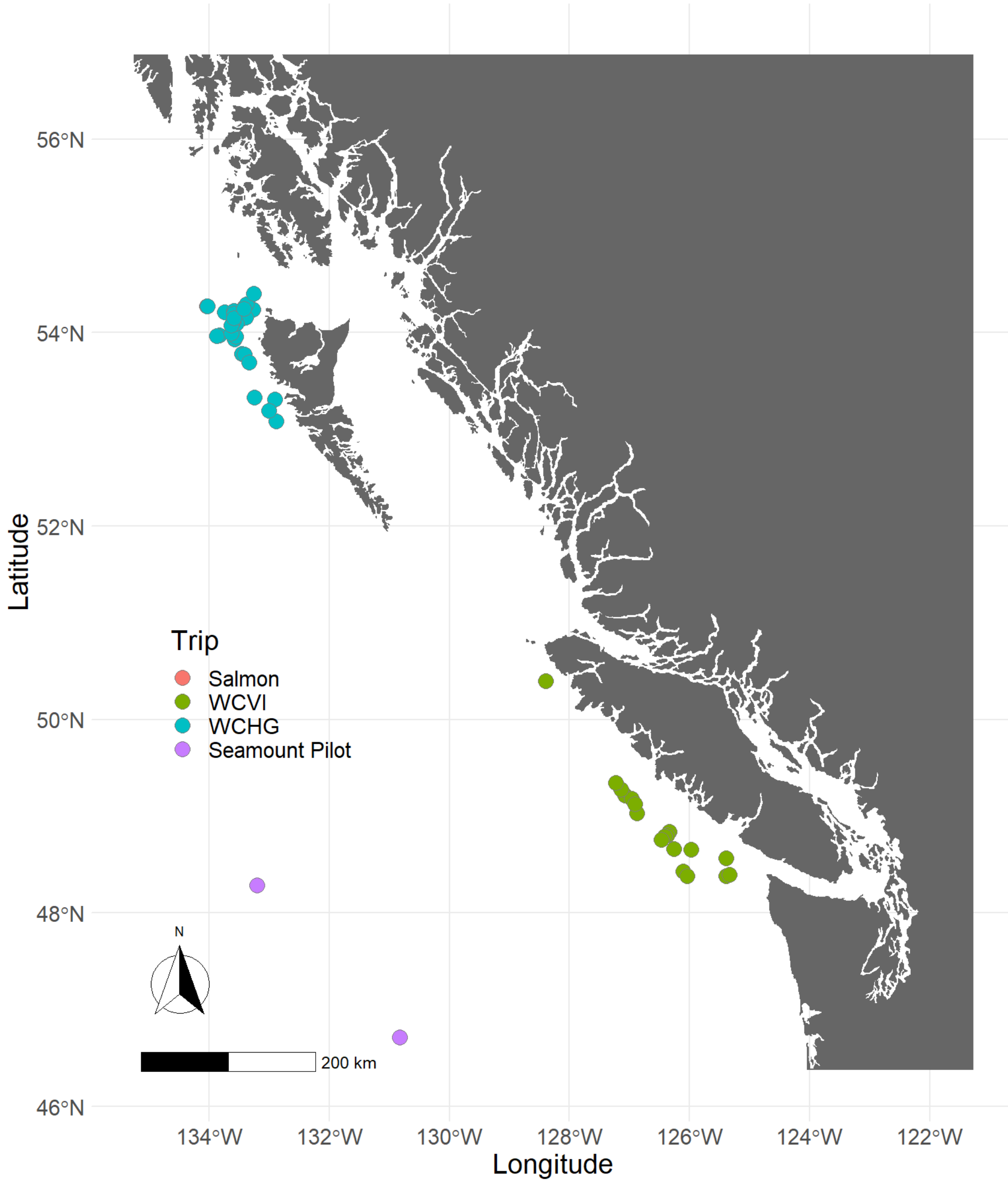


Figure 1. Sample locations from the 2016 WCVI, WCHG and salmon research surveys and 2017 pilot study.

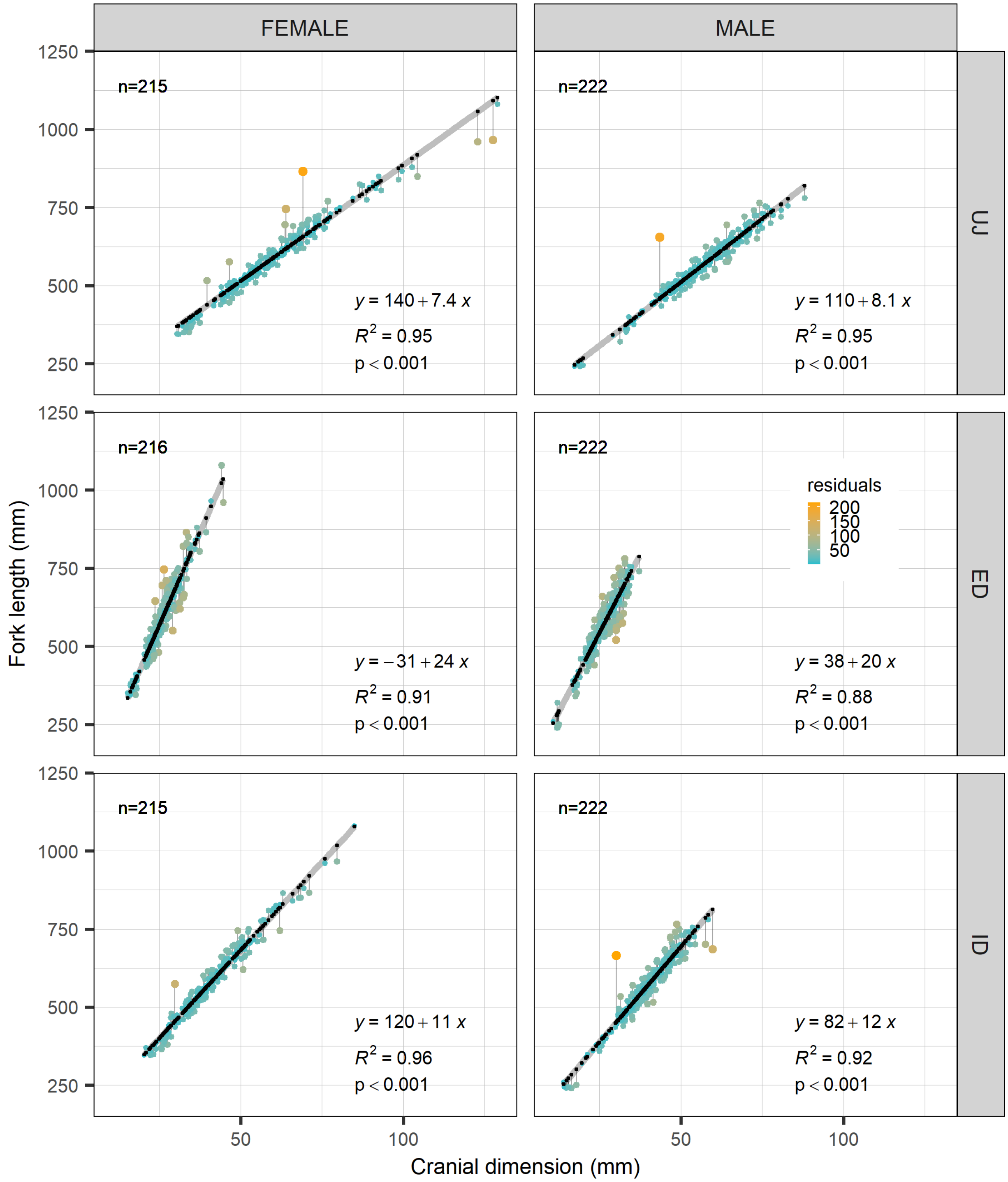


Figure 2. Relationship between cranial lengths (UJ, ED, ID) vs fork length in millimeters. Predicted points represented by black circles, measured values colored by residual scale.

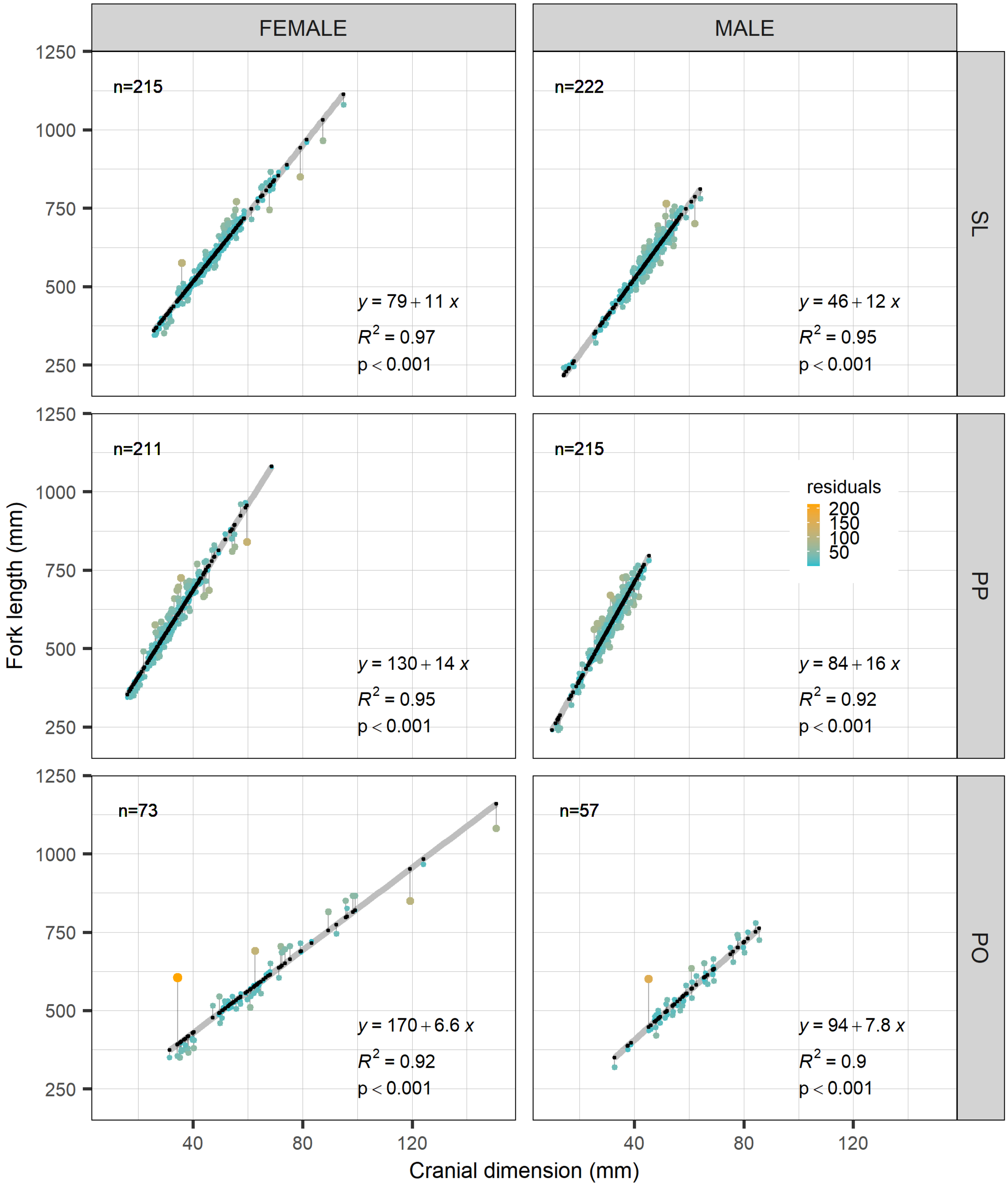
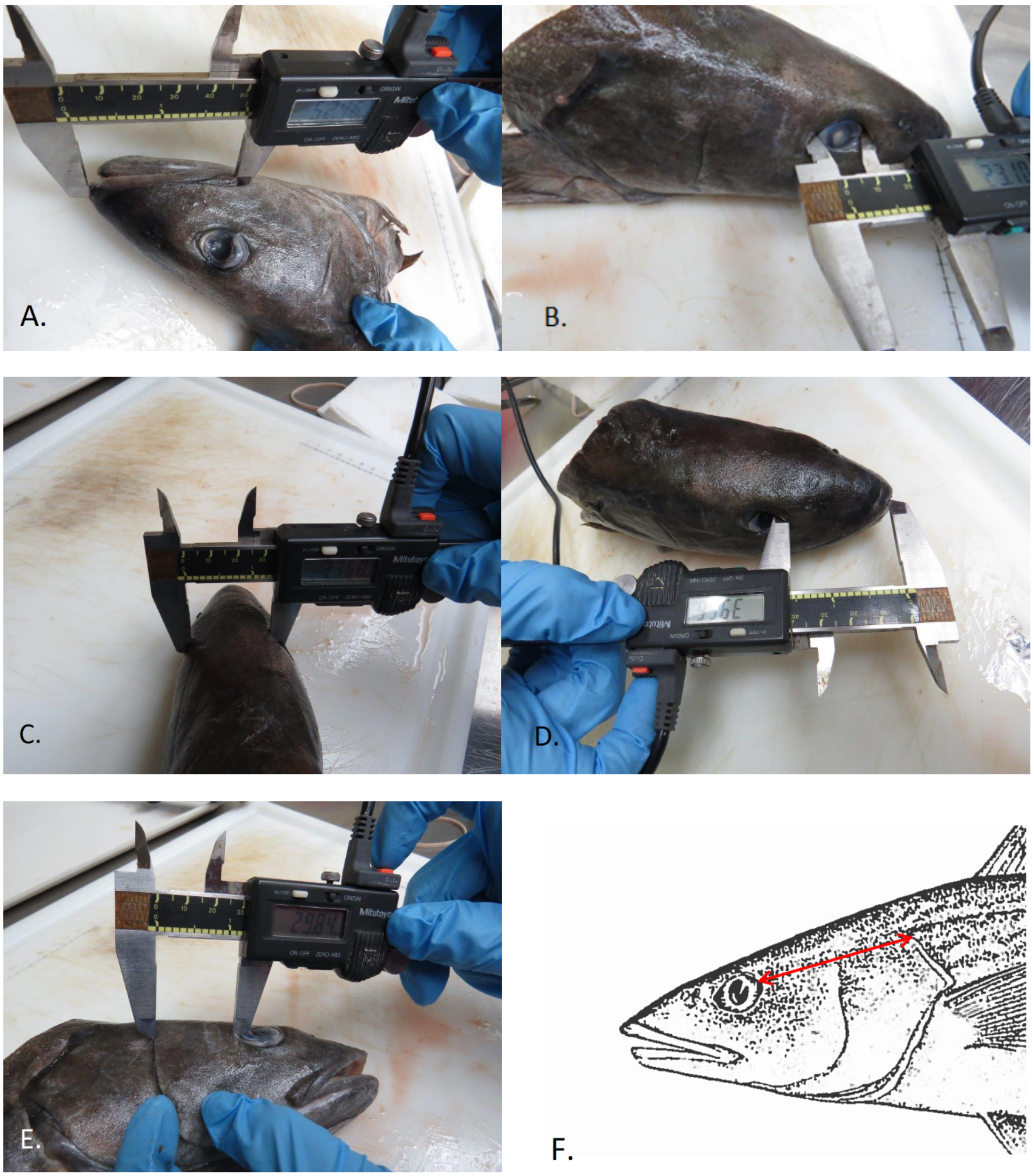


Figure 3. Relationship between cranial lengths (SL, PP, PO) vs fork length in millimeters. Predicted points represented by black circles, measured values colored by residual scale.

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.

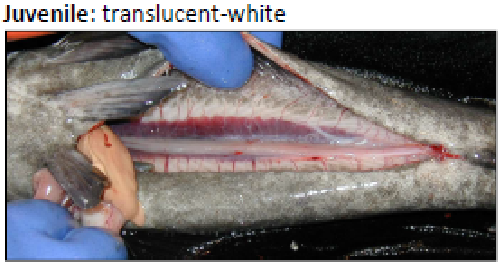
MALES

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

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