Supplemental Materials:

The genetic architecture of novel trophic specialists: higher effect sizes are associated with exceptional oral jaw diversification in a pupfish adaptive radiation

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Running Title: Quantitative trait loci in novel pupfish specialists

Key words: adaptive radiation, innovation, linkage mapping, novelty, diversification rate, ecological speciation, trophic divergence

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Fig. S1

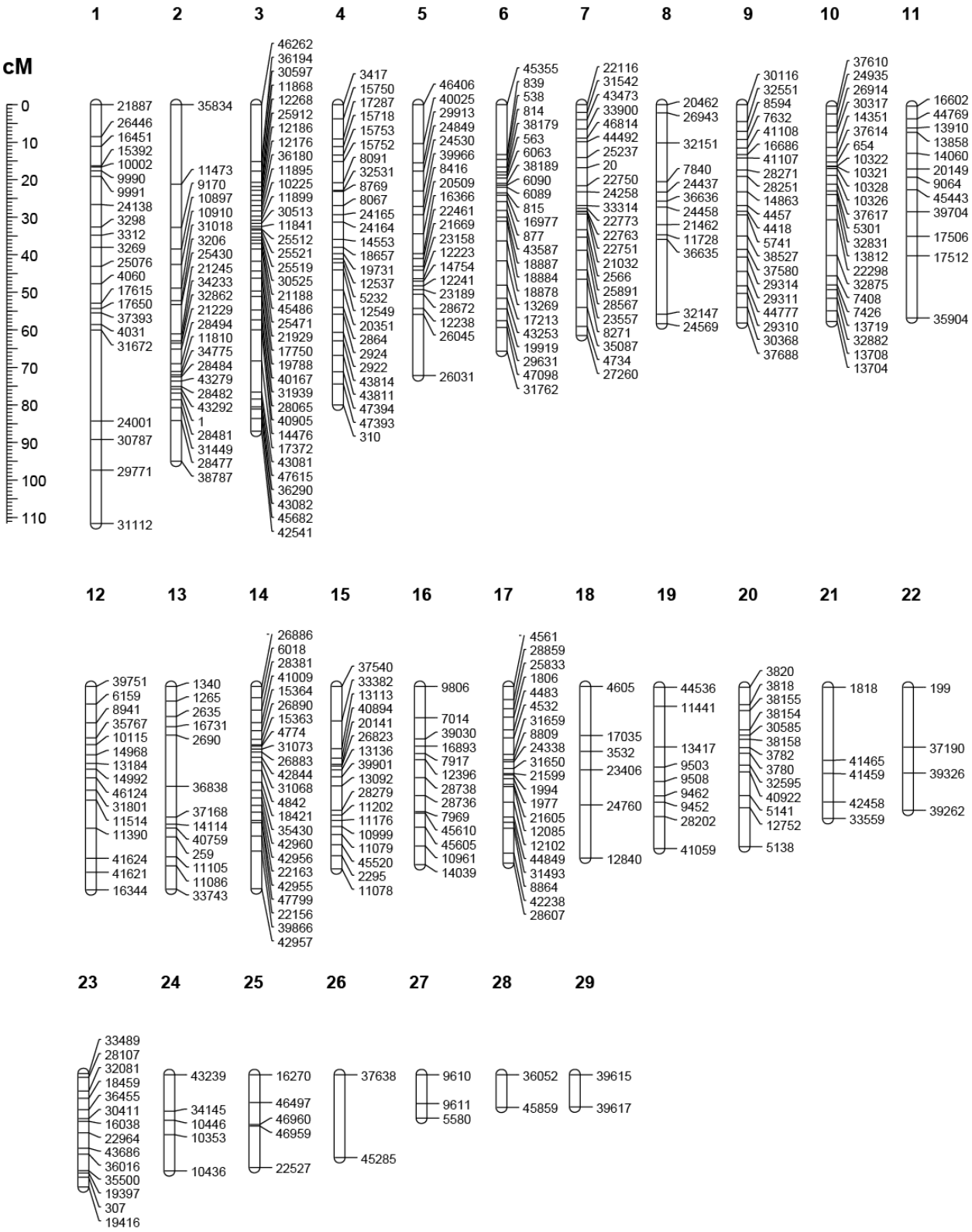
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Fig. S1 *Cyprinodon* linkage map from 416 SNP markers homozygous in a cross between a scale-eating pupfish *C. desquamator* and a molluscivore pupfish *C. brontotheroides*, both endemic to San Salvador Island, Bahamas.

Fig. S2

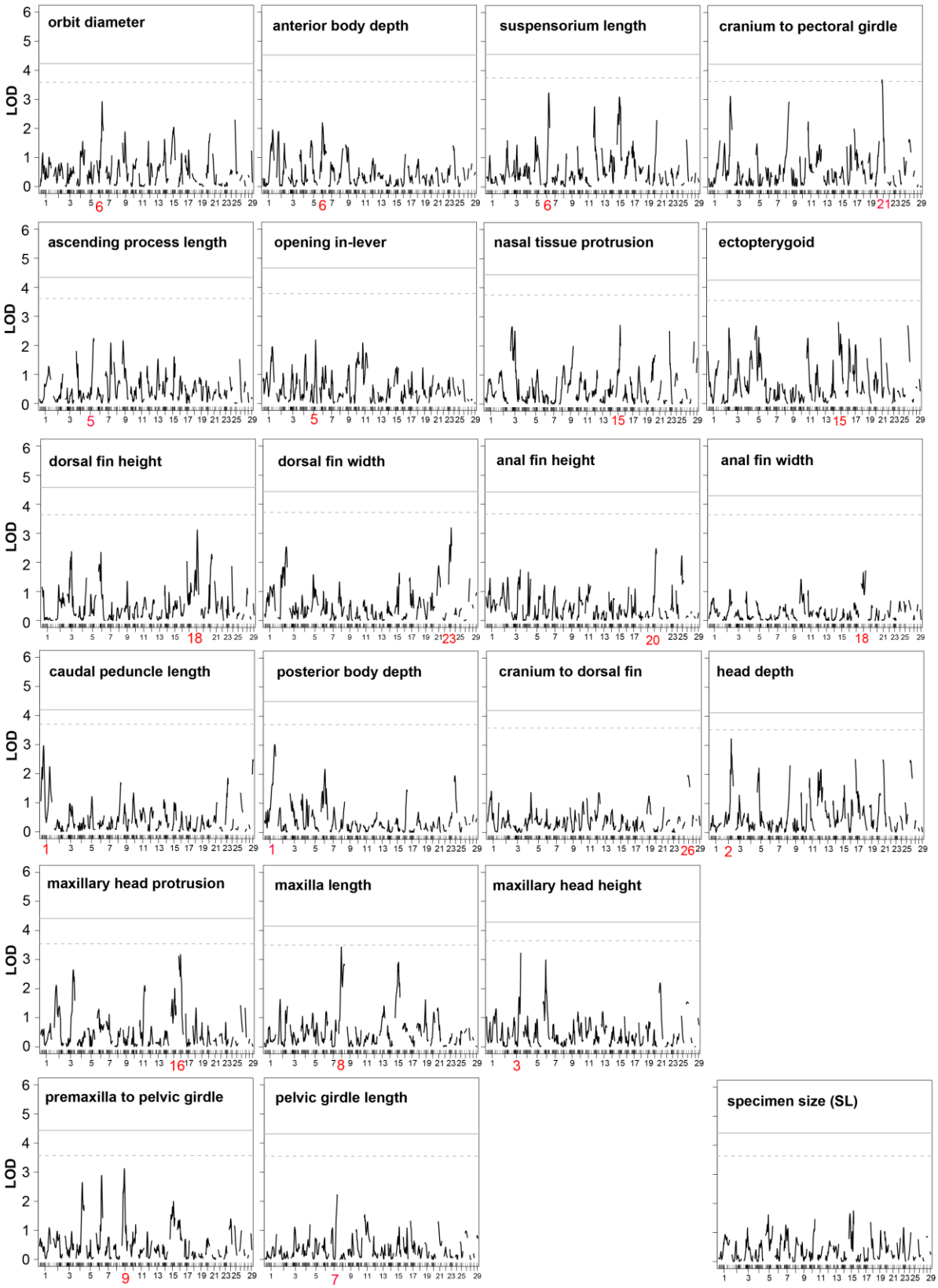
orbit diameter
anterior body depth
suspensorium length
cranium to pectoral girdle
ascending process length
opening in-lever
nasal tissue protrusion
ectopterygoid
dorsal fin height
dorsal fin width
anal fin height
anal fin width
caudal peduncle length
posterior body depth
cranium to dorsal fin
head depth
maxillary head protrusion
maxilla length
maxillary head height
premaxilla to pelvic girdle
pelvic girdle length
specimen size (SL)
LOD

Fig. S2 Skeletal traits not significantly associated with any genetic markers at the $P = 0.05$ threshold within the San Salvador F2 intercross. LOD profiles are plotted relative to position along the 29 linkage groups as estimated by Haley-Knott regression (black line). Genome-wide significance levels of $P = 0.05$ (dotted black line) and $P = 0.01$ (solid black line) were calculated by permutation for each trait. The linkage group most strongly associated with each trait is highlighted in bold red. Specimen size (SL) was included as a control statistical comparison and is not expected to associate with any QTL.

Fig. S3

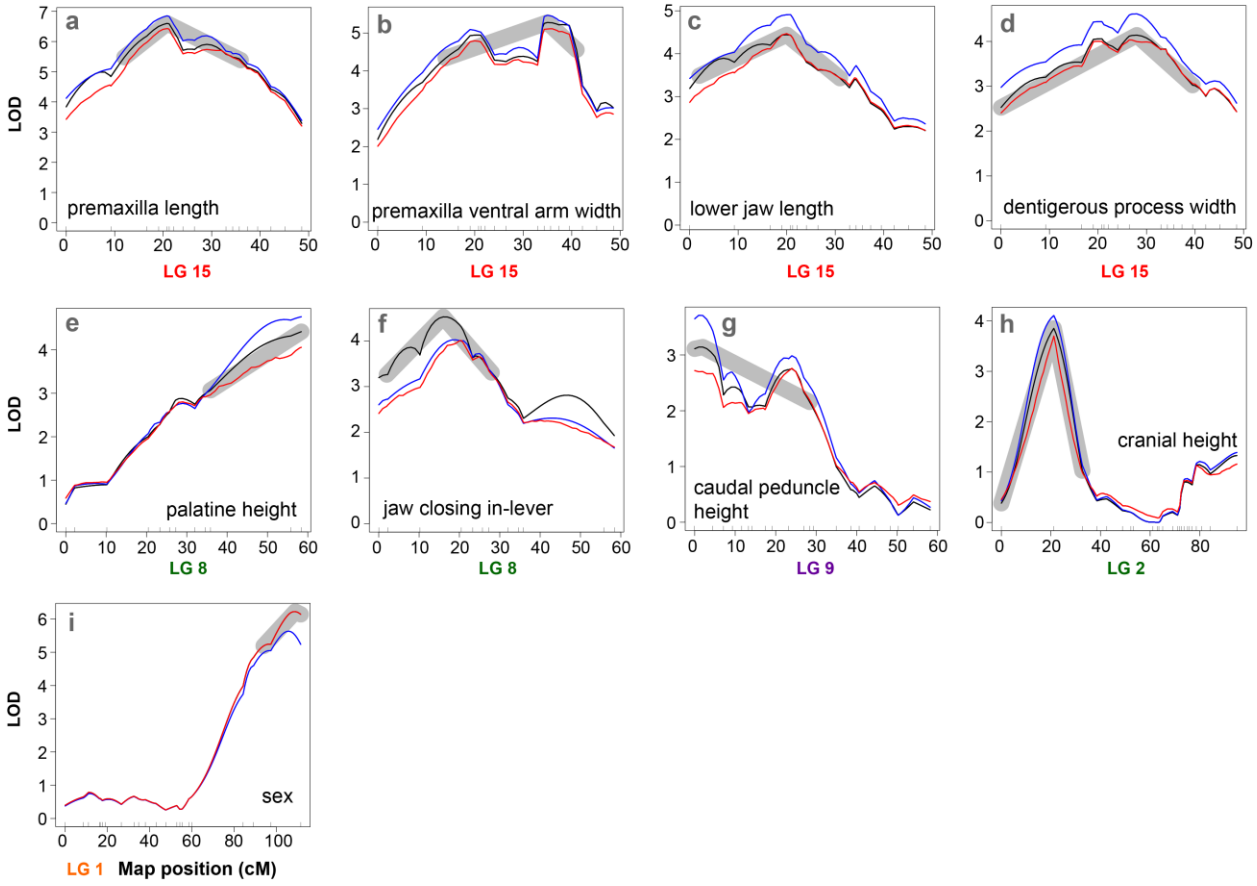

Fig. S3 LOD profiles for significant QTL along each linkage group for *a-h)* eight skeletal traits and *i)* sex within a San Salvador pupfish F2 intercross. LOD profiles are plotted relative to position along each linkage group as estimated by Haley-Knott regression (black line), maximum likelihood (blue line), and multiple imputation (red line). The 95% Bayesian credible interval for each QTL is illustrated by the thick gray line on each linkage group.

Fig. S4

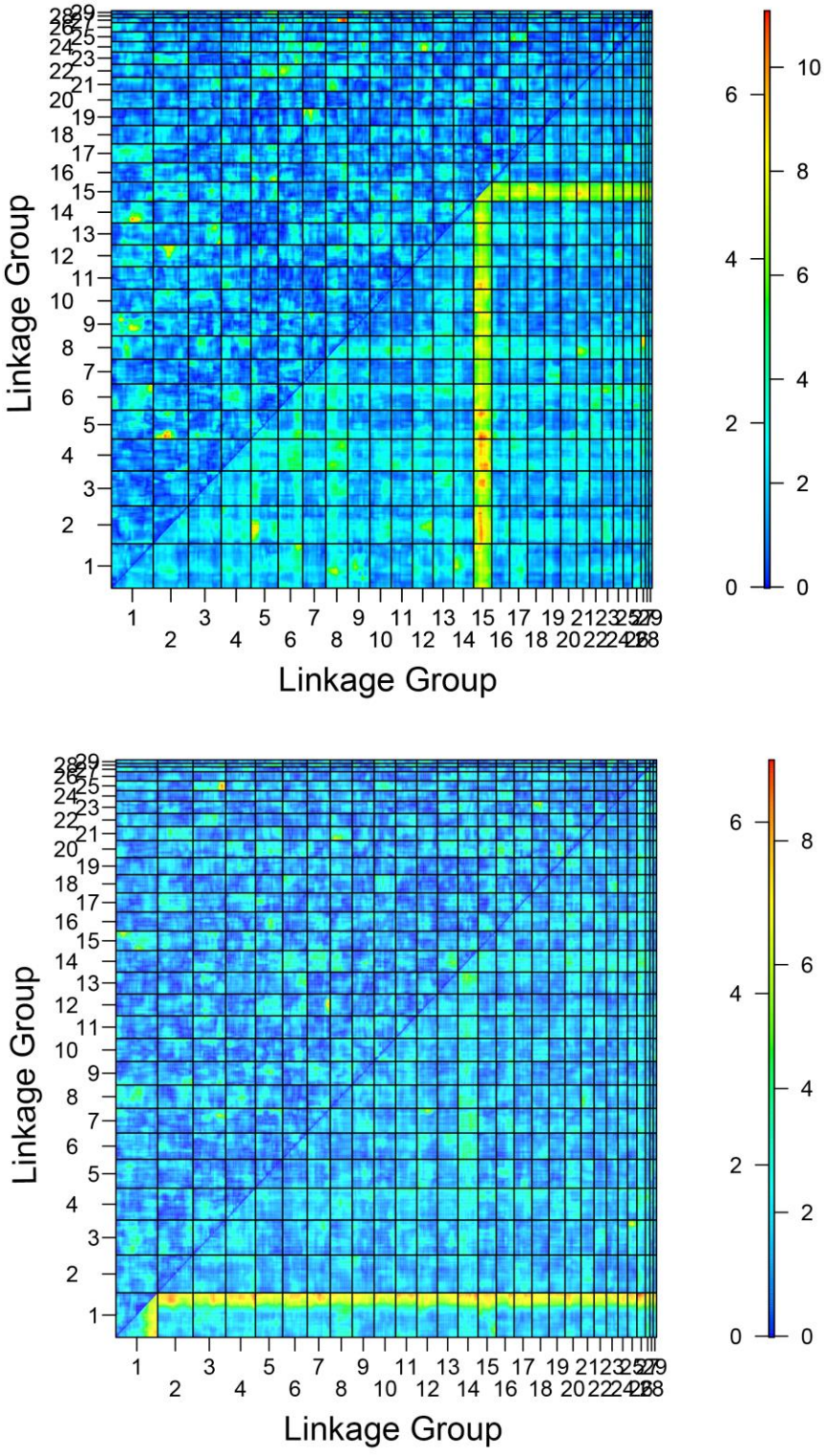

Fig. S4 LOD scores of pairwise QTL interactions across all linkage groups for a) premaxilla length and b) sex using the maximum likelihood model in scantwo. The lower right triangle indicates joint two-locus LOD scores and the upper left triangle indicates epistasis LOD scores. The color scales indicate epistasis (left) and joint (right) LOD scores in each panel. Significant LOD scores for premaxilla length estimated from 1,000 permutations using Haley-Knott regression were 9.02 and 6.47 for the full and interaction models, respectively.

Supplemental Methods

Morphometric landmarks

Dentigerous arm width (landmarks 5-8): distance from the caudal process to the anterior tip of the teeth on the dentigerous arm of the premaxilla.

Dentigerous arm base (landmarks 7-5): distance from the caudal process to the anterior process on the dentigerous arm of the premaxilla.

Lower jaw length (landmark 1-2): distance from the point of rotation of the quadroarticular joint to the most anterior tip of the teeth on the mandible.

Dentigerous arm depth (landmarks 8-9): distance from the anterior tip of the teeth on the dentigerous arm of the premaxilla to the base of the ascending process on the posterior edge of the premaxilla.

Palatine height (landmarks 2-11): distance from the point of rotation of the quadroarticular joint to the point of rotation between the maxilla and palatine marked by a cartilaginous pad.

Jaw closing in-lever (landmarks 2-3): distance from the point of rotation of the quadroarticular joint to the most distal point on the lateral edge of the coronoid process of the articular.

Caudal peduncle height (body landmarks 10-11): distance from the posteroventral edge of the caudal peduncle to the posterodorsal edge of the caudal peduncle anterior to the insertion of the caudal fin rays.

Cranial height (landmarks 15-16): distance from the anterior tip of the infraorbital ring to the posterodorsal edge of the neurocranium.

Orbit diameter (landmarks 14-15): distance from the posterior edge of the ectopterygoid to the anterior tip of the infraorbital ring.

Anterior body depth (body landmarks 4-7): distance from the anterodorsal insertion of the first ray of the dorsal fin to the anteroventral insertion of the first ray of the anal fin.

Posterior body depth (body landmarks 5-8): distance from the posterodorsal insertion of the last ray of the dorsal fin to the posteroventral insertion of last ray of the anal fin.

Suspensorium length (landmarks 2-18): distance from the quadroarticular joint to the anteroventral edge of the pelvic girdle.

Ascending process length (landmarks 9-10): distance from the basal insertion of the ascending process on the posterior edge of the dentigerous arm of the premaxilla to the most posterior point on the ascending process.

Opening in-lever (landmarks 2-4): distance from the point of rotation of the quadroarticular joint to the insertion of the interopercular mandibular ligament on the angular bone.

Nasal tissue protrusion (landmarks 12-19): distance from the anterior skeletal margin of the head of the maxillary protruding process to the anterior distal margin of cartilaginous tissue in the nasal region.

Ectopterygoid (landmarks 11-14): distance from the point of rotation between the maxilla and the palatine to the posterior edge of the ectopterygoid.

Dorsal fin height (body landmarks 4-6): distance from the insertion of the first dorsal fin ray to the most distal margin of this ray.

Dorsal fin width (body landmarks 4-5): distance from the insertion of the first dorsal fin ray to the posterior insertion of the last dorsal fin ray.

Anal fin height (body landmarks 8-9): distance from the insertion of the third most posterior anal fin ray to the most distal margin of this ray, marking the widest margin between body and distal margin of the anal fin.

Anal fin width (body landmarks 7-8): distance from the insertion of the first anal fin ray to the posterior insertion of the last anal fin ray.

Caudal peduncle length (body landmarks 5-11): distance from the posterior insertion of the last dorsal fin ray to the dorsal insertion of the caudal fin.

Cranium to dorsal fin (body landmarks 3-4): distance from the posterodorsal margin of the cranium to the insertion of the first dorsal fin ray.

Head depth (landmarks 16-18): distance from the anteroventral margin of the pectoral girdle to the posterodorsal margin of the neurocranium.

Maxillary head protrusion (landmarks 12-13): distance from the posterior edge of the dorsal head of the maxilla to the protruding anterior distal margin of the dorsal head.

Maxilla length (landmarks 6-11): distance from the ventral arm of the maxilla to the point of rotation with the palatine.

Maxillary head height (landmarks 11-13): distance from the point of rotation between the maxilla and palatine to the anterodorsal margin on the maxilla head.

Premaxilla to pelvic girdle (body landmarks 1-2): distance from the anterior tip of the teeth on the dentigerous arm of the premaxilla to the anteroventral margin of the pelvic girdle.

Pelvic girdle length (landmarks 17-18): distance from the anteroventral margin of the pelvic girdle to the ventral insertion of the lowest pectoral fin ray.

Specimen size (standard length: SL; body landmarks 1-12): distance from the anterior tip of the teeth on the dentigerous arm of the premaxilla to the medial margin of the hypeural plate at the insertion of the caudal fin rays.