Supplementary Tables and Figures. Morphological data as well as the functional innovation and trophic guild classifications used in the study can be found in Supplementary File 1 (Excel format).

Table S1. Evolutionary models fit to locomotion and feeding performance traits.

Trait	Model	ln L	AICc	ΔAICc	Prop.
Fin Aspect Ratio	BM	143.1 (126.7 – 149.4)	-282.2 (-294.8 – -249.3)	0.0	0.962
	EB	143.1 (126.7 – 149.4)	-280.1 (-292.7 – -247.2)	2.1	0.000
	delta	143.5 (130.1 – 149.5)	-280.9 (-292.7 – -254.0)	1.3	0.000
	OU	143.5 (131.1 – 149.4)	-280.9 (-292.7 – -256.0)	1.3	0.038
Gape	BM	121.5 (88.7 – 138.6)	-239.0 (-273.1 – -0.173.3)	2.0	0.015
	EB	121.5 (88.7 – 138.6)	-236.9 (-271.0 – -171.2)	4.1	0.000
	delta	123.1 (89.6 – 139.1)	-240.0 (-272.0 – -172.9)	1.0	0.000
	OU	123.6 (89.9 – 139.0)	-241.0 (-271.8 – -173.8)	0.0	0.985
Protrusion	BM	-46.8 (-61.6 – -31.5)	97.7 (67.0 – 127.3)	28.8	0.000
	EB	-46.8 (-61.6 – -31.5)	99.8 (69.1 – 129.4)	30.9	0.000
	delta	-35.9 (-48.4 – -24.0)	78.0 (54.3 – 102.9)	9.1	0.000
	OU	-31.4 (-41.0 – -22.9)	68.9 (51.9 – 88.3)	0.0	1.000
Adductor Mandibulae	BM	-12.2 (-40.1 – 7.4)	28.5 (-10.7 – 86.1)	22.0	0.000
	EB	-12.2 (-40.1 – 7.4)	30.6 (-8.5 – 88.2)	24.1	0.000
	delta	-3.2 (-31.3 – 12.7)	12.3 (-19.4 – 68.6)	5.8	0.000
	OU	-0.1 (-27.7 – -12.8)	6.5 (-19.4 – 61.6)	0.0	1.000
Sternohyoideus	BM	17.1 (-7.6 – -30.0)	-30.2 (-55.9 – 19.4)	19.4	0.000
	EB	17.1 (-7.6 – -30.0)	-28.1 (-53.8 – 21.5)	21.5	0.000
	delta	25.4 (5.6 – 35.4)	-44.6 (-64.6 – -5.0)	5.0	0.000
	OU	27.9 (14.5 – 36.4)	-49.6 (-66.6 – -22.9)	0.0	1.000
Levator Posterior	BM	-76.0 (-88.3 – -67.5)	156.0 (139.2 – 180.7)	0.2	0.000
	EB	-76.0 (-88.3 – -67.5)	158.1 (141.3 – 182.8)	2.3	0.000
	delta	-74.8 (-84.8 – -67.1)	155.8 (140.5 – 175.8)	0.0	0.522
	OU	-75.1 (-84.8 – -67.5)	156.4 (141.2 – 175.7)	0.6	0.478
Jaw Closing Lever	BM	81.2 (50.9 – 114.9)	-158.2 (-225.7 – 105.9)	15.7	0.000
	EB	81.2 (50.9 – 114.9)	-156.1 (-223.6 – 108.0)	17.8	0.000
	delta	87.3 (28.0 – 115.2)	-168.4 (-224.3 – 62.2)	5.5	0.000
	OU	90.0 (9.8 – 115.4)	-173.9 (-224.0 – -13.4)	0.0	1.000
Jaw Opening Lever	BM	101.6 (2.3 – 121.4)	-199.0 (-238.7 – -0.5)	26.3	0.000
	EB	101.6 (2.3 – 121.4)	-196.9 (-236.6 – 1.6)	28.4	0.000
	delta	111.7 (24.6 – 127.0)	-217.1 (-247.8 – -43.0)	7.8	0.000
	OU	115.7 (79.1 – 127.0)	-225.3 (-247.8 – -151.9)	0.0	1.000
Jaw KT	BM	134.2 (126.1 – 138.9)	-264.3 (-273.7 – -248.1)	5.3	0.000
	EB	134.2 (126.1 – 138.9)	-262.2 (-271.6 – -246.0)	7.4	0.000
	delta	137.1 (131.1 – 140.9)	-268.1 (-275.6 – -256.0)	1.5	0.000
	OU	137.9 (132.6 – 141.3)	-269.6 (-276.4 – -258.9)	0.0	1.000
Hyoid KT	BM	-1.7 (-124.0 – 25.2)	7.5 (-48.2 – 252.1)	20.2	0.000
	EB	-1.7 (-124.0 – 25.2)	9.6 (-46.1 – 254.2)	22.3	0.000
	delta	6.2 (-101.2 – 28.0)	-6.2 (-49 – 208.5)	6.5	0.000
	OU	9.4 (-28.0 – 28.3)	-12.7 (-50.4 – 62.3)	0.0	1.000

Values depict the mean (range) log-likelihood (lnL) and AICc and the mean difference in AICc scores (ΔAICc) across 1000 trees, and the proportion (Prop.) of trees in which the model was the best fit based on AICc scores.
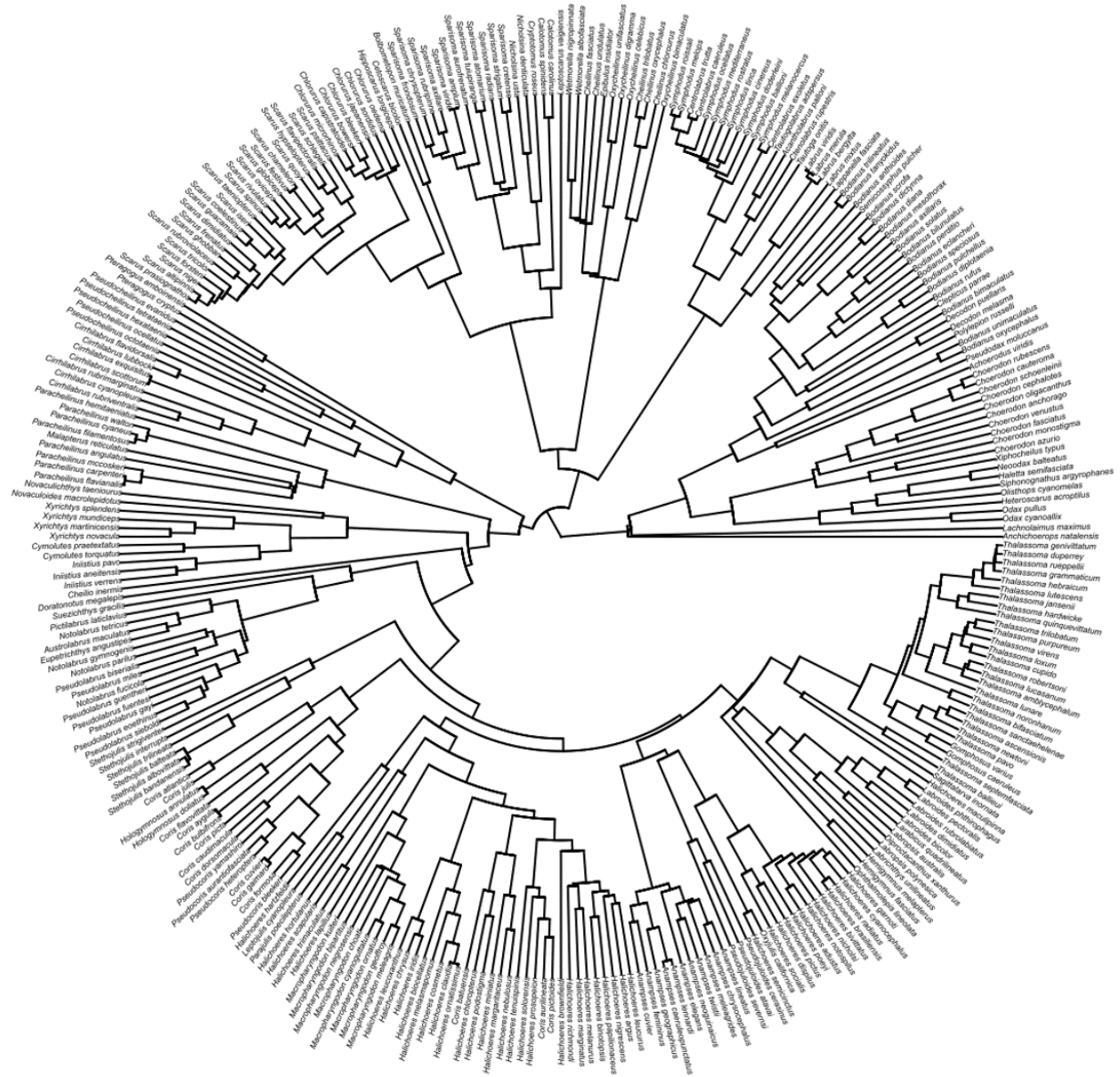
Figure S1. Maximum clade credibility phylogenetic tree used in the paper (originally from Baliga and Law 2016) and that appears in Figures 2 and 4 of the main text.
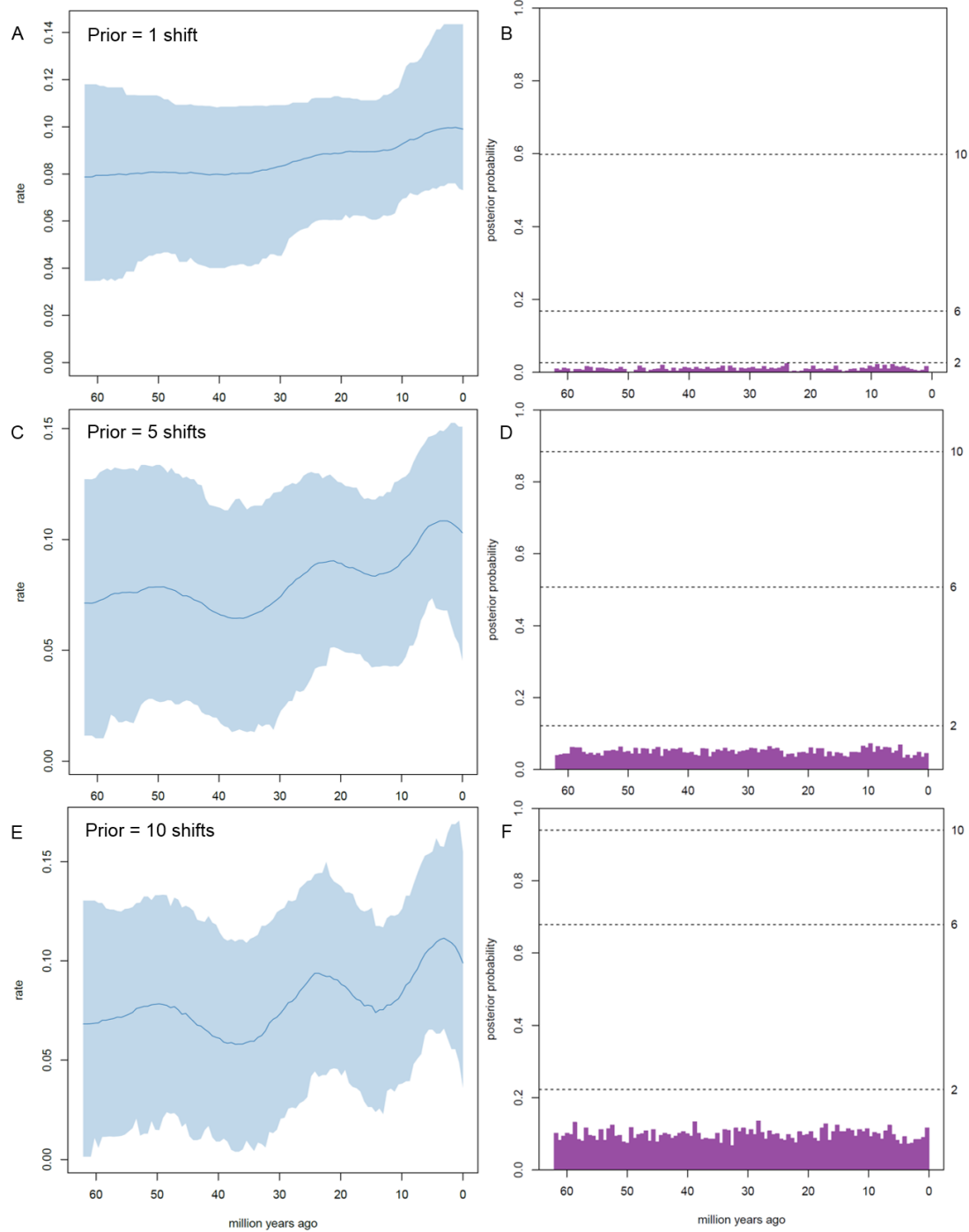
Figure S2. Assessment of sensitivity to the prior number of shifts in speciation rates during analyses of diversification using TESS. The top panels depict net diversification through time (A) and Bayes Factor support for speciation rate shifts through time (B) based on a prior of one shift (i.e, the analyses that appear in the main text of the paper). The middle (C,D) and bottom (E,F) panels depict the same analyses except with the prior number of shifts changed to 5 and 10, respectively. Manipulating the prior created some periodicity in estimated net diversification through time (A,C,E), but did not affect support for rate shifts through time (B,D,F).
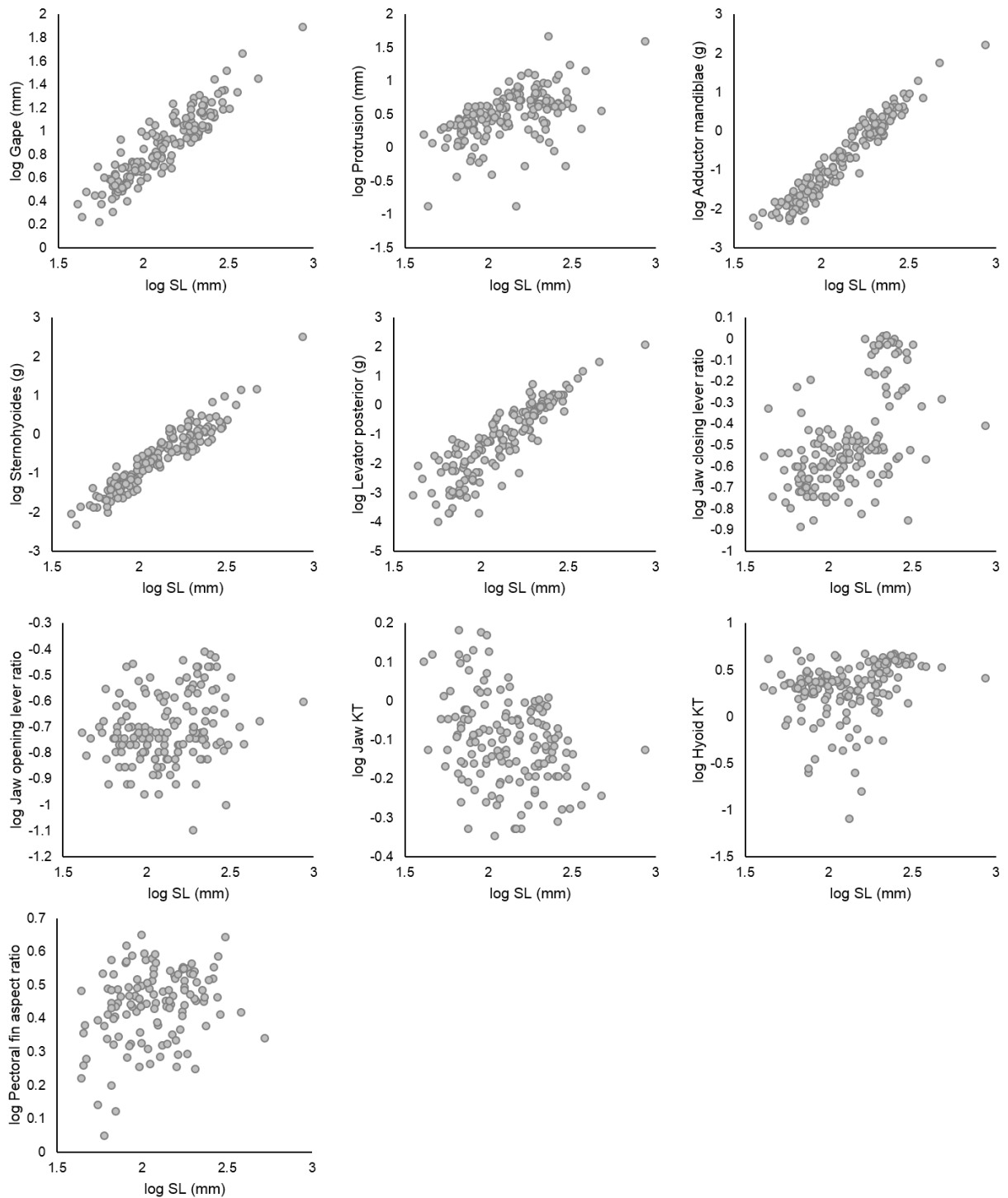
Figure S3. Plots demonstrating the scaling of trait values with body size. For the traits that scaled strongly with body size (i.e., the linear distances and masses), we performed phylogenetic size correction.
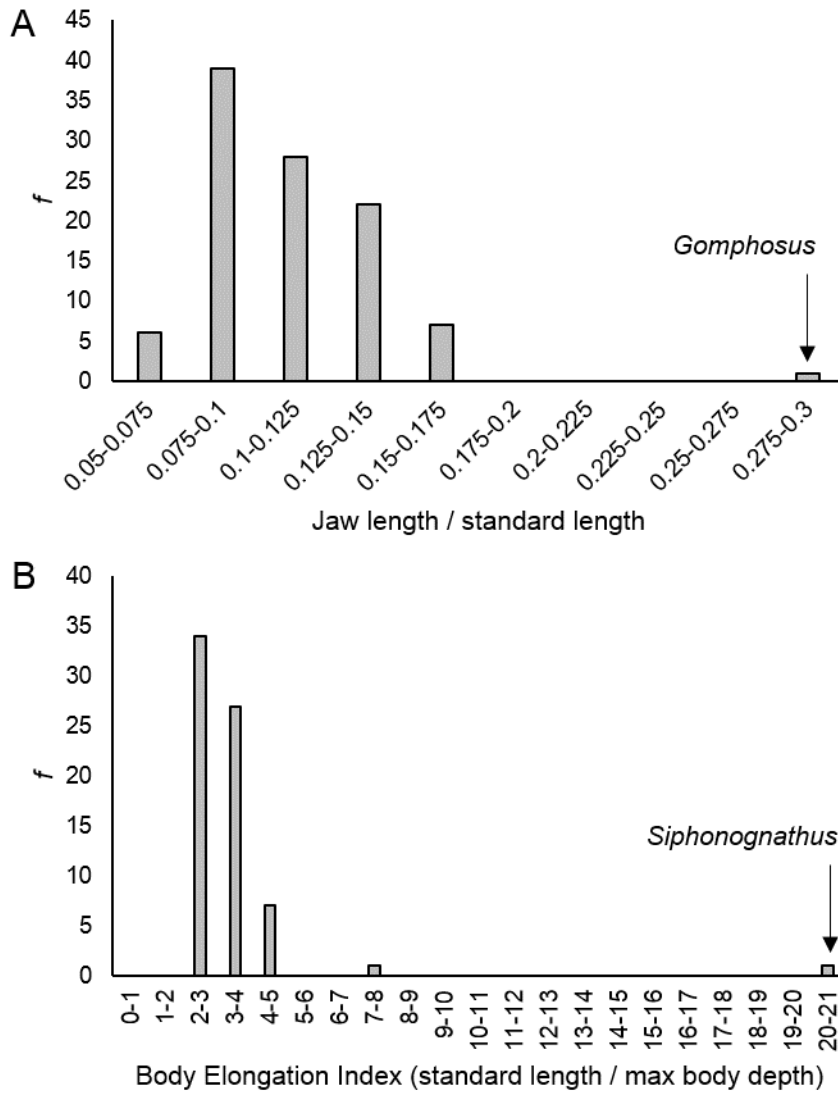
Figure S4. Histograms demonstrating the extreme jaw length (A) and body elongation (B) values observed in *Gomphosus* and *Siphonognathus*, respectively, used to justify treating these cases as discrete innovations. In both panels, the y-axis is the frequency (#) of species with that trait value. Data for jaw length and body elongation are based on species means of 104 and 70 species, respectively.
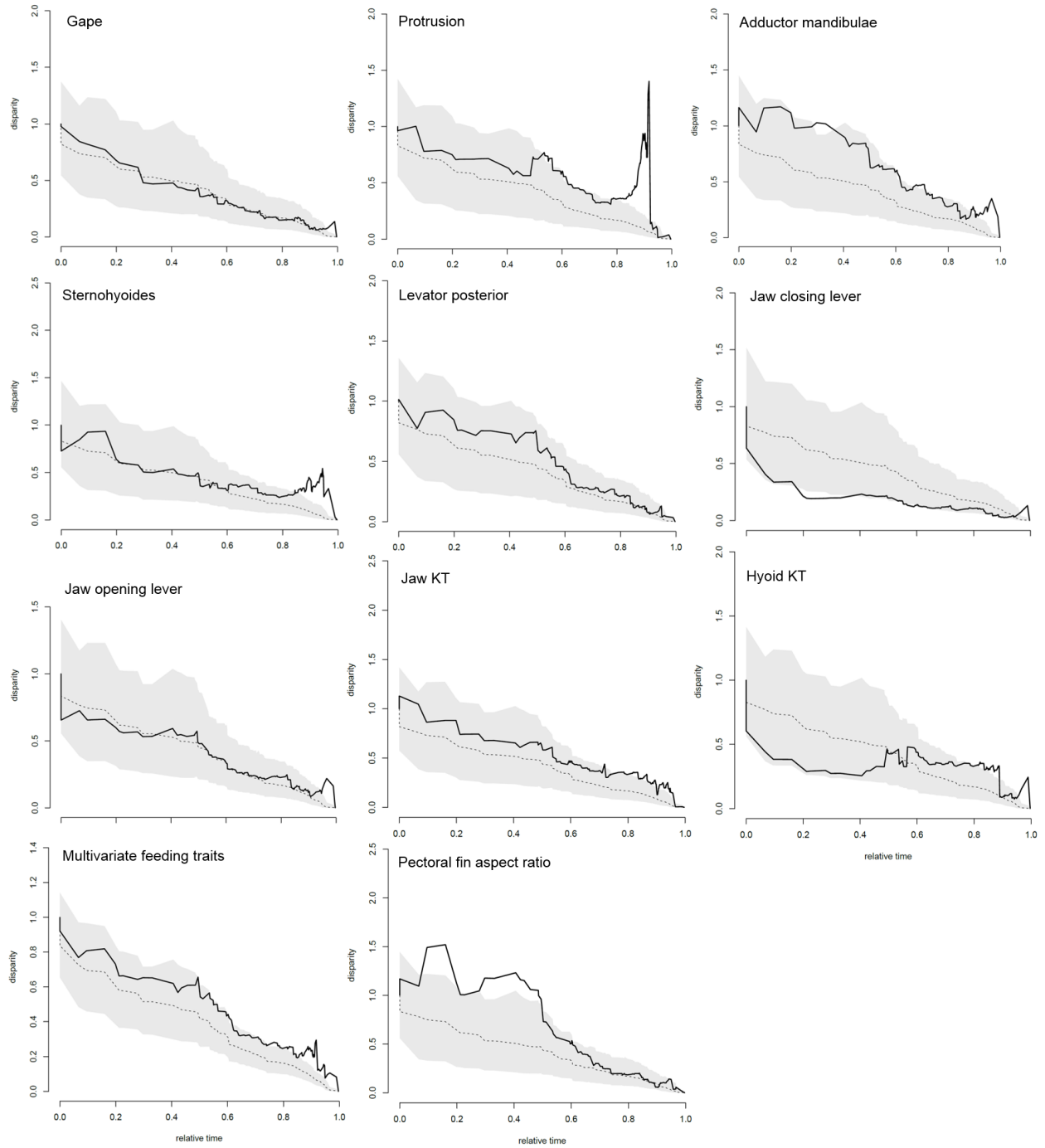
Figure S5. Disparity through time plots based on the MCC tree, for the 10 traits included in the paper. See the main text for summary statistics from analyses across 1000 randomly sampled trees from the posterior distribution.
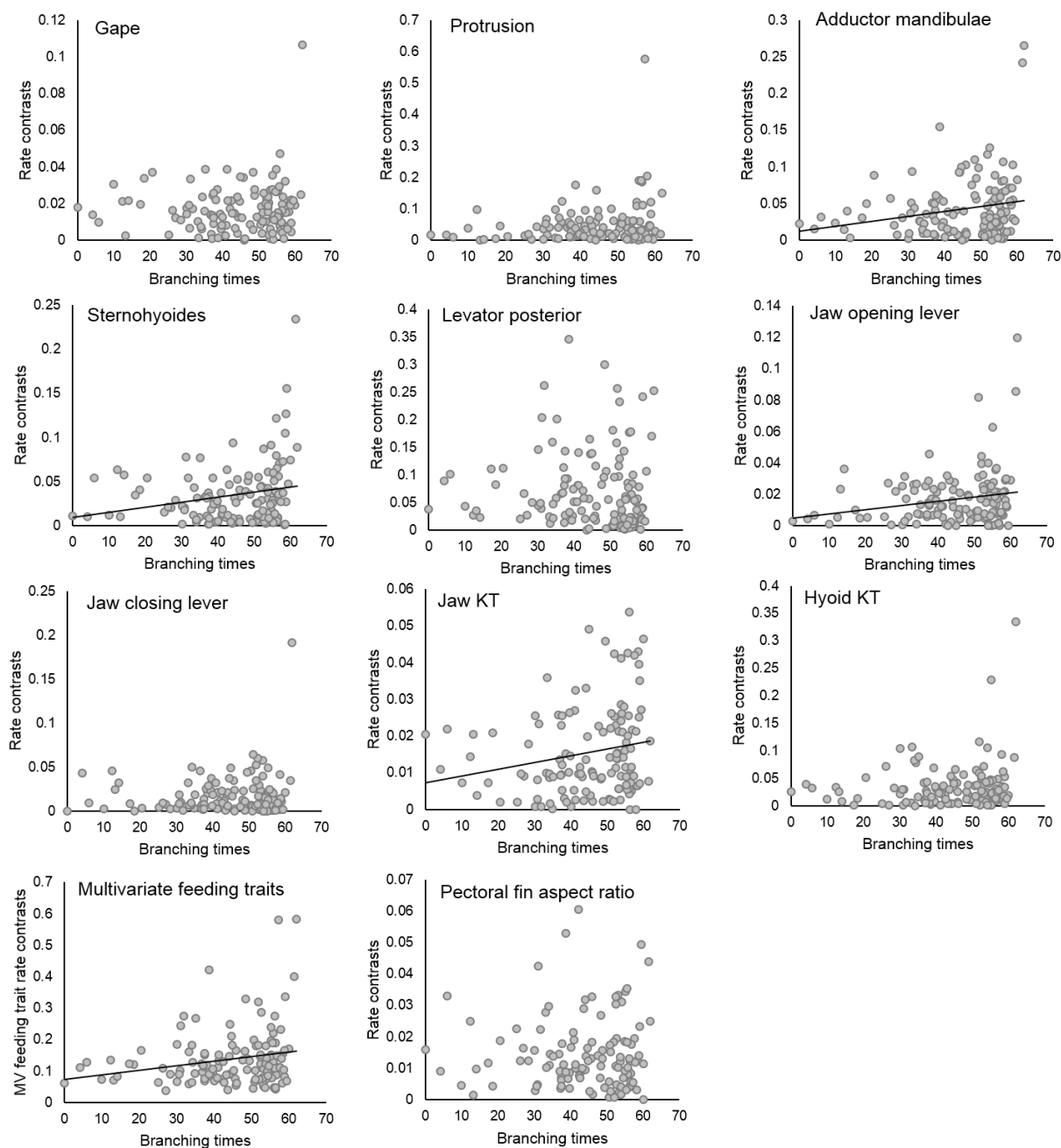
Figure S6. Node-height tests, based on the MCC tree, for the 10 traits included in the paper. Best fit lines depict significant relationships. See the main text for summary statistics from analyses across 1000 randomly sampled trees from the posterior distribution.

Supplementary Information

LABRID TROPHIC CATEGORIES

We established 10 trophic categories for labrids and placed each species from our phylogeny into one of these categories. We tried to use primary literature that described gut contents of field-collected adult fish, and in some cases we relied on species accounts on fishbase or IUCN species descriptions. The diets of many labrids are famously diverse, often including representatives from many different phyla (Randall 1967; Hobson 1974). In order to be placed in a trophic category, at least 50% of the diet had to be from the category. The category names we used are given here with the major prey components that formed the categorical definition:

Shelled Invertebrates: Included hard-shelled decopod crabs, brittlestars, gastropods and pelecypods; **Soft-Shelled Invertebrates**: polychaetes, unshelled crustacean such as isopods, amphipods, copepods, sipunculans, holothurians; **Molluscs**: shelled gastropod and pelecypods, sea urchins; **Fish**: fish, decopod shrimp and mysids; **Zooplankton**: copepods, larvaceans, crab larvae, salps, fish eggs; **Herbivore**: algae, detritus, bluegreen algae, sediment; **Omnivore**: plant material with at least 30% animal prey; **Coral**: mucus from scleractinian coral; **Cleaner**: gnathid copepods, other ectoparasites, fish mucus and bits of skin; **Foraminifera**: Foraminifera (at least 25%), gastropods and pelecypods.

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FUNCTIONAL INNOVATIONS

We surveyed functional novelties of labrid fishes and determined the taxonomic distribution of the innovations across the group. Most of these innovations are decribed in the primary literature.

Pharyngognathy. Pharyngognathy is derived condition of the pharyngeal jaw apparatus that involves fusion of the left and right ceratobranchial bones into a single lower pharyngeal jaw bone, a well-developed diarthrosis between the underside of the neurocranium and the dorsal surface of the upper pharyngeal jaw (fourth pharyngobranchial), and a continuous muscular sling that suspends the lower pharyngeal jaw from the neurocranium, providing a direct biting action (Liem and Greenwood 1981; Stiassny and Jensen 1981; Liem and Sanderson 1986). Pharyngognathy has evolved independently in at least five different groups of acanthomorph fishes (Wainwright et al. 2012) and enhances the ability of fish to handle prey that require intensive grinding, shell-cracking or crushing during processing (Liem and Sanderson 1986; Wainwright 1987). Across all pharyngognathous fishes, this trait has been shown to be associated with higher rates of the evolution of processing diets (McGee et al. 2015).

Phyllodont dentition. This is a derived condition of tooth development in the lower pharyngeal jaw bone in which the teeth arise in stacks (Bellwood 1990; 1994). This condition of the lower pharyngeal teeth is found throughout hypsigenyine genera (Bellwood 1994).

Parrotfish pharyngeal jaw. All scarines plus *Pseudodax* possess a similar, derived condition of pharyngognathy that includes 12 individual synapomorphies (Bellwood 1994). These include modified phylodont dentition, an elongate articulation between the upper pharyngeals and the neurocranium, enlarged epibranchials that stabilize a wide anterior-posterior motion of the upper pharyngeals, and teeth arranged in distinct rows, and being added at the posterior margin of the dentigerous surface. The parrofish pharyngeal jaw is intimately related to their feeding behavior in which algal turfs and sediment are scraped from rocky surfaces and ground into a slurry before being swallowed (Clement et al. 2017).

Incisiform teeth. In *Pseudodax*, the anterior teeth of the premaxilla are enlarged and laterally flattened into an incisor-like shape (Bellwood 1994). These teeth form the scraping surface of the oral jaws in *Pseudodax*, which scrapes turf algae from rocky surfaces.

Folded lips. Species in the genera *Labrichthys*, *Labropsis* and *Diproctacanthus* possess lips with a highly folded epithelium that is richly endowed with mucus-secreting glands (Huertas and Bellwood 2018).

Coalesced teeth of the premaxilla. The teeth of *Odax* and the parrotfish genera *Sparisoma*, *Scarus*, *Chlorurus*, *Hipposcarus*, *Bolbometapon*, and *Cetoscarus* are thickened and coalesce into a dental plate that gives the fish a beak-like jaw (Bellwood 1994). This fused and thickened toothed edge of the jaws is used to scrape rocky substrates to remove algae and detritus when feeding.

Intra-mandibular jaw joint. In *Scarus*, *Chlorurus* and *Hipposcarus*, the articulation between the dentary and articular bones of the lower jaw forms a rotating joint (Bellwood 1994). This joint permits motion between the two bones, in addition to the joint between the quadrate

and articular, making the lower jaw double-jointed. The joint is thought to allow parrotfish to open the jaws wider than they would otherwise, and to modulate the orientation of the dentary, which may help fit the jaws to the uneven surface of the reef during their scraping behavior (Konow et al. 2008).

Rotating quadrate. In *Epibulus*, the quadrate bone is elongate and the proximal end forms a rotating joint with the hymandibula. As the distal end forms a hinge joint with the articular bone, the splint-like quadrate permits extensive protrusion of the lower jaw, giving this suction feeding wrasse the most protrusible jaws ever reported in teleost fishes (Westneat and Wainwright 1989).

Fin waving. Several species of *Choerodon* will wave their pectoral fin, generating a pulse of water flow that they use to spread sand and expose buried prey (Bernardi 2012; Cure et al. 2015).

Highly elongate body shape. Among the temperate odacines, *Siphonognathus argyrophanes* has an exceptionally slender, elongate body shape. This species mimics the blades of seagrasses it lives among while hunting small, mobile invertebrate prey (MacArthur and Hyndes 2007; Mabuchi et al. 2007).

Highly elongate jaws. The two species of *Gomphosus* possess highly elongate upper and jower jaws (Wainwright et al. 2004). In Hawaii, *G. varius* feeds extensively on small xanthid crabs that it takes from inside the tightly branching *Pocillopora* coral and other crevices on the reef (Hobson 1974), for which the elongate, forceps-like jaws are presumably well-adapted. The extent of reliance on crevice-dwelling xanthid crabs is greater in *Gomphosus* than closely related species of *Thalassoma* (Bellwood et al. 2006; Randall 1967; Hobson 1974).

Split lower lip. The cleaner wrasses of the genus *Labroides* all possess a midline split in the lower lip that exposes the teeth of the lower jaw ventrally. Species in this group swim across their client fish at a shallow angle, almost parallel to the surface of the client (Baliga et al. 2017). The split lip may facilitate access of the toothed jaws to the ectoparasite prey these fish remove from clients.

Recurved teeth. Species of *Anampses* all possess anteriorly oriented, recurved canine teeth that do not point in the direction of jaw adduction (Wainwright et al. 2004). Canines in other wrasses are used extensively to grab prey in a fashion not possible in *Anampses*. The anteriorly oriented canines appear to be used to probe turf algae for the small amphipods and polychaetes that these species feed upon.

Large pharyngeal tooth. Species of *Macrophayrngodon* have a single hypertrophied, oval mollariform tooth in the center of the lower paryngeal jaw (Randall 1978; Wainwright et al. 2004). This appears to be used when crushing the foraminifera, gastropods and bivalves that species of this genus feed upon (Yamaoka 1978; Bellwood et al. 2006) in spite of their very small body size that rarely exceeds 125 mm (Randall 1978).

Anti-freeze proteins. Cunner (*Tautogolabrus aspersus*) express type I antifreeze proteins in their body tissues (Hobbs et al. 2011). Anti freeze proteins bind with ice crystals, preventing their propagation and have evolved nuermous times in teleost fishes in assocaition with adaptation to extremely cold waters (Graham et al. 2013). Cunner are found along the eastern coast of North American from the Chesapeake bay region north to Newfoundland and Gulf of St. Lawrence in Canada.

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