Table S1: Database of acuity (cycles/degree) in adult ray-finned fish, method of acuity measurement, environmental/ecological categories, and citations. Number of significant figures in the measure of acuity is based on the number of significant figures reported in the original citation.

Order	Family	*Genus*	*Species*	Acuity (CPD)	Method[1]	LL[2]	T[3]	H[4]	D[5]	Citation
Anguilliformes	Nemichthyidae	*Avocettina*	*infans*	8.3	LO	Dark	Clear	F	MB	[1]
Aulopiformes	Chlorophthalmidae	*Chlorophthalmus*	*albatrossis*	3.9	PR	Dim	Med	HD	P	[2]
	Evermannellidae	*Coccorella*	*atlantica*	2.9	LO					[1]
	Notosudidae	*Scopelosaurus*	*hoedti*	10.6	LO					[1]
	Scopelarchidae	*Scopelarchus*	*michaelsarsi*	5.6	RGC					[3]
Batrachoidiformes	Batrachoididae	*Halophryne*	*diemensis*	4	RGC					[4]
Beloniformes	Adrianichthyidae	*Oryzias*	*latipes*	0.563	B					[5]
	Adrianichthyidae	*Oryzias*	*latipes*	1.0	B					[6]
	Scomberesocidae	*Cololabis*	*saira*	7.1	PR	Dim	Clear	F	MB	[7]
Beryciformes	Anoplogastridae	*Anoplogaster*	*cornuta*	8.3	LO	Dark	Clear	F	P	[1]
Clupeiformes	Clupeidae	*Alosa*	*pseudoharengus*	2.4	PR	Dim	Med	HD	P	[8]
	Clupeidae	*Clupea*	*harengus*	9	PR	Dim	Med	HD	P	[9]
Cypriniformes	Cyprinidae	*Abramis*	*brama*	4	RGC	Dim	Med	HD	MB	[10]
	Cyprinidae	*Aspius*	*aspius*	4	RGC					[10]
	Cyprinidae	*Carassius*	*auratus*	1.1	B					[11]
	Cyprinidae	*Carassius*	*auratus*	3.0	B					[12]
	Cyprinidae	*Carassius*	*auratus*	3.0	B					[13]
	Cyprinidae	*Carassius*	*auratus*	3.2	B					[14]
	Cyprinidae	*Carassius*	*auratus*	3.4	B					[15]
	Cyprinidae	*Carassius*	*auratus*	1.2	B					[16]
	Cyprinidae	*Carassius*	*auratus*	13.64	B					[17]
	Cyprinidae	*Carassius*	*auratus*	2.5	PR					[12]
	Cyprinidae	*Carassius*	*auratus*	3	PR					[18]
	Cyprinidae	*Carassius*	*auratus*	3.7	PR					[15]
	Cyprinidae	*Carassius*	*auratus*	3.8	PR					[19]
	Cyprinidae	*Cyprinus*	*carpio*	4	RGC	Dim	Med	HD	S	[10]
	Cyprinidae	*Danio*	*rerio*	0.589	B	Dim	Murky	HD	MB	[5]
	Cyprinidae	*Danio*	*rerio*	0.871	PR	Dim	Murky	HD	MB	[20]

Journal of Experimental Biology • Supplementary information

	Cyprinidae	*Exoglossum*	*maxillingua*	2.10	RGC	Dim	Med	HD	MB	[21]
	Cyprinidae	*Pelecus*	*cultratus*	5	RGC	Dim	Med	HD	P	[10]
	Cyprinidae	*Phoxinus*	*laevis*	5.56	B					[22]
	Cyprinidae	*Phoxinus*	*laevis*	5.45	PR					[22]
	Cyprinidae	*Rutilus*	*rutilus*	3	RGC	Bright	Murky	HD	S	[10]
	Cyprinidae	*Rutilus*	*rutilus*	4	PR	Bright	Murky	HD	S	[23]
	Cyprinidae	*Semotilus*	*atromaculatus*	2.69	RGC					[21]
Cyprinodontiformes	Poeciliidae	*Lebistes*	*reticulatus*	6.7	B					[24]
Gadiformes	Gadidae	*Theragra*	*chalcogramma*	6.0	PR	Dark	Med	F	P	[25]
Lampriformes	Regalecidae	*Regalecus*	*glesne*	5.9	LO	Dim	Clear	F	P	[1]
	Stylephoridae	*Stylephorus*	*chordatus*	9.2	RGC					[26]
Lepisosteiformes	Lepisosteidae	*Lepisosteus*	*platyrhincus*	2.3	RGC	Dim	Murky	HD	P	[27]
Myctophiformes	Myctophidae	*Benthosema*	*suborbitale*	13	LO					[1]
	Myctophidae	*Lampanyctus*	*festivus*	2.0	RGC	Dark	Clear	F	P	[26]
	Myctophidae	*Lepidophanes*	*guentheri*	3.2	LO					[1]
	Myctophidae	*Myctophum*	*punctatum*	3.6	RGC	Dark	Clear	F	P	[28]
	Myctophidae	*Nannobrachium*	*atrum**	1.3	RGC	Dark	Clear	F	P	[26]
Osmeriformes	Alepocephalidae	*Alepocephalus*	*bairdii*	22.9	RGC					[26]
	Alepocephalidae	*Alepocephalus*	*rostratus*	11.9	RGC					[3]
	Alepocephalidae	*Bathytroctes*	*microlepis*	13.5	RGC					[3]
	Alepocephalidae	*Conocara*	*macroptera*	10.4	RGC					[26]
	Alepocephalidae	*Conocara*	*salmonea*	13.5	RGC					[26]
	Alepocephalidae	*Narcetes*	*stomias*	10.0	RGC					[26]
	Alepocephalidae	*Rouleina*	*attrita*	12.7	RGC	Dark	Clear	F	P	[3]
	Alepocephalidae	*Xenodermichthys*	*copei*	6.4	RGC	Dark	Clear	F	P	[3]
	Argentinidae	*Glossanodon*	*semifasciatus**	6.5	PR					[2]
	Bathylagidae	*Melanolagus*	*bericoides*	5.0	LO					[1]
	Opisthoproctidae	*Dolichopteryx*	*spp.*	4.8	RGC					[26]
	Opisthoproctidae	*Opisthoproctus*	*grimaldii*	5.7	RGC					[26]
	Opisthoproctidae	*Opisthoproctus*	*soleatus*	12	LO					[1]
	Opisthoproctidae	*Opisthoproctus*	*soleatus*	4.3	RGC					[26]
	Opisthoproctidae	*Winteria*	*telescopa*	14.29	RGC					[28]
	Platytroctidae	*Platytroctes*	*apus*	9.3	RGC					[3]
Osmeriformes	Platytroctidae	*Searsia*	*koefoedi*	7.4	RGC					[3]

Journal of Experimental Biology • Supplementary information

Perciformes	Acanthuridae	*Prionurus*	*scalprum**	7.1	PR	Bright	Med	C	S	[2]
	Acropomatidae	*Malakichthys*	*wakiyae*	7.6	PR					[2]
	Apogonidae	*Apogon*	*lineatus*	4.2	PR					[2]
	Blenniidae	*Petroscirtes*	*variabilis*	4	RGC					[4]
	Carangidae	*Carangoides*	*bartholomaei**	2.6	LO	Bright	Med	C	P	[1]
	Carangidae	*Carangoides*	*equula*	9.09	RGC	Dim	Med	C	P	[28]
	Carangidae	*Selar*	*crumenophthalmus*	2.9	LO	Dim	Clear	F	MB	[1]
	Carangidae	*Seriola*	*dumerili*	20	PR	Bright	Med	C	P	[29]
	Carangidae	*Seriola*	*quinqueradiata*	4.4	PR	Bright	Med	HD	P	[30]
	Carangidae	*Seriola*	*quinqueradiata*	6.90	PR	Bright	Med	HD	P	[2]
	Carangidae	*Trachurus*	*declivis*	9.1	PR	Dim	Med	HD	P	[31]
	Carangidae	*Trachurus*	*japonicus*	7.0	PR	Dim	Clear	F	P	[2]
	Centrarchidae	*Ambloplites*	*rupestris*	40	PR	Dim	Med	HD	MB	[32]
	Centrarchidae	*Lepomis*	*macrochirus*	5.00	B	Dim	Med	HD	MB	[33]
	Centrarchidae	*Lepomis*	*macrochirus*	6.7	PR	Dim	Med	HD	MB	[33]
	Centrarchidae	*Lepomis*	*macrochirus*	8.1	PR	Dim	Med	HD	MB	[34]
	Centrarchidae	*Lepomis*	*macrochirus*	22	PR	Dim	Med	HD	MB	[32]
	Centrarchidae	*Micropterus*	*salmoides*	5.9	PR	Dim	Med	HD	P	[35]
	Centrarchidae	*Pomoxis*	*annularis*	7.8	PR	Dim	Murky	HD	P	[36]
	Cichlidae	*Astronotus*	*ocellatus*	11	B					[37]
	Cichlidae	*Cichlasoma*	*portalegrense*	10	B					[38]
	Cichlidae	*Haplochromis*	*bicolor*	2.9	PR					[39]
	Cichlidae	*Haplochromis*	*elegans*	2.9	PR					[39]
	Cichlidae	*Haplochromis*	*hiatus*	3.3	PR					[39]
	Cichlidae	*Haplochromis*	*microdon*	3.5	PR					[39]
	Cichlidae	*Haplochromis*	*mylodon*	2	PR					[40]
	Cichlidae	*Haplochromis*	*sauvagei*	3.1	PR					[39]
	Cichlidae	*Haplochromis*	*squamipinnis*	2	PR	Dim	Med	HD	MB	[40]
	Cichlidae	*Haplochromis*	*iris*	3.3	PR					[39]
	Cichlidae	*Hemichromis*	*bimaculatus*	8.6	B					[24]
	Cichlidae	*Xenotilapia*	*flavipinnis*	0.591	B					[41]
	Cichlidae	*Xenotilapia*	*leptura**	2.670	B					[41]
	Cichlidae	*Xenotilapia*	*melanogenys**	1.367	B					[41]

Journal of Experimental Biology • Supplementary information

Cichlidae	*Xenotilapia*	*spilopterus**	0.592	B					[41]
Coryphaenidae	*Coryphaena*	*hippurus*	30	RGC	Dim	Med	F	P	[29]
Gempylidae	*Diplospinus*	*multistriatus*	4.8	LO	Dark	Med	F	P	[1]
Gerreidae	*Parequula*	*melbournensis*	16	PR	Bright	Med	HD	MB	[31]
Girellidae	*Girella*	*punctata*	7.7	PR	Bright	Med	C	MB	[2]
Istiophoridae	*Istiophorus*	*albicans*	32	PR	Dim	Clear	F	P	[29]
Istiophoridae	*Kajikia*	*albida**	33	PR					[29]
Istiophoridae	*Makaira*	*nigricans*	8.5	RGC	Dim	Clear	F	P	[42]
Kyphosidae	*Microcanthus*	*strigatus*	12	B	Dim	Med	C	MB	[43]
Kyphosidae	*Microcanthus*	*strigatus*	18	PR	Dim	Med	C	MB	[43]
Labridae	*Choerodon*	*cyanodus**	15	RGC					[4]
Lateolabracidae	*Lateolabrax*	*japonicus*	7.1	PR	Bright	Med	C	P	[2]
Leiognathidae	*Leiognathus*	*equulus**	5.2	PR	Dim	Med	C	MB	[2]
Lethrinidae	*Gymnocranius*	*audleyi**	27	RGC					[4]
Lethrinidae	*Lethrinus*	*miniatus**	22	RGC	Dim	Med	C	MB	[4]
Percidae	*Perca*	*flavescens*	3.0	PR	Dim	Med	HD	MB	[8]
Percidae	*Perca*	*flavescens*	3.5	PR	Dim	Med	HD	MB	[23]
Percidae	*Perca*	*flavescens*	7	PR	Dim	Med	HD	MB	[44]
Percidae	*Perca*	*fluviatilis*	2	PR	Dim	Med	HD	MB	[40]
Pinguipedidae	*Parapercis*	*cylindrica*	7	RGC	Bright	Med	C	MB	[4]
Pomacanthidae	*Dascyllus*	*marginatus*	1.3	B	Bright	Med	C	P	[45]
Pomacanthidae	*Dascyllus*	*marginatus*	8.6	PR	Bright	Med	C	P	[45]
Pomacanthidae	*Pomacanthus*	*semicirculatus*	7	RGC	Bright	Med	C	S	[4]
Pomacentridae	*Amblyglyphidodon*	*curacao*	8	RGC	Bright	Med	C	MB	[4]
Priacanthidae	*Heteropriacanthus*	*cruentatus**	10.3	PR	Dim	Med	C	P	[2]
Scombridae	*Acanthocybium*	*solandri*	25	PR	Bright	Clear	F	P	[29]
Scombridae	*Euthynnus*	*affinis*	8.11	B					[46]
Scombridae	*Euthynnus*	*alletteratus*	20	PR	Dim	Med	C	P	[29]
Scombridae	*Katsuwonus*	*pelamis*	10.7	B	Dim	Clear	F	P	[46]
Scombridae	*Katsuwonus*	*pelamis*	14.0	PR	Dim	Clear	F	P	[46]
Scombridae	*Katsuwonus*	*pelamis*	26	PR	Dim	Clear	F	P	[29]
Scombridae	*Scomber*	*australasicus*	10.8	PR	Dim	Clear	F	P	[47]
Scombridae	*Scomber*	*japonicus*	8.0	PR	Dim	Clear	F	P	[2]

Journal of Experimental Biology • Supplementary information

	Scombridae	*Scomberomorus*	*cavalla*	12	PR	Bright	Med	C	P	[29]
	Scombridae	*Thunnus*	*albacares*	16.4	B	Bright	Clear	F	P	[48]
	Scombridae	*Thunnus*	*albacares**	27	PR	Bright	Clear	F	P	[29]
	Serranidae	*Cephalopholis*	*miniatus*	14	RGC	Bright	Med	C	P	[4]
	Serranidae	*Epinephelus*	*chlorostigma*	9.8	PR	Dim	Med	C	P	[2]
	Serranidae	*Epinephelus*	*septemfasciatus*	14.3	PR					[2]
	Sillaginidae	*Sillago*	*flindersi*	7.8	PR	Bright	Med	HD	MB	[31]
	Sparidae	*Acanthopagrus*	*berda**	9.7	PR	Dim	Med	HD	MB	[2]
	Sparidae	*Acanthopagrus*	*schlegelii**	8.7	PR	Bright	Med	HD	MB	[2]
	Sparidae	*Dentex*	*tumifrons**	8.8	PR	Dim	Med	HD	MB	[2]
	Sparidae	*Pagrus*	*auratus**	9.4	PR	Dim	Med	C	MB	[2]
	Sparidae	*Pagrus*	*major*	3.5	PR	Dim	Med	HD	MB	[49]
	Sphyraenidae	*Sphyraena*	*barracuda*	19	PR	Dim	Med	C	P	[29]
	Terapontidae	*Rhynchopelates*	*oxyrhynchus**	6.2	PR					[2]
	Toxotidae	*Toxotes*	*chatareus*	3.23	B	Dim	Murky	C	P	[50]
	Toxotidae	*Toxotes*	*chatareus*	4.00	PR	Dim	Murky	C	P	[50]
	Trichiuridae	*Trichiurus*	*lepturus*	13.3	PR	Dim	Med	HD	P	[51]
	Tripterygiidae	*Forsterygion*	*varium*	1.1	B					[52]
	Tripterygiidae	*Forsterygion*	*varium*	6.7	PR					[52]
Pleuronectiformes	Bothidae	*Lophonectes*	*gallus*	4.6	PR	Dim	Med	HD	NB	[31]
	Pleuronectidae	*Cleisthenes*	*pinetorum*	7.64	PR					[53]
	Pleuronectidae	*Hippoglossoides*	*dubius*	6.52	PR	Dim	Med	HD	P	[53]
	Pleuronectidae	*Microstomus*	*achne*	5.51	PR	Dim	Med	HD	MB	[53]
	Pleuronectidae	*Pleuronectes*	*platessa*	5	B					[54]
	Pleuronectidae	*Pleuronectes*	*platessa*	2	PR					[54]
	Scophthalmidae	*Scophthalmus*	*maximus*	6	B					[54]
	Scophthalmidae	*Scophthalmus*	*maximus*	3	PR					[54]
Salmoniformes	Salmonidae	*Coregonus*	*hoyi*	3.0	PR					[8]
	Salmonidae	*Oncorhynchus*	*mykiss*	4.29	B					[55]
Scorpaeniformes	Cottidae	*Alcichthys*	*elongatus*	8.33	PR					[56]
	Platycephalidae	*Platycephalus*	*bassensis*	9.4	PR	Dim	Med	HD	P	[31]
	Platycephalidae	*Platycephalus*	*richardsoni**	9.5	PR	Dim	Med	HD	P	[31]
	Sebastidae	*Helicolenus*	*dactylopterus*	5.7	PR	Dim	Med	HD	P	[2]
	Sebastidae	*Sebastes*	*schlegelii*	6.32	PR	Bright	Med	HD	MB	[57]

Journal of Experimental Biology • Supplementary information

	Sebastidae	*Sebastiscus*	*marmoratus*	9.0	PR	Bright	Med	HD	MB	[2]
	Triglidae	*Chelidonichthys*	*kumu*	8.8	PR					[2]
	Triglidae	*Lepidotrigla*	*mulhalli*	7.1	PR					[31]
Stephanoberyciformes	Melamphaidae	*Scopeloberyx*	*robustus*	5.0	LO	Dark	Clear	F	P	[1]
Stomiiformes	Gonostomatidae	*Sigmops*	*elongatus**	7.7	LO					[1]
	Sternoptychidae	*Argyropelecus*	*aculeatus*	7.7	LO	Dim	Clear	F	P	[1]
	Sternoptychidae	*Argyropelecus*	*affinis*	7.9	RGC	Dim	Clear	F	P	[26]
	Sternoptychidae	*Argyropelecus*	*gigas*	8.7	RGC	Dim	Clear	F	P	[26]
	Sternoptychidae	*Argyropelecus*	*hemigymnus*	5.0	RGC					[26]
	Sternoptychidae	*Argyropelecus*	*sladeni*	6.00	RGC	Dim	Clear	F	P	[3]
	Sternoptychidae	*Sternoptyx*	*diaphana*	11	LO					[1]
	Stomiidae	*Astronesthes*	*lucifer*	8.3	LO					[1]
	Stomiidae	*Chauliodus*	*sloani*	4.4	LO	Dark	Clear	F	P	[1]
	Stomiidae	*Idiacanthus*	*antrostomus*	6.3	LO	Dark	Clear	F	P	[1]
	Stomiidae	*Malacosteus*	*niger*	5.6	LO	Dark	Clear	F	P	[1]
Syngnathiformes	Aulostomidae	*Aulostomus*	*chinensis*	15	RGC	Bright	Med	C	P	[4]
	Syngnathidae	*Hippocampus*	*abdominalis*	3.06	RGC	Dim	Med	HD	MB	[58]
	Syngnathidae	*Hippocampus*	*abdominalis*	11.4	PR	Dim	Med	HD	MB	[58]
	Syngnathidae	*Hippocampus*	*taeniopterus*	3.32	RGC					[58]
	Syngnathidae	*Hippocampus*	*taeniopterus*	13.0	PR					[58]
Tetraodontiformes	Balistidae	*Balistoides*	*conspicillum*	12	RGC	Bright	Med	C	MB	[4]
	Balistidae	*Rhinecanthus*	*aculeatus*	1.75	B	Bright	Med	C	MB	[59]
	Balistidae	*Rhinecanthus*	*aculeatus*	3.40	RGC	Bright	Med	C	MB	[59]
	Balistidae	*Rhinecanthus*	*aculeatus*	7.75	PR	Bright	Med	C	MB	[59]
	Monacanthidae	*Thamnaconus*	*degeni*	9.1	PR					[31]
	Monacanthidae	*Thamnaconus*	*modestus**	9.4	PR	Bright	Med	C	P	[2]
	Tetraodontidae	*Marilyna*	*pleurosticta**	5	RGC					[4]
	Tetraodontidae	*Takifugu*	*chrysops**	4.2	PR					[2]
	Tetraodontidae	*Takifugu*	*niphobles**	8.6	PR	Bright	Med	HD	MB	[2]

[1]Methods are lens optics (LO), photoreceptor density (PR), peak retinal ganglion cell density (RGC), and behavior (B); [2]Light level categories are: Bright, Dim, and Dark; [3]Turbidity categories are Clear, Medium (Med), and Murky; [4]Habitat Complexity categories are: Complex (C), horizon-dominated (HD), and featureless (F); [5]Diet categories are: pelagic (P), motile-benthic (MB), and sessile (S)
*Indicates species listed under a different name in the original publication; species in the database have had their names synonymized with updated taxonomies from Fishbase.org.

Journal of Experimental Biology • Supplementary information

Table S2. Comparison of PGLS regression lines of acuity on eye size obtained using photoreceptor density only, RGC density only, or a combined dataset.

Dataset	**Slope [95%CI]**	**Intercept [95%CI]**	**F-Statistic**	**p**	**r^2**	**Power**
Photoreceptor Density (n= 54)	0.773 [0.56-0.98]	0.354 [0.19-0.52]	51.5	<0.001	0.51	0.76
Retinal Ganglion Cell Density (n= 27)	0.862 [0.51-1.21]	0.330 [-0.08-0.74]	23.46	<0.001	0.54	0.40[1]
Combined (n= 81)	0.806 [0.63-0.97]	0.341 [0.21-0.47]	84.41	<0.001	0.55	0.89

[1]Power analyses showed that to achieve significance at an effect size and power equivalent to that of the photoreceptor-only analysis, a sample size of 47 would be necessary in the RGC-only dataset.

Table S3. PGLS multivariate models of acuity versus eye size (ES), while controlling for method of acuity measurement. ΔAIC values were calculated relative to the best-fit model.

Morphological Variable	**Model**	**AIC**	**ΔAIC**	ℓ_i	w_i
Eye size	Log(Acuity)~Log(ES)	-16.33	0	1.00	0.59
	Log(Acuity)~Log(ES)+Method	-14.81	1.52	0.47	0.28
	Log(Acuity)~Log(ES)*Method	-13.41	2.92	0.23	0.14
	Log(Acuity)~Method	26.7	43.03	0.00	0.00

Journal of Experimental Biology • Supplementary information

Table S4. The results of stepwise model selection on PGLS regressions of acuity versus lens diameter and ecological variables. Initial models are shown for each step, along with the AIC values of each model considered during each step. The final model from each step is the initial model in the following step. LD=lens diameter, LL=light level, T=turbidity, HC=habitat complexity, and D=diet.

Step	Model (or factor subtracted)	Degrees of Freedom	AIC
1	Log(Acuity)~Log(LD)+LL+T+HC+D		57.59
	-LL	2	54.219
	-D	2	54.219
	-T	2	56.023
	-none		57.591
	-log(LD)	1	59.915
	-HC	2	66.930
2	Log(Acuity)~Log(LD)+T+HC+D		53.76
	-D	2	50.290
	-T	2	52.117
	-none		53.759
	-log(LD)	1	56.327
	-HC	2	63.320
3	Log(Acuity)~Log(LD)+T+HC		50.29
	-T	2	48.484
	-none		50.290
	-log(LD)	1	53.246
	-HC	2	60.002
4	Log(Acuity)~Log(LD)+HC		48.48
	-LD	1	52.142
	-HC	2	56.613
Final Model	Log(Acuity)~Log(LD)+HC		48.48

Journal of Experimental Biology • Supplementary information

Supplementary Figures

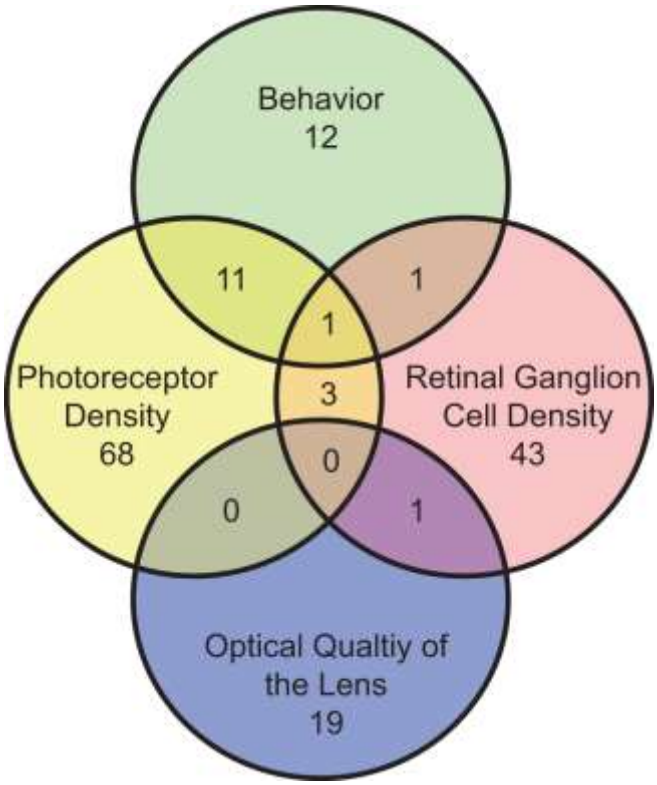
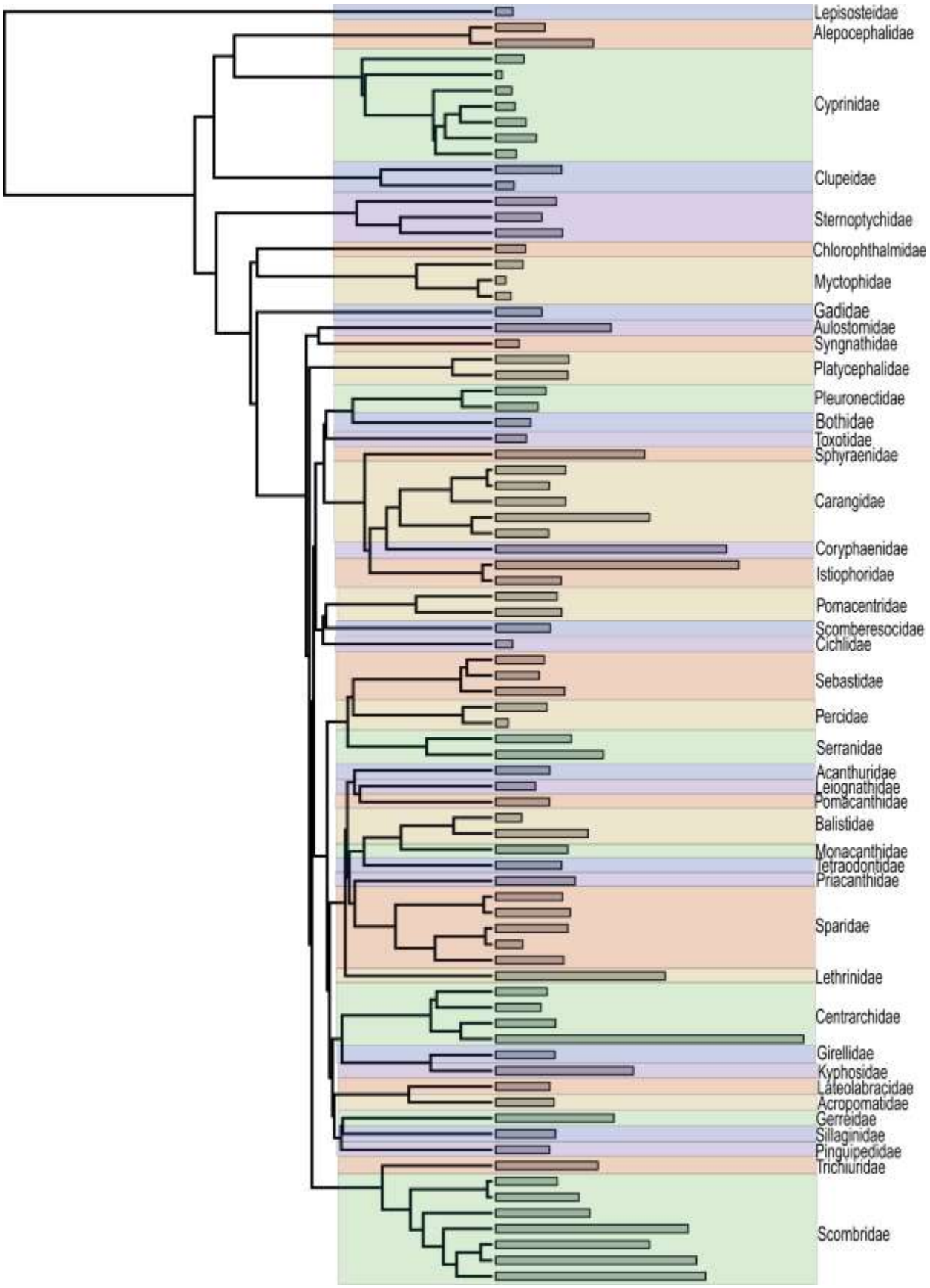


Figure S1. Number of species in the acuity database for which acuity has been measured using each method, or a combination of methods.

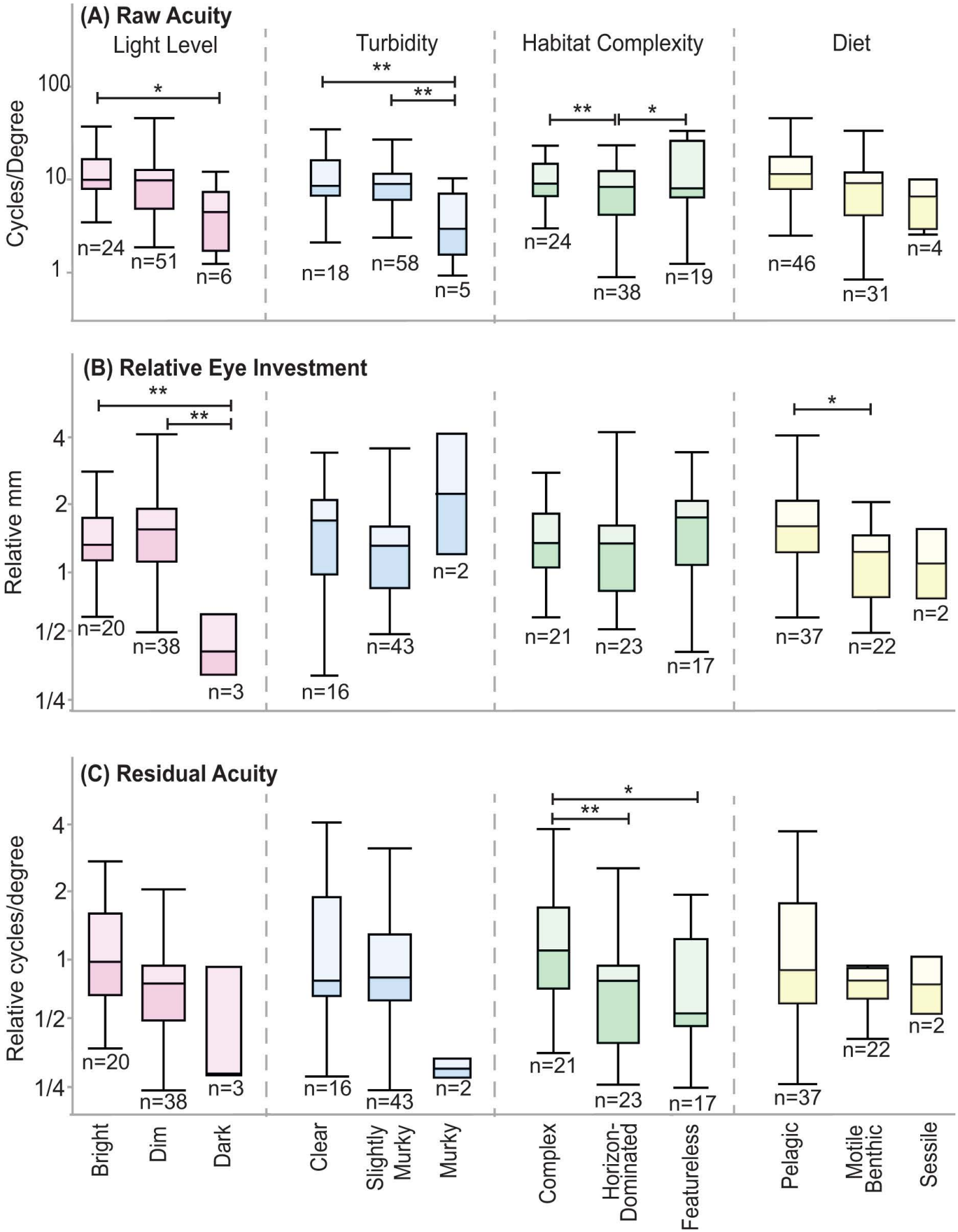
Journal of Experimental Biology • Supplementary information



Journal of Experimental Biology • Supplementary information

Figure S2. Acuity across the fish phylogeny, for the 81 species for which we had phylogeny data, and for which acuity had been measured using either photoreceptor density or peak retinal ganglion cell density. Colored boxes and labels designate families. The gray bars represent acuity in cycles/degree. Phylogeny from [60].

Journal of Experimental Biology • Supplementary information



Journal of Experimental Biology • Supplementary information

Figure S3. (A) Raw acuity (uncorrected for morphology or phylogeny), in cycles/degree, (b) relative eye investment, and (c) residual acuity across light level (pink), turbidity (blue), habitat spatial complexity (green), and diet (yellow) categories. Sample sizes are presented below each box. Statistics are from pairwise Student's t-tests. Because each panel involved three pairwise comparisons, we used a Bonferroni-correction to correct for multiple comparisons; therefore, only comparisons with p-values of 0.02 or less are significant, as 0.02 is the Bonferroni-corrected significance level. See Figure 3 for further details about units.

Journal of Experimental Biology • Supplementary information

Supplementary Literature Cited

1. Gagnon, Y. L., Sutton, T. T. & Johnsen, S. 2013 Visual acuity in pelagic fishes and mollusks. *Vision Res.* **92**, 1–9. (doi:10.1016/j.visres.2013.08.007)
2. Tamura, T. 1957 A study of visual perception in fish, especially on resolving power and accommodation. *Bull. Japanese Soc. Sci. Fish.* **22**, 536–557.
3. Collin, S. P. & Partridge, J. C. 1996 Retinal specializations in the eyes of deep-sea teleosts. *J. Fish Biol.* **49**, 157–174.
4. Collin, S. P. & Pettigrew, J. D. 1989 Quantative comparisons of the limits on visual spatial resolution set by the ganglion cell layer in twelve species of reef teleosts. *Brain, Behav. Evol.* **34**, 184–192.
5. Tappeiner, C., Gerber, S., Enzmann, V., Balmer, J., Jazwinska, A. & Tschopp, M. 2012 Visual acuity and contrast sensitivity of adult zebrafish. *Front. Zool.* **9**, 10. (doi:10.1186/1742-9994-9-10)
6. Carvalho, P. S. ., Noltie, D. B. & Tillitt, D. E. 2002 Ontogenetic improvement of visual function in the medaka Oryzias latipes based on an optomotor testing system for larval and adult fish. *Anim. Behav.* **64**, 1–10. (doi:10.1006/anbe.2002.3028)
7. Hajar, M. A. I., Inada, H., Hasobe, M. & Arimoto, T. 2008 Visual acuity of Pacific Saury Cololabis saira for understanding capture process. *Fish. Sci.* **74**, 461–468. (doi:10.1111/j.1444-2906.2008.01547.x)
8. Miller, T. J., Crowder, L. B. & Rice, J. A. 1993 Ontogenetic changes in behavioural and histological measures of visual acuity in three species of fish. *Environ. Biol. Fishes* **37**, 1–8. (doi:10.1007/BF00000707)
9. Blaxter, J. H. S. & Jones, M. P. 1967 The development of the retina and retinomotor responses in the herring. *J. Mar. Biol. Assoc. UK* **47**, 677–697. (doi:10.1017/S002531540003527X)
10. Zaunreiter, M., Junger, H. & Kotrschal, K. 1991 Retinal morphology of cyprinid fishes: a quantitative histological study of ontogenetic changes and interspecific variation. *Vision Res.* **31**, 383–394. (doi:10.1016/0042-6989(91)90091-I)
11. Hodos, W. & Yolen, N. M. 1976 Behavioral correlates of tectal compression in goldfish 2. Visual acuity. *Brain. Behav. Evol.* **13**, 468–474.
12. Hester, F. J. 1968 Visual contrast thresholds of the goldfish (Carassius auratus). *Vision Res.* **8**, 1315–1335. (doi:10.1016/0042-6989(68)90053-9)
13. Wilkinson, F. 1972 A behavioral measure of grating acuity in the goldfish.
14. Bilotta, J. & Powers, M. K. 1991 Spatial contrast sensitivity of goldfish: Mean luminance, temporal frequency and a new psychophysical technique. *Vision Res.* **31**, 577–585. (doi:10.1016/0042-6989(91)90108-H)
15. Northmore, D. & Dvorak, C. A. 1979 Sensitivity and acuity of the goldfish. *Vision Res.* **19**, 255–261.
16. Neumeyer, C. 2003 Wavelength dependence of visual acuity in goldfish. *J. Comp. Physiol. A Neuroethol. Sensory, Neural, Behav. Physiol.* **189**, 811–821. (doi:10.1007/s00359-003-0457-4)
17. Penzlin, V. H. & Stubbe, M. 1977 Studies on the visual acuity in the Goldfish. *Zool. Jb. Physiol. Bd.* **81**, 310–326.
18. Johns, P. R. & Easter, S. S. J. 1977 Growth of the adult goldfish eye. II. Increase in retinal cell number. *J. Comp. Neurol.* **176**, 331–342. (doi:10.1002/cne.901760303)

Journal of Experimental Biology • Supplementary information

19. Charman, W. N. & Tucker, J. 1973 The optical system of the goldfish eye. *Vision Res.* **13**, 1–8.
20. Haug, M. F., Biehlmaier, O., Mueller, K. P. & Neuhauss, S. C. 2010 Visual acuity in larval zebrafish: behavior and histology. *Front. Zool.* **7**, 8. (doi:10.1186/1742-9994-7-8)
21. Collin, S. P. & Ali, M. A. 1994 Multiple areas of acute vision in two freshwater teleosts, the creek chub, Semotilus atromaculatus (Mitchill) and the cutlips minnow, Exoglossum maxillingua (Lesueur). *Can. J. Zool.* **72**, 721–730.
22. Brunner, G. 1934 Ueber dis Sehschärfe der Erlitze (Phoxinus laevis) bei verschiedenen Helligkeiten. *Z. vergl Physiol.* **21**, 296.
23. Wanzenböck, J., Zaunreiter, M., Wahl, C. M. & Noakes, L. G. 1996 Comparison of behavioral and morphological measures of visual resolution during ontogeny of roach (Rutilus rutilus) and yellow perch (Perca flavescens). *Can. J. Fish. Aquat. Sci.* **53**, 1506–1512.
24. Baburina, E. A., Bogatyrev, P. B. & Protasov, V. R. 1968 A study of age variation of acuity of sight of some fish. *Zool Zhurnal* **48**, 1364–1369.
25. Zhang, X. M. & Arim, T. 1993 Visual physiology of walleye pollock (Theragra chalcogramma) in relation to capture by trawl nets. *ICES mar. Sci. Symp.* **196**, 113–116.
26. Wagner, H.-J., Frölich, E., Negishi, K. & Collin, S. P. 1998 The eyes of deep-sea fish II. Functional morphology of the retina. *Prog. Retin. Eye Res.* **17**, 637–685.
27. Collin, S. P. & Northcutt, R. G. 1993 The visual system of the Florida garfish, Lepisoteus platyrhinchus (Ginglymodi). III. Retinal ganglion cells. *Brain. Behav. Evol.* **42**, 295–320.
28. 2011 *Evolutionary shifts in vertebrate visual ecology and visual system morphology*. Durham, NC: A working group of the National Evolutionary Synthesis Center.
29. Tamura, T. & Wisby, W. J. 1963 The visual sense of pleagic fishes especially the visual axis and accommodation. *Bull. Mar. Sci.* **13**, 433–448.
30. Miyagi, M., Akiyama, S. & Arimoto, T. 2001 The development of visual acuity in Yellowtail Seriola quinqueradiata. *Nippon Suisan Gakkaishi* **67**, 455–459. (doi:10.1248/cpb.37.3229)
31. Hunt, D. E., Rawlinson, N. J. F., Thomas, G. A. & Cobcroft, J. M. 2015 Investigating photoreceptor densities, potential visual acuity, and cone mosaics of shallow water, temperate fish species. *Vision Res.* **111**, 13–21. (doi:10.1016/j.visres.2015.03.017)
32. Williamson, M. & Keast, A. 1988 Retinal structure relative to feeding in the rock bass (Ambloplites rupestris) and bluegill (Lepomis macrochirus). *Can. J. Zool.* **66**, 2840–2846.
33. Northmore, D. P. M., Oh, D.-J. & Celenza, M. A. 2007 Acuity and contrast sensitivity of the bluegill sunfish and how they change during optic nerve regeneration. *Vis. Neurosci.* **24**, 319–331. (doi:10.1017/S0952523807070307)
34. Hairston, N. G. J., Li, K. T. & Easter, S. S. J. 1982 Fish vision and the detection of planktonic prey. *Science (80-.).* **218**, 1240–1242.
35. Kawamura, G. & Kishimoto, T. 2002 Color vision, accommodation and visual acuity in the largemouth bass. *Fish. Sci.* **68**, 1041–1046. (doi:10.1046/j.1444-2906.2002.00530.x)
36. Browman, H. I., Gordon, W. C., Evan, B. I. & O'Brien, W. J. 1990 Correlation between histological and behavioral measures of visual acuity in a zooplanktivorous fish, the white crappie (Pomoxis annularis). *Brain. Behav. Evol.* **35**, 85–97. (doi:10.1159/000115858)
37. Weiler, I. J. 1966 Regeneration of visual acuity after optic nerve section and regeneration, in Astronotus ocellatus. *Exp. Neurol.* **15**, 377–386.

Journal of Experimental Biology • Supplementary information

38. Baerends, G. P., Bennema, B. E. & Vogelzang, A. A. 1960 Über die Änderung der Sehschärfe mit dem Wachstum bei Aequidens portalegrensis (Hensel) (Pisces, Cichlidae). *Zool. Jahhbücher Abteilung für Syst. Oecologie und Geogr. der Tiere* **88**, 67–78.
39. Van der Meer, H. J. & Anker, G. C. 1984 Retinal resolving power and sensitivity of the photopic system in seven Haplochromine species (Teleostei, Cichlidae). *Netherlands J. Zool.* **34**, 197–209. (doi:10.1017/CBO9781107415324.004)
40. Otten, E. 1981 Vision during growth of a generalized Haplochromis species: H. elegans Trewavas 1933 (Pisces, Cichlidae). *Netherlands J. Zool.* **31**, 650–700. (doi:10.1017/CBO9781107415324.004)
41. Dobberfuhl, A. P., Ullmann, J. F. P. & Shumway, C. A. 2005 Visual acuity, environmental complexity, and social organization in African cichlid fishes. *Behav. Neurosci.* **119**, 1648–1655. (doi:10.1037/0735-7044.119.6.1648)
42. Fritsches, K. A., Marshall, N. J. & Warrant, E. J. 2003 Retinal specializations in the blue marlin: Eyes designed for sensitivity to low light levels. *Mar. Freshw. Res.* **54**, 333–341. (doi:10.1071/MF02126)
43. Yamanouchi, T. 1956 The visual acuity of the coral fish Microcanthus strigatus (Cuvier & Valenciennes). *Publ. Seto Mar. Biol. Lab.* **5**, 133–156. (doi:10.1113/jphysiol.1902.sp000918)
44. Wahl, C. M., Mills, E. L., McFarland, W. N. & DeGisi, J. S. 1993 Ontogenetic changes in prey selection and visual acuity of the Yellow Perch, Perca flavescens. *Can. J. Fish. Aquat. Sci.* **50**, 743–749.
45. Brokovich, E., Ben-Ari, T., Kark, S., Kiflawi, M., Dishon, G., Iluz, D. & Shashar, N. 2010 Functional changes of the visual system of the damselfish Dascyllus marginatus along its bathymetric range. *Physiol. Behav.* **101**, 413–421. (doi:10.1016/j.physbeh.2010.07.006)
46. Nakamura, E. L. 1968 Visual acuity of two tunas, Katsuwonus pelamis and Euthynnus affinis. *Copeia* **1968**, 41–49.
47. Kawamura, G. 1979 Fundamental study on application of the vision of spotted mackerel, Pneumatophorus tapeinocephalus (Bleeker), to angling techniques-I. Importance of vision estimated from brain pattern, visual acuity of the retina, and accommodation. *Bull. Japanese Soc. Sci. Fish.* **45**, 281–286.
48. Nakamura, E. L. 1979 Visual acuity of yellowfin tuna, Thunus albacares. *FAO Fish. Aquac. Rep.* **3**, 463–468.
49. Shiobara, Y., Akiyama, S. & Arimoto, T. 1998 Developmental changes in the visual acuity of Red Sea Bream Pagrus major. *Fish. Sci.* **64**, 944–947.
50. Temple, S. E., Manietta, D. & Collin, S. P. 2013 A comparison of behavioural (Landolt C) and anatomical estimates of visual acuity in archerfish (Toxotes chatareus). *Vision Res.* **83**, 1–8. (doi:10.1016/j.visres.2013.02.014)
51. Kawamura, G. & Ohashi, S. 1988 The habit of cutlassfish as inferred from the retina. *Nippon Suisan Gakkaishi* **54**.
52. Pankhurst, P. M., Pankhurst, N. W. & Montgomery, J. C. 1993 Comparison of behavioural and morphological measures of visual acuity during ontogeny in a teleost fish, Forsterygion. *Brain. Behav. Evol.* **42**, 178–188.
53. Matsuda, K., Torisawa, S., Hiraishi, T. & Yamamoto, K. 2008 Comparison of visual acuity and visual axis of three flatfish species with different ecotypes. *Fish. Sci.* **74**, 562–572. (doi:10.1111/j.1444-2906.2008.01559.x)
54. Neave, D. A. 1984 The development of visual acuity in larval plaice (Pleuronectes

Journal of Experimental Biology • Supplementary information

platessa L.) and turbot (Scophthalmus maximus L.). *J. Exp. Mar. Biol. Ecol.* **78**, 167–175. (doi:10.1016/0022-0981(84)90077-7)

55. Rahmann, H., Jeserich, G. & Zeutzius, I. 1979 Ontogeny of visual acuity of rainbow trout under normal conditions and light deprivation. *Behaviour* **68**, 315–322.
56. Matsuda, K., Torisawa, S., Hiraishi, T., Nashimoto, K. & Yamamoto, K. 2005 Visual acuity and spectral sensitivity of the elkhorn sculpin Alcichthys alcicornis. *Fish. Sci.* **71**, 1136–1142. (doi:10.1111/j.1444-2906.2005.01073.x)
57. Torisawa, S., Hiraishi, T., Yamamoto, K. & Nashimoto, K. 2002 Visual acuity and spectral sensitivity of Jacopever Sebastes schlegeli. *Fish. Sci.* **68**, 984–990. (doi:10.1046/j.1444-2906.2002.00522.x)
58. Lee, H. R. & O'Brien, K. M. B. 2011 Morphological and behavioral limit of visual resolution in temperate (Hippocampus abdominalis) and tropical (Hippocampus taeniopterus) seahorses. *Vis. Neurosci.* **28**, 351–360. (doi:10.1017/S0952523811000149)
59. Champ, C., Wallis, G., Vorobyev, M., Siebeck, U. & Marshall, J. 2014 Visual acuity in a species of coral reef fish: Rhinecanthus aculeatus. *Brain. Behav. Evol.* **83**, 31–42. (doi:10.1159/000356977)
60. Rabosky, D. L., Santini, F., Eastman, J., Smith, S. A., Sidlauskas, B., Chang, J. & Alfaro, M. E. 2013 Rates of speciation and morphological evolution are correlated across the largest vertebrate radiation. *Nat. Commun.* **4**, 1958. (doi:10.1038/ncomms2958)

Journal of Experimental Biology • Supplementary information