1	ASSESSING METABOLIC CONSTRAINTS ON THE MAXIMUM BODY SIZE OF ACTINOPTERYGIANS:
2	LOCOMOTION ENERGETICS OF LEEDSICHTHYS PROBLEMATICUS (ACTINOPTERYGII:
3	PACHYCORMIFORMES)
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25 ABSTRACT

Maximum body sizes attained by living osteichthyans are much smaller than those reached by 26 27 chondrichthyans. Several factors, including the high metabolic requirements of bony fishes, have been proposed as possible body-size constraints but no empirical approaches have been 28 conducted to assess this. Remarkably, the evidence coming from the fossil record has rarely been 29 considered in studies dealing with this topic, despite some extinct actinopterygians reaching body 30 sizes comparable to those of the largest living sharks. Here, we have assessed the locomotion 31 32 energetics of *Leedsichthys problematicus*, an extinct gigantic suspension-feeder and the largest osteichthyan ever known, shedding light on the metabolic limits of body size in actinopterygians and 33 the possible underlying factors that drove gigantism in Mesozoic pachycormiforms. For this, 34 phylogenetic generalized least squares analyses and power performance curves established in 35 36 living actinopterygians were used to infer the metabolic budget ( $\approx$ routine metabolic rate, RMR) 37 and locomotion costs (≈net costs of swimming, NCS) of *L. problematicus* in a wide range of 38 phylogenetic and environmental scenarios. Our approach predicts that specimens with up to 44.9 tons would have been energetically viable and suggests that similar or even larger body sizes could 39 also be possible among living taxa. As a consequence, we discard metabolic factors as likely body 40 41 size constraints in actinopterygians, and suggest that other aspects, such as the high degree of 42 endoskeletal ossification, oviparity, indirect development or the establishment of some sharks and cetaceans as large suspension-feeders, could have hindered the evolution of gigantism among 43 post-Mesozoic ray-finned fish groups. From this perspective, the evolution of anatomical 44 innovations that allowed the transition towards a suspension-feeding lifestyle in medium-sized 45 pachycormiforms and the emergence of ecological opportunity during the Mesozoic are proposed 46 47 as the most likely factors for promoting the acquisition of gigantism in this successful lineage of 48 actinopterygians.

Key words: metabolic constraints, body size, gigantism, actinopterygians, Pachycormiformes,
 *Leedsichthys problematicus*

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GIANT animals have intrigued both popular culture and the scientific community for many 53 centuries. The largest living vertebrates occur in the oceans as massive suspension-feeders, closely 54 linked to areas of high planktonic productivity (Vermeij 2016). Although this ecological role has 55 exclusively been occupied by mysticete cetaceans and some chondrichthyans throughout the 56 Cenozoic, the first unequivocal gigantic suspension-feeders were representatives of a Mesozoic 57 group of actinopterygians called pachycormids (Friedman et al. 2010). The largest representative 58 of this extinct lineage is by far Leedsichthys problematicus, a Middle Jurassic species known from 59 60 the Callovian of England (Peterborough, Christian Malford), France (Normandy), northern 61 Germany (Wiehengebirge), the Oxfordian of Chile (east of Antofagasta) and the Kimmeridgian of France (Cap de la Hève) (Liston 2010), dwarfing subsequent Cretaceous suspension-feeding 62 pachycormids (SFPs) (Schumacher et al. 2016), as well as its two contemporary SFPs (Liston 2008; 63 2013). Leedsichthys preserves in the fossil record as isolated, poorly ossified (Liston 2004) and 64 fragmentary skeletal remains, leading to its frequent misidentification as organisms other than fish 65 (Liston 2010, Liston and Gendry 2015), and most frequently as a stegosaurian dinosaur (Liston 66 2016). The most complete specimen ever recorded still represents only a partial individual (Liston 67 2006), but some remains have served to indicate the large size of this taxon with great clarity 68 (Liston and Noè 2004, Liston 2008). As such, body size estimates of L. problematicus have been 69 based on allometric relationships established in other closely related bony fishes with comparable 70 form (i.e., Saurostomus esocinus) (Liston 2007; Liston et al. 2013). The dimensions of preopercular 71 72 remains found with a ventral gill basket (Liston 2008) suggest that *L. problematicus* reached body

lengths of up to 16.5 m. (Liston *et al.* 2013), which would make it the largest osteichthyan known
among both living and fossil species, and approximating the size of the largest chondrichthyan.

Recently, some metabolic aspects have been proposed as constraining factors of the body size and 75 76 activity level in animals. Makarieva et al. (2006) suggested that the physiological viability of all organisms is limited by a minimum critical value of mass-specific metabolic rate (mgO<sub>2</sub>·h<sup>-1</sup>·kg<sup>-1</sup>). 77 Thus, since mass-specific metabolic rate decreases as the size of organisms increases, larger sizes 78 are not physiologically viable once this limit has been reached. Similarly, this implies that costs of 79 locomotion at certain swimming speeds or highly energetic activities are not affordable over 80 particular size thresholds (Ferrón et al. 2017). Ferrón (2017) has recently established a 81 82 methodology for assessing the energetic budget and the cost of locomotion in extinct aquatic vertebrates, allowing the determination of the range of sizes within which a given activity (e.g., 83 84 active predation or suspension-feeding) can be sustained on a long-term basis. Based on this idea, 85 we here establish a similar framework to evaluate the swimming energetics of L. problematicus, shedding light on the metabolic limits of body size in actinopterygians, and discuss the possible 86 underlying factors that drove the gigantism and success of Mesozoic pachycormid fishes. 87

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### 89 MATERIAL AND METHODS

90 The swimming energetics of *Leedsichthys problematicus* were evaluated assuming different 91 environmental and phylogenetic scenarios by comparing estimates of its energy budget (assessed 92 by its routine metabolic rate) with independent inferences of its locomotion energy requirements 93 (i.e., net cost of swimming).

Routine metabolic rate (RMR), defined as the mean metabolic rate measured in an animal performing random physical activity over a given period (Dowd 2003), can be considered in a broad sense as equivalent to its energetic budget (Willmer *et al.* 2009; Clarke 2013). The scaling of

RMR with mass has been established in living ectothermic actinopterygians and used for inferring 97 98 RMR of *L. problematicus*. For this, 94 records of RMR and body mass of actinopterygians have been compiled from FishBase (Froese and Pauly 2017) (Appendix S1). RMR data were temperature 99 adjusted to 20°C, 25°C and 30°C with a Q<sub>10</sub> of 2, covering the presumed range of temperatures 100 inhabited by this species (Anderson et al. 1994; Jenkyns et al. 2012). RMR and body mass data 101 were log-transformed and a phylogenetic generalized least squares (PGLS) analysis was conducted, 102 at each temperature, by means of R software version 3.4.0 (R Development Core Team 2017) 103 104 using the ape package version 4.1 (Paradis et al. 2017) and the caper package version 0.5.2 (Orme 2013). The phylogenetic tree provided in Betancur et al. (2013) was used for the PGLS analysis 105 after modification in Mesquite software Version 3.2 (Maddison and Maddison 2017). RMR of L. 106 problematicus was then inferred from its body mass in all three scenarios. L. problematicus body 107 108 mass was calculated following Webb (mass = 0.01L<sup>3</sup>, Webb 1975, following Bainbridge 1961), 109 utilising the previously-derived estimates of body length from five specimens of *Leedsichthys* (Liston et al. 2013), and cross-checked with a scale model as per Motani (2001) (see Liston 2007 110 for full description). 111

Net costs of swimming (NCS) of L. problematicus have been calculated from power-performance 112 113 curves of living actinopterygians as the difference between the total metabolic rate (TMR, oxygen consumption at a particular swimming speed) and the standard metabolic rate (SMR, oxygen 114 consumption at resting). We selected power performance curves from Soofiani and Priede (1985), 115 McKenzie et al. (2001a, b) and Lee et al. (2003) which relate the relative swimming speed and the 116 oxygen consumption of both living non-teleostean (Acipenser naccarii) and teleostean fishes 117 (Oncorhynchus kisutch and Gadus morhua) in different environments (marine, brackish and 118 119 freshwater). Although L. problematicus is regarded as Neopterygii incertae sedis (Arratia and 120 Schulttze 2013), a close to teleostean affinity (Arratia 2004) under true-marine conditions (Liston

2010) would be the most appropriate taxonomic and environmental parameters to employ. NCS were inferred in each case at three different swimming speeds: 0.05 body lengths \* s<sup>-1</sup> (as a conservative speed based on records of similar-sized living suspension-feeder fishes; see S4 Table in Ferrón 2017), 0.14 body lengths \* s<sup>-1</sup> (as the optimal suspension-feeding speed for a 16.5 m fish according to Weihs and Webb 1983's model) and 0.30 body lengths \* s<sup>-1</sup> (as the optimal cruising speed for a 16.5 m fish according to Peters 1983's approach).

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## 128 **RESULTS AND DISCUSSION**

Maximum body sizes of living osteichthyans and chondrichthyans differ considerably. The heaviest 129 extant bony fish (Mola mola with up to 2.3 tonnes; Pope et al. 2010) is one order of magnitude 130 smaller than the largest cartilaginous fish (*Rhincodon typus* with up to 34 tonnes; Froese and Pauly 131 132 2017) and much smaller than many other sharks (see Ebert et al. 2013). Among zoologists, such 133 size discrepancy is a matter of debate and constraints of different nature have been proposed for explaining this phenomenon (see a detailed review in Freedman and Noakes 2002). Remarkably, 134 evidence coming from fossil groups has rarely been considered, despite the fact that some key 135 taxa, such as large pachycormiforms, could provide important clues in this regard. In fact, here, we 136 estimate that the largest specimens of Leedsichthys problematicus could have weighed up to 44.9 137 tons, reaching a considerably larger body mass than the heaviest known chondrichthyans and 138 making this extinct fish a target taxon for exploring the limiting factors of body size in 139 actinopterygians. 140

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142 Is the maximum body size of actinopterygians constrained by energetics?

143 Metabolic rate acts as a constraining factor of activity, feeding strategy and body size in living 144 organisms (Makarieva *et al.* 2005*a*, *b*, 2006; Ferrón *et al.* 2017). The high metabolic demand of

bony fishes has sometimes been proposed as a possible explanation of the notorious differences 145 146 in the maximum body size of living chondricthyans and osteichthyans (Freedman and Noakes 2002 and references therein). Recently, Ferrón (2017) established a methodology for assessing the 147 locomotion energetics and metabolic constraints on body size of sharks by comparing estimates of 148 their energetic budget (≈ routine metabolic rate, RMR) and locomotion energetic requirements (≈ 149 net costs of swimming, NCS). Here, based on that work, we have developed a parallel 150 methodology from living actinopterygian data in order to explore the locomotion energetics of L. 151 problematicus, assessing the body size metabolic limits of ray-finned fishes. The phylogenetic 152 generalized least squares (PGLS) analyses detect a high correlation between RMR and body mass 153 (p-value = 2.2<sup>-16</sup>) and all points adjust properly to a linear model showing a good fit and low 154 dispersion (R<sup>2</sup>= 0.85) (Appendix S2). These aspects support the relationship between both 155 156 variables as being well-founded, and that the analysis can be reliably used for predicting the RMR 157 (and the energetic budget) of extinct actinopterygians. On the other hand, power performance curves calculated in small living fishes (relating the oxygen consumption and swimming speed) 158 have been revealed as suitable models for predicting the costs of locomotion of free-swimming 159 larger species (Sundström and Gruber 1998; Semmens et al. 2013) and extinct taxa (Ferrón 2017). 160 161 More specifically, the use of net cost of swimming (NCS) as an approximation of the energy expenditure of thrust generation during swimming is especially useful when considering different 162 environmental scenarios, since this parameter seems to be independent of the water temperature 163 (William and Beamish 1990; Claireaux et al. 2006; Ohlberger et al. 2007) (see Ferrón 2017 for 164 further discussion). Here, power performance curves of living actinopterygians have been used for 165 the first time to assess the NCS in an extinct taxon. According to the established approach, the 166 energetic budget of L. problematicus (i.e., RMR) considerably exceeded its locomotion costs (i.e., 167 168 NCS) in a wide range of scenarios, considering this taxon as a teleostean and non-teleostean

actinopterygian swimming at different speeds, water temperatures and salinities (Fig. 1). Given that costs derived from locomotion constitute the main amount of the energetic expenditure in fishes (Priede 1985), these results suggest that metabolic aspects cannot be regarded as a main constraining factor of the size of living actinopterygians and that individuals with similar (or even bigger) body masses to that of *L. problematicus* could be also potentially viable in energetic terms among extant groups. Therefore, other aspects should be discussed as potential limiting factors of maximum body size in living ray-finned fishes.

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### 177 *Possible constraints on the maximum body size of actinopterygians.*

Many factors have been regarded as potential size constraints in osteichthyans (see Freedman and 178 Noakes 2002 and references therein), however only a few of them seem to be better supported 179 180 on existing evidence and deserve special attention in future studies. Life-history and ontogenetic 181 traits such as the existence of oviparity and indirect development have been proposed as the most likely limiting factors of the maximum size of teleosts. The small size of the larvae/juveniles 182 imposed by the production of tiny eggs as well as the high energetic expenditure derived from the 183 metamorphosis are indeed determinant factors of the final adult size in fishes (Freedman and 184 185 Noakes 2002). In fact, most of the biggest aquatic animals, including an important number of sharks, coelacanths, extinct marine reptiles and marine mammals, belong to groups that have 186 direct development of relatively large offspring (Wourms et al. 1991; Folkens and Randall 2002; 187 Motani 2009; Ebert et al. 2013). Besides that, endoskeletal ossification (particularly important in 188 teleostean fishes) could also constitute a constraining element in this sense, given that bone takes 189 more time and energy to create than cartilage (Gilbert 2000), and a high bone mass can 190 191 considerably increase the energy required for acceleration and deceleration in water (Biewener 192 1983). Freedman and Noakes (2002) argued that this might not represent a real limitation for the

maximum size of aquatic animals as there are numerous examples of giant cetaceans and extinct 193 194 marine reptiles with calcified skeletons. However, these examples comprise only endo- or mesotherm taxa, which have an accelerated metabolism and a wider metabolic budget than 195 ectotherms (Careau et al. 2014), entailing faster growth rates and a greater capacity to deal with 196 197 higher metabolic demands. In fact, the largest ectothermic fishes belong to groups with poorlycalcified cartilaginous endoskeletons (such as chondrichthyans or chondrosteans Nelson et al. 198 2016) or have secondarily acquired this condition from bony ancestors (e.g., the teleostean Mola 199 200 mola; Pope et al. 2010). Therefore, it is likely that the energetic investment of developing and 201 swimming with a well-ossified endoskeleton constitutes an important trade-off for ectothermic aquatic vertebrates. Finally, the evolution of different lineages of giant vertebrates follows similar 202 203 trajectories (i.e., cetaceans, pachycormids and placoderms), where the acquisition of the largest 204 body sizes occurs always after the apparent adaptation to suspension feeding (Friedman 2012). 205 Therefore, ecological scenarios that prevent the occupation of such ecospaces may also hinder the evolution of gigantic body sizes. In this sense, well-established lineages of Cenozoic suspension 206 feeder cetaceans and chondrichthyans could have competitively excluded actinopterygians from 207 exploring similar lifestyles. 208

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## 210 The rise of gigantic suspension-feeding pachycormiforms.

A subset of pachycormiforms successfully faced these limitations reaching the most gigantic sizes ever recorded in osteichthyans. Despite the exceptionality of these taxa, the reasons that promoted the acquisition of such huge body sizes have been little discussed so far and remain unclear (see Liston 2007; Friedman 2012; Liston *et al.* 2013). This group of pachycormiforms sequentially acquired a number of anatomical innovations that facilitated, in medium-sized forms, the ecological shift from an ancestral macropredatory lifestyle to a suspension-feeding strategy

(Fig. 2). Modifications in the mandibular aspect ratio, the loss of the dentition and the acquisition 217 218 of well-developed gill rakers played a crucial role in this evolutionary transition (Liston 2013, Friedman 2012 and references therein). The attainment of gigantic sizes occurred after the 219 ecological shift to suspension-feeding was completed, mirroring the patterns followed by most 220 other groups of gigantic vertebrates (Friedman 2012). Interestingly, such parallelism may be 221 satisfactorily explained from a metabolic perspective, considering that mass-specific metabolic 222 rate decreases with increasing body mass and, as a consequence, gigantic sizes are only 223 energetically viable with the previous acquisition of modes of life that entail low energetic 224 requirements (Ferrón et al. 2017). In fact, the reduction of the dermoskeleton and bone mass with 225 increasing adult size is also a phyletic trend across the pachycormiforms that could be interpreted 226 as an adaptation for minimizing energetic expenditure in the biggest species (Liston 2007; Liston et 227 al. 2013) (Fig. 2). On the other hand, high local productivity of some areas (Liston 2007 and 228 229 references therein) and the absence of other big suspension feeder taxa during most of the Mesozoic (Friedman et al. 2010) could have offered the pachycormiforms an ecological 230 opportunity for filling this ecospace. Unfortunately, other aspects that seem to be relevant in the 231 evolution of gigantic sizes of living taxa, such as the reproductive strategy (Freedman and Noakes 232 233 2002), remain speculative in pachycormiforms because of the lack of fossil evidence (Liston 2007). 234 In any case, the evolution of viviparity with direct development in this group could be considered as a likely scenario given the large sizes reached by its largest representatives, especially if we take 235 into account that this reproductive strategy has repeatedly evolved throughout the evolutionary 236 history of osteichthyans (Blackburn 2015). Therefore, pending new fossil evidence, we propose 237 that the ecological shift to a suspension feeding lifestyle in medium-sized forms, and the 238 emergence of ecological opportunity, were the primary factors that permitted pachycormiforms 239 240 to explore new zones within the potential metabolic spectrum of osteichthyans, and the acquisition of gigantic sizes, triggering in conjunction the rise of this successful lineage of giganticsuspension feeders.

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Figure 1. Comparison between routine metabolic rate (RMR) and net cost of swimming (NCS) (at 0.05, 0.14 and 0.30 body lengths\*s<sup>-1</sup>) of a 44.9 tons *Leedsichthys problematicus* considering different environmental and phylogenetic scenarios. Green gradation represents RMR at different water temperatures (see color code chart). NCS calculated from power-performance curves of (A, B and C) Acipenser naccarii from McKenzie et al. (2001a, b), (D) Oncorhynchus kisutch from Lee et al. (2003) and (E) Gadus morhua from Soofiani and Priede (1985). NCS are constant in all temperature scenarios (see text). 





Figure 2. Main anatomical innovations and body size dynamics along the evolutionary ecological shift from macropredation to suspension feeding strategy in pachycormiforms. 1, Unossified sections in the vertebral column; 2, Unossified vertebral column and loss of some dermal skull elements; 3, Loss of scales and pleural ribs, and modifications in mandibular aspect ratio; 4, Loss of dentition and well-developed gill rakers. Figure modified from Friedman (2012) following phylogenetic relationships proposed by Schumacher *et al.* (2016).

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# 453 Appendix S1. Routine metabolic rate (RMR) and body mass of actinopterygians compiled from

# 454 FishBase (Froese and Pauly 2017).

Acigencer scelarusG11371564.7521.1641.91926.781310.071833.77Arnosis interruptaE1003103101201301400.272Angular contratG122348200315.551.241.762.242Angular contratE08236.825.01.7501.912.703.72Aristotomics lungfrE00320105.03.507.307.310.731.46Bertonbelle lengtaE003103.857.53.508.771.2401.754Callery any AryE0946.771.411.82.001.2451.791.704Caron higposE0831.03.857.058.771.2401.744Caron higposE0846.781.471.82.001.241.794Caron higposE0846.002.006.1502.521.565.043Cheno charonsE0156.002.501.641.0101.641.64Cheno charonsE0156.002.501.641.0101.641.64Cheno charonsE0156.002.500.041.011.641.64Cheno charonsE0156.002.500.041.011.641.64Cheno charonsE0156.002.500.041.011.641.64Cheno charonsE0156.002.500.041.011.641.64Cheno charonsE015	Species	Specimen in the phylogeny (Betancur et al., 2013)	Body mass (g)	Temperatur e (ºC)	RMR (mg O <sub>2</sub> kg <sup>-1</sup> h <sup>-1</sup> )	RMR (mg O <sub>2</sub> h <sup>-1</sup> ) (20ºC)	RMR (mg O₂ h⁻¹) (25ºC)	RMR (mg O <sub>2</sub> h <sup>-1</sup> ) (30ºC)
Anbasis interrupta1100120120012000.280.4000.77Ameirur natalia011909.43147115.001.181.121.27Ameirur natalia0102014820.00115.501.131.201.22Anspina control1005021.005.001.0100.441.181.77Benthabelia congata1003135.001.300.307.331.0.371.161.77Benthabelia congata103335.001.501.501.501.7.401.7.401.7.40Control topomatica10241.021.601.501.7.301.6.601.7.31.6.60Secretorinia pomatica10341.021.6.101.7.201.4.61.5.801.7.31.7.60Control topomatica10131.021.7.001.7.001.7.201.6.601.7.201.6.60Contropomatica10131.5.001.7.001.5.001.7.201.6.601.7.201.6.60Contropomatica10141.5.001.0.001.0.001.6.201.6.201.6.201.6.201.6.20Contropomatica10157.6002.53.9.001.0.001.6.201.6.201.6.201.6.20Contropomatica10141.6007.002.6.203.001.6.211.6.201.6.20Contropomatica10157.6001.6.201.6.201.6.201.6.211.6.20Contropomatica	Acipenser stellatus	G1187	1554.75	21.1	641.91	926.78	1310.67	1853.57
Amelurus notaris61199.8319.7115.001.361.922.72Angular caratra612023.942.0011.5.51.241.762.48Anoplogater caranta66823.90.011.051.1400.841.181.77Sentabalelle elongata60333.930.33.93.007.3310.3714.46Baractanaise ponumera60336131.031.8711.807.541.582.741.744Compositive ponumera603462.671.411.88.201.67.91.2431.7441.744Compositive ponumera61341.031.472.55.001.2441.7691.748Compositive ponumera61341.921.87.001.1615.838.331.431.468Commos drive ponumera61331.1602.721.87.001.1612.721.87.001.1611.75.0Comos driven61341.931.472.55.001.241.76.91.751.661.25.21.661.971.1611.661.161.661.161.661.161.661.161.661.161.661.661.161.661.161.661.161.661.161.66	Ambassis interrupta	E1100	3.10	25.0	130.00	0.28	0.40	0.57
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Anoplogester conutarE066238.621.01.7.501.912.703.82Aristotations hulferE00512.105.013.000.481.181.67Bentholbeline lenopatoE003330.3033.500.3353.508.7753.508.771.60Bentholbeline lenopatoE003310.367.553.508.771.58922.4731.78Callionymus lyraE004662.7614.1168.701.58922.4833.30Carnar hipposiE013310.0314.0025.2236.0025.2336.00Cartar prist striatE113351.202.94426.2011.3716.6022.75Chenor striataE113351.202.94426.2011.3716.6022.75Chenor striataE113351.602.5030.0010.0514.210.010Chenor macrolepisE00455.602.5030.0010.0514.210.010Chroms chromisE0016.312.15291.751.662.3533.33Chroms chromisE00315.0015.0010.001.702.403.33Chroms chromisE00415.0015.0010.001.702.403.33Chroms chromisE00315.0015.0010.001.702.403.33Chroms chromisE00415.0015.0010.001.702.403.33Chroms chromisE00415.0	Anguilla rostrata	G1202	3.94	20.0	315.56	1.24	1.76	2.48
Artscatamios luniferE006521105.014.000.841.181.167Benthallein elengata1003153.007.3310.3714.66Borostomis panamenis101310.387.535.007.7310.3714.66Borostomis panamenis101310.387.515.8015.8915.8915.8015.8015.8015.8015.8015.8014.1615.8015.90	Anoplogaster cornuta	E0662	38.62	5.0	17.50	1.91	2.70	3.82
Bencholeckia constantCOOS353.007.3310.3711.466Boratinia panamentsF08110.887.585.508.7712.4017.54Callenymus hraF084612.6711.41168.0015.8022.4731.78Campostan ananyaF015012.5217.917.0014.1652.8024.4738.83Caranx hipposF083438.3014.7225.0012.4417.6024.89Cantar hipposF083438.3014.7225.0012.4417.6024.89Channa strivatF101545.0020.065.0012.5235.6650.44Channa strivatF016150.0020.065.0013.3145.0022.70Chanos chanosF001450.0020.065.0010.0014.2120.10Chanos chanosF015176.602.539.0010.0514.2120.10Chanos chanosF001450.0012.0177.602.539.0010.0514.2333.33Chans chanceF015176.602.539.0010.0514.2120.1039.33Chans chanceF015176.602.539.0010.0514.2120.10Chans chanceF015176.602.579.0010.0514.2120.10Chans chanceF015176.607.6377.6310.6912.75Chans chanceF015170.607.6377.6310.61 </td <td>Aristostomias lunifer</td> <td>E0065</td> <td>21.10</td> <td>5.0</td> <td>14.00</td> <td>0.84</td> <td>1.18</td> <td>1.67</td>	Aristostomias lunifer	E0065	21.10	5.0	14.00	0.84	1.18	1.67
Boractomics panamentsE0813103.857.53.5.508.7712.4017.54Callionyma lyraE094662.7614.1168.2015.8922.4713.78Campastoma anomalum6123619.2517.9187.0041.465.898.33Carnar hippoE08483.3014.7225.0012.445.0342.48Centrapristis strianaE01635.0327.0101.883.134.436.62Chelon macrolegisE03455.0327.0101.883.134.436.62Chelon macrolegisE03455.0327.0101.883.134.436.62Chelon macrolegisE03455.0327.0101.83.134.436.62Chelon macrolegisE03455.0327.0101.81.4110.10Chromod ningerE11576.602.53.0010.051.4210.10Chromod ningerE105176.612.513.001.001.4210.10Chromod ningerE0216.0315.08.0001.702.403.33Chromod ningerE12612.043.554.000.641.215Corregonus autumalis61271.301.5.5450.001.831.66Corregonus autumalis61271.301.5.5450.001.331.882.65Cychtone microdon61271.301.5.5450.001.331.882.65Cy	Benthalbella elongata	E0033	35.30	0.3	53.00	7.33	10.37	14.66
Callionymus lyraF094662.7614.1168.2015.8922.4731.78Campostama anomalum6123619.2517.9187.004.165.898.33Carrany kilpsosF083438.3014.7225.0012.4417.6022.57Channa striatuF11315.1227.4426.2013.1716.0922.75Channa striatuF1135.0327.01011.883.134.436.26Cheion macrolepisF08456.0026.00.841.191.68Channa striatuF11576.602.53.9.01.00.54.1120.13Chrams throaden nigerF11576.602.53.9.01.0.54.433.33Chrams throaden niger6126120.8216.9111.602.8.8140.757.63Chrams throaden niger6126120.8216.9111.602.8.8140.757.63Chrams throaden niger6126120.8216.9111.602.8.8140.757.63Chrams throaden striper6126120.8216.9111.602.8.8140.757.63Corpheren hippurus60970.9013.5650.001.181.6.97.74Cotta gabo62721.3015.565.001.181.6.97.74Cotta gabo16071.221.301.5.01.111.6.97.74Cotta gabo16121.331.6.355.001.31 <td< td=""><td>Borostomias panamensis</td><td>E0813</td><td>103.85</td><td>7.5</td><td>35.50</td><td>8.77</td><td>12.40</td><td>17.54</td></td<>	Borostomias panamensis	E0813	103.85	7.5	35.50	8.77	12.40	17.54
Campostom onnomulue6123619.2517.9187.004.165.898.33Caranx hippos608488.0314.7225.0012.4417.6042.49Centraprisk strinta616341.0020.0615.0022.2235.6650.43Chans chanos613451.2029.4426.2010.11.814.3144.3062.75Chans chanos634550.3027.010.11.81.3144.3062.65Cheon macrolegis68456.0029.0262.000.841.191.68Chans chanos602016.3121.5291.751.662.3333.33Chronic thormis602016.3115.0020.001.702.4233.33Chronic thormis612315.007.00202.6777.0310.89.33154.05Coregonus autumnis612612.9013.5450.000.440.401.77Cubicego white eggit607202.6777.0310.89.31.612.77Cubicego white eggit61621.422.43524.710.560.791.11Cubicego white eggit61621.422.43524.710.560.791.11Cubicego white eggit610253.001.501.783.501.181.67Cubicego white eggit610253.001.501.783.501.111.57Cubicego white eggit610253.001.501.78<	Callionymus lyra	E0946	62.76	14.1	168.20	15.89	22.47	31.78
Caranx hippesE083438.3014.7225.0012.4417.6024.89Centraprists striataE016341.0020.0615.0025.2235.6660.43Chanas striataE11351.2029.4446.2011.3716.0922.75Chanos striataE034550.3327.01011.8831.3344.3062.66Chelon macrolegisE04550.0327.0101.0514.2120.10Chelon macrolegisE04560.012.539.0010.0514.2120.10Chelon macrolegisE004355.0015.080.001.702.403.33Charrodon niger612420.8.2616.9111.602.8340.7557.63Carregonus autumnis6126315.0017.020.669.001.772.403.39Carregonus autumnis6126315.007.020.677.7310.662.972.77Cukceps whiteleggit16071.3013.5650.001.331.882.652.991.11Dipdoks aurgus sargusE08072.28814.0227.507.891.111.157.78Cukceps whiteleggit16121.301.35650.001.331.882.657.991.11Dipdoks aurgus sargusE08072.28814.0227.507.891.111.157.78Cukceps whiteleggit16121.422.43554.110.551.51 <td>Campostom a anom alum</td> <td>G1236</td> <td>19.25</td> <td>17.9</td> <td>187.00</td> <td>4.16</td> <td>5.89</td> <td>8.33</td>	Campostom a anom alum	G1236	19.25	17.9	187.00	4.16	5.89	8.33
Centrapristi striataE016341.0020.0615.0025.2235.6650.43Chanan striataF113351.2029.4446.2011.3716.0922.75Chans chanosE03455.0327.01011.883.134.436.66Chelon macrolepisE03456.0029.0262.000.06514.210.010Chrams chanisE02016.5112.5291.751.662.353.33Chrams chanisE003115.0015.080.001.702.403.39Conger conger61261208.2616.9111.6028.8140.7557.63Coregons autumolis612315.007.0320.6777.03108.93154.05Coregons autumolis612315.0013.5450.001.1816.72.37Cubers whiteleggiE0970.9013.5450.001.1816.72.37Cubers whiteleggiE0971.3013.5550.001.331.882.65Cyclethone microdon61220.780.32.3000.070.100.14Diploki sargus sargusE08072.28.814.0227.507.891.111.57Darssoma cepedianutE1051.301.6354.190.310.446.885.88Etholsto alteralis61023.851.5057.500.310.446.88Etholsto alteralis61232.971.633.61 <td>Caranx hippos</td> <td>E0834</td> <td>38.30</td> <td>14.7</td> <td>225.00</td> <td>12.44</td> <td>17.60</td> <td>24.89</td>	Caranx hippos	E0834	38.30	14.7	225.00	12.44	17.60	24.89
Channa striataE113351.2029.4426 2011.3716.0922.75Chanos chanosE03455.0327.01011 883.134.436.26Chelon macrolegisE08456.0029.0262.000.841.191.66Charos charonsE02016.3121.539.0010.0514.2120.10Chromis chromisE02016.3121.5291.751.662.353.33Correg conger61261208.2616.9111.602.8.140.7557.63Corregonus autumalis61263154.007.0202.6777.03108.93154.05Carryphaena hippurusE09370.9013.5450.000.640.901.27Catus gabiaE09370.9013.5650.001.331.8.82.65Cyclothone microdon612727.780.323.000.070.100.14Cyclothone microdon612727.780.323.000.070.100.14Cyclothone microdon612727.780.323.000.070.100.14Cyclothone microdon612727.780.323.000.070.100.14Cyclothone microdon612727.781.680.791.11.61.78Darosoma cepedinumE101635.3016.3674.1930.7643.5061.51Embiotoca lateralisE012599.0015.01.73.43.444	Centropristis striata	E0163	41.00	20.0	615.00	25.22	35.66	50.43
Chanos chanosE03455.0327.01011.883.134.436.26Chelon macrolepisE08456.0029.0262.000.841.191.68Chismodon nigerE111576.602.539.0010.0514.210.010Chromis chromisE0016.1121.5291.751.662.353.33Cithrichty stigmaeusE004315.0015.080.001.702.403.39Conger congerG1261208.2616.9111.6028.8140.0557.63Coregonus auturnalisE10370.9013.545.000.6440.091.77Cotts golioE0370.9013.5650.001.331.882.65Cyclothone microdonG12720.780.323.000.070.100.44Cyclothone microdonG12720.780.323.000.070.100.44Cyclothone microdonG12720.780.323.000.070.100.44Cyclothone microdonG12720.780.367.410.560.791.11Diplodus sargus sargusE0072.281.4027.507.931.161.57.8Darcosoma cepedianumF101635.301.50107.0090.64128.1918.12Exex masquinongyG12891.4021.501.74.44.866.88Fundulus parvipinnisE035207.911.650.731.61.50.7	Channa striata	E1133	51.20	29.4	426.20	11.37	16.09	22.75
Chelon macrolepisE08456.0029.0262.000.841.191.68Chiasmodon nigerE111576.602.539.0010.0514.2120.10Chromis chromisE02016.3121.5291.751.662.353.33Charichthy stigmaeusE00315.0015.080.001.702.403.39Conger congerG1261208.2616.9111.6028.8140.7557.63Coregonus autumnolisG1263154.007.0202.6777.03108.93154.05Corus gonioE03710.9013.5455.001.181.672.73Cubiceps whiteleggiiE06721.3013.5650.001.331.882.65Cyclothone microdonG12720.780.32.3000.070.100.14Cupinodon variegatusE10661.422.43524.710.560.791.11Diplodus sargui sargusE08772.2814.0227.507.891.161.57Cubices netrolisE012059.0015.0107.009.64128.191.62Enadulus parvipinnisE03894.051.921.81.00.734.651.93Fundulus parvipinnisE0394.051.921.83.100.731.111.57Godus morhuaE037207.941.956.35.0273.403.86.6454.68Gradus gorcE0470180.000.06.30 <td>Chanos chanos</td> <td>E0345</td> <td>5.03</td> <td>27.0</td> <td>1011.88</td> <td>3.13</td> <td>4.43</td> <td>6.26</td>	Chanos chanos	E0345	5.03	27.0	1011.88	3.13	4.43	6.26
Chiasmadon nigerE11576.602.539.0010.0514.2120.10Chromis chromisE0216.3121.5291.751.662.353.33Citharichthys stigmeeusE04315.0015.080.001.702.403.39Conger congerG1261208.2616.9111.6028.8140.7557.63Corspona autumalusG1263154.007.0202.6777.03108.93115.05Corpheen hipurusE0970.9013.5450.000.640.901.77Cuticeps whiteleggiiE0671.3013.5650.001.331.882.65Cyclathone microdonG12720.780.323.000.070.100.14Cybinodon variegatusE10661.4224.3524.710.560.791.11Diplodus sargus sargusE0872.2.8814.027.507.891.165.78Dorosom cepedinumE01559.9015.0107.0090.64128.19181.28Etheostoma rufilmectus61233.5216.2173.443.444.866.88Etheostoma rufilmectus6129207.949.565.50273.4036.6456.80Gadus agarcE04716.8118.9371.2046.5765.879.71Gadus agarcE04716.8218.9371.2046.5765.879.31Gadus agarcE015279.419.565.50 <td>Chelon macrolepis</td> <td>E0845</td> <td>6.00</td> <td>29.0</td> <td>262.00</td> <td>0.84</td> <td>1.19</td> <td>1.68</td>	Chelon macrolepis	E0845	6.00	29.0	262.00	0.84	1.19	1.68
Chromis hormisE02016.3.121.5291.751.6.62.3.53.3.3Citharichthys stigmaeusE004315.0015.080.001.702.4.03.3.9Conger congerG1261208.2616.9111.602.8.8140.7557.6.3Coregonus autumnalisG1263154.007.0202.6777.03108.93154.05Corypheena hippurusE037.0.9013.5450.000.440.901.77Cattus gobiaE02812.9018.0355.001.181.672.37Cubiceps white/eggiiE06721.3013.5650.001.331.882.65Cyclotnom microdonG12720.780.323.000.070.100.14Cybnonom variegatusE10661.422.43524.710.660.791.11Diplodus sargus sargusE10672.8814.0227.507.8911.1615.78Darossom cegedianumE0120599.0015.0107.0090.64128.19181.18Esox masquinongyG128914.0215.0173.443.444.866.88Etheostoma rufilineatumE01523.8515.057.500.310.440.63Gadus agacE0470180.000.063.0045.3664.1590.72Gadus agacE0470180.000.063.0045.3664.1590.72Gadus agacE01719.9910.41	Chiasmodon niger	E1115	76.60	2.5	39.00	10.05	14.21	20.10
Citharichthys stigmeeusE004315.0015.0080.001.702.403.39Conger congerG1261208.2616.9111.6028.8140.7557.63Coregonus autumnalisG1263154.007.0202.6777.03108.93154.05Corryphena hippurusE09370.9013.5450.000.640.901.27Cottus gobioE02812.9018.0355.001.181.672.37Cubiceps whiteleggiiE06721.3013.5650.001.331.882.65Cyclothone microdonG12720.780.323.000.070.100.14Cypinodon variegatusE10661.4224.3524.710.560.791.11Dipladus sargus sargusE08072.2.8814.0227.507.8911.1615.78Dorasoma cepedianumE101635.3016.3674.1930.7643.5066.15Embiotoca lateralisE0120599.0015.0107.0090.64128.19181.28Exar masquinangyG12935.2218.21068.446.318.9312.63Fundulus parvipinnisE03752079.419.563.50273.40386.64546.80Gadus agrinE0120.9910.4180.000.350.490.63Gadus agrinG129.029116.5818.9371.2065.765.8793.15Gadus agrinG129.03<	Chromis chromis	E0201	6.31	21.5	291.75	1.66	2.35	3.33
Conger congerG1261208.2616.9111.6028.8140.7557.63Coregonus autumalisG1263154.007.0202.6777.03108.93154.05Coryphena hippurusE09370.9013.5450.000.640.901.27Cottus gobioE02812.9018.0355.001.181.672.37Cubiceps whiteleggiiE06721.3013.5650.001.331.882.65Cyclothone microdonG12720.780.32.3000.070.100.14Cypinodon variegatusE10661.4224.3524.710.560.791.11Dipladus sargus sargusE08072.28.814.0227.507.8911.1615.78Darasoma cepedianumE101635.3016.3674.1930.7643.5061.51Enbiotoca lateralisE0120599.0015.0107.0090.64128.19181.28Exax masquinongyG128914.0215.0173.443.444.666.88Etheostoma rufilineatumE01523.8515.057.500.310.440.63Fundulus parvipinmisE03952079.419.563.50273.40386.64546.80Gadus aogracE0470180.000.063.0045.350.490.69Gradus adfirisG1290.9910.4180.000.350.490.63Gradus adgrinsG1020.9910.6	Citharichthys stigmaeus	E0043	15.00	15.0	80.00	1.70	2.40	3.39
Coregonus autumnalis         61263         154.00         7.0         202.67         77.03         108.93         154.05           Corphaena hippurus         E0937         0.90         13.5         450.00         0.64         0.90         1.77           Cottus gabia         E0281         2.90         18.0         355.00         1.18         1.67         2.37           Cubiceps whiteleggii         E0672         1.30         13.5         650.00         1.33         1.88         2.65           Cyclathone microdon         61272         0.78         0.3         23.00         0.07         0.10         0.14           Cyprinodon variegatus         E1066         1.42         2.43         524.71         0.56         0.79         1.11           Dipladus sargus sargus         E0807         22.88         14.00         227.50         7.89         11.16         15.78           Darosoma cepedianum         E1016         35.30         16.3         674.19         30.76         43.50         61.51           Embiotoca lateralis         E0129         14.02         15.0         177.44         3.44         4.86         6.88           Ethostoma rufilineatum         E0152         207.94         19.5 <td>Conger conger</td> <td>G1261</td> <td>208.26</td> <td>16.9</td> <td>111.60</td> <td>28.81</td> <td>40.75</td> <td>57.63</td>	Conger conger	G1261	208.26	16.9	111.60	28.81	40.75	57.63
Coryphaena hippurus         E0937         0.90         13.5         450.00         0.64         0.90         1.27           Cottus gobio         E0281         2.90         18.0         355.00         1.18         1.67         2.37           Cubiceps whiteleggii         E0672         1.30         13.5         650.00         1.33         1.88         2.65           Cyclothone microdon         G1272         0.78         0.3         23.00         0.07         0.10         0.14           Cyprinodon variegatus         E1066         1.42         24.3         524.71         0.56         0.79         1.11           Diplodus sargus sargus         E0807         22.88         14.00         227.50         7.89         11.16         15.78           Dorosoma cepedianum         E1016         35.30         16.3         674.19         30.76         43.50         61.51           Embiotoca laterails         E0120         599.00         15.0         107.00         90.64         128.19         181.28           Esox masquinongy         G1293         5.22         18.2         1066.44         6.31         8.93         12.63           Fundulus heterocitus         G1293         207.9         180.00	Coregonus autumnalis	G1263	154.00	7.0	202.67	77.03	108.93	154.05
Catus gabioE02812.9018.0355.001.181.672.37Cubiceps whiteleggiiE06721.3013.5650.001.331.882.65Cyclathone microdonG12720.780.323.000.070.100.14Cyprinodon variegatusE10661.4224.3524.710.560.791.11Diplodus sargus sargusE080722.8814.0227.507.8911.1615.78Dorosoma cepedianumE101635.3016.3674.1930.7643.5061.51Embiotaca lateralisE0120599.0015.0107.0090.64128.19181.28Exax masquinongyG128914.0215.0173.443.444.866.88Etheostoma rufilineatumE01523.8515.057.500.310.446.63Fundulus heterocitusG12935.2218.21068.446.318.9312.63Gadus agacE0470180.000.063.0045.3664.1590.72Garbusia affinisG12960.2920.2399.110.110.160.23Garbusia affinisG1297116.5818.9371.2046.5765.8793.15Gorbusia affinisG1529470.000.323.0042.3559.8984.70Granbusia affinisG1529470.000.323.0042.3559.8984.70Granbusia affinisG1529470.000.	Coryphaena hippurus	E0937	0.90	13.5	450.00	0.64	0.90	1.27
Cubiceps whiteleggii         E0672         1.30         13.5         650.00         1.33         1.88         2.65           Cyclathane micradan         61272         0.78         0.3         23.00         0.07         0.10         0.14           Cyprinadan variegatus         E1066         1.42         24.3         524.71         0.56         0.79         1.11           Diplodus sargus sargus         E0807         22.88         14.0         227.50         7.89         11.16         15.78           Darosoma cepedianum         E1016         35.30         16.3         674.19         30.76         43.50         61.51           Embiotaca lateralis         E0120         599.00         15.0         107.00         90.64         128.19         181.28           Exax masquinongy         G1289         14.02         15.0         173.44         3.44         4.86         6.88           Etheastoma rufilineatum         E0152         3.85         15.0         57.50         0.31         0.44         0.63           Fundulus heterocitus         G1293         5.22         18.2         1068.44         6.31         8.93         12.63           Gadus agac         E0470         180.00         0.0	Cottus gobio	E0281	2.90	18.0	355.00	1.18	1.67	2.37
Cyclathone microdon         G1272         0.78         0.3         23.00         0.07         0.10         0.14           Cyprinodon variegatus         E1066         1.42         24.3         524.71         0.56         0.79         1.11           Diplodus sargus sargus         E0807         22.88         14.0         227.50         7.89         11.16         15.78           Dorosoma cepedianum         E1016         35.30         16.3         674.19         30.76         43.50         61.51           Embiotoca lateralis         E0120         599.00         15.0         107.00         90.64         128.19         181.28           Exax masquinongy         G1289         14.02         15.0         173.44         3.44         4.86         6.88           Etheostoma rufilineatum         E0152         3.85         15.0         57.50         0.31         0.44         0.63           Fundulus heteroclitus         G1293         5.22         18.2         1068.44         6.31         8.93         12.63           Gadus agac         E0470         180.00         0.0         63.50         273.40         386.64         546.80           Gadus agac         E0197         116.58         18.9	Cubiceps whiteleggii	E0672	1.30	13.5	650.00	1.33	1.88	2.65
Cyprinodon variegatus         E1066         1.42         24.3         524.71         0.56         0.79         1.11           Diplodus sargus sargus         E0807         22.88         14.0         227.50         7.89         11.16         15.78           Dorosoma cepedianum         E1016         35.30         16.3         674.19         30.76         43.50         61.51           Embiotaca lateralis         E0120         599.00         15.0         107.00         90.64         128.19         181.28           Esox masquinongy         G1289         14.02         15.0         173.44         3.44         4.86         6.88           Etheostoma rufilineatum         E0152         3.85         15.0         57.50         0.31         0.44         0.63           Fundulus heteroclitus         G1293         5.22         18.2         1068.44         6.31         8.93         12.63           Fundulus parvipinnis         E0389         4.05         19.2         183.10         0.78         1.11         15.7           Gadus ogac         E0470         180.00         0.0         63.50         273.40         386.64         546.80           Garbusia affinis         G1296         0.29         20.2<	Cyclothone microdon	G1272	0.78	0.3	23.00	0.07	0.10	0.14
Diplodus sargus sargus         E0807         22.88         14.0         227.50         7.89         11.16         15.78           Dorosoma cepedianum         E1016         35.30         16.3         674.19         30.76         43.50         61.51           Embiotoca lateralis         E0120         599.00         15.0         107.00         90.64         128.19         181.28           Esox masquinongy         61289         14.02         15.0         173.44         3.44         4.86         6.88           Etheostoma rufilineatum         E0152         3.85         15.0         57.50         0.31         0.44         0.63           Fundulus heterociltus         61293         5.22         18.2         1068.44         6.31         8.93         12.63           Fundulus parvipinnis         E0389         4.05         19.2         183.10         0.78         1.11         1.57           Gadus ogac         E0470         180.00         0.0         63.00         45.36         64.15         90.72           Gambusia affinis         61296         0.29         20.2         399.11         0.11         0.16         0.23           Garterosteus aculeatus         E0197         116.58         18.9<	Cyprinodon variegatus	E1066	1.42	24.3	524.71	0.56	0.79	1.11
Dorosoma cepedianum         E1016         35.30         16.3         674.19         30.76         43.50         61.51           Embiatoca lateralis         E0120         599.00         15.0         107.00         90.64         128.19         181.28           Esox masquinongy         G1289         14.02         15.0         173.44         3.44         4.86         6.88           Etheostoma rufilineatum         E0152         3.85         15.0         57.50         0.31         0.44         0.63           Fundulus heteroclitus         G1293         5.22         18.2         1068.44         6.31         8.93         12.63           Fundulus parvipinnis         E0389         4.05         19.2         183.10         0.78         1.11         1.57           Gadus morhua         E0375         2079.41         9.5         63.50         273.40         386.64         546.80           Gadus ogac         E0470         180.00         0.0         63.00         45.35         64.15         90.72           Gambusia affinis         G129         0.29         20.2         399.11         0.11         0.16         0.23           Garburstateratis         E0197         116.58         18.9	Diplodus sargus sargus	E0807	22.88	14.0	227.50	7.89	11.16	15.78
Embiotoca lateralis         E0120         599.00         15.0         107.00         90.64         128.19         181.28           Esox masquinongy         G1289         14.02         15.0         173.44         3.44         4.86         6.88           Etheostoma rufilineatum         E0152         3.85         15.0         57.50         0.31         0.44         0.63           Fundulus heteroclitus         G1293         5.22         18.2         1068.44         6.31         8.93         12.63           Fundulus parvipinnis         E0389         4.05         19.2         183.10         0.78         1.11         1.57           Gadus morhua         E0375         2079.41         9.5         63.50         273.40         386.64         546.80           Gadus ogac         E0470         180.00         0.0         63.00         45.36         64.15         90.72           Gambusia affinis         G129         0.29         20.2         399.11         0.11         0.16         0.23           Gisterosteus aculeatus         E0197         116.58         18.9         371.20         46.57         65.87         93.15           Gobionotothen gibberifrons         G1529         470.00         0.3<	Dorosoma cepedianum	E1016	35.30	16.3	674.19	30.76	43.50	61.51
Esox masquinongy         G1289         14.02         15.0         173.44         3.44         4.86         6.88           Etheostoma rufilineatum         E0152         3.85         15.0         57.50         0.31         0.44         0.63           Fundulus heterocitus         G1293         5.22         18.2         1068.44         6.31         8.93         12.63           Fundulus parvipinnis         E0389         4.05         19.2         183.10         0.78         1.11         1.57           Gadus morhua         E0375         2079.41         9.5         63.50         273.40         386.64         546.80           Gadus ogac         E0470         180.00         0.0         63.00         45.36         64.15         90.72           Gambusia affinis         G1296         0.29         20.2         399.11         0.11         0.16         0.23           Gasterosteus aculeatus         E1012         0.99         10.4         180.00         0.35         0.49         0.69           Girlela nigricans Gobionatothen gibberifrons         E0197         116.58         18.9         371.20         46.57         65.87         93.15           Gobionatothen gibberifrons         G1529 <t< td=""><td>Embiotoca lateralis</td><td>E0120</td><td>599.00</td><td>15.0</td><td>107.00</td><td>90.64</td><td>128.19</td><td>181.28</td></t<>	Embiotoca lateralis	E0120	599.00	15.0	107.00	90.64	128.19	181.28
Etheostoma rufilineatumE0152 $3.85$ $15.0$ $57.50$ $0.31$ $0.44$ $0.63$ Fundulus heteroclitus $61293$ $5.22$ $18.2$ $1068.44$ $6.31$ $8.93$ $12.63$ Fundulus parvipinnisE0389 $4.05$ $19.2$ $183.10$ $0.78$ $1.11$ $1.57$ Gadus morhuaE0375 $2079.41$ $9.5$ $63.50$ $273.40$ $386.64$ $546.80$ Gadus ogacE0470 $180.00$ $0.0$ $63.00$ $45.36$ $64.15$ $90.72$ Gambusia affinis $61296$ $0.29$ $20.2$ $399.11$ $0.11$ $0.16$ $0.23$ Gasterosteus aculeatusE1012 $0.99$ $10.4$ $180.00$ $0.35$ $0.49$ $0.69$ Girella nigricans gibberifrons $E0197$ $116.58$ $18.9$ $371.20$ $46.57$ $65.87$ $93.15$ Godinotothen gibberifrons $E0140$ $37.60$ $17.5$ $168.50$ $7.53$ $10.66$ $15.07$ Gymnadraco acuticeps $E0155$ $74.40$ $-0.9$ $47.00$ $14.89$ $21.05$ $29.78$	Esox masquinongy	G1289	14.02	15.0	173.44	3.44	4.86	6.88
Fundulus heteroclitus         G1293         5.22         18.2         1068.44         6.31         8.93         12.63           Fundulus parvipinnis         E0389         4.05         19.2         183.10         0.78         1.11         1.57           Gadus morhua         E0375         2079.41         9.5         63.50         273.40         386.64         546.80           Gadus ogac         E0470         180.00         0.0         63.00         45.36         64.15         90.72           Gambusia affinis         G1296         0.29         20.2         399.11         0.11         0.16         0.23           Gasterosteus aculeatus         E1012         0.99         10.4         180.00         0.35         0.49         0.69           Girlla nigricans Gobionotothen gibberifrons         E0197         116.58         18.9         371.20         46.57         65.87         93.15           Gobionotothen gibberifrons         E0140         37.60         17.5         168.50         7.53         10.66         15.07           Gymnodraco acuticeps         E0155         74.40         -0.9         47.00         14.89         21.05         29.78	Etheostoma rufilineatum	E0152	3.85	15.0	57.50	0.31	0.44	0.63
Fundulus parvipinnis         E0389         4.05         19.2         183.10         0.78         1.11         1.57           Gadus morhua         E0375         2079.41         9.5         63.50         273.40         386.64         546.80           Gadus ogac         E0470         180.00         0.0         63.00         45.36         64.15         90.72           Gambusia affinis         G1296         0.29         20.2         399.11         0.11         0.16         0.23           Gasterosteus aculeatus         E1012         0.99         10.4         180.00         0.35         0.49         0.69           Girella nigricans gibberifrons         E0197         116.58         18.9         371.20         46.57         65.87         93.15           Goymnocephalus cernua         E0140         37.60         17.5         168.50         7.53         10.66         15.07           Gymnodraco acuticeps         E0155         74.40         -0.9         47.00         14.89         21.05         29.78	Fundulus heteroclitus	G1293	5.22	18.2	1068.44	6.31	8.93	12.63
Gadus morhua         E0375         2079.41         9.5         63.50         273.40         386.64         546.80           Gadus ogac         E0470         180.00         0.0         63.00         45.36         64.15         90.72           Gambusia affinis         G1296         0.29         20.2         399.11         0.11         0.16         0.23           Gasterosteus aculeatus         E1012         0.99         10.4         180.00         0.35         0.49         0.69           Girella nigricans gibberifrons         E0197         116.58         18.9         371.20         46.57         65.87         93.15           Gomocephalus cernua         E0140         37.60         17.5         168.50         7.53         10.66         15.07           Gymnodraco acuticeps         E0155         74.40         -0.9         47.00         14.89         21.05         29.78	Fundulus parvipinnis	E0389	4.05	19.2	183.10	0.78	1.11	1.57
Gadus ogac         E0470         180.00         0.0         63.00         45.36         64.15         90.72           Gambusia affinis         G1296         0.29         20.2         399.11         0.11         0.16         0.23           Gasterosteus aculeatus         E1012         0.99         10.4         180.00         0.35         0.49         0.69           Girella nigricans gibberifrons         E0197         116.58         18.9         371.20         46.57         65.87         93.15           Gormocephalus cernua         E0140         37.60         0.3         23.00         42.35         59.89         84.70           Gymnodraco acuticeps         E0155         74.40         -0.9         47.00         14.89         21.05         29.78	Gadus morhua	E0375	2079.41	9.5	63.50	273.40	386.64	546.80
Gambusia affinis         G1296         0.29         20.2         399.11         0.11         0.16         0.23           Gasterosteus aculeatus         E1012         0.99         10.4         180.00         0.35         0.49         0.69           Girella nigricans Gobionotothen gibberifrons         E0197         116.58         18.9         371.20         46.57         65.87         93.15           Gymnocephalus cernua         E0140         37.60         0.3         23.00         42.35         59.89         84.70           Gymnodraco acuticeps         E0155         74.40         -0.9         47.00         14.89         21.05         29.78	Gadus ogac	E0470	180.00	0.0	63.00	45.36	64.15	90.72
Gasterosteus aculeatus         E1012         0.99         10.4         180.00         0.35         0.49         0.69           Girella nigricans Gobionotothen gibberifrons         E0197         116.58         18.9         371.20         46.57         65.87         93.15           Gobionotothen gibberifrons         G1529         470.00         0.3         23.00         42.35         59.89         84.70           Gymnocephalus cernua         E0140         37.60         17.5         168.50         7.53         10.66         15.07           Gymnodraco acuticeps         E0155         74.40         -0.9         47.00         14.89         21.05         29.78	Gambusia affinis	G1296	0.29	20.2	399.11	0.11	0.16	0.23
Girella nigricans Gobionotothen gibberifrons         E0197         116.58         18.9         371.20         46.57         65.87         93.15           Gobionotothen gibberifrons         G1529         470.00         0.3         23.00         42.35         59.89         84.70           Gymnocephalus cernua         E0140         37.60         17.5         168.50         7.53         10.66         15.07           Gymnodraco acuticeps         E0155         74.40         -0.9         47.00         14.89         21.05         29.78	Gasterosteus aculeatus	E1012	0.99	10.4	180.00	0.35	0.49	0.69
Gobionotothen gibberifrons         G1529         470.00         0.3         23.00         42.35         59.89         84.70           Gymnocephalus cernua         E0140         37.60         17.5         168.50         7.53         10.66         15.07           Gymnodraco acuticeps         E0155         74.40         -0.9         47.00         14.89         21.05         29.78	Girella nigricans	E0197	116.58	18.9	371.20	46.57	65.87	93.15
Gymnocephalus cernua         E0140         37.60         17.5         168.50         7.53         10.66         15.07           Gymnodraco acuticeps         E0155         74.40         -0.9         47.00         14.89         21.05         29.78	Gobionotothen gibberifrons	G1529	470.00	0.3	23.00	42.35	59.89	84.70
<i>Gymnodraco acuticeps</i> E0155 74.40 -0.9 47.00 14.89 21.05 29.78	Gymnocephalus cernua	E0140	37.60	17.5	168.50	7.53	10.66	15.07
	Gymnodraco acuticeps	E0155	74.40	-0.9	47.00	14.89	21.05	29.78
Gymnoscopelus opisthanterus 61309 23.55 0.2 22.00 2.05 4.19 5.00	Gymnoscopelus opisthonterus	61309	22 55	0.5	22.00	2 05	<u>л</u> 10	5 00
Heteropheustes fassilis         G1323         32 73         26 6         312 64         6 48         9 16         12 96	Heteroppeustes fossilis	61323	23.33	26.5	312.00	6.19	9.16	12 96

Kuhlia sandvicensis	E0957	58.00	23.0	147.88	6.97	9.85	13.93
Lagodon rhomboides	G1346	12.89	23.4	194.93	1.99	2.82	3.98
Leiostomus xanthurus	G1349	14.24	25.0	89.83	0.90	1.28	1.81
Lepomis cyanellus	E0132	10.00	25.0	219.67	1.55	2.20	3.11
Lepomis macrochirus	E1113	61.03	20.1	167.49	10.18	14.40	20.36
Limanda limanda	E0690	7.00	10.0	97.00	1.36	1.92	2.72
Liza richardsonii	E0808	28.21	22.1	361.77	8.83	12.49	17.66
Lota lota	E0489	213.00	11.3	74.00	28.81	40.74	57.62
Lutjanus campechanus	E0592	365.50	17.5	81.00	35.21	49.79	70.41
Macrognathus aculeatus	G1367	38.54	26.3	95.32	2.37	3.35	4.73
Melamphaes acanthomus	E0427	20.05	7.5	35.50	1.69	2.39	3.39
Melanocetus johnsonii	E0657	50.55	2.5	23.00	3.91	5.53	7.82
Micropterus salmoides	E1110	20.53	22.7	438.56	7.47	10.57	14.94
Mugil curema	E0031	44.42	22.2	427.10	16.35	23.12	32.69
Muqil cephalus	E0049	47.23	23.1	185.74	7.08	10.02	14.17
Myoxocephalus	E0221	140.08	10.0	59 75	16 56	22 /2	22.12
Mystus aulio	61387	140.90	27.0	156.00	1 15	1.62	2 20
Nannohrachium rogalo	61387	2.00	27.0 E 0	150.00	0.12	1.05	0.26
Natathania aariisana	E0790	2.90	5.0	10.00	141.50	200.24	0.20
	G1526	/30.00	0.6	50.67	141.59	200.24	283.18
Oncornynchus nerka	E0437	11.98	14.2	117.00	2.10	2.97	4.20
Oneirodes acanthias	EU65	4.20	5.0	11.00	0.13	102.05	0.26
Opsanus tau	E0040	325.00	20.0	400.00	130.00	183.85	260.00
Oreochromis niloticus	G1407	100.91	25.1	215.08	15.26	21.58	30.52
Oryzias latipes	G1408	0.26	25.0	656.97	0.12	0.17	0.24
Parophrys vetulus	E0445	70.00	15.0	100.00	9.90	14.00	19.80
Perca fluviatilis	G1428	36.50	17.9	185.53	7.81	11.05	15.63
Pimephales promelas	G1439	2.00	18.0	156.50	0.36	0.51	0.72
Platichthys stellatus Plecoglossus altivelis	E0026	15.00	15.0	100.00	2.12	3.00	4.24
altivelis	G1440	10.70	19.0	801.00	9.19	12.99	18.37
Pleuronectes platessa	E0053	2.90	14.0	531.00	2.33	3.30	4.67
Poecilia latipinna	E1065	3.25	24.3	251.36	0.61	0.86	1.21
Pollachius pollachius	E0372	512.50	18.5	261.50	148.70	210.30	297.41
commersonnii	E0761	571.30	20.0	155.13	88.63	125.34	177.25
Pomoxis annularis	E0131	11.50	17.4	91.00	1.25	1.77	2.51
Poromitra crassiceps	E1061	10.80	2.7	28.00	1.01	1.42	2.01
Pseudopleuronectes americanus	F0035	20.11	15.6	64 67	1 77	2 50	3 54
Sagamichthys ahei	E0366	5 70	5.0	23.00	0.37	0.52	0.74
Salmo salar	61522	6.84	17.1	392.36	3.28	4 64	6.56
Sander vitreus	F1109	290.67	20.5	75 92	21 31	30.14	42.63
Scopelengys tristis	G1479	49.80	5.0	13.00	1.83	2 59	3 66
Scopeloagdus mizolenis	E0670	3.60	5.0	20.00	0.20	0.29	0.41
Scopeloguus maximus	E1161	320.00	15.0	11/ 00	51 59	72.96	103.18
Scorngeng norcus	E1101 E0512	320.00 30 1E	10 1	127 50	A 10	, 2.90 6 7 7	2 02
Serranus scriba	E0335	20.15	16.1	166.00	4.43	1.27	0.00
Solea solea	E0054	4.10	17.0	174 50	15.00	1.27	1.80
Spinachia spinachia	C1401	/3.00	17.0	1/4.50	15.06	21.30	50.12
Spiriucriiu spinacnia	01491	2.65	18.3	354.00	1.06	1.50	2.12
รเลทออาสติกันร	EUUb/	4.35	7.5	80.00	0.83	1.17	1.66

#### leucopsarus

Stamias danas	F0027	12.90	2.5	42.00	1.05	2.76	2.00
Stornius aunue Symbolophorus	E0037	13.80	2.5	42.00	1.95	2.70	3.90
californiensis	E0061	0.80	5.0	86.00	0.19	0.28	0.39
Syngnathus acus	E0821	7.30	18.5	236.50	1.92	2.71	3.83
Trematomus pennellii	G1527	183.00	-0.9	43.00	33.50	47.38	67.00
Zoarces viviparus	E0370	0.25	5.0	103.50	0.07	0.10	0.15

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476 Appendix S2. Phylogenetic generalized least squares analyses between routine metabolic rate (RMR) and body mass of actinopterygians at three different temperature scenarios. 477

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**20°C** LogRMR (20°C) = 2.344724 + 0.926953\*LogMass  $R^2 = 0.85$ 

LogMass