nature climate change

SUPPLEMENTARY INFORMATION

DOI: 10.1038/NCLIMATE1691

Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems

Method

Dynamic Bioclimate Envelope Model (DBEM)

As a first step, we predicted the current (1970-2000) distribution map of each species an algorithm described in [1,2]. This algorithm estimates the relative abundance of a species on a 30' latitude x 30' longitude grid of the world ocean. Input parameters for DBEM include the species' maximum and minimum depth limits, northern and southern latitudinal range limits, an index of association to major habitat types (seamounts, estuaries, inshore, offshore, continental shelf, continental slope and the abyssal) and known occurrence boundaries. The parameter values of each species, which are posted on the *Sea Around Us* Project website (http://www.seaaroundus.org/distribution/search.aspx), were derived from data in online databases, mainly FishBase (www.fishbase.org). Jones *et al*. [3] compared the predicted species distribution from this algorithm with empirically observed occurrence records and found that the algorithm has high predictive power, and that its skills are comparable with other commonly used species distribution modelling approach for marine species such as Maxent[4] and Aquamap[5].

As a second step, we used DBEM to identify the 'environmental preference profiles' of the studied species, defined by outputs from the Earth System Models, including sea water temperature (bottom and surface), depth, salinity, distance from sea-ice and habitat types. Preference profiles are defined as the suitability of each of these environmental conditions to each species, with suitability calculated by overlaying environmental data (1970-2000) with maps of relative abundance of the species [6]. For example, for each species, DBEM calculated a temperature preference profile for the adult and pre-recruit phases based on the relative abundance and the computed recruitment strength of the species. Sea surface temperature is then

© 2012 Macmillan Publishers Limited. All rights reserved.

used for temperature preference profiles for pre-recruit phase while bottom temperature is applied to preference profiles for adult demersal species.

The model represents individual growth of fish using a growth function:

$$W_t = W_\infty[1 - e^{-K(t-t_0)}]^{1/(1-a)} \quad \text{eq. S1}$$

$$W_\infty = \left(\frac{H}{k}\right)^{\frac{1}{1-a}} \quad \text{eq. S2}$$

$$K = k \cdot (1 - a) \quad \text{eq. S3}$$

where $a = 0.7$, $H = g \cdot [O_2] \cdot e^{-j/T}$ and $k = h \cdot e^{-i/T}$ in which T is environmental temperature, j and $i = E_a/R$ with E_a and R representing the activation energy and Boltzmann constant in the Arrhenius equation [7] (Figure S1). k is the coefficient for the catabolic term of the growth equation which is independent of oxygen supply [8].

We set values of j based on empirically estimated metabolic scaling exponents. Meta-analysis of the resting metabolic rate of teleosts suggests that the within-species Q_{10} of temperature ranges from 0.45 to 3.41, with a median of 2.4 [9]. We assume that the resting metabolic rate represents metabolic demand for basic body functions and maintenance. Thus, we calculated a i in the Arrhenius equation for catabolism that would result in the reported Q_{10} over a wide temperature range (with median of the temperature preference profiles of the studied species that ranges between 1 – 28^o C) of approximately 8. Given that anabolism is considered to be less temperature sensitive then catabolism [10] and based on the fact that the slope of the regression between log(K) and log(W_∞) among different populations of a species is ≈ 0.7 [8], we estimate that j should be ≈ 4.5. We tested the effect of alternative values of a, i, and j on the simulation for Atlantic cod to examine the sensitivity of the results to these parameters.

© 2012 Macmillan Publishers Limited. All rights reserved.

The mean values of the coefficients g and h were derived from asymptotic weight (W_∞), von Bertalanffy growth parameter K, the average environmental temperature (T) and oxygen concentration [O_2] estimated from the predicted current distribution and the average T and [O_2] within their distribution (weighted by the relative abundance of the species). Parameter values for asymptotic (L_∞) and K were obtained from FishBase (www.fishbase.org). W_∞ was then calculated from the length-weight conversion:

$$W_\infty = a \cdot {L_\infty}^b$$

where a and b are the length-weight conversion parameters obtained from FishBase. In a few cases where published values of a and b were not available, we assumed that W_∞ (in g) scales isometrically (i.e., $b = 3$) with L_∞ (in cm) and $a = 0.01$, which approximately corresponds to the fusiform shape of a cod (*Gadus morhua*; www.fishbase.org). In any case, the parameter a is a scaling factor and its value does not affect the projected change in body weight. The model then simulates the population dynamics and changes in relative abundance on each spatial cell given changes in annual average sea water temperature (surface and bottom), ocean current, salinity, oxygen concentration and sea-ice concentration projected by the Earth System Models.

Carrying capacity is expressed as a function of expected biomass per recruit and recruitment. Expected biomass per recruit was determined by a size-based population model [7]. The size-transition matrix (X), a matrix of probabilities of an individual growing from a particular body-size class to other size classes in a time step (year), was computed from [11]:

$$\theta_{y,l',l} = exp\left[-\frac{(\overline{l_l}-[l_\infty(1-e^{-K})+\overline{l_{l'}}\,e^{-K}])^2}{2\sigma^2}\right] \quad \text{and}$$

© 2012 Macmillan Publishers Limited. All rights reserved.

$$X_{l',l} = \frac{\theta_{l',l}}{\sum_{l'} \theta_{l',l}}$$

where l_∞ is the asymptotic length, l and l' are adjacent length classes, y is age of fish, σ is the variation in growth which is assumed to have a coefficient of variation of 20% and is independent of length and age. The biomass per recruit (BPR) was calculated from:

$$BPR = \sum_y \sum_l \bar{W}_l \cdot X_{l',l} \cdot e^{-M}$$

where $\bar{W}$ is mean weight of the fish in length class l. Natural mortality rate (M) was predicted from Pauly's empirical equation [12]:

$$\log M = 0.2107 - 0.0824 \cdot \log W_{inf} + 0.6757 \cdot logK + 0.4627 \cdot logT'$$

where T' is temperature in degree Celsius.

Initial relative recruitment strength (R) is calculated from the initial relative abundance (A, normalized across the 30' x 30' degree resolution grid) and calculated biomass per recruit in each cell, as $BPR = c \cdot A/R$. where c is a constant that scales from relative abundance to absolute abundance. Thus, $R = c \cdot A/BPR$ and $A = BPR \cdot R/c$.

The model simulates changes in relative abundance of a species by:

$$\frac{dA_i}{dt} = \sum_{j=1}^{N} G_i + L_{ji} + I_{ji}$$

© 2012 Macmillan Publishers Limited. All rights reserved.

where A_i is the relative abundance of a 30' x 30' cell i, G is the intrinsic population growth and L_{ji} and I_{ji} are settled larvae and net immigrated adults from surrounding cells (j), respectively.

Intrinsic population growth is modeled by a logistic equation:

$$G_i = r \cdot A_i \cdot (1 - \frac{A_i}{A_{\infty,i}})$$

where r is the intrinsic rate of population increase, A_∞ is the carrying capacity calculated from the expected biomass per recruit and recruitment (see above). The model explicitly represents larval dispersal through ocean current with an advection-diffusion-reaction model (see [6,13] for details).

Thus, changes in ocean conditions will be transformed by the model into changes in life history, growth, carrying capacity, population growth, net migration, and thus, relative abundance of a species, in each cell it occupies. Given the projected changes in ocean conditions under climate change scenarios, the model simulates the annual changes in distribution of relative abundance of each species on the global 30' x 30' grid.

Scenarios of biogeochemical changes in the ocean

Our scenario of ocean conditions is based on outputs from the Earth System Model (ESM2.1)[14] developed at the Geophysical Fluid Dynamic Laboratory (GFDL) of the US National Oceanic and Atmospheric Administration (NOAA) and the Earth System Model IPSL-CM4-LOOP[15] developed by the French Institut Pierre Simon Laplace (IPSL). ESM2.1 is a dynamic atmosphere-ocean general circulation model [16] coupled to a marine biogeochemistry model which includes major nutrients and three phytoplankton functional groups with variable stoichiometry [17]. The IPSL-CM4-LOOP model is a fully coupled climate and carbon cycle model

© 2012 Macmillan Publishers Limited. All rights reserved.

(e.g. see [15] and references therein). It consists of the Laboratoire de Météorologie Dynamique atmospheric model (LMDZ-4) with a horizontal resolution of about 3.6°x2.5° and 19 vertical levels, coupled to the OPA-8 ocean model with a horizontal resolution of 2° to 0.5° and 31 vertical levels and the LIM sea ice model. The terrestrial biosphere is represented by the global vegetation model ORCHIDEE and the marine carbon cycle is simulated by the PISCES model.

The scenario considered here is the IPCC's Special Report on Emission Scenario (SRES) A2, which assumes atmospheric CO_2 concentration to become around 860 ppm by 2100. We interpolated the original resolution of the model outputs on a 30' x 30' grid by using the nearest neighbour method. The outputs from the Earth System Models considered by the DBEM included sea bottom temperature, sea surface temperature, sea bottom oxygen concentration, surface current advection (horizontal), salinity and sea ice concentration. Annual average values of each variable were used. Delineation of ocean basin is based on the United Nations Food and Agriculture Organization Statistical Area (Figure S4).

Calculation of mean assemblage-level body weight

We calculated the mean (geometric) assemblage-level body weight from the predicted distribution and maximum body weight of the modelled fish species. We identified species that were predicted to occur in each 30' lat. x 30' lat. cell. We then calculated the mean (geometric) predicted maximum body weight in each cell weighted by the predicted relative abundance of each species (corrected by area of the grid cells) and their historically observed maximum catch. Fish body weights range over several orders of magnitude, thus geometric mean provides a better representation of the relative changes in body weight across the size spectrum of the assemblage. Historically observed maximum catch was calculated from time-series catch data (1950 to the

© 2012 Macmillan Publishers Limited. All rights reserved.

present) obtained from the United Nations Food and Agriculture Organization (FAO) and processed by the *Sea Around Us* project (www.seaaroundus.org). For each species, we calculated the average maximum annual catch from the mean of the five highest annual catches across the time-series. The mean assemblage-level body weight (W') at cell *i* was then calculated from:

$$W'_i = \frac{\sum_{j=1}^{n} \log(W_{\infty\, i,j}) \cdot Abd_{i,j} \cdot C_j}{\sum_{j=1}^{n} Abd_{i,j} \cdot C_j}$$

where $W_{\infty,i,j}$ is maximum body weight of species *j*, *Abd* is the predicted relative abundance and *C* is the maximum catch (scaled to the area of each cell). The values of W'_i are calculated for each year from 1971 to 2060.

Calculation of latitudinal centroid shift

Latitudinal centroid (*LC*) of each species was calculated from:

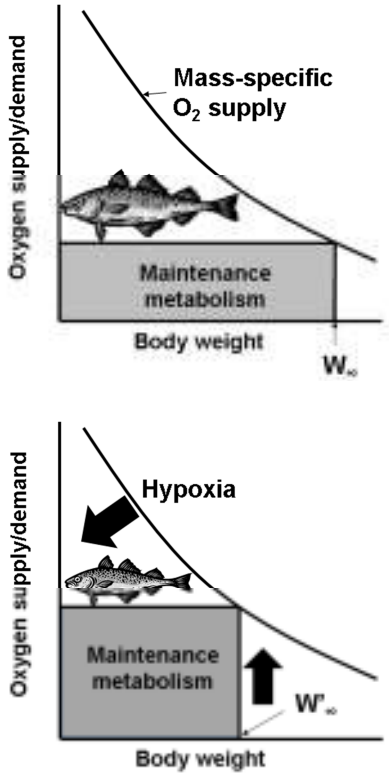
$$LC = \frac{\sum_{i=1}^{n} Lat_i \cdot Abd_i}{\sum_{i=1}^{n} Abd_i}$$

where Lat_i is the latitude of the centre of the spatial cell (*i*), *Abd* is the predicted relative abundance in the cell (corrected by area of the grid cells), and *n* is the total number of cells. Range shift was then calculated from difference between the latitudinal centroid of the projected and reference years. Shift in distance (km) was then calculated from:

$$Distance\ shift = \cos^{-1} \cdot \left[\sin\left(Lat_m \cdot \frac{\pi}{180}\right) \cdot \sin\left(Lat_n \cdot \frac{\pi}{180}\right) + \cos\left(Lat_m \cdot \frac{\pi}{180}\right) \cdot \cos\left(Lat_n \cdot \frac{\pi}{180}\right)\right] \cdot 6378.2$$

© 2012 Macmillan Publishers Limited. All rights reserved.

Supplementary figures



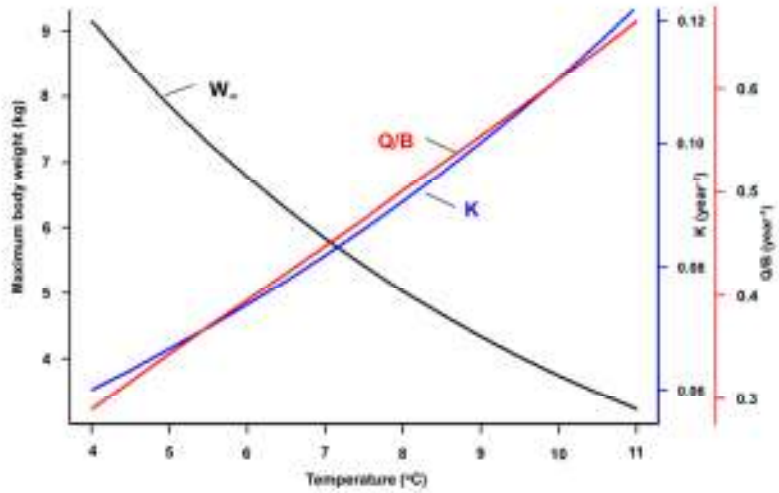
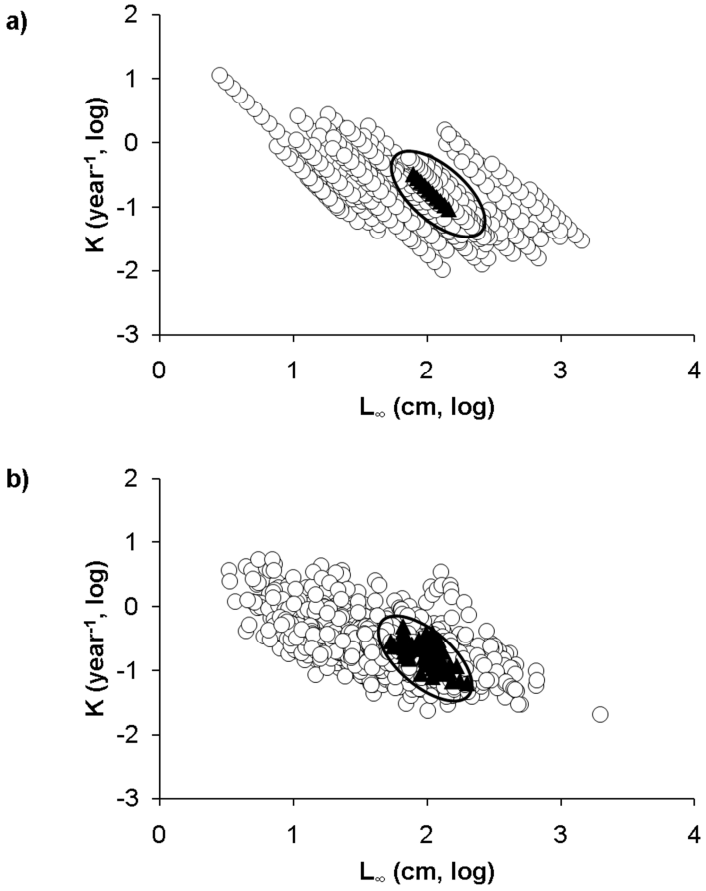


Figure S1. Schematic diagram illustrating how oxygen supply and demand determine maximum (i.e., asymptotic) body weight (W_∞) (upper panel), the effects of warming (black upward arrow) and hypoxia on growth and asymptotic weight (W'_∞) (middle panel) (Redrawn from [7]), and

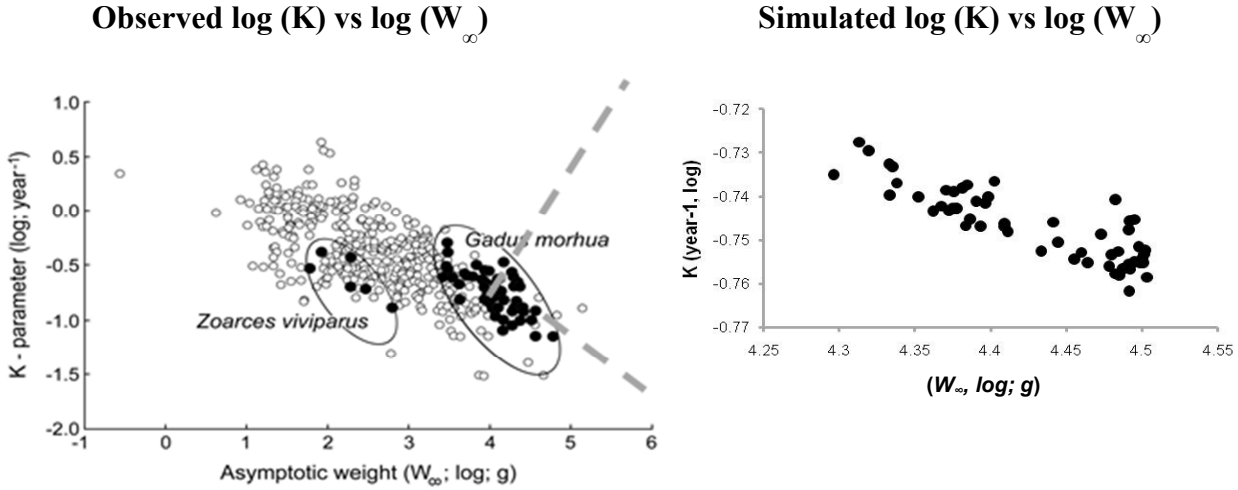
© 2012 Macmillan Publishers Limited. All rights reserved.

example of the theoretical relationship between W_∞, von Bertalanffy growth parameter K, consumption to biomass ratio (Q/B) of Atlantic cod and temperature of its habitat. The relationship of W_∞ and temperature is predicted from eq. S1, K and temperature is from eq. S2, and Q/B and temperature is from an empirical equation to estimate Q/B from temperature (T), asymptotic body size (W_∞) aspect ratio of the fish (A), and type of food item (F)[18]. i.e., $Q/B = -0.1775 - 0.2018 \ln W_\infty + 0.6121 \ln T + 0.5156 \ln A + 1.26F$.

© 2012 **Macmillan Publishers Limited. All rights reserved.**



c)



© 2012 Macmillan Publishers Limited. All rights reserved.

Figure S2. Plot of log K against log L_∞ of (a) 120 demersal fishes over the 5th and 95th percentile of their predicted habitat temperature (as predicted from the dynamic bioclimate envelope model); (b) published empirical estimates of VBGF of 2015 fishes (available from FishBase); and (c) Comparing observed changes in growth parameters (left) with simulated changes from the dynamic bioclimate envelope model under future scenarios of changes in ocean biogeochemistry and physical conditions (right) (redrawn from Cheung *et al*. 2011). The black triangles in (a) and (b) represent predictions and estimates for different Atlantic cod populations. Using Atlantic cod as an example, the predicted slope between log$K$ and logL_∞ not significantly different ($p<0.05$) from the slope calculated from observed log$K$ and logL_∞ (Taylor 1958).

© 2012 **Macmillan Publishers Limited. All rights reserved.**

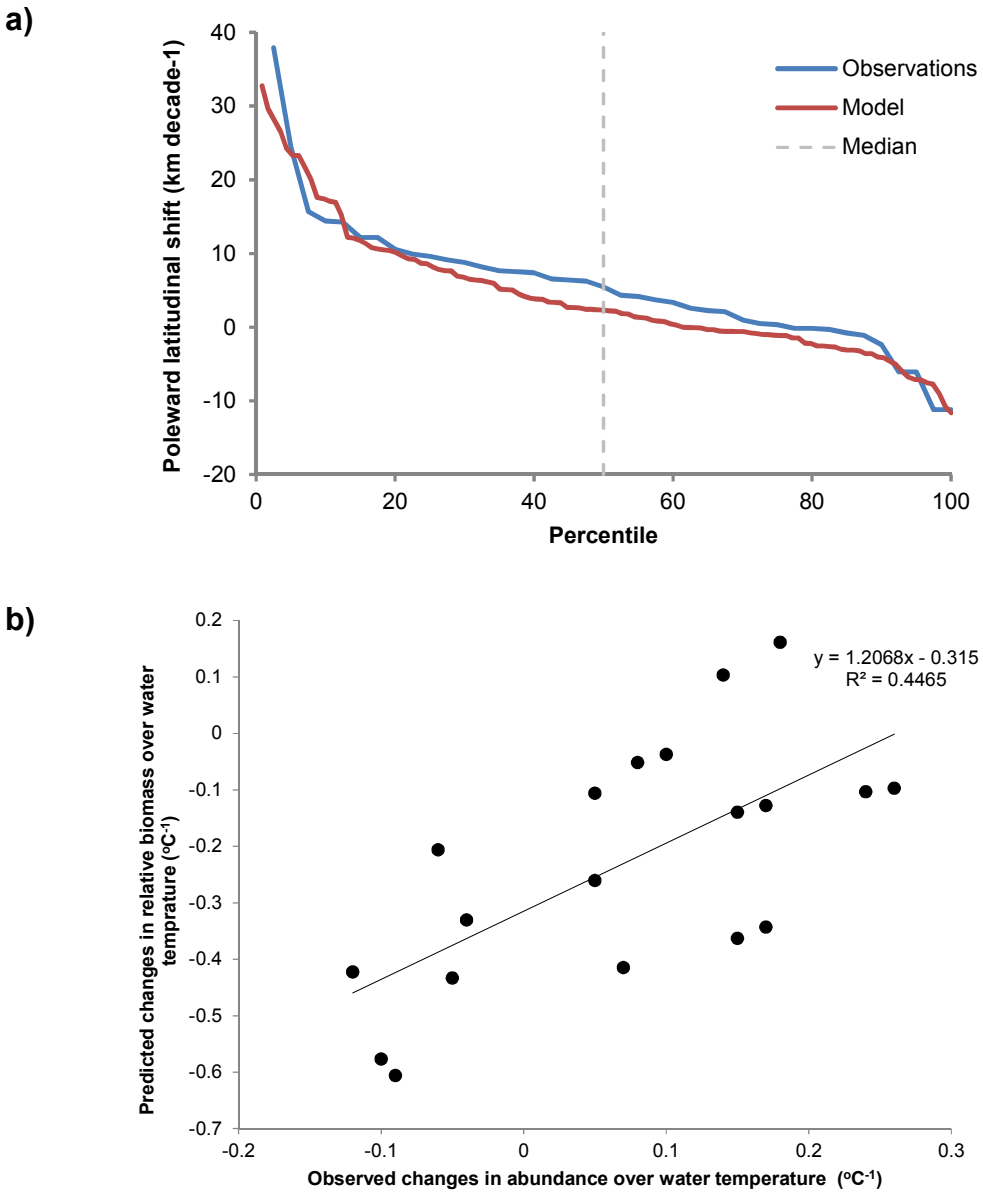


Figure S3. Comparison between observations and predictions from Dynamic Bioclimate Envelope Model for (A) Bering Sea (Large Marine Ecosystem) and (B) waters around the UK (North Sea and Irish Sea Large Marine Ecosystems). For (A), observations (blue line) are estimated rate of change of latitudinal centroid calculating using catch-per-unit-effort data from fishing survey in 1975 - 2001 in the Bering Sea (N = 40) (see [19]) while predictions (red line) are calculated rate of change of latitudinal centroids (N = 114) in the Bering Sea Large

© 2012 Macmillan Publishers Limited. All rights reserved.

Marine Ecosystem from model outputs that are driven by historical simulation of global ocean biogeochemistry through the NOAA's GFDL ESM2.1 forced with historical reanalysis climate data. For (B), observations are the average estimated slope of abundance against water temperature from 1975 to 2007 (see [20] for details) while predictions are the slope of change in modelled relative biomass in the North Sea and Irish Sea Large Marine Ecosystems of species that correspond to Simpson *et al*. (2011) (N = 19). Only species that show significant trends between abundance and temperature ($p < 0.05$) are included in the analysis.

© 2012 **Macmillan Publishers Limited. All rights reserved.**

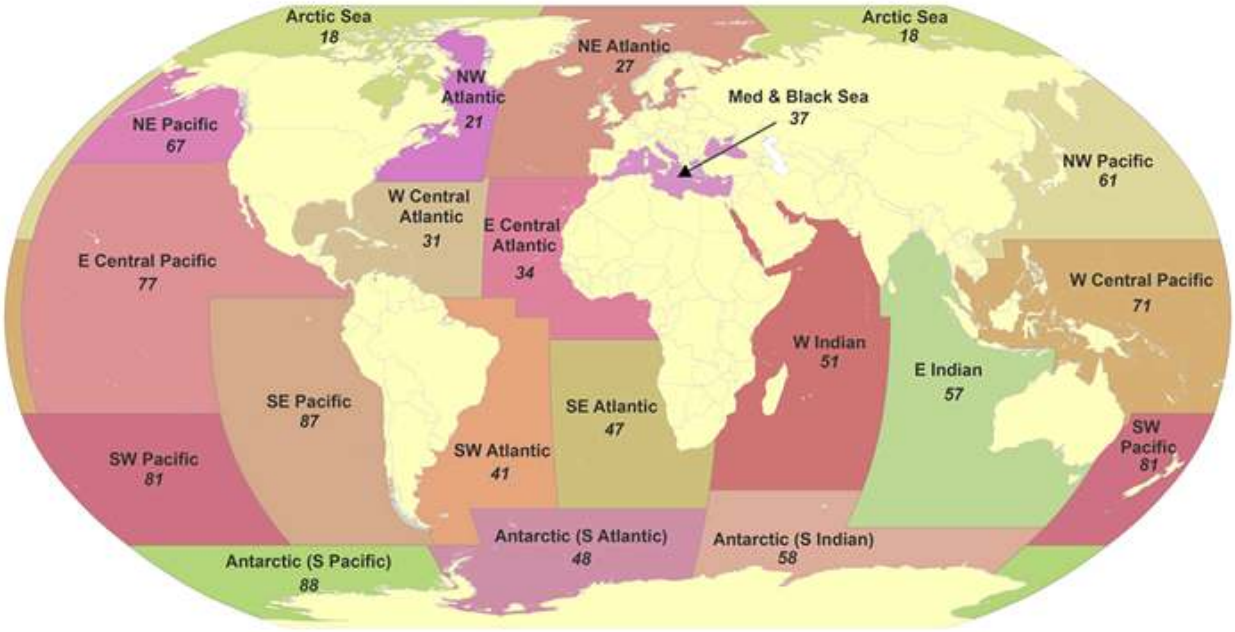


Figure S4. FAO Statistical Area (source: *Sea Around Us* Project: www.seaaroundus.org).

© 2012 **Macmillan Publishers Limited. All rights reserved.**

A.

B.

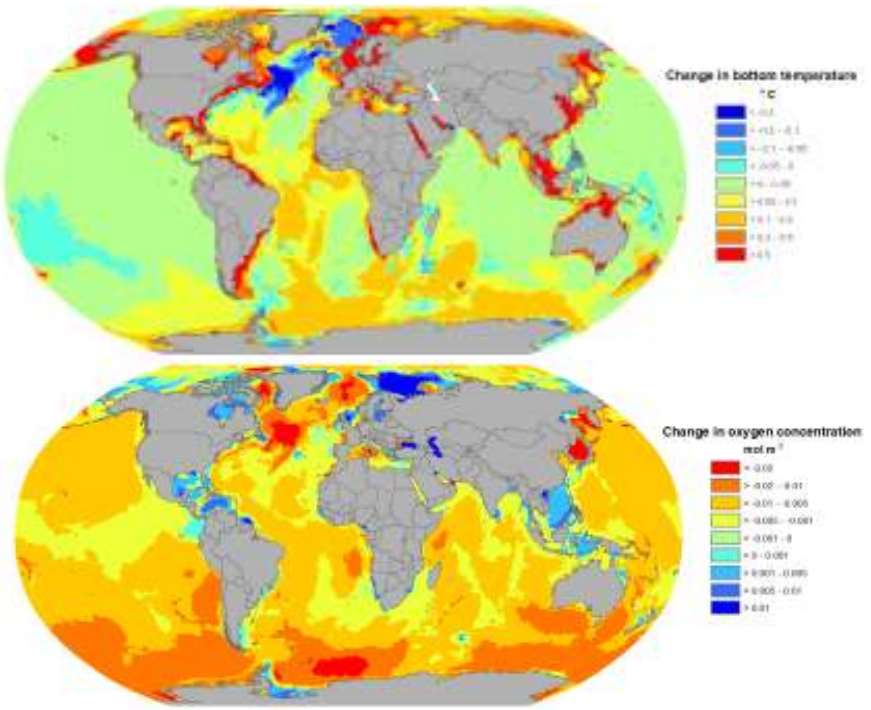


Figure S5. Projected changes in (A) sea bottom temperature and (B) sea bottom oxygen concentration from 1991 – 2000 to 2041 – 2060, averaged between outputs from GFDL ESM 2.1 and IPSL-CM4-LOOP.

© 2012 **Macmillan Publishers Limited. All rights reserved.**

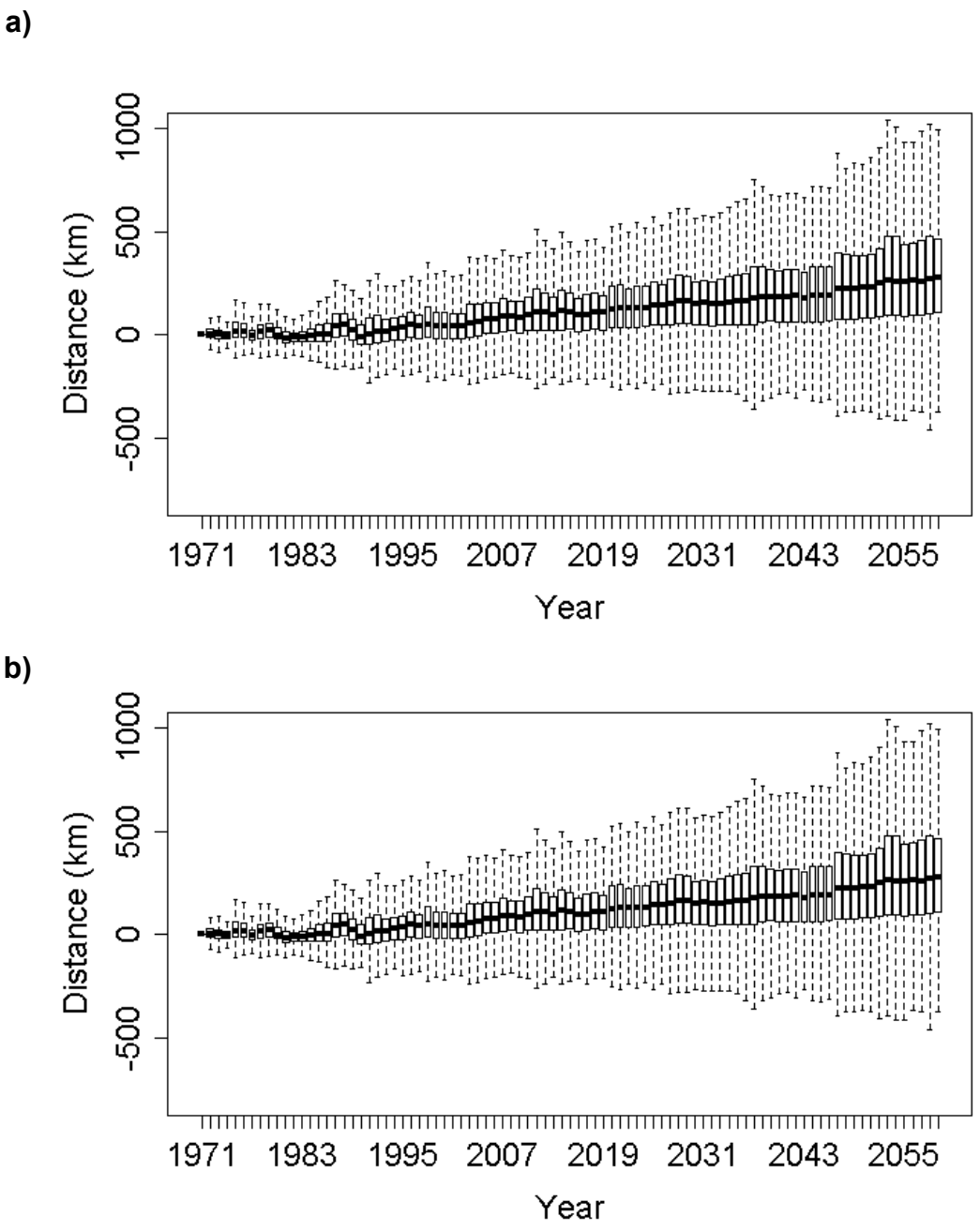


Figure S6. Predicted latitudinal shift of distribution centroids of 610 species of demersal fishes from 1971 to 2060 under the SRES A2 scenario based on outputs from (A) GFDL ESM2.1 and (B) IPSL-CM4-LOOP. The thick dark bar represents the median shift of all the species in a year, the lower and upper boundaries of the box represent the 25% and 75% quartiles, respectively. Positive value indicates poleward shift relative to average latitudinal centroids in 1971 - 2000.

© 2012 **Macmillan Publishers Limited. All rights reserved.**

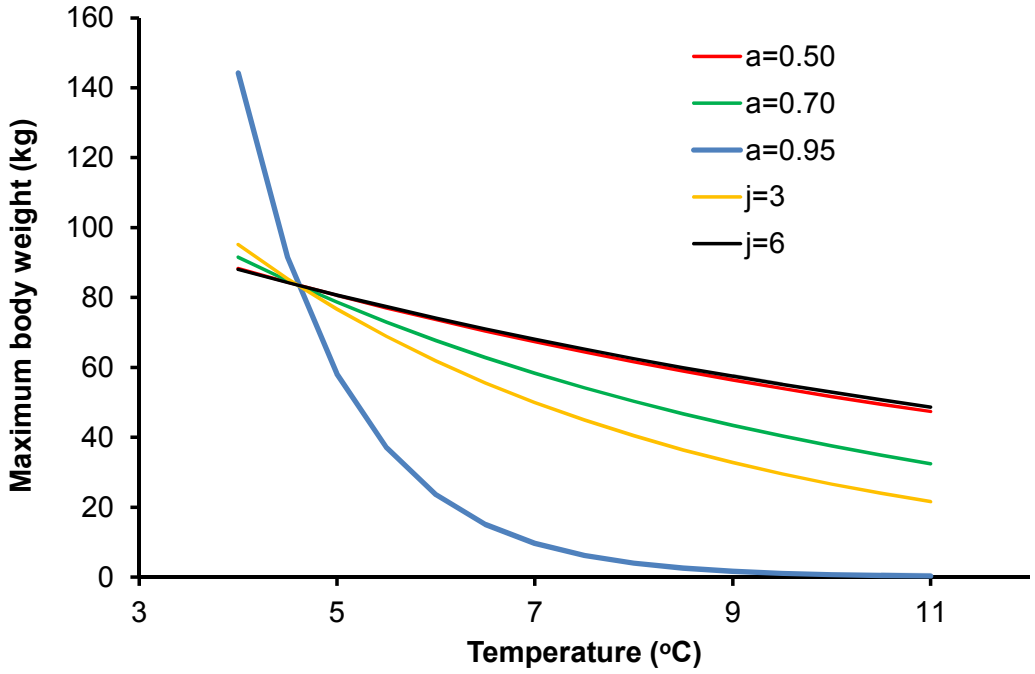


Figure S7. Predicted change in maximum body size for Atlantic cod under different environmental temperature from alternative parameter values for the growth and metabolic scaling models: (1) parameter a = 0.50, (2) parameter a = 0.7, (3) parameter a = 0.95, (4) parameter j = 3, (5) parameter j = 6.

© 2012 Macmillan Publishers Limited. All rights reserved.

Table S1. List of fish species included in the analysis, with their von Bertanlanfy growth parameters (L_∞ and K) and the corresponding parameters of their length-weight relationships (a, b).

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* (year^{-1})	*a*	*b*
Abudefduf luridus	Canary damsel	15.9	0.47	0.01000	3.0
Acanthistius brasilianus	Sea bass	62.2	0.18	0.01000	3.0
Acanthopagrus berda	Picnic seabream	92.7	0.24	0.02380	3.0
Acanthopagrus bifasciatus	Twobar seabream	50.0	0.19	0.00176	3.0
Acanthopagrus latus	Yellowfin seabream	50.0	0.22	0.05430	2.9
Acanthopagrus schlegeli	Black porgy	52.0	0.14	0.01000	3.0
Acanthurus monroviae	Monrovia doctorfish	46.9	0.25	0.00181	3.1
Acanthurus sohal	Sohal surgeonfish	41.7	0.34	0.01000	3.0
Acipenser gueldenstaedtii	Russian sturgeon	253.0	0.05	0.00390	3.1
Acipenser medirostris	Green sturgeon	250.0	0.09	0.01000	3.0
Acipenser ruthenus	Sterlet	125.0	0.12	0.00020	3.9
Acipenser stellatus	Starry sturgeon	220.0	0.05	0.03400	2.6
Acipenser sturio	Sturgeon	500.0	0.03	0.00950	2.9
Acipenser transmontanus	White sturgeon	610.0	0.04	0.00290	3.2
Aethaloperca rogaa	Redmouth grouper	62.2	0.18	0.01000	3.0
Albula vulpes	Bonefish	104.0	0.24	0.02330	2.9
Alepes djedaba	Shrimp scad	40.0	0.61	0.00169	2.8
Alepocephalus bairdii	Bairds smooth-head	100	0.08	0.01000	3.0
Alepocephalus rostratus	Rissos smooth-head	50.0	0.08	0.00590	3.0
Alepocephalus umbriceps	Slickhead	65.3	0.09	0.01000	3.0
Allocyttus niger	Black oreo	47.0	0.06	0.00800	3.3
Alopias superciliosus	Bigeye thresher	488.0	0.09	0.00102	2.8
Alopias vulpinus	Thintail thresher	760.0	0.10	0.00188	2.5
Amblyraja georgiana	Antarctic starry skate	102.8	0.15	0.01000	3.0
Amblyraja taaf	Whiteleg skate	92.7	0.16	0.01000	3.0
Ammodytes personatus	Pacific sandeel	15.9	0.56	0.0404	3.0
Anarhichas denticulatus	Northern wolffish	180.0	0.10	0.07800	2.6
Anarhichas lupus	Wolf-fish	150.0	0.12	0.00400	3.2
Anarhichas minor	Spotted wolfish	180.0	0.09	0.00170	3.4
Anoplopoma fimbria	Sablefish	120.0	0.29	0.00580	3.1
Anthias anthias	Swallowtail seaperch	28.4	0.31	0.01000	3.0
Aphanopus carbo	Black scabbardfish	139.0	0.25	0.00020	3.4
Aphanopus intermedius	Intermediate scabbardfish	102.8	0.29	0.01000	3.0
Aphareus rutilans	Rusty jobfish	147.0	0.16	0.00154	3.0
Archosargus probatocephalus	Sheepshead seabream	91.0	0.36	0.04480	2.9
Archosargus rhomboidalis	Western Atlantic seabream	34.5	0.25	0.00180	3.1
Arctoscopus japonicus	Sailfin sandfish	31.5	0.37	0.01000	3.0

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* ($year^{-1}$)	*a*	*b*
Argentina silus	Greater argentine	70.0	0.12	0.00390	3.2
Argyrops spinifer	King soldierbream	96.4	0.08	0.00010	2.5
Argyrosomus hololepidotus	Southern meagre	203.4	0.10	0.01000	3.0
Argyrosomus regius	Meagre	230.0	0.09	0.00900	2.9
Argyrozona argyrozona	Carpenter seabream	90.0	0.07	0.00800	3.2
Ariomma indica	Indian ariomma	25.5	1.10	0.00160	3.0
Arius thalassinus	Giant seacatfish	185.0	0.06	0.09000	2.6
Atheresthes stomias	Arrowtooth flounder	86.6	0.11	0.00198	2.8
Atherina boyeri	Big-scale sand smelt	20.0	0.16	0.00750	3.0
Atractoscion aequidens	Geelbeck croaker	130.0	0.27	0.00840	3.0
Atractoscion nobilis	White weakfish	166.0	0.13	0.00123	2.9
Atrobucca nibe	Longfin kob	58.7	0.14	0.00300	3.2
Atule mate	Yellowtail scad	33.7	0.81	0.02000	3.0
Austroglossus microlepis	West coast sole	77.5	0.14	0.01000	3.0
Austroglossus pectoralis	Mud sole	60.0	0.38	0.00180	3.3
Balistes capriscus	Grey triggerfish	60.0	0.43	0.02140	3.0
Bathylagus antarcticus	Bathylagus antarcticus	14.9	0.17	0.01000	3.0
Bathyraja eatonii	Eatons skate	102.8	0.15	0.01000	3.0
Bathyraja maccaini	McCains skate	123.1	0.12	0.01000	3.0
Bathyraja meridionalis	Dark-belly skate	123.1	0.12	0.01000	3.0
Bathyraja murrayi	Murrays skate	62.2	0.24	0.01000	3.0
Beryx decadactylus	Alfonsino	100.0	0.16	0.01000	3.0
Beryx splendens	Splendid alfonsino	70.0	0.15	0.02260	3.0
Bolbometopon muricatum	Green humphead parrotfish	130.0	0.10	0.01000	3.0
Boops boops	Bogue	36.0	0.18	0.00970	3.0
Boreogadus saida	Polar cod	40.0	0.22	0.00500	3.2
Borostomias antarcticus	Borostomias antarcticus	31.5	0.30	0.01000	3.0
Bothus pantherinus	Leopard flounder	40.7	0.24	0.00200	3.8
Brachydeuterus auritus	Bigeye grunt	30.0	0.32	0.00132	3.1
Brosme brosme	Tusk	120.0	0.14	0.01000	3.0
Brotula barbata	Bearded brotula	94.0	0.19	0.01000	3.0
Caelorinchus marinii	Marinis grenadier	39.7	0.23	0.00104	2.7
Callorhinchus capensis	Cape elephantfish	122.0	0.17	0.01000	3.0
Callorhinchus milii	Ghost shark	125.0	0.22	0.00910	3.0
Capros aper	Boarfish	31.5	0.20	0.02820	2.8
Carangoides ruber	Bar jack	70.0	0.14	0.00180	3.0
Caranx ignobilis	Giant trevally	195.7	0.11	0.02960	3.0
Caranx rhonchus	False scad	60.0	0.30	0.00124	3.1
Carcharhinus brachyurus	Copper shark	385.0	0.04	0.00104	2.9
Carcharhinus falciformis	Silky shark	350.0	0.09	0.00101	3.1
Carcharhinus limbatus	Blacktip shark	275.0	0.28	0.00610	3.0
Carcharhinus longimanus	Oceanic whitetip shark	398.5	0.11	0.00170	3.0

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* (year^{-1})	*a*	*b*
Carcharhinus obscurus	Dusky shark	449.0	0.04	0.00940	2.9
Carcharhinus plumbeus	Sandbar shark	266.0	0.06	0.00580	3.3
Carcharhinus sorrah	Spottail shark	160.0	1.17	0.00070	3.7
Carcharias taurus	Sand tiger shark	323.0	0.14	0.00106	2.9
Carcharodon carcharias	Great white shark	792.0	0.06	0.00720	3.0
Caulolatilus chrysops	Atlantic goldeye tilefish	62.2	0.18	0.00102	3.0
Caulolatilus princeps	Ocean whitefish	104.9	0.11	0.01000	3.0
Centriscops humerosus	Banded yellowfish	31.5	0.24	0.01000	3.0
Centroberyx affinis	Redfish	53.0	0.17	0.01000	3.0
Centrophorus granulosus	Gulper shark	163.3	0.05	0.01000	3.0
Centrophorus lusitanicus	Lowfin gulper shark	163.3	0.05	0.01000	3.0
Centrophorus squamosus	Leafscale gulper shark	164.0	0.04	0.01000	3.0
Centropomus undecimalis	Common snook	140.0	0.30	0.00580	3.0
Centropristis striata	Black seabass	66.0	0.46	0.06490	2.5
Centroscyllium fabricii	Black dogfish	109.9	0.05	0.00090	3.4
Centroscymnus coelolepis	Portuguese dogfish	123.1	0.05	0.00430	3.1
Centroscymnus crepidater	Longnose velvet dogfish	133.1	0.05	0.00240	3.2
Cephalopholis argus	Peacock hind	62.2	0.18	0.00166	3.0
Cephalopholis fulva	Coney	41.0	0.63	0.02230	2.9
Cephalopholis hemistiktos	Yellowfin hind	35.0	0.11	0.01000	3.0
Cephalopholis miniata	Coral hind	46.9	0.11	0.00107	3.1
Cepola macrophthalma	Red bandfish	80.0	0.21	0.00162	2.0
Cetorhinus maximus	Basking shark	1000.0	0.06	0.00490	3.0
Chaenocephalus aceratus	Blackfin icefish	76.5	0.17	0.00050	3.7
Chaenodraco wilsoni	Spiny icefish	44.8	0.29	0.01000	3.0
Channichthys rhinoceratus	Unicorn icefish	62.2	0.22	0.01000	3.0
Chanos chanos	Milkfish	183.4	0.10	0.00193	3.0
Cheilodactylus variegatus	Peruvian morwong	1.1	0.23	0.01000	3.0
Cheimerius nufar	Santer seabream	75.0	0.18	0.07800	2.7
Chelidonichthys capensis	Cape gurnard	80.3	0.10	0.01000	3.0
Chelidonichthys gurnardus	Grey gurnard	60.0	0.77	0.00540	3.1
Chelidonichthys kumu	Bluefin gurnard	60.0	0.49	0.00111	3.0
Chelidonichthys lastoviza	Streaked gurnard	40.0	0.37	0.00152	3.0
Chelidonichthys lucerna	Tub gurnard	75.0	0.17	0.00770	3.1
Chelidonichthys spinosus	Red gurnard	41.7	0.26	0.01000	3.0
Chelon haematocheilus	So-iny (redlip) mullet	4.5	2.15	0.01000	3.0
Chelon labrosus	Thicklip grey mullet	75.0	0.12	0.00630	3.0
Chimaera monstrosa	Rabbit fish	150.0	0.07	0.00280	2.8
Chionobathyscus dewitti	Chionobathyscus dewitti	62.2	0.22	0.01000	3.0
Chionodraco hamatus	Hooked icefish	51.0	0.26	0.01000	3.0
Chionodraco myersi	Chionodraco myersi	39.7	0.33	0.01000	3.0
Chionodraco rastrospinosus	Ocellated icefish	54.0	0.25	0.00390	3.9
Chirocentrus dorab	Dorab wolf-herring	102.8	0.17	0.00510	3.0

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* ($year^{-1}$)	*a*	*b*
Chloroscombrus orqueta	Pacific bumper	31.5	0.58	0.01000	3.0
Chromis chromis	Damselfish	25.0	0.25	0.02990	2.8
Chrysophrys auratus	Squirefish	130.0	0.07	0.04470	2.8
Ciliata mustela	Fivebeard rockling	26.3	0.77	0.00640	3.0
Citharichthys sordidus	Pacific sanddab	41.0	0.30	0.01000	3.0
Citharus linguatula	Atlantic spotted flounder	30.0	0.26	0.00500	3.1
Conger conger	European conger	300.0	0.06	0.00050	3.2
Conger myriaster	Whitespotted conger	102.8	0.15	0.01000	3.0
Conger oceanicus	American conger	233.4	0.07	0.00010	3.8
Conger orbignyanus	Argentine conger	115.0	0.13	0.00020	3.4
Conodon nobilis	Barred grunt	35.2	0.31	0.02430	3.1
Coregonus lavaretus	Common whitefish	73.0	0.27	0.00116	2.9
Coregonus oxyrinchus	Houting	50.0	0.38	0.01000	3.0
Coris julis	Mediterranean rainbow wrasse	30.0	0.11	0.00690	3.0
Crenidens crenidens	Karenteen seabream	31.5	0.27	0.01000	3.0
Cryodraco antarcticus	Cryodraco antarcticus	41.0	0.27	0.00060	3.5
Ctenolabrus rupestris	Goldsinny-wrasse	18.0	0.31	0.00123	3.0
Cyclopterus lumpus	Lumpsucker	61.0	0.12	0.05870	2.9
Cynomacrurus piriei	Dogtooth grenadier	52.0	0.18	0.01000	3.0
Cynoscion analis	Peruvian weakfish	47.5	0.23	0.01000	3.0
Cynoscion nebulosus	Spotted weakfish	100.0	0.13	0.01000	3.0
Cynoscion regalis	Gray weakfish	98.0	0.26	0.00880	3.0
Cynoscion striatus	S. Amer. striped weakfish	62.2	0.23	0.01000	3.0
Dalatias licha	Kitefin shark	185.4	0.05	0.01000	3.o
Dasyatis akajei	Red stingray	203.4	0.10	0.01000	3.0
Dasyatis centroura	Roughtail stingray	223.4	0.10	0.01000	3.0
Dasyatis pastinaca	Common stingray	59.2	0.09	0.00850	2.9
Deania calcea	Birdbeak dogfish	122	0.14	0.00120	3.3
Dentex angolensis	Angola dentex	58.8	0.11	0.02760	2.9
Dentex congoensis	Congo dentex	50.0	0.35	0.03190	2.8
Dentex dentex	Common dentex	100.0	0.08	0.00171	3.0
Dentex macrophthalmus	Large-eye dentex	65.0	0.18	0.00192	3.0
Dentex maroccanus	Morocco dentex	45.0	0.18	0.00157	3.1
Diagramma pictum	Painted sweetlips	100.0	0.24	0.00144	3.0
Diastobranchus capensis	Basketwork eel	183.4	0.39	0.01000	3.0
Dicentrarchus labrax	European seabass	103.0	0.16	0.00790	3.1
Dicologlossa cuneata	Wedge sole	30.0	0.47	0.00850	3.0
Diplectrum formosum	Sand seabass	30.0	1.50	0.00114	3.1
Diplodus annularis	Annular seabream	24.0	0.25	0.02310	3.0
Diplodus argenteus	South American silver porgy	39.5	0.22	0.01000	3.0
Diplodus cervinus	Zebra seabream	57.1	0.08	0.00116	3.1

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* ($year^{-1}$)	*a*	*b*
Diplodus puntazzo	Sharpsnout seabream	62.2	0.36	0.07170	3.0
Diplodus sargus	White seabream	57.6	0.10	0.00138	3.1
Diplodus vulgaris	Comm. two-banded seabream	45.0	0.36	0.02400	3.0
Dipturus batis	Blue skate	285.0	0.06	0.00108	3.1
Dipturus laevis	Barndoor skate	155.3	0.10	0.01000	3.0
Dipturus linteus	Sailray	126.1	0.12	0.01000	3.0
Dipturus nasutus	New Zealand rough skate	118.0	0.16	0.02180	3.0
Dipturus oxyrinchus	Longnosed skate	153.3	0.10	0.00070	3.4
Dissostichus eleginoides	Patagonian toothfish	218.5	0.08	0.01000	3.0
Dissostichus mawsoni	Antarctic toothfish	185.0	0.06	0.00185	2.9
Drepane africana	African sicklefish	54.3	0.13	0.00128	3.3
Drepane punctata	Spotted sicklefish	50.0	0.19	0.00167	3.2
Echinorhinus brucus	Bramble shark	313.1	0.001	0.01000	3.0
Eleginus gracilis	Saffron cod	55.0	0.18	0.00980	2.9
Eleginus navaga	Navaga	43.8	0.18	0.01000	3.0
Eleutheronema tetradactylum	Fourfinger threadfin	203.4	0.12	0.01000	3.0
Emmelichthys nitidus	Redbait	52.0	0.31	0.01000	3.0
Enchelyopus cimbrius	Fourbeard rockling	41.0	0.20	0.00350	3.1
Eopsetta jordani	Petrale sole	58.6	0.17	0.00610	3.2
Epigonus telescopus	Bulls-eye	77.5	0.03	0.01000	3.0
Epinephelus aeneus	White grouper	120.0	0.23	0.00530	3.2
Epinephelus analogus	Spotted grouper	106.9	0.11	0.01000	3.0
Epinephelus areolatus	Areolate grouper	47.0	0.29	0.00142	3.0
Epinephelus chlorostigma	Brownspotted grouper	75.0	0.29	0.00110	3.0
Epinephelus coioides	Orange-spotted grouper	120.0	0.17	0.00105	3.1
Epinephelus fasciatus	Blacktip grouper	40.0	0.16	0.00161	2.9
Epinephelus flavolimbatus	Yellowedge grouper	115.0	0.10	0.05000	2.8
Epinephelus fuscoguttatus	Brown-marbled grouper	120.0	0.20	0.00133	3.1
Epinephelus goreensis	Dungat grouper	143.2	0.08	0.00164	3.0
Epinephelus guttatus	Red hind	76.0	0.12	0.00840	3.1
Epinephelus marginatus	Dusky grouper	150.0	0.09	0.00127	3.1
Epinephelus morio	Red grouper	125.0	0.12	0.00162	3.0
Epinephelus morrhua	Comet grouper	92.7	0.12	0.00910	3.1
Epinephelus multinotatus	White-blotched grouper	100.0	0.27	0.00167	3.0
Epinephelus nigritus	Warsaw grouper	230.0	0.14	0.02100	3.0
Epinephelus niveatus	Snowy grouper	132.0	0.09	0.02140	2.9
Epinephelus polyphekadion	Camouflage grouper	92.7	0.10	0.00124	3.1
Epinephelus striatus	Nassau grouper	122.0	0.12	0.00650	3.2
Epinephelus summana	Summan grouper	54.0	0.20	0.01000	3.0
Epinephelus tauvina	Greasy grouper	102.0	0.13	0.00156	3.0
Etmopterus spinax	Velvet belly lantern shark	62.2	0.20	0.00180	3.2

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* (year^{-1})	*a*	*b*
Gadus macrocephalus	Pacific cod	119.0	0.27	0.00790	3.1
Gadus morhua	Atlantic cod	200.0	0.18	0.00104	3.0
Gadus ogac	Greenland cod	79.5	0.16	0.00117	3.0
Galeichthys feliceps	White baggar	57.1	0.19	0.00198	3.0
Galeocerdo cuvier	Tiger shark	750.0	0.18	0.00140	3.2
Galeoides decadactylus	Lesser African threadfin	50.0	0.44	0.00119	3.1
Galeorhinus galeus	Tope shark	193.0	0.17	0.00680	2.9
Galeus melastomus	Blackmouth catshark	77.5	0.19	0.00250	3.0
Gasterosteus aculeatus	Three-spined stickleback	11.0	2.40	0.01000	3.0
Genyonemus lineatus	White croaker	42.8	0.72	0.02720	2.9
Genypterus blacodes	Pink cusk-eel	200.0	0.09	0.00110	3.3
Genypterus capensis	Kingklip	180.0	0.19	0.00120	3.3
Genypterus chilensis	Red cusk-eel	153.3	0.08	0.01000	3.0
Genypterus maculatus	Black cusk-eel	102.8	0.19	0.01000	3.0
Gerres nigri	Guinean striped mojarra	21.1	0.61	0.01000	3.0
Gerres oblongus	Slender silverbiddy	31.5	0.35	0.01000	3.0
Gerres oyena	Common silver-biddy	31.5	0.42	0.00940	3.3
Ginglymostoma cirratum	Nurse shark	432.1	0.14	0.00105	2.9
Girella nigricans	Opaleye	68.3	0.33	0.01000	3.0
Girella tricuspidata	Luderick	71.0	0.18	0.00163	3.0
Glossanodon semifasciatus	Deepsea smelt	25.5	1.20	0.01000	3.0
Glyptocephalus cynoglossus	Witch	60.0	0.20	0.00170	3.4
Glyptocephalus zachirus	Rex sole	62.2	0.11	0.00280	3.5
Gnathanodon speciosus	Golden trevally	120.0	0.53	0.03900	2.8
Gobionotothen acuta	Triangular notothen	36.6	0.20	0.01000	3.0
Gobionotothen gibberifrons	Humped rockcod	57.1	0.07	0.00180	3.5
Gobius niger	Black goby	18.0	0.19	0.00160	2.9
Grammoplites suppositus	Spotfin flathead	26.3	0.38	0.01000	3.0
Gymnosarda unicolor	Dogtooth tuna	251.4	0.12	0.00105	3.1
Gymnothorax unicolor	Brown moray	102.8	0.20	0.01000	3.0
Gymnura altavela	Spiny butterfly ray	402.4	0.05	0.02680	3.0
Halaelurus canescens	Dusky catshark	72.4	0.24	0.01000	3.0
Halargyreus johnsonii	Slender codling	58.1	0.28	0.01000	3.0
Halobatrachus didactylus	Lusitanian toadfish	52.0	0.13	0.01000	3.0
Harpadon nehereus	Bombay duck	40.0	0.53	0.00240	3.1
Helicolenus dactylopterus	Blackbelly rosefish	47.0	0.10	0.00104	3.1
Himantura gerrardi	Sharpnose stingray	203.4	0.10	0.01000	3.0
Hippoglossoides elassodon	Flathead sole	54.0	0.35	0.00102	3.0
Hippoglossoides platessoides	American plaice	82.6	0.11	0.00110	3.3
Hippoglossus hippoglossus	Atlantic halibut	470.0	0.03	0.00130	3.2
Hippoglossus stenolepis	Pacific halibut	258.0	0.06	0.00310	3.2
Hoplostethus mediterraneus	Mediterranean slimehead	42.0	0.11	0.00830	3.2

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* ($year^{-1}$)	*a*	*b*
Huso huso	Beluga	500.0	0.02	0.00400	3.2
Hydrolagus colliei	Spotted ratfish	97.0	0.22	0.01000	3.0
Hydrolagus mirabilis	Large-eyed rabbitfish	39.7	0.34	0.01000	3.0
Hydrolagus novaezealandiae	Dark ghost shark	98.8	0.18	0.00190	3.3
Hyperoglyphe antarctica	Antarctic butterfish	140.0	0.31	0.00960	3.2
Hypoptychus dybowskii	Korean sandeel	10.0	3.65	0.01000	3.0
Hyporhamphus ihi	Garfish	27.3	0.79	0.01000	3.0
Isacia conceptionis	Cabinza grunt	62.2	0.18	0.01000	3.0
Isurus oxyrinchus	Shortfin mako	400.0	0.20	0.00167	2.8
Isurus paucus	Longfin mako	419.3	0.10	0.01000	3.0
Kathetostoma giganteum	Giant stargazer	90.0	0.20	0.00198	3.0
Kyphosus cinerascens	Blue seachub	52.2	0.25	0.01000	3.0
Kyphosus sectatrix	Bermuda sea chub	78.5	0.13	0.00174	3.1
Labrus bergylta	Ballan wrasse	65.9	0.10	0.00119	3.1
Labrus merula	Brown wrasse	45.0	0.22	0.00109	3.1
Laemonema longipes	Longfin codling	72.0	0.15	0.00590	2.9
Lamna nasus	Porbeagle	350.0	0.06	0.04700	2.7
Larimichthys croceus	Large yellow croaker	82.6	0.23	0.01000	3.0.o
Larimichthys polyactis	Yellow croaker	40.0	0.44	0.02650	2.9
Lateolabrax japonicus	Japanese seaperch	102.0	0.19	0.05080	2.8
Lates calcarifer	Barramundi	200.0	0.12	0.00107	3.0.0
Leiostomus xanthurus	Spot croaker	36.0	0.43	0.00920	3.1
Lepidonotothen larseni	Lepidonotothen larseni	25.3	0.27	0.00420	3.2
Lepidonotothen mizops	Toad notothen	15.9	0.51	0.01000	3.0
Lepidonotothen nudifrons	Gaudy notothen	20.6	0.34	0.01000	3.0
Lepidonotothen squamifrons	Grey rockcod	55.0	0.12	0.00230	3.4
Lepidoperca pulchella	Orange perch	29.4	0.35	0.01000	3.0
Lepidopsetta bilineata	Rock sole	58.0	0.15	0.02060	2.9
Lepidopus caudatus	Silver scabbardfish	210.0	0.30	0.00040	3.1
Lepidorhombus boscii	Fourspotted megrim	40.0	0.26	0.00340	3.2
Lepidorhombus whiffiagonis	Megrim	60.0	0.13	0.00290	3.3
Lepidotrigla cavillone	Large-scaled gurnard	20.0	0.53	0.00780	3.2
Lethrinus atlanticus	Atlantic emperor	52.0	0.25	0.02420	2.9
Lethrinus borbonicus	Snubnose emperor	41.7	0.31	0.01000	3.0
Lethrinus harak	Thumbprint emperor	50.0	0.46	0.00170	3.0
Lethrinus lentjan	Pink ear emperor	52.0	0.33	0.00189	2.9
Lethrinus mahsena	Sky emperor	65.0	0.10	0.00120	3.2
Lethrinus microdon	Smalltooth emperor	82.0	0.20	0.00188	3.0
Lethrinus nebulosus	Spangled emperor	87.0	0.21	0.00161	3.0
Lethrinus obsoletus	Orange-striped emperor	60.0	0.38	0.00173	3.0
Lethrinus xanthochilus	Yellowlip emperor	72.3	0.14	0.02010	3.0
Leucoraja circularis	Sandy ray	123.1	0.12	0.01000	3.0

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* ($year^{-1}$)	*a*	*b*
Leucoraja erinacea	Little skate	54.0	0.35	0.00270	3.2
Leucoraja fullonica	Shagreen ray	123.1	0.12	0.01000	3.0
Leucoraja naevus	Cuckoo ray	91.6	0.11	0.00240	3.2
Limanda aspera	Yellowfin sole	49.0	0.14	0.00760	3.2
Limanda ferruginea	Yellowtail flounder	64.0	0.34	0.01000	3.0
Limanda limanda	Dab	43.0	0.39	0.00490	3.1
Lithognathus lithognathus	White steenbras	200.0	0.10	0.02280	2.9
Lithognathus mormyrus	Striped seabream	55.0	0.24	0.00154	3.0
Liza klunzingeri	Klunzingers mullet	21.1	0.45	0.01000	3.0
Liza saliens	Leaping mullet	40.0	0.20	0.00102	3.0
Lophius americanus	American angler	158.0	0.09	0.00170	3.0
Lophius budegassa	Black-bellied angler	102.0	0.08	0.00130	3.0
Lophius piscatorius	Angler	200.0	0.11	0.02550	2.8
Lophius vaillanti	Shortspine African angler	52.0	0.20	0.01000	3.0
Lophius vomerinus	Cape monk	100.0	0.14	0.00120	3.0
Lopholatilus chamaeleonticeps	Great northern tilefish	125.0	0.13	0.00490	3.3
Lutjanus argentimaculatus	Mangrove red snapper	150.0	0.19	0.02800	2.8
Lutjanus argentiventris	Yellow snapper	71.0	0.16	0.01000	3.0
Lutjanus bohar	Two-spot red snapper	90.0	0.27	0.00156	3.1
Lutjanus campechanus	Northern red snapper	100.0	0.17	0.00169	3.0
Lutjanus gibbus	Humpback red snapper	50.0	0.40	0.00131	3.1
Lutjanus johnii	Johns snapper	99.4	0.12	0.00182	3.0
Lutjanus kasmira	Common bluestripe snapper	42.4	0.21	0.00117	3.1.0
Lutjanus malabaricus	Malabar blood snapper	100.0	0.19	0.02070	2.9
Lutjanus purpureus	Southern red snapper	100.0	0.13	0.00141	3.0
Lutjanus quinquelineatus	Five-lined snapper	38.0	0.31	0.00123	3.1
Lutjanus synagris	Lane snapper	60.0	0.20	0.02950	2.8
Lycodichthys antarcticus	Lycodichthys antarcticus	25.3	0.45	0.01000	3.0
Macrodon ancylodon	King weakfish	45.0	0.42	0.00330	3.3
Macroramphosus scolopax	Longspine snipefish	20.0	0.46	0.00790	2.9
Macrourus berglax	Onion-eye grenadier	110.0	0.04	0.00980	3.0
Macrourus carinatus	Ridge scaled rattail	102.8	0.10	0.01000	3.0
Macrourus holotrachys	Bigeye grenadier	82.6	0.12	0.01000	3.0
Macruronus magellanicus	Patagonian grenadier	115.0	0.09	0.00310	3.0
Macruronus novaezelandiae	Blue grenadier	120.0	0.26	0.00600	2.8
Melanogrammus aeglefinus	Haddock	112.0	0.12	0.00520	3.2
Mene maculata	Moonfish	30.0	0.19	0.02190	3.1
Menticirrhus littoralis	Gulf kingcroaker	50.3	0.37	0.00400	3.2
Menticirrhus saxatilis	Northern kingcroaker	46.0	0.56	0.01000	3.0
Merlangius merlangus	Whiting	70.0	0.34	0.00620	3.1
Merluccius albidus	Offshore hake	48.6	0.57	0.01000	3.0

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* ($year^{-1}$)	*a*	*b*
Merluccius angustimanus	Panama hake	40.0	0.34	0.01000	3.0
Merluccius australis	Southern hake	126.0	0.31	0.00190	3.3
Merluccius bilinearis	Silver hake	76.0	0.18	0.00390	3.2
Merluccius capensis	Shallow-water Cape hake	140.0	0.11	0.00520	3.1
Merluccius gayi gayi	South Pacific hake	102.0	0.12	0.00700	3.0
Merluccius hubbsi	Argentine hake	95.0	0.13	0.00102	2.9
Merluccius merluccius	European hake	140.0	0.09	0.00430	3.2
Merluccius paradoxus	Deep-water Cape hake	120.0	0.12	0.00610	3.0
Merluccius polli	Benguela hake	80.0	0.39	0.01000	3.0
Merluccius productus	North Pacific hake	91.0	0.13	0.02040	2.7
Merluccius senegalensis	Senegalese hake	85.2	0.17	0.00790	3.0
Meuschenia scaber	Velvet leatherjacket	32.5	0.26	0.05560	2.9
Microchirus variegatus	Thickback sole	35.	0.37	0.00890	3.1
Microgadus proximus	Pacific tomcod	32.0	0.38	0.01000	3.0
Microgadus tomcod	Atlantic tomcod	39.8	0.29	0.01000	3.0
Micromesistius australis	Southern blue whiting	90.0	0.20	0.00410	3.2
Micromesistius poutassou	Blue whiting	50.0	0.37	0.00740	3.0
Micropogonias furnieri	Whitemouth croaker	60.1	0.22	0.00121	3.0
Micropogonias undulatus	Atlantic croaker	55.0	0.35	0.00310	3.2
Microstomus kitt	Lemon sole	65.0	0.15	0.01000	3.0
Microstomus pacificus	Dover sole	76.0	0.26	0.00122	2.9
Miichthys miiuy	Mi-iuy croaker	80.6	0.32	0.01000	3.0
Molva dypterygia	Blue ling	160.0	0.11	0.00190	3.1
Molva molva	Ling	200.0	0.17	0.01000	3.4
Monotaxis grandoculis	Humpnose big-eye bream	62.2	0.21	0.02390	3.0
Morone americana	White perch	52.0	0.07	0.00820	3.2
Morone saxatilis	Striped sea-bass	200.0	0.20	0.00610	3.2
Mugil cephalus	Flathead mullet	100.0	0.27	0.00850	3.0
Mugil liza	Liza	80.0	0.24	0.00130	3.0
Mugil soiuy	So-iuy mullet	97.3	0.14	0.00700	3.1
Mulloidichthys flavolineatus	Yellowstripe goatfish	43.0	0.21	0.00890	3.1
Mullus argentinae	Argentine goatfish	31.5	0.45	0.00300	3.5
Mullus barbatus	Red mullet	30.0	0.21	0.00129	3.1
Mullus surmuletus	Striped red mullet	40.0	0.30	0.00820	3.1
Mustelus asterias	Starry smooth-hound	143.2	0.30	0.00200	3.1
Mustelus canis	Dusky smooth-hound	150.0	0.04	0.00230	3.1
Mustelus henlei	Brown smooth-hound	100.0	0.23	0.01000	3.0
Mustelus lenticulatus	Spotted estuary smooth-hound	161.0	0.11	0.00150	3.2
Mustelus mustelus	Smooth-hound	200.0	0.12	0.00080	3.3
Mustelus schmitti	Narrownose smooth-hound	94.7	0.19	0.01000	3.0
Mycteroperca bonaci	Black grouper	150.0	0.17	0.00173	3.1

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter K (year^{-1})	a	b
Mycteroperca microlepis	Gag	145.0	0.12	0.00130	3.0
Mycteroperca phenax	Scamp	108.0	0.09	0.01000	3.0
Mycteroperca venenosa	Yellowfin grouper	100.0	0.17	0.00122	3.0
Mycteroperca xenarcha	Broomtail grouper	153.3	0.08	0.01000	3.0
Myliobatis aquila	Common eagle ray	186.4	0.17	0.00080	3.3
Naso unicornis	Bluespine unicornfish	70.0	0.14	0.02280	2.9
Negaprion brevirostris	Lemon shark	342.9	0.04	0.00530	3.2
Nemadactylus bergi	White morwong	41.2	0.15	0.01000	3.0
Nemadactylus macropterus	Tarakihi	70.0	0.21	0.02200	3.0
Nemadactylus monodactylus	St. Pauls fingerfin	62.2	0.12	0.01000	3.0
Nemipterus japonicus	Japanese threadfin bream	32.6	0.51	0.00470	2.9
Nemipterus randalli	Randalls threadfin bream	21.9	0.83	0.02230	2.9
Nemipterus virgatus	Golden threadfin bream	49.8	0.30	0.00175	3.0
Neocyttus rhomboidalis	Spiky oreo	41.7	0.03	0.02290	3.0
Neopagetopsis ionah	Bible icefish	58.1	0.23	0.01000	3.0
Nezumia aequalis	Common Atlantic grenadier	37.6	0.16	0.01000	3.0
Nibea mitsukurii	Nibe croaker	77.5	0.21	0.01000	3.0
Notorynchus cepedianus	Broadnose sevengill shark	300.0	0.25	0.01000	3.0
Notothenia coriiceps	Yellowbelly rockcod	62.0	0.13	0.02790	3.0
Notothenia rossii	Marbled rockcod	97.0	0.11	0.00160	3.0
Oblada melanura	Saddled seabream	34.2	0.30	0.00113	3.0
Ocyurus chrysurus	Yellowtail snapper	86.3	0.13	0.03140	2.8
Oncorhynchus gorbuscha	Pink salmon	78.5	0.33	0.00340	3.3
Oncorhynchus keta	Chum salmon	120.0	0.27	0.02300	3.2
Oncorhynchus kisutch	Coho salmon	110.9	0.21	0.01000	3.0
Oncorhynchus masou	Cherry salmon	81.6	0.16	0.00135	3.0
Oncorhynchus mykiss	Rainbow trout	120.0	0.46	0.00118	3.0
Oncorhynchus tshawytscha	Chinook salmon	153.3	0.15	0.01000	3.0
Ophiodon elongatus	Lingcod	152.0	0.18	0.01000	3.0
Orthopristis chrysoptera	Pigfish	47.9	0.20	0.00950	3.0
Otolithes ruber	Tiger-toothed croaker	90.0	0.39	0.02030	2.9
Pagellus acarne	Axillary seabream	36.0	0.21	0.00860	3.1
Pagellus bellottii	Red Pandora	42.0	0.18	0.00131	3.0
Pagellus bogaraveo	Blackspot seabream	70.0	0.09	0.00124	3.1
Pagellus erythrinus	Common pandora	60.0	0.16	0.02060	3.0
Pagrus auriga	Redbanded seabream	82.6	0.09	0.01000	3.0
Pagrus caeruleostictus	Bluespotted seabream	90.0	0.21	0.02220	2.9
Pagrus pagrus	Common seabream	91.0	0.17	0.00152	3.0
Pampus argenteus	Silver pomfret	60.0	0.24	0.04230	2.9
Paradiplospinus gracilis	Slender escolar	54.0	0.26	0.01000	3.0
Paralabrax humeralis	Peruvian rock seabass	56.6	0.34	0.01000	3.0
Paralichthys californicus	California flounder	152.0	0.10	0.01000	3.0

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* ($year^{-1}$)	*a*	*b*
Paralichthys dentatus	Summer flounder	94.0	0.22	0.00540	3.1
Paralichthys olivaceus	Bastard halibut	117.0	0.15	0.00118	3.0
Paralonchurus peruanus	Peruvian banded croaker	53.0	0.40	0.01000	3.0
Parapercis colias	Blue cod	45.0	0.66	0.01000	3.1
Parapristipoma octolineatum	African striped grunt	52.0	0.18	0.01000	3.0
Parastromateus niger	Black pomfret	75.0	0.59	0.02110	3.0
Parona signata	Parona leatherjacket	62.2	0.30	0.01000	3.0
Parophrys vetula	English sole	49.0	0.24	0.00380	3.1
Patagonotothen brevicauda	Patagonian rockcod	24.2	0.35	0.01000	3.0
Patagonotothen ramsayi	Ramsay's icefish	45.8	0.28	0.01000	3.0
Pegusa lascaris	Sand sole	40.0	0.45	0.00690	3.1
Pelates quadrilineatus	Fourlined terapon	31.5	0.33	0.00134	3.0
Pennahia anea	Greyfin croaker	30.0	0.80	0.01000	3.1
Pennahia argentata	White croaker	35.3	0.76	0.01000	3.0
Pentanemus quinquarius	Royal threadfin	35.0	1.08	0.00060	3.4
Peprilus alepidotus	Harvestfish	29.4	0.59	0.01000	3.0
Peprilus simillimus	Pacific pompano	29.4	0.49	0.01000	3.0
Peprilus triacanthus	American butterfish	30.0	0.80	0.00650	3.3
Percophis brasiliensis	Brazilian flathead	55.4	0.14	0.00410	3.0
Petromyzon marinus	Sea lamprey	123.1	0.09	0.00080	3.2
Petrus rupestris	Red steenbras	200.0	0.08	0.02700	3.0
Phycis blennoides	Greater forkbeard	110.0	0.17	0.00120	3.3
Phycis phycis	Forkbeard	65.3	0.19	0.00700	3.2
Platichthys flesus	Flounder	60.0	0.23	0.00930	3.1
Platichthys stellatus	Starry flounder	91.0	0.19	0.00360	3.3
Platycephalus indicus	Bartail flathead	102.8	0.41	0.00660	3.0
Plectorhinchus gaterinus	Blackspotted rubberlips	52.0	0.22	0.01000	3.0
Plectorhinchus macrolepis	Biglip grunt	46.9	0.24	0.01000	3.0
Plectorhinchus mediterraneus	Rubberlip grunt	80.0	0.18	0.02020	2.9
Plectorhinchus pictus	Trout sweetlips	85.0	0.17	0.04400	2.8
Plectorhinchus schotaf	Minstrel sweetlip	82.6	0.14	0.01000	3.0
Plectropomus areolatus	Squaretail coralgrouper	75.5	0.15	0.01000	3.0
Plectropomus pessuliferus	Roving coralgrouper	123.1	0.09	0.01000	3.0
Pleurogrammus azonus	Okhostk atka mackerel	64.3	0.34	0.01000	3.0
Pleuronectes platessus	European plaice	100.0	0.12	0.00103	3.0
Pleuronectes quadrituberculatus	Alaska plaice	62.0	0.10	0.00114	3.0
Pleuronichthys decurrens	Curlfin sole	38.7	0.23	0.01000	3.0
Pogonias cromis	Black drum	170.0	0.17	0.00186	2.9
Pollachius pollachius	Pollack	130.0	0.19	0.00610	3.1
Pollachius virens	Saithe	130.0	0.17	0.00770	3.0
Polydactylus quadrifilis	Giant African threadfin	203.4	0.12	0.00124	3.1

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* (year^{-1})	*a*	*b*
Polyprion americanus	Wreckfish	210.0	0.08	0.02340	2.9
Polyprion oxygeneios	Hapuka	150.0	0.08	0.00142	3.0
Pomacanthus maculosus	Yellowbar angelfish	52.0	0.16	0.01000	3.0
Pomadasys argenteus	Silver grunt	74.1	0.27	0.02670	2.9
Pomadasys incisus	Bastard grunt	50.0	0.22	0.08800	2.5
Pomadasys jubelini	Sompat grunt	60.0	0.30	0.00182	2.9
Pomadasys kaakan	Javelin grunter	80.0	0.57	0.06570	2.7
Pomadasys stridens	Striped piggy	21.1	0.51	0.01000	3.0
Pontinus kuhlii	Offshore rockfish	52.2	0.09	0.00820	3.2
Priacanthus macracanthus	Red bigeye	30.0	1.30	0.02100	2.8
Prionace glauca	Blue shark	400.0	0.16	0.00300	3.3
Prolatilus jugularis	Tilefish	41.7	0.26	0.01000	3.0
Promethichthys prometheus	Roudi escolar	100.0	0.18	0.00500	3.0
Psenopsis anomala	Melon seed	30.0	0.54	0.01000	3.0
Psettichthys melanostictus	West American sand sole	65.3	0.34	0.01000	3.0
Psettodes belcheri	Spottail spiny turbot	82.6	0.29	0.01000	3.0
Psettodes bennettii	Spiny turbot	57.1	0.42	0.01000	3.0
Psettodes erumei	Indian spiny turbot	64.0	0.56	0.00390	3.2
Pseudocaranx dentex	White trevally	125.1	0.06	0.00170	3.0
Pseudochaenichthys georgianus	South Georgia icefish	60.0	0.32	0.00080	3.7
Pseudocyttus maculatus	Smooth oreo	68.0	0.07	0.02900	2.9
Pseudopercis semifasciata	Pigletfish	102.8	0.11	0.00730	3.1
Pseudophycis bachus	Red codling	90.0	0.42	0.00970	3.0
Pseudopleuronectes americanus	Winter flounder	64.0	0.38	0.01000	3.0
Pseudopleuronectes herzensteini	Littlemouth flounder	50.0	0.20	0.00180	3.4
Pseudotolithus elongatus	Bobo croaker	47.0	0.42	0.00320	3.3
Pseudotolithus senegalensis	Cassava croaker	114.0	0.33	0.01000	3.0
Pseudotolithus senegallus	Law croaker	233.4	0.09	0.01000	3.0
Pseudupeneus prayensis	West African goatfish	55.0	0.53	0.00181	3.0
Pterogymnus laniarius	Panga seabream	45.0	0.18	0.02000	3.0
Pteroscion peli	Boe drum	33.5	0.54	0.00112	3.0
Pterothrissus belloci	Longfin bonefish	41.7	0.70	0.01000	3.0
Pterygotrigla picta	Spotted gurnard	36.0	0.24	0.01000	3.0
Pterygotrigla polyommata	Latchet	64.3	0.17	0.01000	3.0
Raja asterias	Starry ray	72.4	0.21	0.00180	3.3
Raja clavata	Thornback ray	105.0	0.21	0.00180	3.3
Raja microocellata	Small-eyed ray	82.6	0.12	0.00890	3.3
Raja montagui	Spotted ray	80.0	0.18	0.00180	3.2
Raja stellulata	Starry skate	78.5	0.19	0.01000	3.0
Raja undulata	Undulate ray	109.0	0.11	0.00210	3.3
Reinhardtius evermanni	Kamchatka flounder	100.0	0.13	0.00370	3.3

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* ($year^{-1}$)	*a*	*b*
Reinhardtius hippoglossoides	Greenland halibut	116.3	0.07	0.00300	3.3
Rexea solandri	Silver gemfish	121.7	0.15	0.00340	3.2
Rhabdosargus globiceps	White stumpnose	65.0	0.16	0.01000	3.0
Rhabdosargus haffara	Haffara seabream	36.6	0.23	0.01000	3.0
Rhinobatos percellens	Chola guitarfish	102.8	0.31	0.00810	2.8
Rhinobatos planiceps	Pacific guitarfish	78.8	0.41	0.01000	3.0
Rhomboplites aurorubens	Vermilion snapper	63.0	0.20	0.02340	2.9
Rhynchobatus djiddensis	Giant guitarfish	313.1	0.11	0.00380	3.1
Ruvettus pretiosus	Oilfish	303.2	0.09	0.01000	3.0
Salilota australis	Tadpole codling	52.0	0.31	0.00172	2.8
Salmo salar	Atlantic salmon	156.0	0.29	0.00920	3.0
Salvelinus alpinus	Charr	107.0	0.05	0.00157	3.1
Sargocentron spiniferum	Sabre squirrelfish	53.0	0.34	0.00154	3.1
Sarpa salpa	Salema	51.0	0.23	0.00134	3.0
Saurida tumbil	Greater lizardfish	60.0	0.70	0.00260	3.3
Saurida undosquamis	Brushtooth lizardfish	50.0	0.60	0.00600	3.0
Scarus ghobban	Blue-barred parrotfish	92.7	0.32	0.00165	3.0
Scarus persicus	Gulf parrotfish	52.0	0.27	0.01000	3.0
Schedophilus ovalis	Imperial blackfish	102.8	0.12	0.01000	3.0
Schedophilus pemarco	Pemarco blackfish	52.0	0.23	0.01000	3.0
Sciaena umbra	Brown meagre	70.0	0.11	0.03520	3.0
Sciaenops ocellatus	Red drum	155.0	0.46	0.00770	3.1
Scolopsis taeniatus	Black-streaked monocle bream	37.6	0.43	0.01000	3.0
Scomberoides commersonnianus	Talang queenfish	123.1	0.16	0.00150	2.9
Scomberomorus cavalla	King mackerel	184.0	0.28	0.00830	3.0
Scomberomorus regalis	Cero	186.4	0.17	0.02020	2.8
Scophthalmus aquosus	Windowpane	45.7	0.24	0.01000	3.0
Scophthalmus maximus	Turbot	100.0	0.26	0.00168	2.9
Scophthalmus rhombus	Brill	75.0	0.50	0.00143	2.9
Scorpaena porcus	Black scorpionfish	37.0	0.16	0.00176	3.0
Scorpaena scrofa	Largescaled scorpionfish	57.2	0.08	0.03130	2.8
Scorpaenichthys marmoratus	Cabezon	99.0	0.34	0.01000	3.0
Scyliorhinus canicula	Smallspotted catshark	100.0	0.53	0.00160	3.2
Scyliorhinus stellaris	Nursehound	173.4	0.11	0.01000	3.0
Sebastes alutus	Pacific ocean perch	53.0	0.12	0.00500	3.2
Sebastes flavidus	Yellowtail rockfish	66.0	0.16	0.01000	3.0
Sebastes goodei	Chilipepper	56.6	0.18	0.01000	3.0
Sebastes marinus	Ocean perch	100.0	0.06	0.01000	3.0
Sebastes melanops	Black rockfish	65.3	0.10	0.01000	3.0
Sebastes paucispinis	Bocaccio	92.4	0.11	0.01000	3.0

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* ($year^{-1}$)	*a*	*b*
Sebastes pinniger	Canary rockfish	76.0	0.14	0.01000	3.0
Sebastes viviparus	Norway redfish	36.0	0.07	0.00115	3.1
Sebastolobus alascanus	Shortspine thornyhead	82.6	0.02	0.01000	3.0
Selene dorsalis	African moonfish	38.6	0.60	0.04280	2.7
Selene setapinnis	Atlantic moonfish	62.2	0.63	0.00156	2.9
Semicossyphus pulcher	California sheephead	93.7	0.16	0.01000	3.0
Seriola dumerili	Greater amberjack	190.0	0.25	0.02400	2.9
Seriola lalandi	Yellowtail amberjack	250.0	0.14	0.05620	2.8
Seriolella brama	Common warehou	78.5	0.16	0.01000	3.0
Seriolella porosa	Choicy ruff	38.3	0.36	0.00470	3.3
Seriolella punctata	Silver warehou	66.0	0.41	0.00850	3.2
Seriolina nigrofasciata	Blackbanded trevally	72.4	0.26	0.01000	3.0
Serranus cabrilla	Comber	40.0	0.11	0.02520	2.8
Sillago sihama	Silver sillago	31.0	0.75	0.00510	3.2
Solea senegalensis	Senegalese sole	62.2	0.15	0.00670	3.1
Solea solea	Common sole	70.0	0.26	0.00620	3.0
Spaniblennius riodourensis	Rio de Oreo blenny	5.5	1.13	0.01000	3.0
Sparisoma cretense	Parrotfish	50.0	0.30	0.00570	3.3
Sparus auratus	Gilthead seabream	70.0	0.37	0.00140	3.0
Sparus hasta	Sobaity seabream	52.0	0.35	0.00116	3.0
Sphoeroides maculatus	Northern puffer	36.0	0.61	0.01000	3.0
Sphyraena barracuda	Great barracuda	200.0	0.09	0.02670	2.9
Sphyraena jello	Pickhandle barracuda	164.5	0.10	0.00140	2.8
Sphyraena obtusata	Obtuse barracuda	55.0	0.50	0.00700	2.9
Sphyrna lewini	Scalloped hammerhead	430.0	0.07	0.00280	3.1
Sphyrna zygaena	Smooth hammerhead	501.3	0.08	0.00140	3.3
Spicara maena	Blotched picarel	25.0	0.31	0.00125	3.0
Spondyliosoma cantharus	Black seabream	60.0	0.18	0.00151	3.0
Squalus acanthias	Piked dogfish	160.0	0.04	0.00310	3.1
Squatina argentina	Argentine angelshark	173.4	0.12	0.01000	3.0
Squatina squatina	Angelshark	186.4	0.08	0.03460	2.7
Stenotomus chrysops	Scup	46.0	0.27	0.01000	3.0
Stephanolepis cirrhifer	Thread-sail filefish	31.5	0.26	0.01000	3.0
Stereolepis gigas	Giant sea-bass	253.4	0.05	0.01000	3.0
Stromateus fiatola	Blue butterfish	52.0	0.29	0.01000	3.0
Symphodus melops	Corkwing wrasse	28.0	0.31	0.00650	3.2
Synagrops japonicus	Japanese splitfin	36.6	0.25	0.01000	3.0
Takifugu vermicularis	Pear puffer	31.5	0.33	0.01000	3.0
Tautoga onitis	Tautog	91.0	0.09	0.02630	3.0
Tautogolabrus adspersus	Cunner	38.0	0.20	0.00270	3.4
Thalassoma pavo	Ornate wrasse	26.3	0.24	0.01000	3.0
Theragra chalcogramma	Alaska pollack	91.0	0.41	0.00104	2.9
Thyrsites atun	Snoek	203.4	0.19	0.00940	2.9

© 2012 **Macmillan Publishers Limited. All rights reserved.**

Scientific name	Common name	Asymptotic length (cm)	Growth parameter *K* ($year^{-1}$)	*a*	*b*
Thyrsitops lepidopoides	White snake mackerel	41.7	0.34	0.00220	3.3
Totoaba macdonaldi	Totoaba	203.4	0.08	0.01000	3.0
Trachinotus blochii	Snubnose pompano	113.0	0.16	0.08800	2.6
Trachinotus carolinus	Florida pompano	66.3	0.29	0.04530	2.3
Trachinotus mookalee	Indian pompano	92.7	0.21	0.01000	3.0
Trachurus declivis	Greenback horse mackerel	64.0	0.20	0.00960	3.0
Trachurus japonicus	Japanese jack mackerel	50.0	0.38	0.01000	3.0
Trachurus lathami	Rough scad	40.0	0.17	0.00105	2.9
Trachurus picturatus	Blue jack mackerel	62.2	0.30	0.00820	3.1
Trachurus trecae	Cunene horse mackerel	46.3	0.26	0.00139	3.0
Trachyrincus scabrus	Roughsnout grenadier	60.0	0.35	0.01000	3.0
Trachyscorpia cristulata	Atlantic thornyhead	52.0	0.10	0.01000	3.0
Trematomus eulepidotus	Blunt scalyhead	35.6	0.24	0.00210	3.6
Trematomus hansoni	Striped rockcod	42.8	0.22	0.00140	3.6
Trichiurus lepturus	Largehead hairtail	234.0	0.25	0.00020	3.3
Trigla lyra	Piper gurnard	74.9	0.11	0.00106	2.9
Tripterophycis gilchristi	Grenadier cod	34.5	0.45	0.01000	3.0
Trisopterus esmarkii	Norway pout	35.0	0.52	0.00660	3.0
Trisopterus luscus	Pouting	46.7	0.21	0.00120	3
Umbrina canosai	Argentine croaker	41.7	0.26	0.00148	3.0
Umbrina cirrosa	Shi drum	86.5	0.28	0.00119	3.0
Urophycis brasiliensis	Brazilian codling	41.7	0.28	0.00400	3.2
Urophycis chuss	Red hake	66.0	0.19	0.01000	3.0
Urophycis tenuis	White hake	136	0.11	0.00400	3.2
Valamugil seheli	Bluespot mullet	60.2	0.23	0.03720	2.6
Variola louti	Yellow-edged lyretail	83.0	0.18	0.00122	3.1
Zenopsis conchifer	Silvery John dory	82.6	0.23	0.00142	3.0
Zenopsis nebulosus	Mirror dory	72.4	0.11	0.00164	3.0
Zeus faber	John dory	90.0	0.29	0.02300	2.9
Zoarces americanus	Ocean pout	122.0	0.11	0.01000	3.0
Zoarces viviparus	Viviparous blenny	52.0	0.19	0.00190	3.2

© 2012 **Macmillan Publishers Limited. All rights reserved.**

References

1 Jones, M., Dye, S., Pinnegar, J., Warren, R. & Cheung, W. W. L. Modelling commercial fish distributions: prediction and assessment using different approaches. *Ecological Modelling* (in press).

2 Close, C. *et al.* in *Fishes in Databases and Ecosystems* Vol. 14(4) (eds D. Palomares, K. I. Stergiou, & D. Pauly) 27-37 (University of British Columbia, 2006).

3 Jones, M., Dye, S., Pinnegar, J., Warren, R. & Cheung, W. W. L. Modelling commercial fish distributions: prediction and assessment using different approaches. *Ecological Modelling* **225**, 133-145 (2012).

4 Phillips, S. J. & Dudík, M. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography* **31**, 161-175, doi:10.1111/j.0906-7590.2008.5203.x (2008).

5 Kaschner, K., Tittensor, D. P., Ready, J., Gerrodette, T. & Worm, B. Current and Future Patterns of Global Marine Mammal Biodiversity. *PLoS ONE* **6**, e19653, doi:10.1371/journal.pone.0019653 (2011).

6 Cheung, W. W. L. *et al.* Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries* **10**, 235-251, doi:10.1111/j.1467-2979.2008.00315.x (2009).

7 Cheung, W. W. L., Dunne, J., Sarmiento, J. L. & Pauly, D. Integrating ecophysiology and plankton dynamics into projected maximum fisheries catch potential under climate change in the Northeast Atlantic. *ICES Journal of Marine Science* **68**, 1008-1018 (2011).

8 Pauly, D. *Gasping Fish and Panting Squids: Oxygen, Temperature and the Growth of Water-Breathing Animals*. (International Ecology Institute, 2010).

© 2012 **Macmillan Publishers Limited. All rights reserved.**

9 Clarke, A. & Johnston, N. M. Scaling of metabolic rate with body mass and temperature in teleost fish. *Journal of Animal Ecology* **68**, 893-905, doi:10.1046/j.1365-2656.1999.00337.x (1999).

10 Perrin, N. About Berrigan and Charnov's Life-History Puzzle. *Oikos* **73**, 137-139 (1995).

11 Quinn, T. J. & Deriso, R. B. *Quantitative fish dynamics*. (Oxford. , 1999).

12 Pauly, D. On the interrelationships between natural mortality, growth parameters and mean environmental temperature in 175 fish stocks. *Journal du Conseil International pour l'Exploration de la Mer* **39**, 175-192. (1980).

13 Cheung, W. W. L., Lam, V. W. Y. & Pauly, D. in *Modelling Present and Climate-shifted Distributions of Marine Fishes and Invertebrates* Vol. 16(3) *Fisheries Centre Research Report* (eds William. W. L. Cheung, Vicky W. Y. Lam, & Daniel Pauly) 5-50 (University of British Columbia, 2008).

14 Dunne, J. P., Gnanadesikan, A., Sarmiento, J. L. & Slater, R. D. Technical description of the prototype version (v0) of tracers of phytoplankton with allometric zooplankton (TOPAZ) ocean biogeochemical model as used in the Princeton IFMIP model. *Biogeosciences* **7(Suppl.):3593** (2010).

15 Schneider, B. *et al.* Climate-induced interannual variability of marine primary and export production in three global coupled climate carbon cycle models. *Biogeosciences* **5**, 597-614, doi:10.5194/bg-5-597-2008 (2008).

16 Delworth, T. L. *et al.* GFDL's CM2 global coupled climate models. Part I: Formulation and simulation characteristics. *Journal of Climate* **19**, 643-674, doi:10.1175/jcli3629.1 (2006).

© 2012 **Macmillan Publishers Limited. All rights reserved.**

17 Dunne, J. P., Sarmiento, J. L. & Gnanadesikan, A. A synthesis of global particle export from the surface ocean and cycling through the ocean interior and on the seafloor. *Global Biogeochem. Cycles* **21**, GB4006, doi:10.1029/2006gb002907 (2007).

18 Palomares, M. L. D. & Pauly, D. Predicting food consumption of fish populations as functions of mortality, food type, morphometrics, temperature and salinity. *Marine and Freshwater Research* **49**, 447-453, doi:http://dx.doi.org/10.1071/MF98015 (1998).

19 Mueter, F. J. & Litzow, M. A. SEA ICE RETREAT ALTERS THE BIOGEOGRAPHY OF THE BERING SEA CONTINENTAL SHELF. *Ecological Applications* **18**, 309-320, doi:10.1890/07-0564.1 (2008).

20 Simpson, S. D. *et al.* Continental Shelf-Wide Response of a Fish Assemblage to Rapid Warming of the Sea. *Current Biology* **21**, 1565-1570, doi:10.1016/j.cub.2011.08.016 (2011).

© 2012 **Macmillan Publishers Limited. All rights reserved.**