Overview of the marine biodiversity literature, with an emphasis on the North Atlantic

Arni Magnusson

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References with 'biodiversity' in title

1) Angel, M.V. 1993. Biodiversity of the pelagic ocean. Conserv. Biol. 7:760–772.

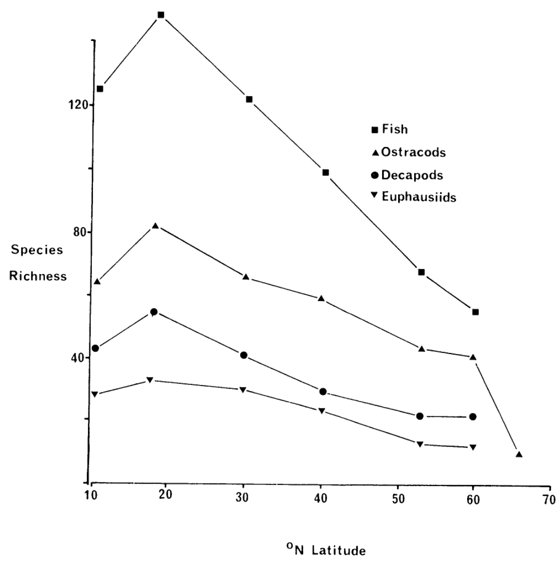

Figure 3. Variations in the total numbers of species of four pelagic taxa collected in the water column to depths of 2000 m at a set of standard stations in the northeast Atlantic approximately along 20° W (based on data in Institute of Oceanographic Sciences Deacon Laboratory pelagic data base).

Fig 3: species richness in N Atlantic by latitude (relatively low around 60°N)

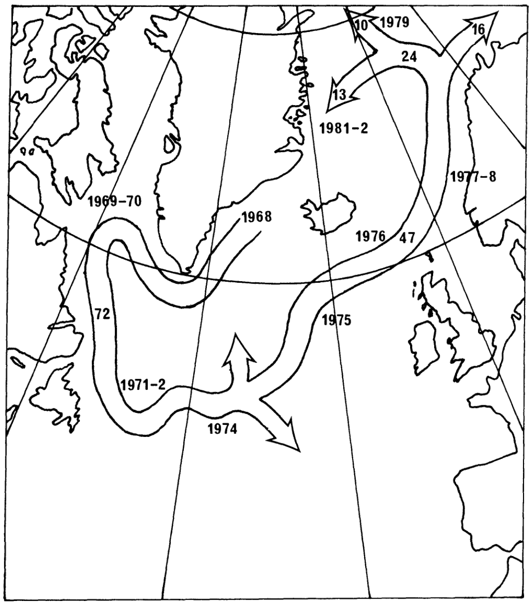

Figure 4. The track and timing of the circulation of the Great Salinity Anomaly around the North Atlantic from 1968 to 1982. The figures along the track indicate the estimated salt deficiency in 10^9 tonnes (modified from Dickson et al. 1988).

Fig 4: map of Great Salinity Anomaly 1968–1982

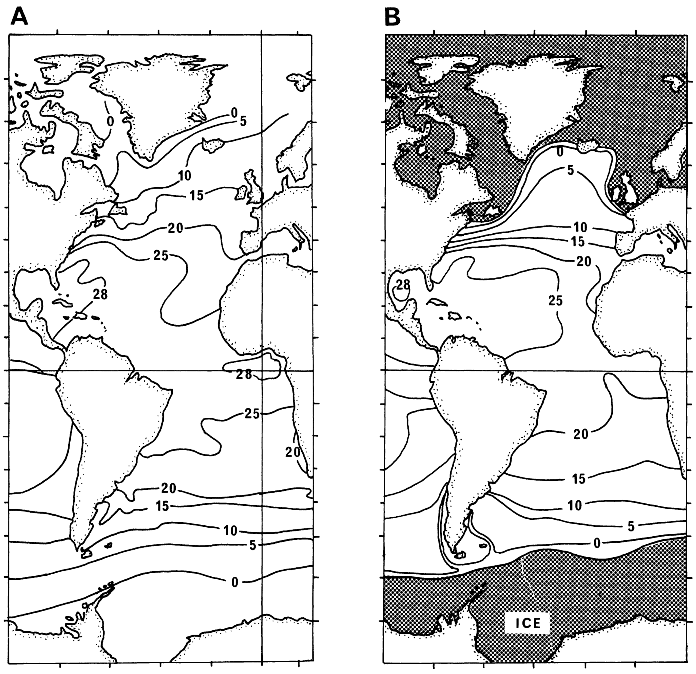

Figure 5. Comparison between summertime sea-surface temperatures in the Atlantic between 18000 before the present at the height of the last glaciation (B) and the present day (A), showing that the changes in the Northern Hemisphere were more extensive, with the polar front moving polarwards from 45° N to its present position to the north of Iceland (based on data from the CLIMAP program and modified from van der Spoel and Heyman [1983]).

Fig 5: map of Atlantic SST during ice age and today

2) **Beaugrand, G., P.C. Reid, F. Ibanez, and B. Planque. 2000. Biodiversity of North Atlantic and North Sea calanoid copepods. Mar. Ecol. Prog. Ser. 204:299–303.**

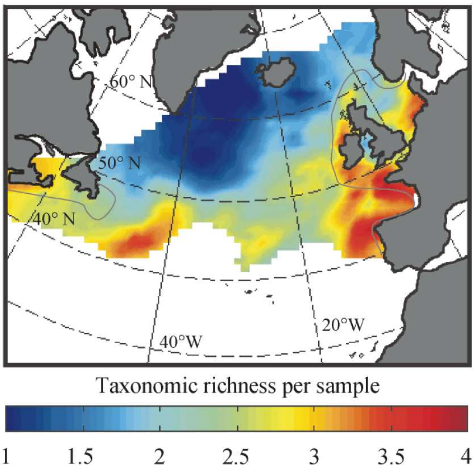

Fig. 2. Mean taxonomic richness of calanoid copepods per CPR sample in the North Atlantic and North Sea. Each pixel is based on exactly 1440 samples to assure that no sampling bias is introduced between regions. Five different diversity indices — the Berger-Parker index (Berger & Parker 1970), Brillouin diversity (Brillouin 1956), Brillouin evenness (Brillouin 1962), Shannon diversity (Shannon & Weaver 1962), and Gini coefficient (Lande 1996) — were also calculated and gave similar results to the taxonomic richness used here. Boundaries of continental shelves are indicated by a grey line representing 200 m depth

Fig 2: map of taxonomic richness of calanoid copepods in N Atlantic (low around Iceland)

3) **Cheung, W.W.L., V.W.Y. Lam, J.L. Sarmiento, K. Kearney, R. Watson, and D. Pauly. 2009. Projecting global marine biodiversity impacts under climate change scenarios. Fish and Fish. 10:235–251.**

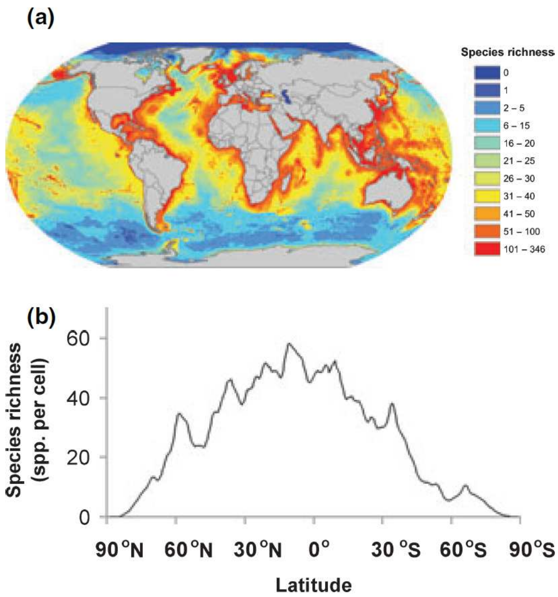

Figure 2 Distribution of species richness (1066 species of fish and invertebrates): (a) on a 30′ × 30′ grid and (b) averaged across latitude (smoothed by a running mean over 2°lat.).

Fig 2a: map of species richness of fish and invertebrates worldwide (high in Iceland)

Fig 2b: species richness of fish and invertebrates worldwide by latitude (high at 60°N)

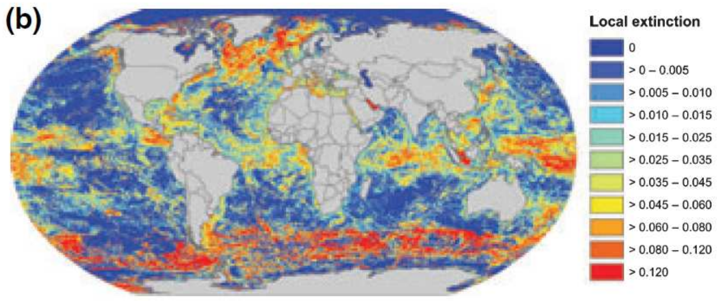

Figure 3 Predicted distribution of biodiversity impact due to warming-induced range shifts in marine metazoans. Biodiversity impact is expressed in terms of: (a) invasion intensity; (b) local extinction intensity and (c) species turnover for the 1066 species of fish and invertebrates in 2050 relative to the mean of 2001–2005 (high-range climate change scenario). Intensity is express as proportional to the initial species richness in each 30′ × 30′ cell.

Fig 3b: map of predicted local extinctions of fish/inverts due to warming worldwide

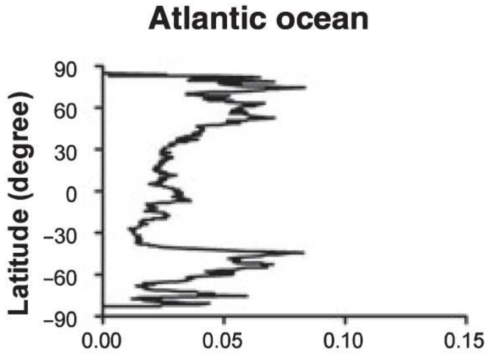

Figure 4 Projected zonal average invasion and local extinction by 30′ latitude across the high, medium and low-range climate scenarios between 2001 to 2005 and 2040 to 2060. (a, b) Global average number of invading and locally extinct species per unit area, respectively; (c, d) Global average invasion intensity measured by the number of invading and locally extinct species relative to the initial species richness from 2001 to 2005; (e,f) Average invasion and local extinction intensity in Pacific Ocean; (g,h) Average invasion and local extinction intensity in Atlantic Ocean; (i,j) Average invasion and local extinction intensity in Atlantic Ocean. Northern and southern hemispheres are distinguished by positive and negative latitudinal values, respectively.

Fig 4h: predicted local extinctions of fish/inverts due to warming in N Atlantic by latitude

Figure 5 Comparison between the past observed rate of poleward shift of high-latitude limit of birds, butterflies and North Sea demersal fish from the present study. The area and time covered by the studies are noted in the horizontal axis. Projection from the high-range (grey box) and low-range (white box) climate scenarios are included. Data with positive shifts are displayed only. 1 – Parmesan and Yohe (2003); 2 – Perry *et al.* (2005).

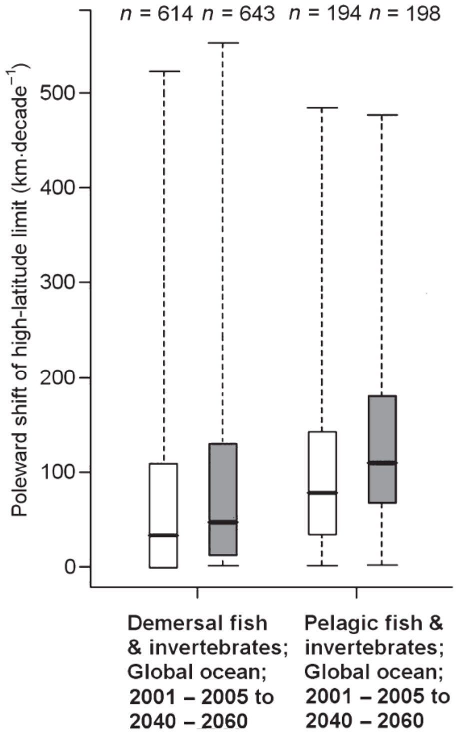

Fig 5: observed rate of poleward shift of fish/inverts due to warming in North Sea

4) **Dulvy, N.K., S. Jennings, S.I. Rogers, and D.L. Maxwell. 2006. Threat and decline in fishes: An indicator of marine biodiversity. Can. J. Fish. Aquat. Sci. 63:1267–1275.**

Fig. 4. Proportion of North Sea fishes meeting each of the three IUCN threatened categories (critically endangered, dotted line; endangered, broken line; and vulnerable, solid line), measured as (*a*) rate of decline with a 10-year window, (*b*) rate of decline with a 15-year window, and (*c*) extent of decline.

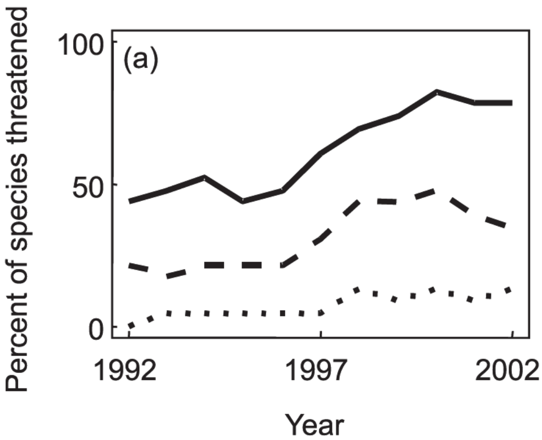

Fig 4a: proportion of North Sea fishes threatened has increased in 1992–2002

5) **Hiddink, J.G., B.R. MacKenzie, A. Rijnsdorp, N.K. Dulvy, E.E. Nielsen, D. Bekkevold, M. Heino, P. Lorance, and H. Ojaveer. 2008. Importance of fish biodiversity for the management of fisheries and ecosystems. Fish. Res. 90:6–8.**

EU fisheries scientists summarize risks to fish biodiversity and recommend solutions

6) **Hutchings, J.A. and J.K. Baum. 2005. Measuring marine fish biodiversity: Temporal changes in abundance, life history and demography. Phil. Trans. R. Soc. B 360:315–338.**

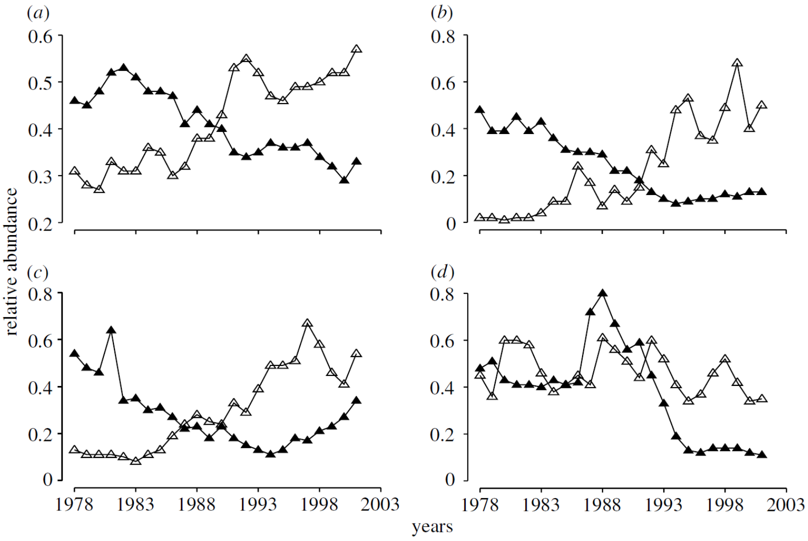

Figure 5. Temporal changes in the abundance of pelagic (open triangle) and demersal (filled triangle) marine fish from four regions in north-temperate oceans from 1978 through 2001. The abundance estimates for each population have been divided by the highest estimate ever recorded for that population prior to 2002. Number of populations represented in each time-series is as follows: (*a*) Northeast Atlantic (demersal: $N=27$; pelagic: $N=14$); (*b*) Northwest Atlantic (demersal: $N=23$; pelagic: $N=2$); (*c*) North mid-Atlantic (demersal: $N=13$; pelagic: $N=2$); (*d*) Northeast Pacific (demersal: $N=1$; pelagic: $N=5$).

Fig 5: relative abundance of demersals/pelagics in N Atlantic and NE Pacific 1978–2001

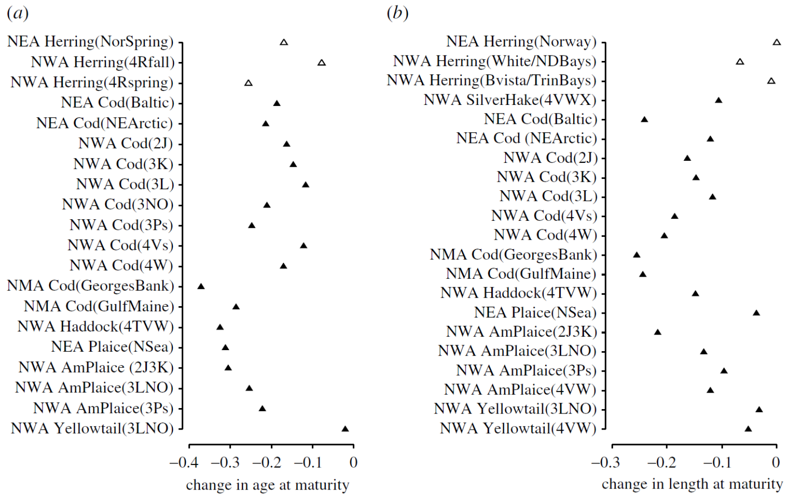

Figure 6. Proportional changes in (*a*) mean age and (*b*) length at maturity for pelagic (open triangle) and demersal (filled triangle) marine fish from four geographical regions in the north-temperate Atlantic and Pacific Oceans. The period of time represented by each datum differs among populations. Population data are described more fully in tables 1 and 2.

Fig 6: decreasing age at maturity in demersals/pelagics in N Atlantic

7) **Rice, J. and L. Ridgeway. 2010. Conservation of biodiversity and fisheries management. In: R.Q. Grafton et al. (eds.) Handbook of marine fisheries conservation and management. Oxford: Oxford University Press, pp. 139–149.**

Review of biodiversity and fisheries management

8) Sala, E. and N. Knowlton. 2006. Global marine biodiversity trends. Annu. Rev. Environ. Resour. 31:93–122.

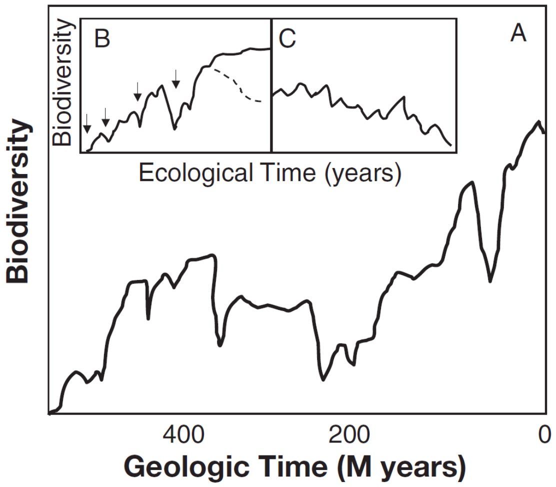

Figure 1 General trends in marine biodiversity over evolutionary and ecological times. (*A*) General increase over geological timescales, punctuated by declines caused by mass extinctions (adapted from Reference 7). Abbreviation: M, million. (*B*) Solid line: typical trend of marine biodiversity (e.g., species richness, ecodiversity, evenness, functional diversity) over ecological timescales in the absence of human disturbance. Arrows indicate pulse disturbances that reset succession. Dashed line represents decrease in ecodiversity during late successional stages in communities with competitively dominant (architectural) species. (*C*) Marine biodiversity trends under chronic human disturbance.

Fig1: biodiversity has increased with time, punctuated by mass extinctions

References on conservation and fish mgmt

9) **Baum, J.K., R.A. Myers, D.G. Kehler, B. Worm, S.J. Harley, and P.A. Doherty. 2003. Collapse and conservation of shark populations in the Northwest Atlantic. Science 299:389–392.**

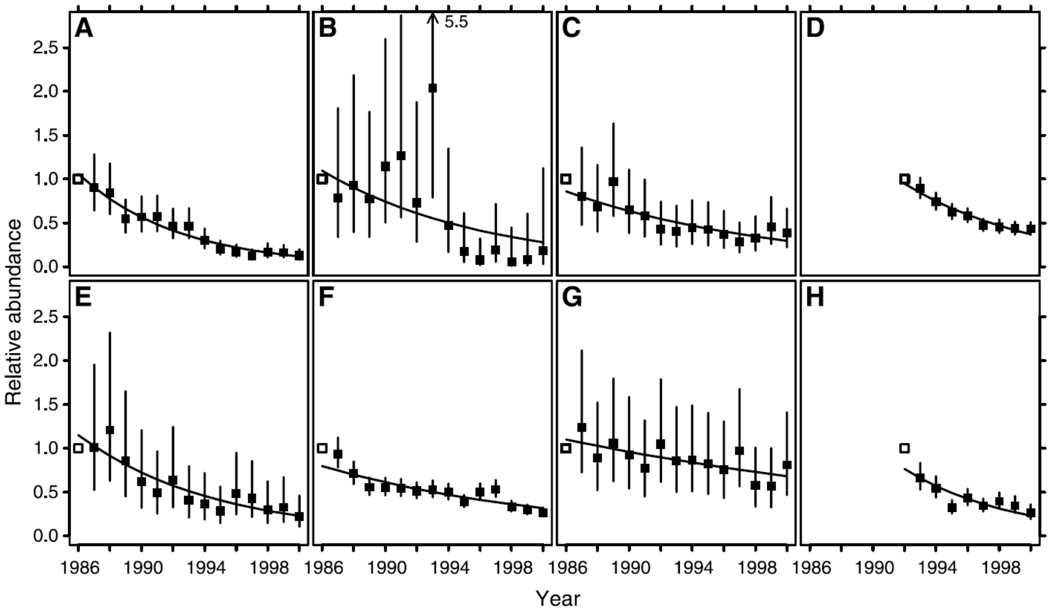

Fig. 2. Declines in estimated relative abundance for coastal shark species: (**A**) hammerhead, (**B**) white, (**C**) tiger, and (**D**) coastal shark species identified from 1992 onward; and oceanic shark species: (**E**) thresher, (**F**) blue, (**G**) mako, and (**H**) oceanic whitetip. For each species, the overall trend (solid line) and individual year estimates (■ ± 95% CI) are shown. Relative abundance is initially set to 1, to allow comparisons among species.

Fig 2: declining abundance of 8 NW-Atlantic shark species 1986–2000

10) Casey, J.M. and R.A. Myers. 1998. Near extinction of a large, widely distributed fish. Science 281:690–692.

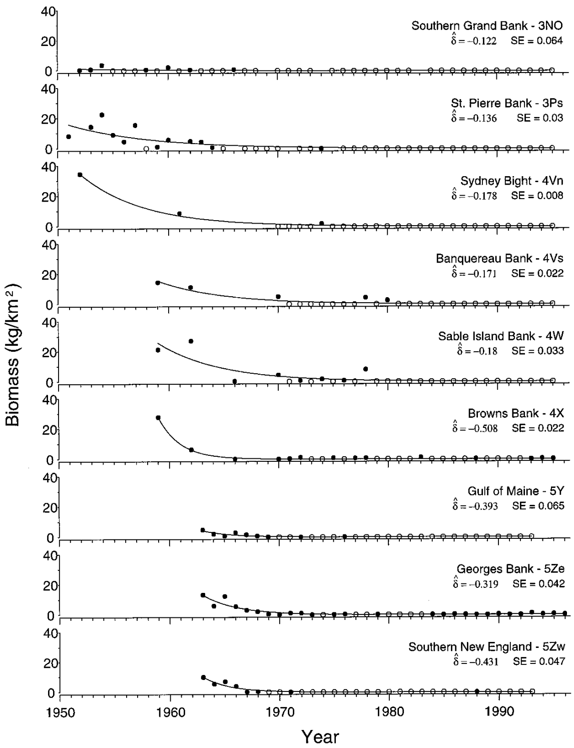

Fig. 2. Estimates of absolute biomass for barndoor skate (*R. laevis*) from the southern Grand Bank (the northern limit of the range) to southern New England (close to the southern limit of the range). Open circles are zero catches. An exponential decay curve ($Ne^{-\delta t}$) was fit to the data with nonlinear least squares, where N is the population size in the first year of the surveys and t is the time since the first year. The estimated rate of population decline ($\hat{\delta}$) was lowest in the northern regions and highest in the southern regions. If only data since 1960 are considered, the population decline on St. Pierre Bank, Sydney Bight, and Banquereau Bank is similar to that in the southernmost regions (that is, Gulf of Maine, Georges Bank, and southern New England). The standard error (SE) of $\hat{\delta}$ is provided.

Fig 2: barndoor skate (*Raja laevis*) is close to extinction, only found in NW Atlantic

11) Christensen, V., S. Guenette, J.J. Heymans, C.J. Walters, R. Watson, D. Zeller, and D. Pauly. 2003. Hundred-year decline of North Atlantic predatory fishes. Fish and Fish. 4:1–24.

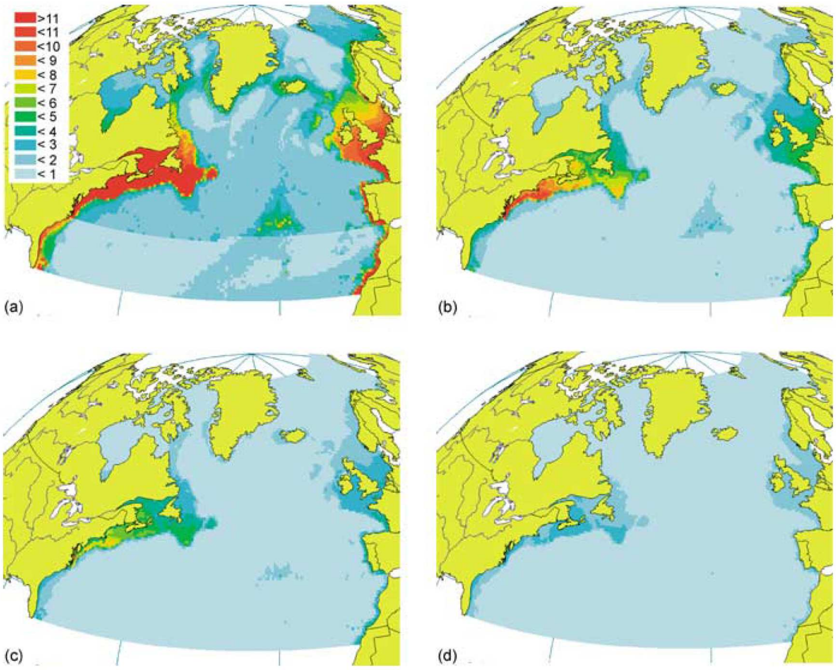

Figure 7 Biomass distributions for high-trophic level fishes in the North Atlantic in (a) 1900 (b) 1950 (c) 1975 and (d) 1999. The distributions are predicted from linear regressions based on primary production, depth, temperature, year, ice cover, latitude and catch composition. Units for the legend are tonnes km^{-2}.

Fig 7: linear model indicates practically no high-trophic level fish around Iceland in 1999

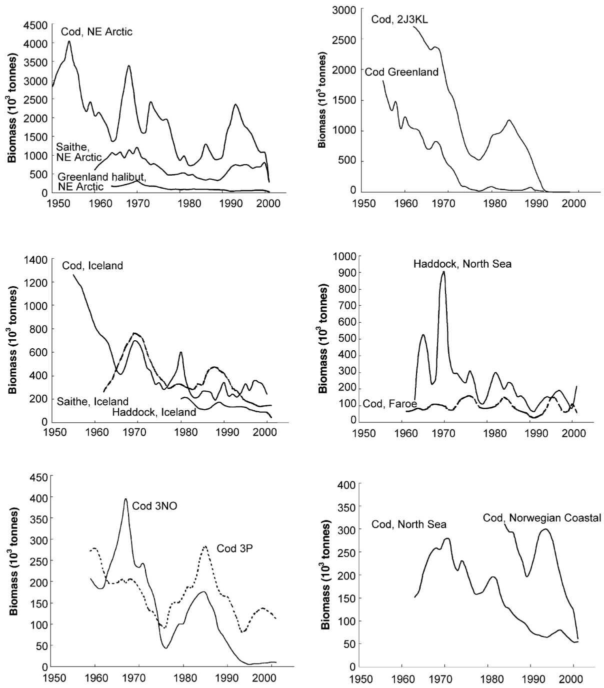

Figure 12 Trend over time (1950–2001) in biomass (thousand tonnes) of a variety of high-trophic level fish stocks in the North Atlantic. The figures are arranged by area with statistical area codes used where appropriate (based on Lilly *et al.* 1998; Brattey *et al.* 2000; NAFO 2000; ACFM 2001; Anonymous 2001a; ICCAT 2001; Lilly *et al.* 2001; O'Brien and Munroe 2001).

Fig 12: declining biomass of cod, saithe, haddock, etc. in N Atlantic 1950–2001

12) **Dayton, P.K. 1998. Reversal of the burden of proof in fisheries management. Science 279:821–822.**

Should fishing only be allowed where it has been shown to have little/no negative effect?

13) **Devine, J.A., K.D. Baker, and R.L. Haedrich. 2006. Deep-sea fishes qualify as endangered: A shift from shelf fisheries to the deep sea is exhausting late-maturing species that recover only slowly. Nature 439:29.**

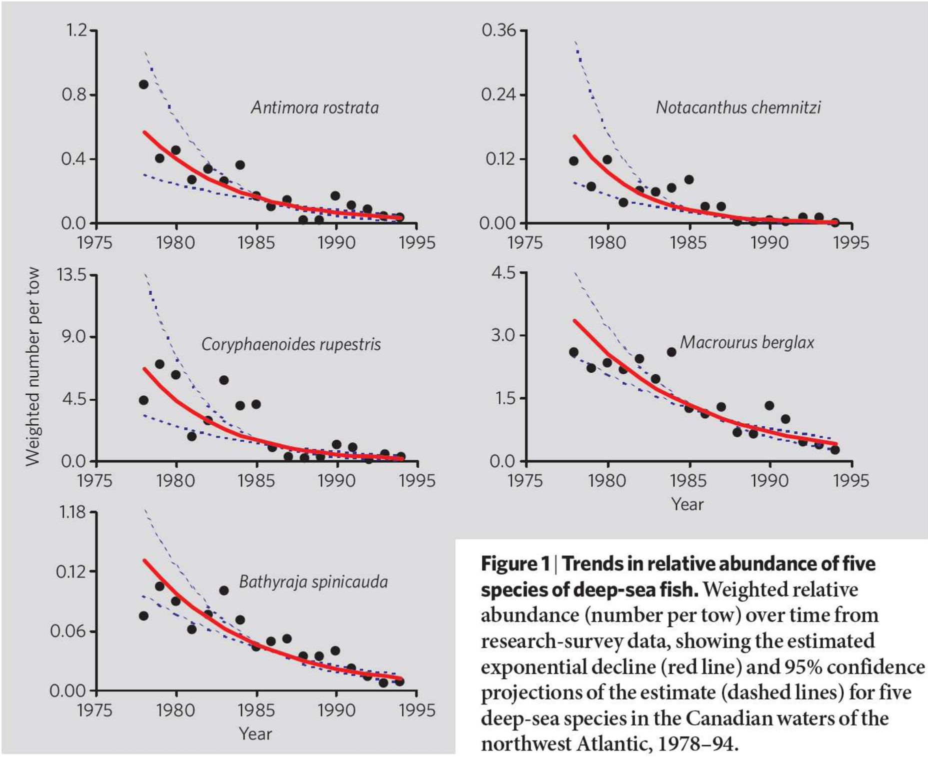

Figure 1 | Trends in relative abundance of five species of deep-sea fish. Weighted relative abundance (number per tow) over time from research-survey data, showing the estimated exponential decline (red line) and 95% confidence projections of the estimate (dashed lines) for five deep-sea species in the Canadian waters of the northwest Atlantic, 1978–94.

Fig 1: abundance of endangered bycatch species (skates etc.) in NW Atlantic 1978–1994

14) Dulvy, N.K., Y. Sadovy, and J.D. Reynolds. 2003. Extinction vulnerability in marine populations. Fish and Fish. 4:25–64.

Table 1 Extinctions of marine populations and species including spatial scale, probable cause, correlate of extinction, detection method, date of last sighting, date extinction was reported and the calculated reporting delay.

Names (Family, latin binomial, common)	Geographical location[1]	Extinction scale[2]	Extinction cause[3]	Extinction correlate[4]	Detection method[5]	Last sighting (year)	Reporting date (year)	Reporting delay (year)	Reference[6]
Mammalia									
Balaenidae									
Balaena mysticetus Bowhead whale	E Greenland	Local	Exploitation	?	Indirect	1828	?	n/a	1
Eubalaena glacialis Right whale	Bay of Biscay	Local	Exploitation	Large size	Indirect	1059	1881	822	2, 3
Delphinidae									
Tursiops truncatus Bottlenose dolphin	Wadden Sea	Local	Habitat loss	Large size	Indirect	1937	1981	44	2, 3
Tursiops truncatus Bottlenose dolphin	Netherlands	Local	Habitat loss	Large size	Indirect	1965	1981	16	2, 3
Dugongidae									
Dugong dugon Dugong	China	Local	Exploitation	Large size	Direct	2000	2000	0	4
Hydrodamalis gigas Steller's sea cow	NW Pacific	Global	Exploitation	Large size	Direct	1768	1768	0	5, 6
Eschrichtidae									
Eschrichtius robustus Gray whale	Wadden Sea	Local	Exploitation	Large size	Indirect	1640	1970	330	2, 3
Pisces									
Acipenseridae									
Acipenser sturio European sturgeon	Adriatic Sea	Local	Exploitation	Large size, specialist	Indirect	1948	2001	53	12
Acipenser sturio European sturgeon	SE North Sea	Local	Exploitation, habitat loss	Large size, specialist	Indirect	1955	2000	45	2, 3
Acipenser oxyrhinchus oxyrhinchus Atlantic sturgeon	Connecticut, St. Marys & St. Johns Rivers, USA	Local	Exploitation, habitat loss	Large size, specialist	Indirect	?	?	n/a	13, 14
Antennariidae									
Antennarius pauciradiatus Dwarf frogfish	Bermuda	Local	Habitat loss	Specialist	Indirect	1930	1999	69	15
Apogonidae									
Apogon affinis Bigtooth cardinalfish	Bermuda	Local	Habitat loss	Specialist	Indirect	1931	1999	68	15
Apogon robinsi Roughlip cardinalfish	Bermuda	Local	Habitat loss ?	Specialist	Indirect	1876	1999	123	15
Phaeoptyx conklini Freckled cardinalfish	Bermuda	Local	Habitat loss ?	Specialist	Indirect	1919	1999	80	15
Clupeidae									
Alosa alosa Allis shad	North Sea	Local	Exploitation, habitat loss, other	Specialist	Indirect	?	2000	n/a	2, 3
Clupea harengus Herring (Zuiderzee race)	Wadden Sea	Local	Habitat loss	Specialist	Indirect	1937	2000	63	2, 3
Clupea harengus Icelandic spring-spawning population	Iceland	Local	Exploitation	Small range	Direct	1972	1990	18	16

Table 1: global and local extinctions worldwide, incl. Icelandic spring-spawning herring

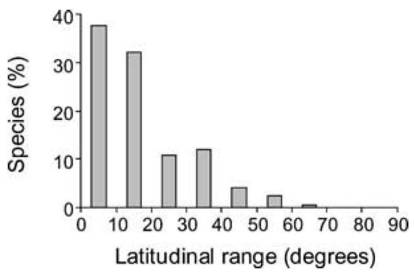

Figure 4 Frequency distribution of skate (Rajidae) latitudinal ranges. Based on data from 202 of 230 described species (Dulvy and Reynolds 2002).

Fig 4: most skate species have narrow latitudinal range

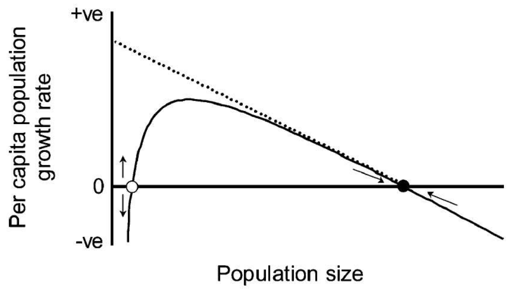

Figure 6 The Allee effect. The per capita rate of population growth indicates whether a population will grow (positive values) or decline (negative values) or remain stable (0). With logistic growth (dotted curve) there is only one equilibrium which is stable (●) at the carrying capacity, and population growth is negative above this carrying capacity and positive below, stabilising this equilibrium (as indicated by the arrows). If an Allee effect occurs (solid curve) then there is a positive relationship between population growth rate and population size at low population sizes and there is a second, lower, unstable equilibrium (○). This lower equilibrium is unstable because if the population drops below this equilibrium size (due to environmental variation, exploitation, predation or zero reproduction) negative population growth rates occur, causing the population to spiral toward extinction.

Fig 6: Allee effect means species cannot be saved if abundance goes under threshold

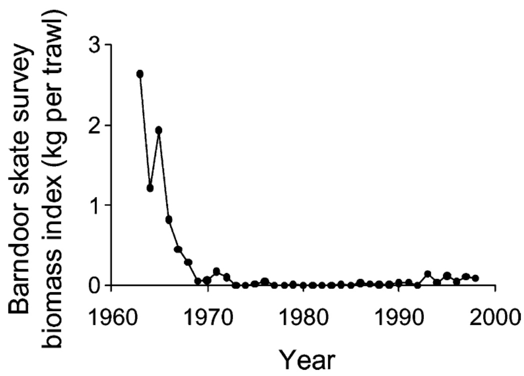

Figure 9 The overall decline in abundance of the barndoor skate from the Gulf of Maine to Southern New England. On average the biomass index of this species has declined by 96% between 1963–1965 and 1996–1998.

Fig 9: barndoor skate is close to extinction, only found in NW Atlantic

15) **Hilborn, R. 2006. Faith-based fisheries. Fisheries 31(11):554–555.**

Scientists have an incentive to overstate risk and declines: published in Nature & Science

16) Kareiva, P. 2001. When one whale matters. Nature 414:493–494.

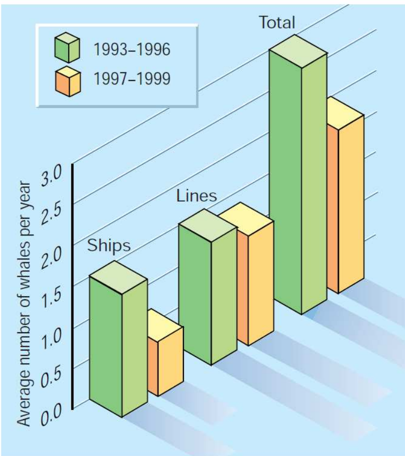

Figure 2 **Annual right whale injuries. Rates of injury before (1993–1996) and after (1997–1999) the most recent US National Marine Fisheries Service (NMFS) regulations were imposed to reduce deaths of North Atlantic right whales. These records are taken from NMFS US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments[7] from 1999, 2000 and 2001. These are surely underestimates of injuries, yet the data draw attention to the fact that technical improvements in fisheries would go a long way to saving the two whales a year that would help this whale population to recover[1]. Injuries are categorized as 'ship' if they involve deep gashes, crushed bones or other indications of impact. Injuries are categorized as 'lines' if there is evidence of having been entangled by fishing gear. Both injuries are likely to cause death.**

Fig 2: regulations have resulted in fewer right whale injuries in 1997–99 than in 1993–96

17) Mora, C. and P.F. Sale. 2011. Ongoing global biodiversity loss and the need to move beyond protected areas: A review of the technical and practical shortcomings of protected areas on land and sea. Mar. Ecol. Prog. Ser. 434:251–266.

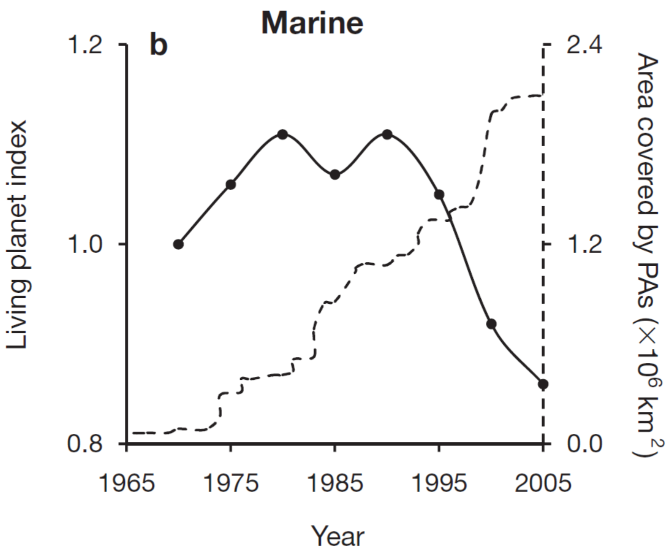

Fig. 1. Temporal trends in the areal extent of protected areas (PAs, dashed lines) and several proxies for biodiversity in marine and terrestrial ecosystems (continuous lines). (a,b) Terrestrial and marine biodiversity, respectively, in terms of the living planet index, which is the population size of >1600 vertebrate species worldwide (Hails 2008). (c,d) Coverage of live coral for Caribbean (Gardner et al. 2003) and Indo-Pacific reefs (Bruno & Selig 2007), respectively. Data on the coverage of PAs on land were obtained from Chape et al. (2005); on the ocean, from Wood et al. (2008); and for Caribbean and Indo-Pacific reefs separately from Mora et al. (2006)

Fig 1: MPAs increased rapidly 1965–2005, while marine biodiversity declined

18) Morato, T., R. Watson, T.J. Pitcher, and D. Pauly. 2006. Fishing down the deep. Fish and Fish. 7:24–34.

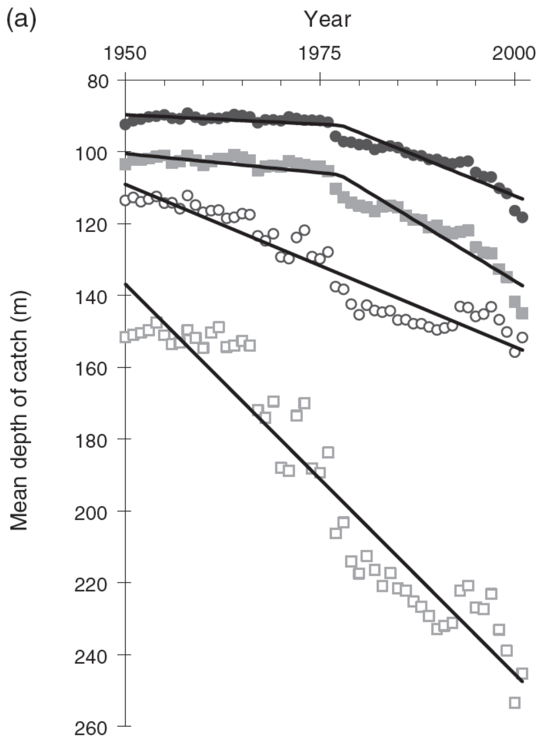

Figure 1 (a) Global trend of mean depth of world marine fisheries catches from 1950 to 2001 for all marine fishes including pelagics (dark grey dots) and for bottom marine fishes only (light grey squares). Open symbols are estimates for high seas areas only (beyond countries EEZs). Trend lines are fitted using the piecewise-polynomial model linear-linear (Hintze 1998) or simple linear regression. (b) Time series of world marine bottom fisheries catches by depth strata. Catch in tonnes are $\log_{10}$ transformed.

Fig 1a: mean depth of worldwide catch 1950–2000 has increased

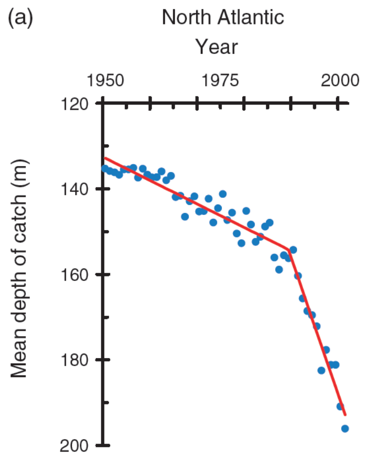

Figure 2 Trend of mean depth of marine bottom fisheries catches for: (a) North Atlantic; (b) Central Atlantic; (c) South Atlantic; (d) North Pacific; (e) Central Pacific; (f) South Pacific; (g) the Indian Ocean; and (h) Antarctic. Trend lines are fitted using the piecewise-polynomial model linear-linear (Hintze 1998).

Fig 2a: mean depth of N-Atlantic bottom fisheries 1950–2000 has increased

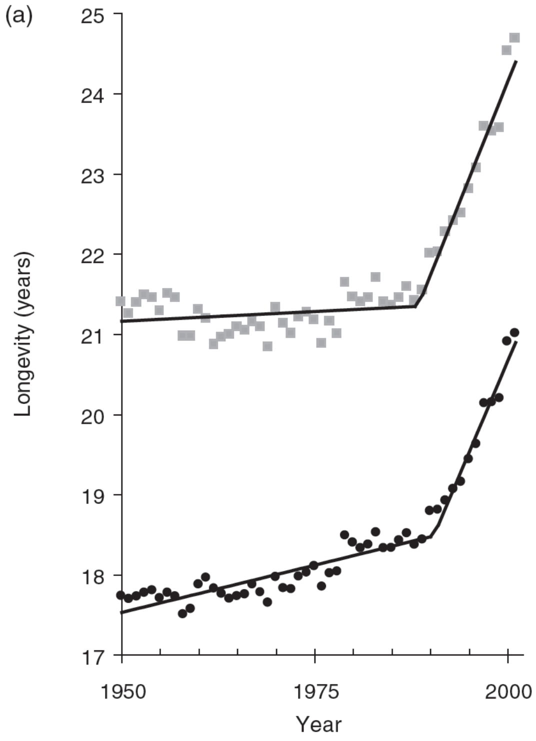

Figure 4 (a) Global trend of mean fish longevity of the catches for all marine fishes including pelagics (dark grey dots), and for bottom marine fishes only (light grey squares). (b) Global trend of mean longevity of the 2001 world bottom marine fisheries catch by depth. Line is the least squares fit through points by using a logarithmic equation ($r^2 = 0.75$). Mean age at maturity shows a similar pattern.

Fig 4a: mean fish longevity of worldwide catch 1950–2000 has increased

19) Musick, J.A. 1999. Criteria to define extinction risk in marine fishes. Fisheries 24(12):6–14.

Comment.

20) Musick, J.A. 1999. Ecology and conservation of long-lived marine animals. In: J.A. Musick (ed.) Life in the slow lane: Ecology and conservation of long-lived marine animals. Bethesda, MD: American Fisheries Society, pp. 1–10.

Comment.

21) Musick, J.A., S.A. Berkeley, G.M. Caillet, M. Camhi, G. Huntsman, M. Nammack, and M.L. Warren Jr. 2000. Protection of marine fish stocks at risk of extinction. Fisheries 25(3):6–8.

Comment.

22) Myers, R.A. and B. Worm. 2003. Rapid worldwide depletion of predatory fish communities. Nature 423:280–283.

Comment.

23) **Myers, R.A. and B. Worm. 2005. Extinction, survival or recovery of large predatory fishes. Phil. Trans. R. Soc. B 360:13–20.**

Comment.

24) **Pauly, D. 1995. Anecdotes and the shifting baseline syndrome of fisheries. TREE 10:430.**

Comment.

25) **Pauly, D. 1997. Putting fisheries management back in places. Rev. Fish Biol. Fish. 7:125–127.**

Comment.

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Comment.

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42) **Scott, A.P. and C.D. Robinson. 2008. Fish vitellogenin as a biological effect marker of oestrogenic endocrine disruption in the open sea. In: A. Payne et al. (eds.) Advances in fisheries science: 50 years on from Beverton and Holt. Oxford: Blackwell, pp. 472–490.**

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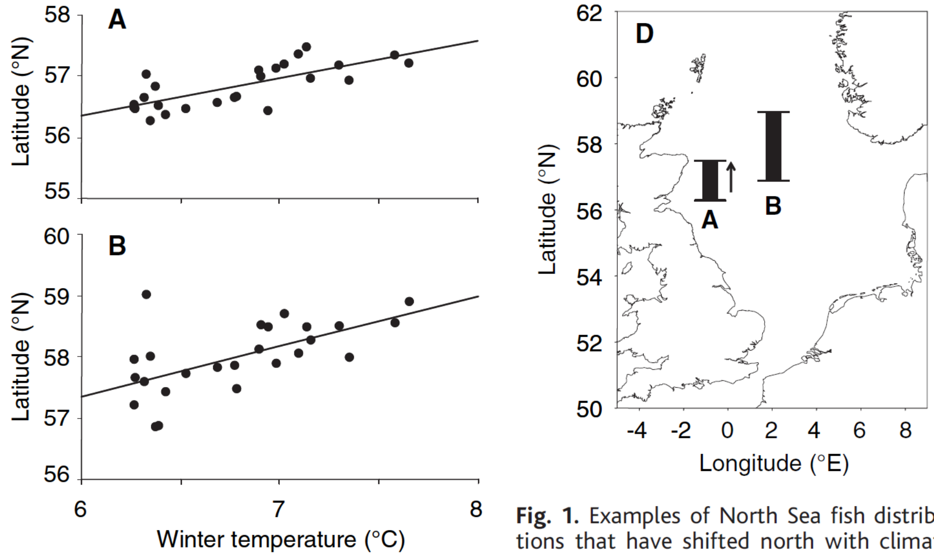


Fig. 1. Examples of North Sea fish distributions that have shifted north with climatic warming. Relationships between mean latitude and 5-year running mean winter bottom temperature for (**A**) cod, (**B**) anglerfish, and (**C**) snake blenny are shown. In (**D**), ranges of shifts in mean latitude are shown for (A), (B), and (C) within the North Sea. Bars on the map illustrate only shift ranges of mean latitudes, not longitudes. Arrows indicate where shifts have been significant over time, with the direction of movement. Regression details are in Table 1.

Fig 1a: northward shift of North Sea cod due to warming

Fig 1b: northward shift of North Sea monkfish due to warming

50) **Rosenberg, A.A., W.J. Bolster, K.E. Alexander, W.B. Leavenworth, A.B. Cooper, and M.G. McKenzie. 2005. The history of ocean resources: Modeling cod biomass using historical records. Front. Ecol. Environ. 3:78–84.**

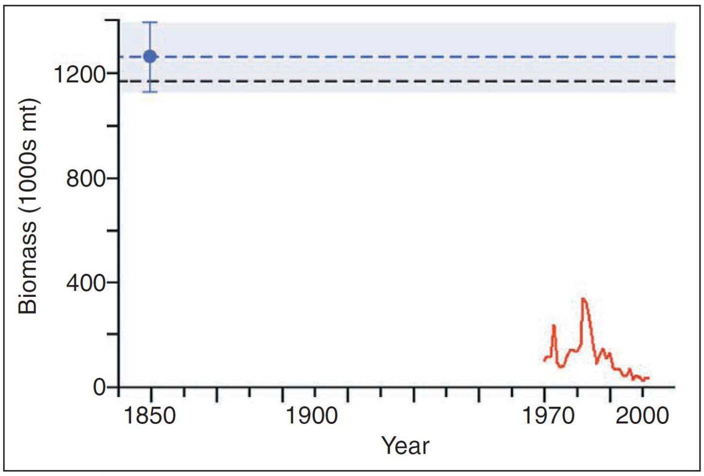


Figure 4. Biomass estimates for Scotian Shelf Cod: ● this study, with confidence interval (1852); – – – estimated carrying capacity of this marine ecosystem from late 20th century data (Myers et al. 2001); —— total biomass estimates from 1970 to 2000 for cod, 4X,4VsW (Mohn 1998; Canada DFO 2000; Fanning 2003).

Fig 4: two analyses of different data agree, cod carrying capacity 4x higher than B_{1980s}

Bottom effect

51) Kaiser, M.J., K.R. Clarke, H. Hinz, M.C.V. Austen, P.J. Somerfield, and I. Karakassis. 2006. Global analysis of response and recovery of benthic biota to fishing. Mar. Ecol. Prog. Ser. 311:1–14.

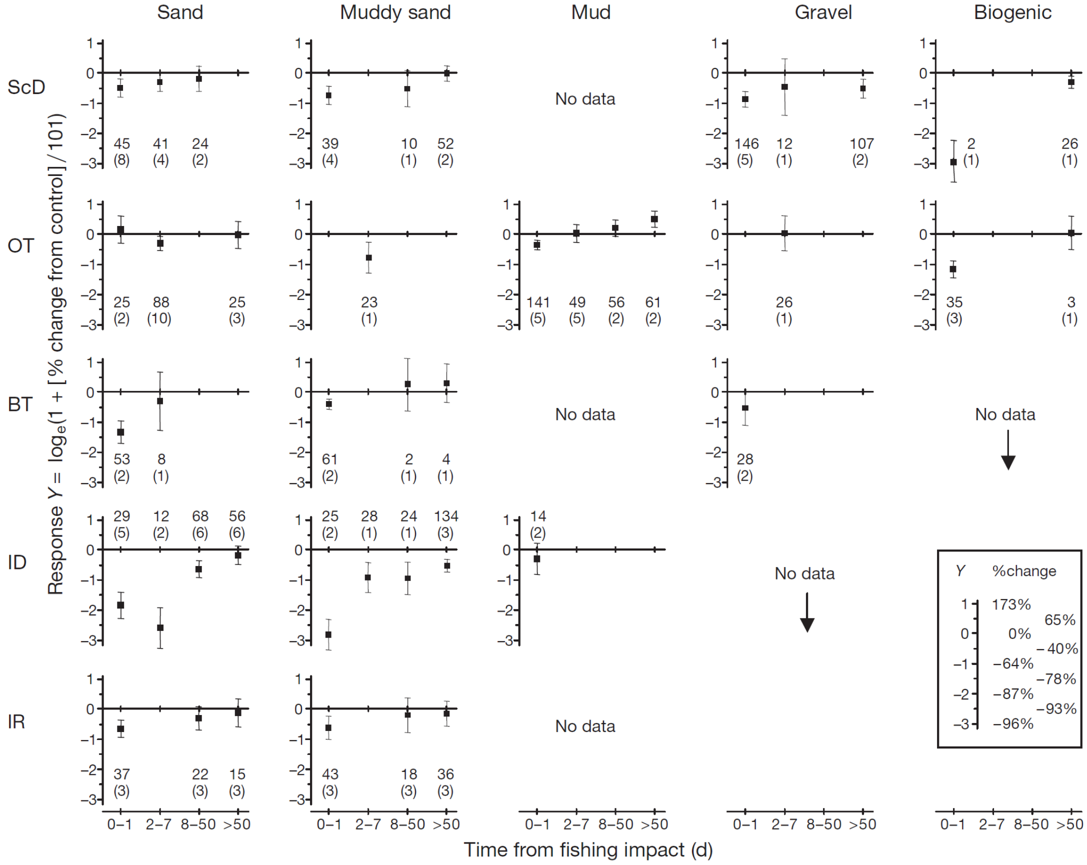


Fig. 2. Response *Y* of benthic taxa to disturbance by different types of fishing gear in different habitat categories. *Y* is log-transformed percentage change in abundance of each taxon in relation to control conditions (*Y* = –4.6: complete removal, –2.2: 90% reduction, –0.7: 50% reduction, –0.22: 20% reduction, 0: no change, +0.22: 25% increase, +0.7: 100% increase). The response is shown for 4 time categories (0–1, 2–7, 8–50 and >50 d); note that the final time bin varies between Days 50 and 1460 after a disturbance event. Data are means ± 2 SE (from pooled SD for each plot); hence, there is no significant difference from a zero-response (no impact of trawling) if the error bar intersects the *x*-axis. For certain combinations of fishing gear and habitat there were either insufficient or no data. Numbers at the bottom or top of each graph: numbers of data points for that time interval and (parentheses) number of different studies contributing data points. ScD: scallop-dredging; OT: otter-trawling; BT: beam-trawling; ID: intertidal dredging; IR: intertidal raking

Fig 2: benthic taxa decrease in abundance after fishing impact, and sometimes recover

Genetic effect

52) **Jakobsdottir, K.B., H. Pardoe, A. Magnusson, H. Bjornsson, C. Pampoulie, D.E. Ruzzante, and G. Marteinsdottir. 2011. Historical changes in genotypic frequencies at the Pantophysin locus in Atlantic cod (*Gadus morhua*) in Icelandic waters: Evidence of fisheries-induced selection? Evol. Appl. 4:562–573.**

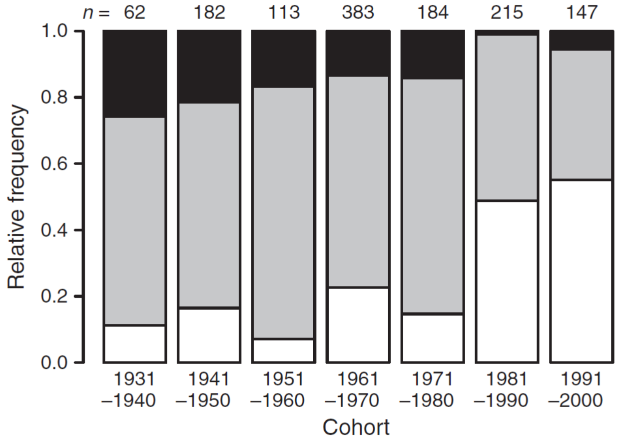


Figure 5 Observed *Pan* I genotype frequencies (white: *Pan* I^{AA}, grey: *Pan* I^{AB}, black: *Pan* I^{BB}) for Icelandic cod from different (10 year) cohort classes. The corresponding sample size is listed above each column.

Fig 5: frequency of $PanI^{A}$ allele has increased 1931–2000, while $PanI^{B}$ has decreased

MPA

53) **Balmford, A., P. Gravestock, N. Hockley, C.J. McClean, and C.M. Roberts. 2004. The worldwide costs of marine protected areas. Proc. Natl. Acad. Sci. USA 101:9694–9697.**

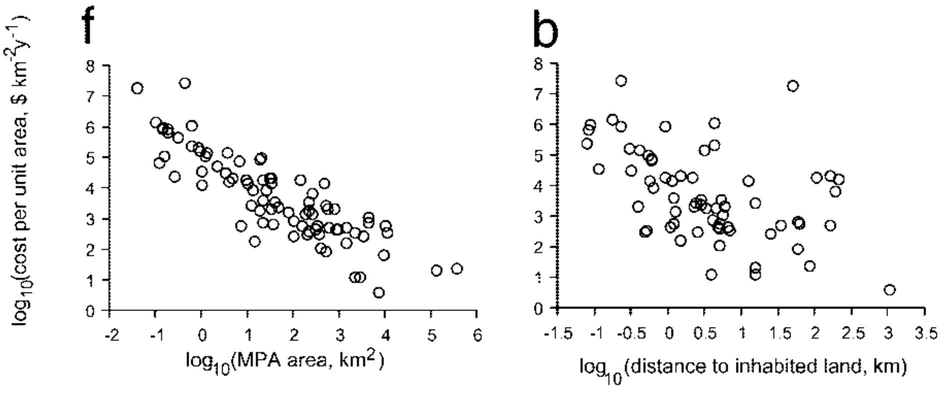


Fig. 1. The total annual cost per unit area of running MPAs in relation to the number of people living within 50 km (*a*); distance from inhabited land (*b*); national PPP (*c*); per capita GNP (*d*); whether or not the MPA was wholly protected from fishing (*e*); and MPA size (*f*). The columns in *e* give means ± SE of log_{10}-transformed costs.

Fig 1: MPAs cost more (economically) if they are large and/or close to land

54) Gell, F.R. and C.M. Roberts. 2003. Benefits beyond boundaries: The fishery effects of marine reserves. TREE 18:448–455.

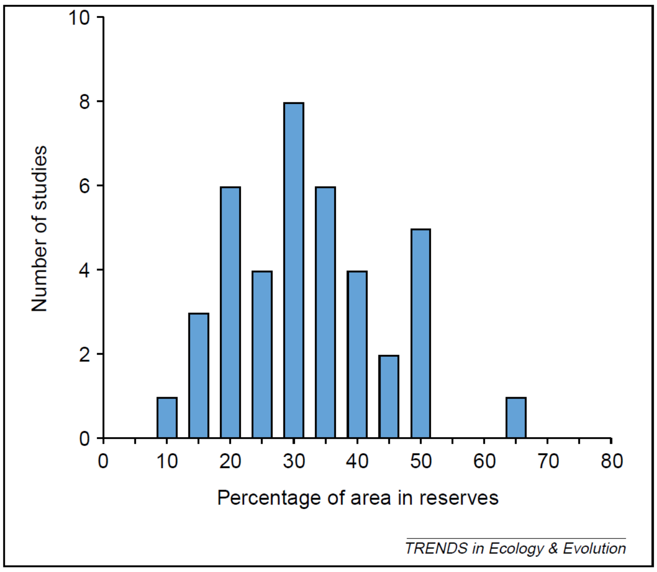


Fig. 1. Frequency distribution of the fraction of fishing grounds recommended to be included in marine reserves, based on 40 studies (mainly theoretical) that examine the question of how much area should be protected from fishing. Data points were derived by first obtaining the range of estimates over which some measure or measures of reserve performance were maximized/optimized/achieved and then taking either the mid-point or, where this was different, the point of greatest benefit from within that range. Literature included in the survey is available on request from the authors.

Fig 1: most studies recommend that 20–40% of fishing grounds should be MPAs

55) Halpern, B.S. 2003. The impact of marine reserves: Do reserves work and does reserve size matter? Ecol. Appl. 13(S):117–137

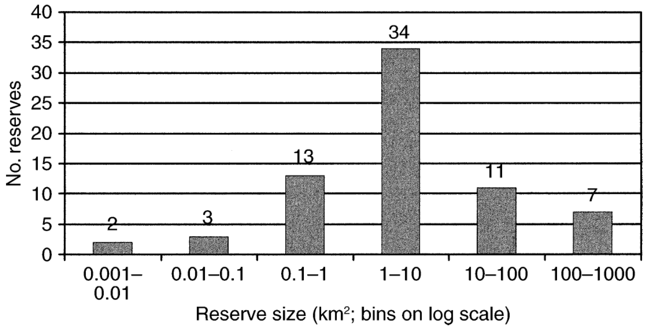


FIG. 1. Sizes of the reserves reviewed in this study. Reserve size is in square kilometers and is binned on a log scale. The range of reserve sizes is 0.002–846 km^2.

Fig 1: most MPAs are less than 10 km^2, but some are 100–1000 km^2

56) Micheli, F., B.S. Halpern, L.W. Botsford, and R.R. Warner. 2004. Trajectories and correlates of community change in no-take marine reserves. Ecol. Appl. 14:1709–1723.

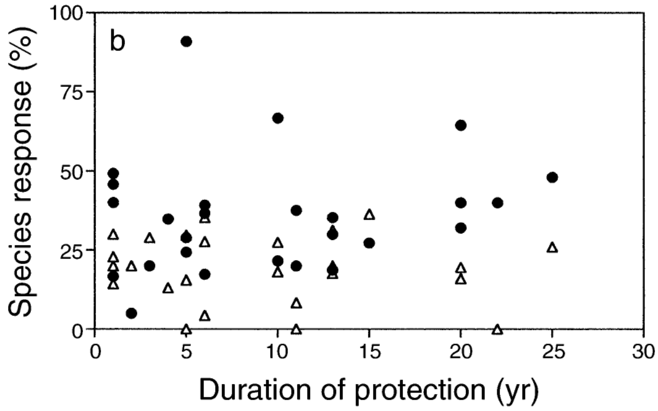
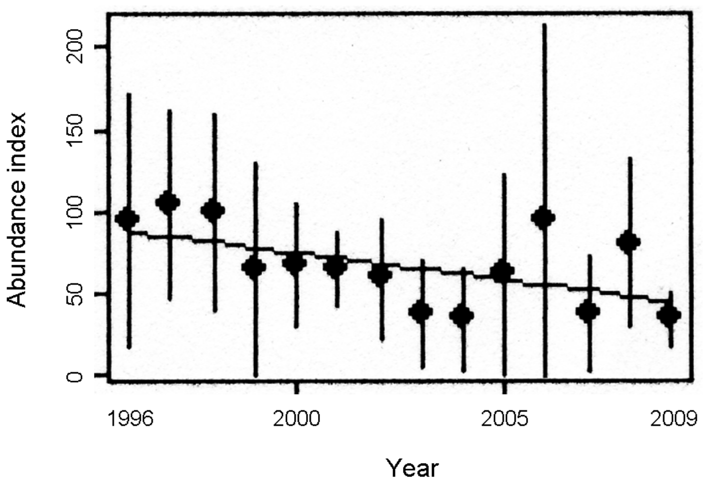


FIG. 1. (a) Response ratios (ln *R*, calculated as the natural log of the ratios between abundances within reserves and in reference conditions) of individual species. (b) Percentages of species within each study exhibiting positive responses (solid circles; ln*R* ≥ 0.69, see *Methods: Variation and correlates of species responses to protection*) or negative responses (open triangles; ln*R* ≤ −0.69) to protection in reserves ranging from one to 25 years of protection.

Fig 1: species inside MPAs that have increased (●) or decreased (Δ) in abundance (decreased abundance can be due to increased predation, competition, etc.)

Threatened Icelandic bycatch species

[1] Klara and European colleagues have looked at Icelandic autumn survey abundance indices that show at least one Icelandic bycatch deepwater species declining in recent years. Spiny-eel (*Notacanthus chemnitzii*, nefbroddabakur) is clearly declining between 1996 and 2009 — probably bycatch in commercial bottom trawl:



Source: Klara Jakobsdottir (unpubl.)

[2] The current abundance of Atlantic halibut (*Hippoglossus hippoglossus*) is very low compare to historical levels, and the abundance index looks similar to the barndoor skate in the NW Atlantic, which is considered almost extinct:

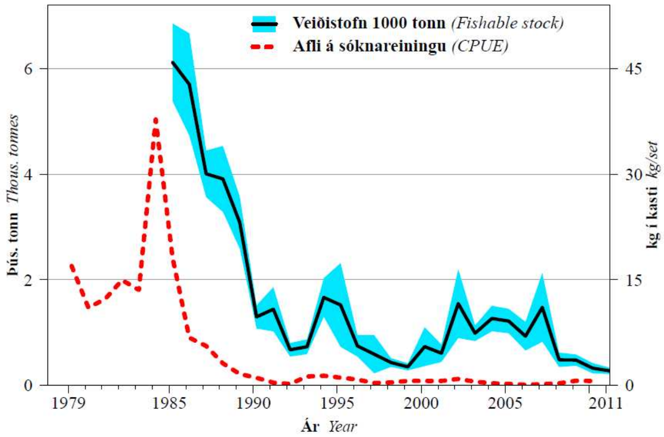


Fig. 2.7.2. ***HALIBUT****. CPUE (kg per set) from seiners during the period 1979–2010 and biomass index in the Icelandic groundfish survey in spring 1985–2011. The shaded area shows one standard deviation in the biomass estimate.*

Productivity at low population levels

Arni Magnusson

12 September 2011

Myers et al. (1995) analyzed recruitment depensation (declining number of recruit per spawning biomass) in 128 fish stocks. Only three stocks showed significant depensation:

1 Icelandic spring-spawning herring

2,3 two pink salmon populations in Alaska

In order to detect significant depensation, one needs a dataset with very low spawning biomass. Myers et al. (1995) mention predator saturation and Allee effect as possible mechanisms behind depensation, but other ecological factors could also interact.

—

Myers, R.A., N.J. Barrowman, J.A. Hutchings, and A.A. Rosenberg. 1995. Population dynamics of exploited fish stocks at low population levels. Science 269:1106–1108.

Ray Hilborn’s take on marine biodiversity

Arni Magnusson

12 September 2011

Hilborn (2005) highlighted seven features of a sustainable fishery, preserving marine biodiversity:

1 Unified jurisdiction

2 Habitat maintenance

3 Monitoring

4 Long-term stakeholder incentives

5 Ability to regulate

6 Ability to live with fluctuations

7 Nondestructive fishing practices

His examples are the NE Pacific halibut and Bering Sea salmon fisheries, but Icelandic fisheries management also scores high on this scorecard.

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Hilborn, R. 2005. Are sustainable fisheries achievable? In: E.A. Norse and L.B. Crowder (eds.) Marine conservation biology: The science of maintaining the sea's biodiversity. Washington: Island, pp. 247–259.