RAPID COMMUNICATION / COMMUNICATION RAPIDE

Trends in the abundance of marine fishes

Jeffrey A. Hutchings, Cóilín Minto, Daniel Ricard, Julia K. Baum, and Olaf P. Jensen

Abstract: The Convention on Biological Diversity (CBD) established a target in 2002 to reduce the rate of biodiversity loss by 2010. Using a newly constructed global database for 207 populations (108 species), we examine whether the 2010 target has been met for marine fishes, while accounting for population biomass relative to maximum sustainable yield, B_{MSY}. Although rate of decline has eased for 59% of populations declining before 1992 (a pattern consistent with a literal interpretation of the target), the percentage of populations below B_{MSY} has remained unchanged and the rate of decline has increased among several top predators, many of which are below $0.5B_{MSY}$. Combining population trends, a global multispecies index indicates that marine fishes declined 38% between 1970 and 2007. The index has been below B_{MSY} since the mid-1980s and stable since the early 1990s. With the exception of High Seas pelagic fishes and demersal species in the Northeast Pacific and Australia – New Zealand, the multispecies indices are currently below B_{MSY} in many regions. We conclude that the 2010 CBD target represents a weak standard for recovering marine fish biodiversity and that meaningful progress will require population-specific recovery targets and associated time lines for achieving those targets.

Résumé : La Convention sur la diversité biologique (« CBD ») s'est donnée en 2002 comme objectif de réduire le taux de perte de la biodiversité avant 2010. Utilisant une nouvelle base de données globale de 207 populations (108 espèces), nous examinons si l'objectif 2010 de la CBD a été atteint pour les poissons marins, tout en tenant compte de la biomasse des populations relative au rendement maximal durable, B_{MSY}. Malgré une diminution du taux de déclin chez 59 % des populations en chute avant 1992 (une tendance qui correspond à une interprétation littérale de l'objectif 2010 de la CBD), le pourcentage des populations sous B_{MSY} s'est maintenu constant et le taux de déclin s'est accéléré chez plusieurs des prédateurs sommitaux, une majorité desquels sont à un niveau inférieur à $0,5B_{MSY}$. Combinant les tendances des populations, un indice global multi-espèces montre que les poissons marins ont diminué de 38 % entre 1970 et 2007. L'indice est inférieur à B_{MSY} depuis le milieu des années 1980 et stable depuis le début des années 1990. Avec l'exception des populations pélagiques de haute mer et des populations démersales du nord-est du Pacifique et de Nouvelle-Zélande – Australie, les indices multi-espèces sont présentement sous B_{MSY} dans plusieurs régions. Nous concluons que l'objectif CBD 2010 représente un faible standard pour récupérer la biodiversité des poissons marins et qu'un progrès réel requerra des cibles claires de récupération spécifiques à chacune des populations et soumises à des échéanciers stricts pour atteindre les objectifs visés.

Introduction

The United Nations declared 2010 to be the International Year of Biodiversity. This was a direct response to initiatives by the Convention on Biological Diversity (CBD) to (*i*) conserve biological diversity, (*ii*) use biological diversity in a sustainable fashion, and (*iii*) share the benefits of biological diversity fairly and equitably (CBD; http://www.cbd.int). In 2002, the Conference of the Parties adopted a strategic plan for the CBD, the mission statement of which articulated what has become known as the 2010 Biodiversity Target: "to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on Earth" (http://cbd.int/2010-target/about.shtml).

Received 27 February 2010. Accepted 26 June 2010. Published on the NRC Research Press Web site at cjfas.nrc.ca on 15 July 2010. J21684

Paper handled by Associate Editor Eric Taylor.

J.A. Hutchings[1] and D. Ricard. Department of Biology, Dalhousie University, Halifax, NS B3H 4J1, Canada.
C. Minto. Department of Biology, Dalhousie University, Halifax, NS B3H 4J1, Canada; Marine and Freshwater Research Centre, Galway-Mayo Institute of Technology, Dublin Road, Galway, Ireland.
J.K. Baum. National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara, 735 State Street, Suite 300, Santa Barbara, CA 93101, USA.
O.P. Jensen.[2] School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA 98195-5020, USA.

[1]Corresponding author (e-mail: jeff.hutchings@dal.ca).
[2]Present address: Rutgers University, Institute of Marine and Coastal Sciences, 71 Dudley Road, New Brunswick, NJ 08901, USA.

Among the biodiversity indicators identified by the CBD to evaluate progress in meeting the target are those that examine "trends in the abundance and distribution of selected species" and "trends in genetic diversity ... of fish species of major socio-economic importance". An intermediate and arguably more important metric of biodiversity is that of quantifying trends in the abundance of populations of selected species. This population-level approach, for example, underpins the only marine index formally under consideration by the CBD — the Marine Living Planet Index or MLPI (World Wildlife Fund for Nature (WWF) 2008). As Schindler et al. (2010) have shown recently, maintenance of population diversity can be of fundamental importance to the stability and persistence of species.

Our overall objective is to determine whether the CBD's 2010 target has been met for marine fishes. Our analysis represents a significant extension of the only global and regional examination of marine fish population trends (Hutchings and Baum 2005): trends are now considered for 207 populations (up from 177); the multispecies index includes 174 populations (up from 87); the most recent year included is now 2009 (compared with 2004); and the spatial scale has increased from one centred in the North Atlantic to one considerably more global in coverage.

Materials and methods

Our analyses utilize population biomass estimates compiled from assessments undertaken by national and international fisheries management agencies (soon to be available at www.marinebiodiversity.ca/RAMlegacy/srdb; detailed summaries of the data used in the present study are available upon request to J.A. Hutchings). Regionally, data were available from Northeast Atlantic (Iceland east to Baltic Sea), Northwest Atlantic (Canada, northeastern US), North Mid-Atlantic (southeastern US, Gulf of Mexico), Northeast Pacific (Bering Sea to southern California), Australia – New Zealand, High Seas (Atlantic, Pacific), and a limited number of populations from South Africa and South America.

Given that the 2010 target is based on the rate of change, we compared the slopes of linear regressions of log-transformed spawning stock biomass (SSB) against time for two different periods. For each population, we compared regression slopes for all available data up to 1991 (the year before the CBD was open for signature) with those for all available data from 1992 onwards (usually to 2007). The slopes for each population were estimated using the continuous piece-wise model:

$$\ln(\mathrm{SSB}_t) = \alpha + \beta t + \delta_\beta (t - 1992)\eta_t + \varepsilon_t \quad (1)$$

where SSB_t is the spawning stock biomass (in tonnes) in year t, α is the overall intercept, η_t is a class variable determining whether year t is before ($\eta_t = 0$) or after ($\eta_t = 1$) 1992, β is the slope prior to 1992, δ_β is the change in slope post-1992, and $\varepsilon_t \sim \mathrm{N}(0, \sigma_\varepsilon^2)$ comprises the residuals. Under this model, a reduction in the rate of decline for those populations with negative slopes before 1992 would be reflected in a positive slope difference (i.e., $\delta_\beta > 0$), consistent with the 2010 target. Our analyses included populations (n = 207) for which there were at least 10 years of data before and after 1992 (Supplementary Table S1[3]). To examine the robustness of our results, we also fit a discontinuous piecewise model with no continuity constraint and a random-walk state–space model (Durbin and Koopman 2001) with pre- and post-1992 drift terms, using a Kalman filter (both are described in the Supplementary data[3]; all model fits and parameter estimates are shown in Supplementary Fig. S1 and Table S1[3]).

Potential consequences to biodiversity of positive and negative slope differences were evaluated by comparing each population's biomass (SSB or total biomass, TB) with the relevant estimated biomass at which maximum sustainable yield is achieved, i.e., $\mathrm{SSB}_{\mathrm{MSY}}$ or $\mathrm{TB}_{\mathrm{MSY}}$; for simplicity, we shall refer to these collectively as B_{MSY}. Following Worm et al. (2009), estimates of B_{MSY} available directly from stock assessments are based on SSB for all but two populations; these populations (North Atlantic albacore tuna, *Thunnus alalunga*; eastern Atlantic bluefin tuna, *Thunnus thynnus*) and those estimated from a Schaefer surplus production model, external to the stock assessments, are based on total biomass.

Multispecies abundance indices were constructed for 1970 (the initial year of WWF's MLPI) to 2007, using 174 populations in total (n = 159 having reference point estimates) for which data were available from at least 1978 until 2002 (ensuring a minimum of 25 years of data and at least 10 years of post-1992 data). To combine the series across populations, we standardized the SSB or TB data (depending on which reference point was available) by log-transforming and subtracting the biomass reference point on the log scale. For each year, the multispecies index was calculated using a mixed-effects model with a fixed-effect mean index per year, an overall random effect deviation for each population, and a first-order autocorrelation structure on the residuals. The trend was returned to the original scale by taking the exponent of the fixed-effect mean. The average of the first and last five years of this index were then used to calculate a percentage change across the 1970–2007 time period for all populations combined and for pelagic and demersal populations separately (habitat categories are indicated in Supplementary Table S1[3]).

Results

Temporal changes in rate of decline

Among 152 populations (73% of 207) declining prior to 1992, the slope difference was positive for 59% (n = 90; Fig. 1; four South African populations are not plotted), indicative of an easing of rates of decline after 1992. While 55 of these 90 populations showed an increasing trend after 1992, 35 of them were still declining, despite the positive slope difference. For the remaining 62 of 152 populations (41%), the rate of decline after 1992 was greater than that prior to 1992.

Information on B_{MSY} was available for 136 of the 152 populations in decline prior to 1992 (85 of which were obtained from assessments); the slope difference was positive for 62% of these, indicative of an easing of rates of decline after 1992. Among these 84 populations, 32 were still de-

[3] Supplementary data for this article are available on the journal Web site (http://cjfas.nrc.ca).

clining after 1992. For the remaining 52 of 136 populations (38%), the rate of decline increased after 1992.

Although rates of decline eased for more than half of marine fish populations globally, the proportional representation of populations above and below B_{MSY} did not change appreciably. For the 136 populations in decline prior to 1992, 84 were below B_{MSY} in 1992 (39 as estimated from assessments, 45 from surplus production models) compared with 81 at present (41 estimated from assessments and 40 from surplus production models). Among declining populations that were below B_{MSY} in 1992, the slope difference was positive for 58 of 84 (69%) after 1992.

To interpret temporal changes in slope difference within the context of potential reference points, we restrict regional descriptions to those populations for which estimates of B_{MSY} are available. (This data restriction has little effect on our results given the similarities in the proportional representation of populations experiencing various trends noted above and the minor reduction (n = 16) in populations considered.)

Regionally, the slope difference was positive for most populations in the Northwest Atlantic (78%), Northeast Atlantic (70%), and North Mid-Atlantic (90%), areas in which most populations were below B_{MSY} in 1992 and, on average, remain so today (Figs. 1*a*–1*c*). By comparison, the slope difference was positive for slightly less than half of the populations on the High Seas (45%), Australia – New Zealand (48%), and Northeast Pacific (45%) (Figs. 1*d*–1*f*), areas where most populations were larger than B_{MSY} in 1992.

For populations in decline prior to 1992 and that are still exhibiting a declining trend after 1992, despite a reduction in the rate of decline (n = 32), there were broad-scale regional differences in abundance relative to the MSY reference point. In the North Atlantic (Figs. 1*a*–1*c*), all 12 of these populations are below their reference targets and more than half (n = 7) are below $0.5B_{MSY}$. By contrast, among the remaining 19 populations (which are found in other regions), 14 are larger than B_{MSY} and only one (*Chrysophrys auratus*; New Zealand Area 8) is below $0.5B_{MSY}$ (Figs. 1*d*–1*f*). (Populations below $0.5B_{MSY}$ are defined as being overfished in the US and Australia (Hilborn and Stokes 2010).)

Most of the populations for which the rate of decline has increased since 1992 are top-level predators (maximum trophic level ≥ 4.3 for the 37 of 53 populations for which species-level diet data are available from www.fishbase.org), such as Atlantic cod (*Gadus morhua*), orange roughy (*Hoplostethus atlanticus*), and hoki (*Macruronus novaezelandiae*). Regionally, among the 15 North Atlantic populations declining more rapidly since 1992 (Figs. 1*a*–1*c*), 14 are below B_{MSY} and 12 are below $0.5B_{MSY}$. By comparison, few populations declining at faster rates elsewhere are below $0.5B_{MSY}$ (6 of 37 populations) and almost half (18 of 37) are above B_{MSY} (Figs. 1*d*–1*f*). Percentage changes were slightly higher when estimated by the discontinuous piecewise and random-walk models (Supplementary Table S1, Supplementary Figs. S1, S2)[3].

Multispecies indices of abundance

Overall, populations (n = 174) declined 38% between the first (1970–1974) and the last five years (2005–2009) in the time series. However, the index has stabilized since the early 1990s. The pattern of temporal change differed between pelagic and demersal fishes, which declined 28% and 41%, respectively.

Restricting the multispecies indices to the 159 populations for which estimates of B/B_{MSY} were available for the time period under consideration, populations declined 38% overall (from B/B_{MSY} = 1.28 to 0.79; Fig. 2*a*) and by 37% for pelagic (1.18 to 0.75) and 38% for demersal (1.30 to 0.80) populations (Fig. 2*b*). Regional B/B_{MSY} indices (Figs. 2*c*–2*h*) indicate that the steady decline in pelagic populations since the early 1970s, to levels below B_{MSY} beginning in the early 1990s (Fig. 2*b*), is evident in all regions except the North Mid-Atlantic (Fig. 2*e*). With the exception of High Seas populations (Fig. 2*h*), pelagic populations are, on average, below B_{MSY} on a regional basis.

Since declining from the early 1970s to the early mid-1990s, the demersal multispecies index has stabilized or possibly increased in recent years; demersal populations have been below B_{MSY} since the early 1980s (Fig. 2*b*). Comparing B/B_{MSY} in 2005–2009 with that from 1970–1974, demersal populations have declined 44% in the Northwest Atlantic (from B/B_{MSY} = 0.61 to 0.34), 46% in the Northeast Atlantic (0.88 to 0.47), 67% in the North Mid-Atlantic (1.40 to 0.47), and 59% in Australia – New Zealand (2.70 to 1.12). On average, demersal populations are below B_{MSY} in most regions except the Northeast Pacific and Australia – New Zealand.

Discussion

Interpreted literally, the CBD 2010 target might be said to have been met for marine fishes. Globally, rates of decline have eased for most (59%) populations declining prior to 1992. In three of six regions examined, rates of decline have eased for 63% or more of the populations. In the other regions examined, where rates of decline have eased for 45%–50% of populations, many declining populations (52 of 75) remain above B_{MSY} and would not normally be considered of conservation concern. In regions where populations are below B_{MSY}, multispecies trends in abundance appear to have stabilized in some areas and to be possibly increasing in others.

However, a strong argument can be made that a simple change in trends (which is what the 2010 target ultimately amounts to quantitatively) is insufficient as a metric for monitoring meaningful changes in biodiversity (Balmford et al. 2005; Hutchings and Baum 2005; Walpole et al. 2009). One obvious limitation is that it is not actually necessary for populations to be increasing in abundance for the target to be met; they simply need not be declining at a rate equal to or greater than what was experienced previously. Compounding this caveat is the observation that many populations remain low relative to their MSY reference points. For example, despite an easing of their rates of decline, all North Atlantic populations still decreasing after 1992 remain below B_{MSY} and more than half are below $0.5B_{MSY}$. Underscoring further the weak standard offered by the 2010 target are the observations that despite a reduction in rate of loss by 59% of marine fish populations, (*i*) the percentage of populations below B_{MSY} has remained unchanged since 1992 and (*ii*) the rate of decline has increased for 41% of populations, most of which comprise top predators and several of which (e.g., 80% of North Atlantic populations) are

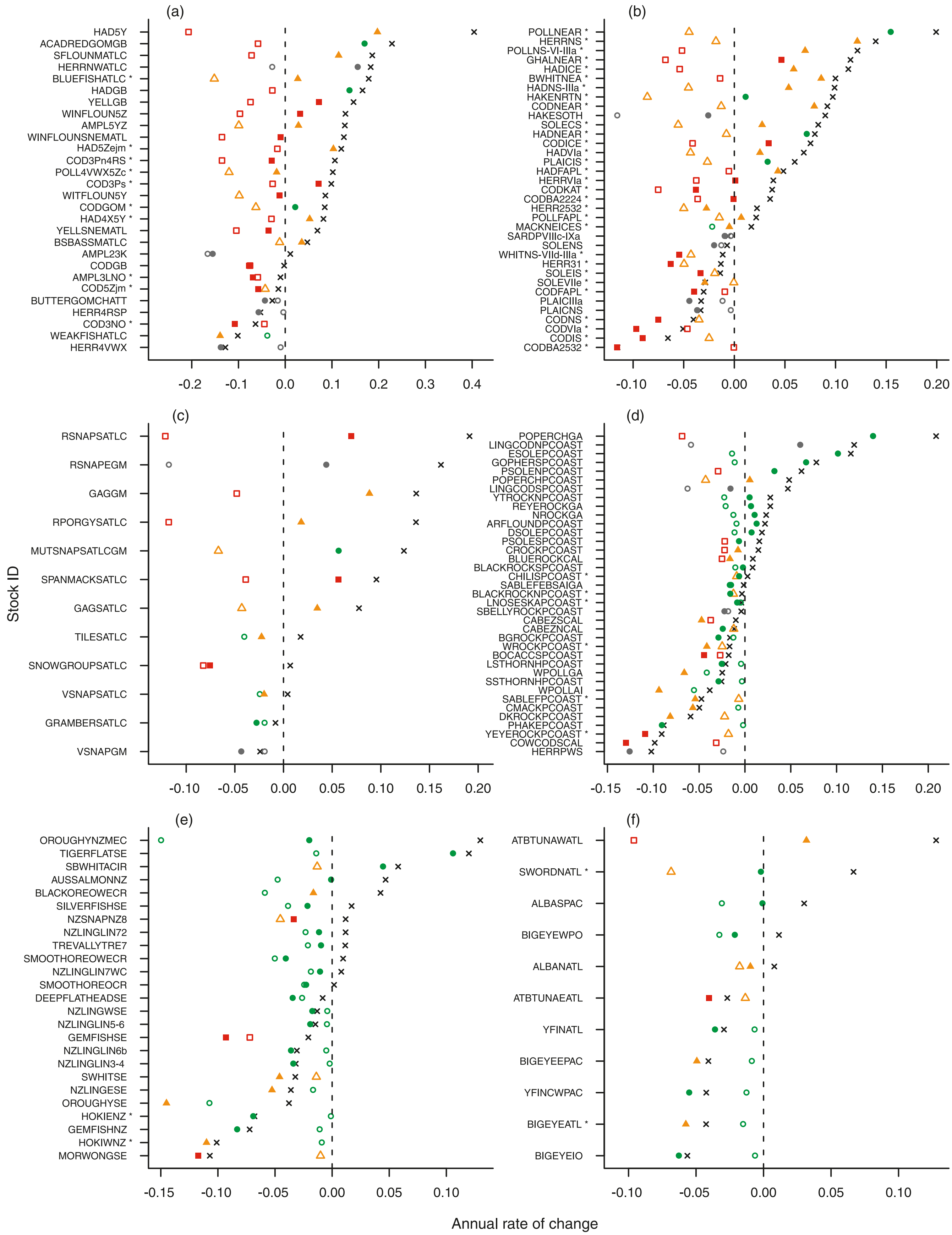
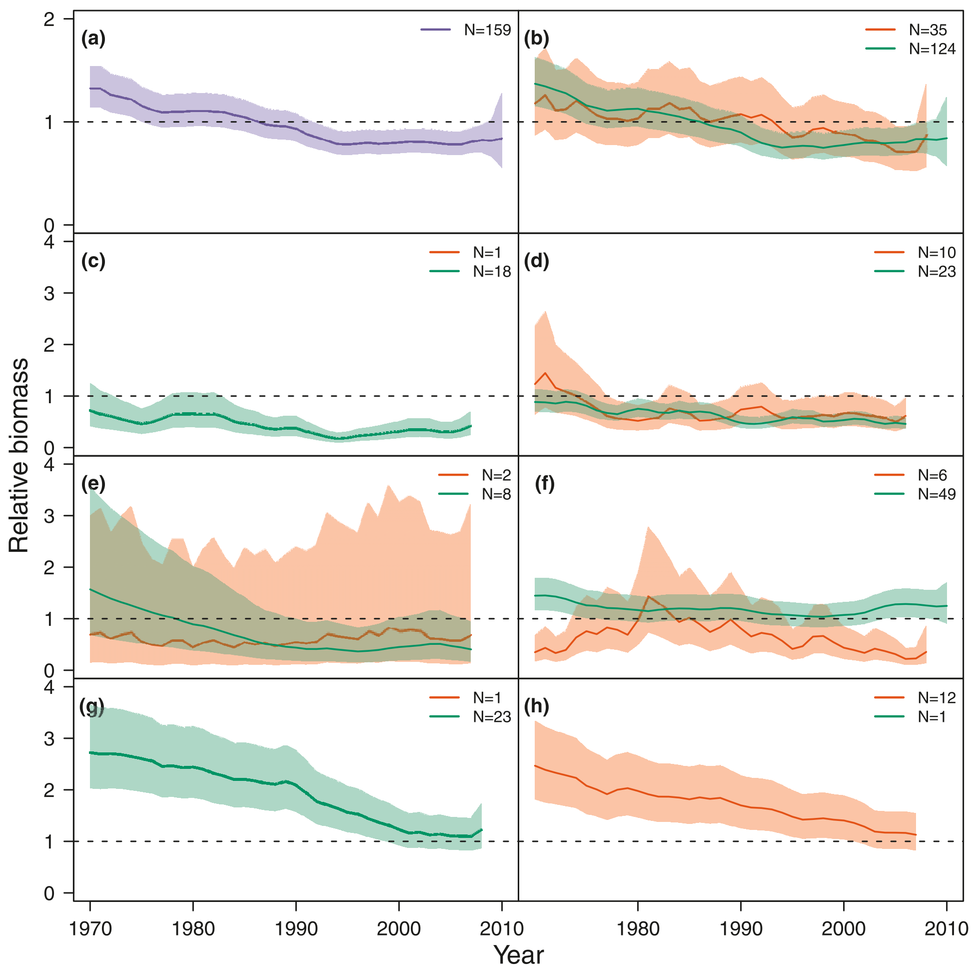

(a)
HAD5Y
ACADREDGOMGB
SFLOUNMATLC
HERRNWATLC
BLUEFISHATLC *
HADGB
YELLGB
WINFLOUN5Z
AMPL5YZ
WINFLOUNSNEMATL
HAD5Zejm *
COD3Pn4RS *
POLL4VWX5Zc *
COD3Ps *
WITFLOUN5Y
CODGOM *
HAD4X5Y *
YELLSNEMATL
BSBASSMATLC
AMPL23K
CODGB
AMPL3LNO *
COD5Zjm *
BUTTERGOMCHATT
HERR4RSP
COD3NO *
WEAKFISHATLC
HERR4VWX
-0.2 -0.1 0.0 0.1 0.2 0.3 0.4
(b)
POLLNEAR *
HERRNS *
POLLNS-VI-IIIa *
GHALNEAR *
HADICE *
BWHITNEA *
HADNS-IIIa *
HAKENRTN *
CODNEAR *
HAKESOTH
SOLECS *
HADNEAR *
CODICE *
HADVIa *
PLAICIS *
HADFAPL *
HERRVIa *
CODKAT *
CODBA2224 *
HERR2532 *
POLLFAPL *
MACKNEICES *
SARDPVIIIc-IXa
SOLENS
WHITNS-VIId-IIIa *
HERR31 *
SOLEIS *
SOLEVIIe *
CODFAPL *
PLAICIIIa
PLAICNS
CODNS *
CODVIa *
CODIS *
CODBA2532 *
-0.10 -0.05 0.00 0.05 0.10 0.15 0.20
(c)
RSNAPSATLC
RSNAPEGM
GAGGM
RPORGYSATLC
MUTSNAPSATLCGM
SPANMACKSATLC
GAGSATLC
TILESATLC
SNOWGROUPSATLC
VSNAPSATLC
GRAMBERSATLC
VSNAPGM
-0.10 -0.05 0.00 0.05 0.10 0.15 0.20
(d)
POPERCHGA
LINGCODNPCOAST
ESOLEPCOAST
GOPHERSPCOAST
PSOLENPCOAST
POPERCHPCOAST
LINGCODSPCOAST
YTROCKNPCOAST
REYEROCKGA
NROCKGA
ARFLOUNDPCOAST
DSOLEPCOAST
PSOLESPCOAST
CROCKPCOAST
BLUEROCKCAL
BLACKROCKSPCOAST
CHILISPCOAST *
SABLEFEBSAIGA
BLACKROCKNPCOAST *
LNOSESKAPCOAST *
SBELLYROCKPCOAST
CABEZSCAL
CABEZNCAL
BGROCKPCOAST
WROCKPCOAST *
BOCACCSPCOAST
LSTHORNHPCOAST
WPOLLGA
SSTHORNHPCOAST
WPOLLAI
SABLEFPCOAST *
CMACKPCOAST
DKROCKPCOAST
PHAKEPCOAST
YEYEROCKPCOAST *
COWCODSCAL
HERRPWS
-0.15 -0.10 -0.05 0.00 0.05 0.10 0.15 0.20
Stock ID
(e)
OROUGHYNZMEC
TIGERFLATSE
SBWHITACIR
AUSSALMONNZ
BLACKOREOWECR
SILVERFISHSE
NZSNAPNZ8
NZLINGLIN72
TREVALLYTRE7
SMOOTHOREOWECR
NZLINGLIN7WC
SMOOTHOREOCR
DEEPFLATHEADSE
NZLINGWSE
NZLINGLIN5-6
GEMFISHSE
NZLINGLIN6b
NZLINGLIN3-4
SWHITSE
NZLINGESE
OROUGHYSE
HOKIENZ *
GEMFISHNZ
HOKIWNZ *
MORWONGSE
-0.15 -0.10 -0.05 0.00 0.05 0.10
(f)
ATBTUNAWATL
SWORDNATL *
ALBASPAC
BIGEYEWPO
ALBANATL
ATBTUNAEATL
YFINATL
BIGEYEEPAC
YFINCWPAC
BIGEYEATL *
BIGEYEIO
-0.10 -0.05 0.00 0.05 0.10
Annual rate of change

Fig. 1. Estimates of pre- and post-1992 slopes of the temporal trends (i.e., annual rate of change) of spawning stock biomass, log(SSB), for marine fish populations estimated to have been in decline prior to 1992. Descriptions of stock alphanumeric identification codes are given in Supplementary Table S1.[3] Data are plotted for populations in six regions: (*a*) Northwest Atlantic (n = 28); (*b*) Northeast Atlantic (n = 35); (*c*) North Mid-Atlantic (n = 12); (*d*) Northeast Pacific (n = 37); (*e*) Australia and New Zealand (n = 25); and (*f*) High Seas (n = 11). Within each region, populations are ordered by the difference in slope before and after 1992, indicated by an "×". Open symbols represent the temporal slope prior to 1992; solid symbols represent the temporal slope after 1992. Estimates of B_{MSY} obtained from stock assessments are indicated by an asterisk adjacent to the population name on the vertical axis of each panel; estimates of B_{MSY} for those without asterisks were obtained from a Schaefer surplus production model. Colours and shapes are used to categorize the 1992 and current size of each population relative to their MSY reference points: populations greater than B_{MSY} are green and are indicated by circles; those below B_{MSY} but greater than $0.5B_{MSY}$ are orange and are indicated by triangles; and those below $0.5B_{MSY}$ are red and are indicated by squares. Populations for which estimates of B_{MSY} are unavailable are indicated as shaded circles.

Fig. 2. Temporal trends in current biomass (B) relative to the estimated biomass at which the maximum sustainable yield should be obtained (B_{MSY}). B_{MSY} is set to 1 in each panel (broken lines). Multispecies index for all populations and regions combined is shown in (*a*). Remaining panels illustrate multispecies indices for pelagic (red) and demersal (green) populations separately (trend data for single populations within regions are not shown). Data for all regions by habitat type are shown in (*b*). Data are plotted separately for populations in six regions: (*c*) Northwest Atlantic; (*d*) Northeast Atlantic; (*e*) North Mid-Atlantic; (*f*) Northeast Pacific; (*g*) Australia and New Zealand; and (*h*) High Seas. The solid lines represent the fixed-effect mean yearly estimates, based on a mixed-effects model with population as a random effect. The shaded regions represent the 95% confidence intervals on the fixed-effect mean.



below $0.5B_{MSY}$. Even in regions dominated by populations larger than their single-species based estimates of B_{MSY} (e.g., Australia, Northeast Pacific), increased rates of decline by top predators may be of biodiversity concern within a multispecies, ecosystem context.

Since 1970, we estimate marine fish abundance to have decreased 38% globally (38% also for populations with estimates of B_{MSY}), a pattern that could be interpreted as being inconsistent with attempts to reduce biodiversity loss. The decline in the multispecies index reported here exceeds the 11% reduction in cumulative biomass since 1977 estimated by Worm et al. (2009), in part because trends in the latter were dominated by few large populations, whereas the multispecies index used here weighted each population equally. The decline that we report for marine fishes is more than double the 14% reduction of the MLPI between 1970 and 2005 (WWF 2008). Given that the MLPI includes abundance trends for multiple marine taxa (148 fish, 137 birds, 49 mammals, 7 reptiles), one possible explanation for our result is that marine fishes have been declining at a faster rate than other marine species.

One potential strength of our analysis is that it is limited to data obtained from models prepared and peer-reviewed by fisheries stock assessment scientists. We elected not to include trend data based solely on survey and fishery catch rates because of unestimated temporal and spatial biases that can exist in these data. However, by excluding catch and catch-rate data, we have also excluded data-poor species from areas where severe depletions are thought to have occurred (e.g., west Africa, southeast Asia), noncommercial species, and many species of conservation concern. For example, of the 38 marine fishes assessed as being endangered, threatened, or of special concern in Canadian waters (www.cosewic.gc.ca; accessed 4 June 2010), only eight are represented here. Our strict criterion also resulted in the exclusion of all but one chondrichthyan, a class of fishes considered to be at heightened risk of extinction worldwide (Baum et al. 2003; Dulvy and Forrest 2010). Our findings should also be tempered by the fact that many species whose catches (direct and incidental) are illegal or unreported have not been included.

It is difficult to judge precisely how the inclusion of these species might have influenced our results. On the one hand, their inclusion might have increased the percentage of populations meeting the 2010 target. Of Hutchings and Baum's (2005) 54 data sets that were based solely on catch rates, 76% showed a positive slope difference, which might partially account for the considerably higher percentage of populations (81%) that they reported as having a positive slope difference since 1992. On the other hand, because of their generally higher pre-1992 slopes and higher post-1992 slope differences, inclusion of these populations may have had the effect of accentuating some declines or of dampening some increases in multispecies indices of abundance.

The present work represents a significant expansion of data considered in the only previous analysis of changes in the rate of decline of marine fishes (Hutchings and Baum 2005). Most populations assessed by national and international agencies were declining before 1992. Since then, the rate of decline has been reduced in 59% of populations, a pattern consistent with the 2010 CBD target. For the remaining 41% of populations, most of which comprise top predators, the rate of decline has increased; most of those in the North Atlantic remain below $0.5B_{MSY}$, whereas the majority of those elsewhere are above their MSY reference target. Although declining trends have been reversed in many populations, meaningful progress in recovering marine fish biodiversity will almost certainly involve the establishment of specific recovery targets and specific time lines to achieve those targets (Hutchings and Baum 2005; Shelton and Sinclair 2008).

Acknowledgements

We are pleased to acknowledge numerous colleagues and institutions from around the world for sharing the fisheries stock assessment data that comprise the RAM Legacy Database and that formed the primary empirical source of our analyses. In this regard, we also wish to thank members of the National Center for Ecological Analysis and Synthesis (NCEAS) Working Group organized by R. Hilborn and B. Worm and to acknowledge the financial support for database construction provided by Natural Sciences and Engineering Research Council (NSERC) grants to J.A.H. and a Canadian Foundation for Innovation Grant to H. Lotze. The present study was supported by a NSERC Discovery Grant to J.A.H.; J.K.B. and O.P.J. were supported by David H. Smith Conservation Research Fellowships and a Schmidt Research Vessel Foundation Fellowship. We are also grateful to the anonymous referees who reviewed a previous version of the manuscript.

References

Balmford, A., Crane, P., Dobson, A., Green, R.E., and Mace, G.M. 2005. The 2010 challenge: data availability, information needs and extraterrestrial insights. Philos. Trans R. Soc. B Biol. Sci. **360**(1454): 221–228. doi:10.1098/rstb.2004.1599.

Baum, J.K., Myers, R.A., Kehler, D.G., Worm, B., Harley, S.J., and Doherty, P.A. 2003. Collapse and conservation of shark populations in the Northwest Atlantic. Science (Washington, D.C.), **299**(5605): 389–392. doi:10.1126/science.1079777. PMID:12532016.

Dulvy, N.K., and Forrest, R.E. 2010. Life histories, population dynamics and extinction risks in chondrichthyans. *In* Sharks and their relatives II: biodiversity, adaptive physiology, and conservation. *Edited by* J.C. Carrier, J.A. Musick, and M.R. Heithaus. CRC Press, Boca Raton, Florida. pp. 639–679.

Durbin, J., and Koopman, S.J. 2001. Time series analysis by state space methods. Oxford University Press, Oxford, UK.

Hilborn, R., and Stokes, K. 2010. Defining overfished stocks: have we lost the plot? Fisheries, **35**(3): 113–120. doi:10.1577/1548-8446-35.3.113.

Hutchings, J.A., and Baum, J.K. 2005. Measuring marine fish biodiversity: temporal changes in abundance, life history and demography. Philos. Trans. R. Soc. B Biol. Sci. **360**(1454): 315–338. doi:10.1098/rstb.2004.1586.

Schindler, D.E., Hilborn, R., Chasco, B., Boatright, C.P., Quinn, T.P., Rogers, L.A., and Webster, M.S. 2010. Population diversity and the portfolio effect in an exploited species. Nature (London), **465**(7298): 609–612. doi:10.1038/nature09060. PMID:20520713.

Shelton, P.A., and Sinclair, A.F. 2008. It's time to sharpen our definition of sustainable fisheries management. Can. J. Fish. Aquat. Sci. **65**(10): 2305–2314. doi:10.1139/F08-151.

Walpole, M., Almond, R.E.A., Besançon, C., Butchart, S.H.M., Campbell-Lendrum, D., Carr, G.M., Collen, B., Collette, L., Davidson, N.C., Dulloo, E., Fazel, A.M., Galloway, J.N., Gill, M., Goverse, T., Hockings, M., Leaman, D.J., Morgan, D.H.W., Revenga, C., Rickwood, C.J., Schutyser, F., Simons, S., Stattersfield, A.J., Tyrrell, T.D., Vié, J.-C., and Zimsky, M. 2009. Ecology. Tracking progress toward the 2010 biodiversity target and beyond. Science (Washington, D.C.), **325**(5947): 1503–1504. doi:10.1126/science.1175466. PMID:19762630.

World Wildlife Fund for Nature. 2008. Living planet report 2008. World Wide Fund for Nature (WWF), Gland, Switzerland. Available from http://assets.panda.org/downloads/living_planet_report_2008.pdf

Worm, B., Hilborn, R., Baum, J.K., Branch, T.A., Collie, J.S., Costello, C., Fogarty, M.J., Fulton, E.A., Hutchings, J.A., Jennings, S., Jensen, O.P., Lotze, H.K., Mace, P.M., McClanahan, T.R., Minto, C., Palumbi, S.R., Parma, A.M., Ricard, D., Rosenberg, A.A., Watson, R., and Zeller, D. 2009. Rebuilding global fisheries. Science (Washington, D.C.), **325**(5940): 578–585. doi:10.1126/science.1173146. PMID:19644114.