PROCEEDINGS OF THE ROYAL SOCIETY B

Proc. R. Soc. B (2005) **272**, 1957–1962
doi:10.1098/rspb.2005.3175
Published online 2 August 2005

Rapidly shifting environmental baselines among fishers of the Gulf of California

Andrea Sáenz-Arroyo[1,2], Callum M. Roberts[1,*], Jorge Torre[2], Micheline Cariño-Olvera[3] and Roberto R. Enríquez-Andrade[4]

[1]*Environment Department, University of York, York, YO10 5DD, UK*
[2]*Comunidad y Biodiversidad A.C., Bahía de Bacochibampo, S/N Colonia Lomas de Cortés, Guaymas, 85450, Sonora, Mexico*
[3]*Autónoma de Baja California Sur, Área Interdisciplinaria de Ciencias Sociales, Apartado Postal 19 -B, La Paz, 23080 Baja California Sur, Mexico*
[4]*Facultad de Ciencias Marinas, Universidad Autónoma de Baja California, Apartado Postal 453, Ensenada 22870, Baja California, Mexico*

Shifting environmental baselines are inter-generational changes in perception of the state of the environment. As one generation replaces another, people's perceptions of what is natural change even to the extent that they no longer believe historical anecdotes of past abundance or size of species. Although widely accepted, this phenomenon has yet to be quantitatively tested. Here we survey three generations of fishers from Mexico's Gulf of California ($N = 108$), where fish populations have declined steeply over the last 60 years, to investigate how far and fast their environmental baselines are shifting. Compared to young fishers, old fishers named five times as many species and four times as many fishing sites as once being abundant/productive but now depleted (Kruskal–Wallis tests, both $p < 0.001$) with no evidence of a slowdown in rates of loss experienced by younger compared to older generations (Kruskal–Wallis test, n.s. in both cases). Old fishers caught up to 25 times as many Gulf grouper *Mycteroperca jordani* as young fishers on their best ever fishing day (regression $r^2 = 0.62$, $p < 0.001$). Despite times of plentiful large fish still being within living memory, few young fishers appreciated that large species had ever been common or nearshore sites productive. Such rapid shifts in perception of what is natural help explain why society is tolerant of the creeping loss of biodiversity. They imply a large educational hurdle in efforts to reset expectations and targets for conservation.

Keywords: overfishing; historical ecology; biodiversity loss; fishing; fisheries

1. INTRODUCTION

In 1995, Pauly described the phenomenon of shifting environmental baselines, noting that each generation of scientists subconsciously views as 'natural' the way the environment appeared in their youth (Pauly 1995). Although he described shifting baselines in relation to fisheries science, the phenomenon is general and applies to all sectors of society. As one generation replaces another, people's perspectives change such that they fail to appreciate the extent of past environmental modifications by humanity. Much of the evidence for shifting baselines is anecdotal. For example, an idea of the former abundance of whales in the Atlantic can be gained from the account of George Shelvocke. Sailing along the coast of South America in 1718 he wrote

> whales, grampuses, and other fish of a monstrous bulk, are in such numbers off the coast of Patagonia that they were really offensive to us very often. For they would come sometimes so close to us as to stifle us with their stench when they blew, and would lie so near us that I have frequently thought it impossible to escape striking upon them on every send of a sea.
>
> (Shelvocke 1726, p. 36)

Recent genetic studies reveal much greater abundance of whales in the Atlantic than historical estimates suggested (Roman & Palumbi 2003), lending new credibility to Shelvocke's observations.

A second more recent example comes from a study of data from research vessels surveying for new tuna fishing grounds in the late 1950s in the Gulf of Mexico. Comparison of their catch records with recent surveys found that the current population of the oceanic whitetip shark *Carcharhinus longimanus* may be less than 1% of what it was in the 1950s (Baum & Myers 2004). The researchers noted that the phenomenon of the shifting baseline has acted within the Gulf of Mexico scientific community to such an extent that papers on sharks in the area showed no recognition of the oceanic whitetip shark's former presence and abundance in the ecosystem.

Although the concept of shifting baselines is receiving growing scientific and popular recognition (Dayton *et al.* 1998; Myers & Worm 2003; Roberts 2003; Baum & Myers 2004; see footnote 1), we are unaware of any quantitative tests in the field. Here we put the concept to the test among fishers from the Gulf of California, a semi-enclosed sea in northwest Mexico. The Gulf of California is a place of exceptional biodiversity (Brusca *et al.* in press) and conservation importance (Sala *et al.* 2002). It is rich in endemic species (Roberts *et al.* 2002) and is one of the few

* Author for correspondence (cr10@york.ac.uk).

Received 3 February 2005
Accepted 24 May 2005

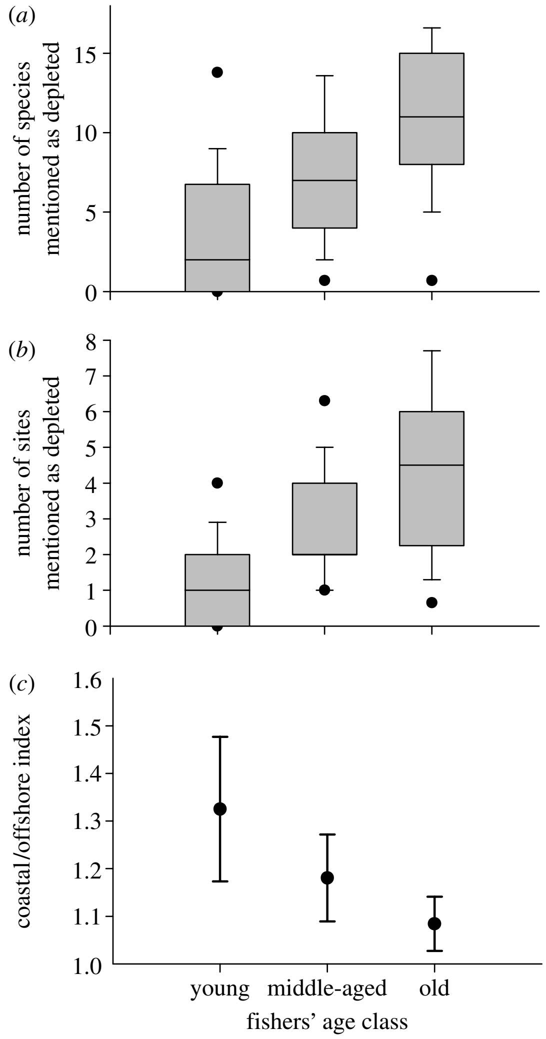

Figure 1. (*a*) Number of species mentioned by each generation of fishers as depleted (Kruskal–Wallis test, $\chi^2_2=37.7$, $p<0.001$). Boxes show median, 5, 25, 50 and 95th percentiles of the data; dots show range. (*b*) Number of sites mentioned by each generation of fishers as depleted (Kruskal–Wallis test, $\chi^2_2=39.0$, $p<0.001$). (*c*) Sites mentioned as depleted were coded as coastal (1) or offshore (2). Mean scores (+95% CI) show a significant shift from the mention of mainly coastal sites by old fishers to more offshore sites amongst the young generation (Kruskal–Wallis test, $\chi^2_2=12.0$, $p=0.002$). In total, old fishers listed 95 sites as depleted by fishing, middle-aged fishers 72 sites and young fishers 40 sites.

places in the world where we can still find large concentrations of marine megafauna such as hammerhead sharks (Sphyraenidae), manta rays (Mobulidae), billfish (Istiophoriidae and Xiphiidae) and cetaceans. In contrast to ecosystems such as the North Sea (Wolff 2000; Christensen *et al.* 2003) or the Caribbean (Jackson 1997) where the megafauna was depleted long ago, fisheries have only recently intensified in the Gulf of California (Poder Ejecutivo Federal 2000), threatening the megafauna which is now in rapid decline. This provides a natural laboratory to study how humans perceive changes in the natural environment.

2. MATERIAL AND METHODS

We interviewed 108 fishers selected randomly from three generations in 11 fishing communities of central Baja California: young (15–30 years old, $N=40$), middle-aged (31–54, $N=34$), and old (more than 55, $N=34$). To elicit fishers' perceptions of how fishing has altered the marine environment, we asked them to name species and places that they considered to have been depleted by fishing. Given that fishers use common names for species, and some names differ among communities, we used fish guides and photographs to clarify species identifications during the interviews (Kerstitch 1989; Fisher *et al.* 1995; Allen & Robertson 1998; Gotshall 1998; Thomson *et al.* 2000).

We also questioned them about the fishery for the Gulf grouper, *Mycteroperca jordani*. Specifically, we asked fishers about the best catch they ever remembered landing, the largest animal they ever caught, and the year in which these catches were made. We asked them to draw on the ground or on a wall the length of the largest fish they had ever caught. This was then measured to the nearest centimetre and converted to biomass using a length–weight relationship for *Mycteroperca* species. Breeding populations of this grouper, which can reach approximately 2 m in length, are restricted to the northeastern Mexican Pacific. Attributes such as large body size and a restricted geographic range make a species vulnerable to overfishing and even extinction (Morris *et al.* 2000; Reynolds *et al.* 2001). Once abundant, the Gulf grouper is now rare and is listed as Vulnerable in the World Conservation Union's Red List of Threatened Species (Hudson & Mace 1996). Our own historical research, based on fishers' anecdotes, systematic documentation of naturalists' observations and grey literature, suggests that today's population is at most a few percent of the size of that present in the 1940s (Sáenz-Arroyo *et al.* 2005).

Interviews were conducted from May to September 2002. To avoid results being influenced by biogeographic differences in species composition and abundance, we conducted interviews exclusively in the central Gulf of California, one of the three biogeographic regions of the sea defined by Walker (1960). We followed technical and ethical recommendations in Bunce *et al.* (2000), who provide detailed advice on conducting respectful interviews acknowledging local customs and culture, and minimizing disruption to people's routines. They also give guidelines on sample size considering the trade-offs in resources available (time, personnel and money) and the goal of achieving a representative sample of adequate size. Our questionnaire was answered by between 5 and 25% of the fishing population in each of 11 localities visited, with the figure depending on size of the fishing village. The sample size for each locality and age class was determined from data in the State Population Census (INEGI 2002). To approximate randomization, the questionnaire was applied at random to fishers we met on the beach in each community until the appropriate sample size for each age category was reached. All interviews were conducted in private. We visited old retired fishers in their homes after asking younger fishers where to find them (see Electronic Appendix for questionnaire and further sampling details). Data were tested for normality prior to analysis and non-parametric statistics used where necessary.

3. RESULTS

Our results show that, although the majority of fishers interviewed (84%) considered that fishing had led to depletion or loss of some species or fishing sites, analysis of their answers reveals a rapid inter-generational shift in their perception of how the seascape looked in the past.

Table 1. The percentages of respondents from three generations of fishers that considered populations of different exploited species to have been depleted by fishing.

species			maximum length (cm)	young 15–30 years, value in percentage ($N=40$)	middle-aged 31–54 years, value in percentage ($N=34$)	old ≥55 years, value in percentage ($N=34$)
sharks	large↓	white shark (*Carcharodon carcharias*)	800	0	2	0
	small	tiger shark (*Galeocerdo cuvieri*)	740	2	6	14
		bull shark (*Carcharhinus leucas*)	350	2	0	32
		hammerhead shark (*Sphyrna* spp.)	150–450	7	9	32
		blacktip shark (*Carcharhinus limbatus*)	247	7	9	32
coastal groupers	large↓	goliath grouper (*Epinephelus itajara*)	240	0	15	8
(Serranidae)	small	gulf grouper (*Mycteroperca jordani*)	190	10	56	85
		leopard grouper (*Mycteroperca rosacea*)	100	37	76	67
coastal snappers	large↓	dog snapper (*Lutjanus novemfasciatus*)	170	7	29	47
(Lutjanidae)	small	barred pargo (*Hoplopagrus guentherii*)	92	10	18	35
		yellow snapper (*Lutjanus argentiventris*)	66	5	17	12
turtles		pacific green turtle (*Chelonia mydas agassissi*)	117 (carapace)	20	32	62
invertebrates		pearl oyster (*Pinctada mazatlanica*)	n.a.	0	3	18
		purple lip rock oyster (*Spondylus calcifer*)	n.a.	7	20	23
		cortez conch (*Strombus galeatus*)	n.a.	2	26	35
		pinto spiny lobster (*Panulirus inflatus*)	n.a.	13	29	32

The median number of species mentioned by old fishers as depleted was 11, middle-aged mentioned seven and young fishers two (figure 1*a*; Kruskal–Wallis test, $\chi^2=37.65$, $p<0.001$). Since older fishers have had more opportunity to see species loss, we calculated rates of loss by dividing the number of species mentioned by the number of years fishing by each respondent. There was no significant difference in loss rate across generations, indicating no slow down in biodiversity decline (Kruskal–Wallis test, $\chi^2=2.00$, $p=0.37$).

Old fishers remembered times when large and vulnerable animals were much more abundant, as were easily overexploited invertebrates (table 1). These people began fishing when the sea supported abundant medium-sized sharks like the bull shark (*Carcharinus leucas*), hammerheads (*Sphyrna* spp.), large groupers (e.g. *M. jordani*), large snappers (e.g. *Lutjanus novemfasciatus*), Pacific green turtle (*Chelonia mydas agassisii*) and large edible invertebrates such as the purple lip rock oyster (*Spondylus calcifer*) and Cortez conch (*Strombus galeatus*). They testified how these populations were depleted over the years in which they worked. By contrast middle-aged fishers showed less appreciation of past abundances and few young fishers seemed aware that such species had ever been common (table 1).

Although old fishers recalled an ecosystem in a better condition than that experienced by young fishers, their baselines also appeared shifted from what early Europeans visiting the area witnessed. Few old fishers commented on the once valuable fishery for pearl oysters (*Pinctada mazatlanica*; Cariño-Olvera 2000), abundant and extensive from the beginning of the seventeenth century to 1940 when the pearl banks collapsed (Monteforte & Cariño-Olvera 1992; Cariño-Olvera 2000). None of their testimonies fitted with the seascape observed by seventeenth century Spaniards such as Nicolás de Cardona who wrote

> along the seacoast of the interior region, over a distance of 100 leagues all that one sees are heaps of pearl oysters
>
> (Cardona 1632, p. 99)

Few also mentioned as depleted the largest predators such as the white shark (*Carcharodon carcharias*) and goliath grouper (*Epinephelus itajara*), the latter a well documented and common meal of seventeenth and eighteenth century buccaneers who haunted the area (Dampier 1697).

Shifting perspectives were also evident across the three generations in the sites mentioned as being depleted by fishing. The median number of sites reported as depleted by old fishers was 4.5, by middle-aged fishers 2 and young fishers 1 (figure 1*b*, Kruskal–Wallis test, $\chi_2^2=39.0$, $p<0.001$). Again, converting these data to sites depleted by year of fishing experience of respondents, there was no evidence in a slow down of the rate of depletion across generations (Kruskal–Wallis test, $\chi^2=1.2$, $p=0.54$). In total, old fishers named 95 sites as depleted, middle-aged 72 and young fishers 40.

We plotted on maps all sites mentioned as once being productive and now depleted and coded them as coastal, or offshore (seamounts) (figure 1*c*). There was a significant inter-generational shift from the mention of nearshore to offshore sites (Kruskal–Wallis test, $\chi^2=12.0$, $p=0.002$). There was a time when fishers could land large catches and big fish from sites close to shore. As fishing depleted those sites fishers moved further offshore. Amongst younger fishers, many did not realize that nearshore sites had once been more productive, since few mentioned them as depleted. However, they were concerned about more recent impacts of fishing in offshore areas.

Large predators, such as the Gulf grouper, were once common in the area but appeared to exist now only in historical documents and the memories of old fishers.

Figure 2. Photograph of two fishers hauling a good-sized Gulf grouper. Although the photograph is not dated, the harpoon, the canoe and fishers' clothes characterize the middle of last century. Reproduced with kind permission of Gene Kira (Kira 1999).

Descriptions by early twentieth century naturalists portray a seascape where Gulf groupers dominated the reef ecosystem (Sáenz-Arroyo *et al.* in press). In 1932 the naturalist Griffing Bancroft wrote of Gulf groupers from San Idelfonso Island in the central Gulf of California

> In unimaginable numbers, from one edge to the other, Garopuas (sic) haunt the rocky ledges of coast and islands. If a jigger is trolled at a speed of about four miles an hour over the proper bottom there is no question of catching something, the only gamble is in species and size. The slogan 'a ton an hour' can often be bettered.[2]
>
> (Bancroft 1932, pp. 250–251)

Richard Crocker of the California Division of Fish and Game concurred, writing in 1937 'Sport fishermen who angle in Mexican waters encounter no difficulty in catching their fill of the abundant cabrilla and grouper. In fact they find it virtually impossible to catch anything else along the rocky shores inhabited by these voracious and unwary fish that will strike at any moving object smaller than themselves'.[3] Contemporary photographs also picture smiling fishers sporting giant catches (Kira 1999; figure 2), and many other historical documents agree that this species, which is a rarity today, was once incredibly abundant (Sáenz-Arroyo *et al.* in press).

Only the oldest fishers we interviewed had experienced the heyday of fishing for giant groupers. We asked fishers what had been their best ever day's catch of the Gulf grouper and when they caught it. In the 1940s and 1950s fishers recalled catching up to 25 fish in a day (figure 3*a*), by the 1960s this had dropped to 10 or 12, and by the 1990s it was one or two. We can also see a shifting baseline in the fraction of fishers from each generation who had ever caught a Gulf grouper. While 96% of old fishers and 90% of middle-aged fishers had caught the species, only 45% of young fishers had. Accepting that younger fishers had had less time to catch the species, it does however provide a context for the finding (table 1) that only 10% of young fishers considered the species depleted compared to 56% of middle-aged and 85% of older fishers. We also asked fishers how big the largest Gulf grouper they had landed was and when was it caught. Again, experiences were significantly different across generations (figure 3*b*). The average size of the largest fish ever caught by old fishers, estimated from a length–weight relationship, was 84 kg, by middle-aged 72 kg and by young fishers 63 kg. This result is not simply an artefact of older fishers being more skilled or having fished for longer. A regression of the year in which fishers recalled landing their largest fish against the size of the fish shows that the biggest fish really are disappearing (figure 3*c*).

4. DISCUSSION

Like Pandora's box, which when opened allows all human's miseries to escape, the shifting baselines syndrome spreads insidiously, challenging much of our knowledge of species biogeography, past ranges of distribution, original population numbers and the ecosystem roles played by species in the past (Jackson *et al.* 2001; Pitcher 2001; Baum *et al.* 2003; Christensen *et al.* 2003; Myers & Worm 2003; Baum & Myers 2004). This condition not only concerns the scientific community, but also affects all of society. For example, few Californians are aware that the bear in their flag was exterminated by humans long ago (Diamond 1992); nor have we pondered on how abundant the now threatened golden eagle (*Aquila chrysaetos*) must have been in central pre-hispanic México for it to become the symbol of the Mexican culture (de la Garza 1996).

The speed with which environmental baselines are shifting among fishers of the Gulf of California is troubling. We might expect environmental baselines to be changing in today's more urbanized populations who have less direct contact with nature than past generations. However, it is evident that baselines shift rapidly even among people whose occupations bring them into daily contact with nature. Such rapid shifts help explain why human societies are so tolerant to the creeping loss of biodiversity. Compared to many other parts of the world where the marine megafauna was depleted perhaps hundreds of years ago (Wolff 2000; Jackson *et al.* 2001;

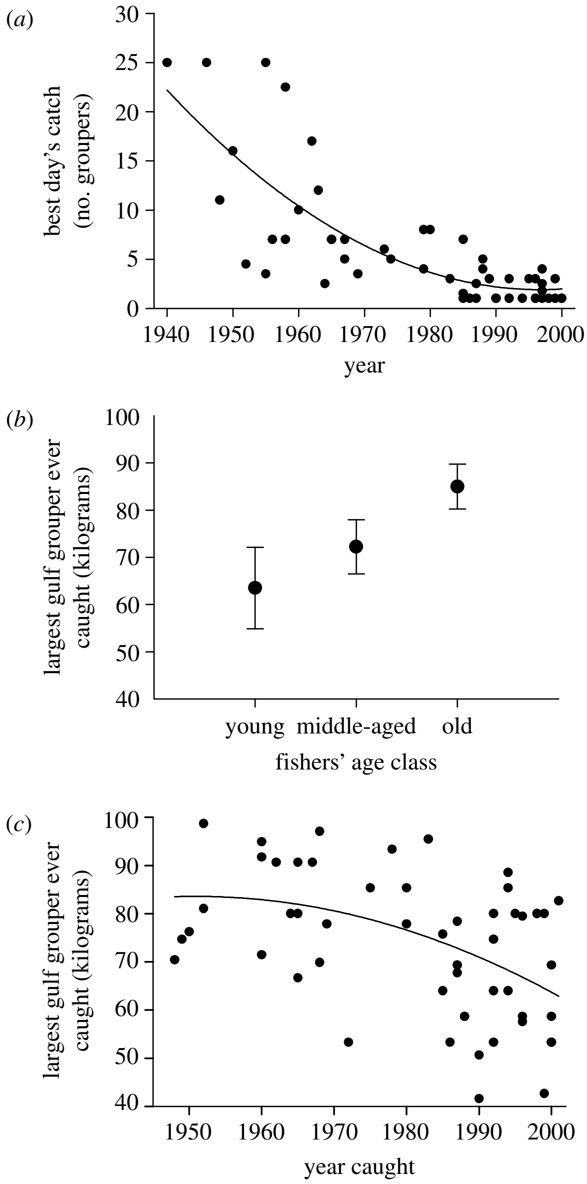

Figure 3. (*a*) Size of the best day's catch of Gulf groupers plotted against the year in which the fisher remembered landing it (with a second order regression line shown $r^2=0.62$, $p<0.001$). (*b*) Mean weight (+95% CI) of the largest Gulf grouper ever landed by three generations of fishers (one-way ANOVA, $p<0.001$; LSD test, all groups significantly different at $p<0.05$). (*c*) Second order regression ($r^2=0.21$, $p<0.001$) of the weight of the largest Gulf grouper fishers recollected catching versus year in which it was landed.

Pitcher 2001), loss of megafauna in the Gulf of California is still within living memory. Many of the young fishers we interviewed came from fishing families. Despite having older family members who remembered the past abundances of large fish, that knowledge does not seem to have been passed on, or young people have not appreciated its significance.

When we explained to fishers why their memories were important to our study, they were happy to collaborate. When the generation of people that began fishing in the 1940s have died, their insight into how the environment once looked will be gone forever. Although it is still challenging to incorporate traditional knowledge into scientific analyses (Huntington 2000; Johannes *et al.* 2000), that knowledge can offer important insights into the former state of ecosystems (Johannes 1981), especially in countries where written records are sparse. Passing on that knowledge to younger generations is critical to slow the process of shifting environmental baselines, particularly in developing countries that have populations which are highly skewed towards young people. In Mexico, for example, 66% of the population is under 30 years old (INEGI 2000). Most of these young people have no experience or understanding of previous ecosystem states even in the relatively recent past. This implies an enormous educational hurdle to overcome in efforts to promote conservation and set appropriate targets for restoration of depleted and degraded environments, whether they are on land or in the sea.

We thank Consejo Nacional de Ciencia y Tecnología—México (CONACYT), The Pew Charitable Trusts and Comunidad y Biodiversidad A.C. for supporting this research. D. Raffaelli and J. Lovett gave helpful advice on methodology. Logistic support from Parque Nacional Bahía de Loreto, Sociedad de Historia Natural Niparajá and Area de Proteccion de Flora y Fauna—Islas del Golfo de California in Baja California Sur, was invaluable. M. Mandujano, A. Castro, K. Peláez. A. Eslimán and E. Castañón helped with fieldwork. V. Perez-Cirera and J. Hawkins revised and improved the final manuscript.

ENDNOTES

[1]www.shiftingbaselines.org.

[2]Since 'garropa de astillero' is the local Spanish name for Gulf grouper and 'garropa jaspeada' for the broomtail grouper (*Mycteroperca xenarcha)* and some life stages of the latter are restricted to estuaries or mangroves, which are uncommon around San Idelfonso, Bancroft is most likely referring to the Gulf grouper.

[3]In his note Crocker identified the Gulf grouper (*M. jordani*) as grouper, and another grouper, *Epinephelus analogus*, as cabrilla.

REFERENCES

Allen, G. R. & Robertson, D. N. 1998 *Peces del Pacífico oriental tropical*. México City: CONABIO.

Bancroft, G. 1932 *Lower California: a cruise. The flight of the least petrel*. New York: GP Putnam & Sons.

Baum, J. K. & Myers, R. A. 2004 Shifting baselines and the decline of pelagic sharks in the Gulf of Mexico. *Ecol. Lett.* 7, 135–145. (doi:10.1111/j.1461-0248.2003.00564.x.)

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

Brusca, R. C., Findley, L. T., Hastings, P. A., Hendricks, M. E., Torre, J. & Heiden, A. v. d. In press. Macrofaunal biodiversity in the Gulf of California. In *Biodiversity, ecosystems and conservation in northern Mexico* (ed. J.-L. E. Cartron, R. S. Felger & G. Ceballos). Oxford University Press.

Bunce, L., Townsley, P., Pomeroy, R. & Pollnac, R. 2000 *Socioeconomic manual for coral reef management*. IUCN. The World Conservation Union. Australian Institute of Marine Science. Townsville, Australia: NOAA.

Cardona, N. 1632 *Descriptions of many northern and southern lands and seas in the Indies, specifically of the discovery of the kingdom of California*. Baja California travel series. Los Angeles California: Dawson's Book Shop. Translated and edited by Michael Mathes, 1974

Cariño-Olvera, M. M. 2000 *Historia de la relaciones hombre naturaleza en Baja California Sur 1500–1940*. La Paz: B.C.S. UABCS.

Christensen, V., Guenette, S., Heymans, J. J., Walters, C., Zeller, D. & Pauly, D. 2003 Hundred-year decline of North Atlantic predatory fish. *Fish Fish.* **4**, 1–24.

Dampier, W. & 1697, A. 1968 *A new voyage round the world*. New York: Dover Publications, Inc..

Dayton, P. K., Tegner, M. J., Edwards, P. B. & Raiser, K. L. 1998 Sliding baselines, ghosts and reduced expectations in kelp forest communities. *Ecol. Appl.* **8**, 309–322.

de la Garza, M. 1996 El águila real, simbolo de la identidad mexicana. *México Desconocido* 235. Available on the internet: consulted in June 2005. (http://www.mexicodes-conocido.com.mx/espanol/cultura_y_sociedad/fiestas_y_tradiciones/detalle.cfm?idpag=3606&idsec=15&idsub=64#.)

Diamond, J. 1992 *The third chimpanzee. The evolution and future of the human animal*. New York: Harper Perennial.

Fisher, W., Krupp, F., Schneider, W., Sommer, C., Carpenter, K. E. & Niem, V. H. 1995 *Guia FAO para la identificación de especies para los fines de la pesca. Pacifico centro-oriental*. Rome: FAO.

Gotshall, D. W. 1998 *Sea of Cortez marine animals*. Monterrey, California: Sea Challengers.

Hudson, E. & Mace, G. G. 1996 *Marine fish and the IUCN Red List of Threatened Animals*. London: Zoological Society.

Huntington, H. P. 2000 Using traditional ecological knowledge in science: methods and applications. *Ecol. Appl.* **10**, 1270–1274.

INEGI. 2000 *Estadísticas del Medio Ambiente 1999*. México City.

INEGI. 2002 *XII Censo general de población y vivienda 2000. Tabulados básicos. Instituto Nacional de Geografía Estadística e Informática*. Aguascalientes, Ag.

Jackson, J. B. C. 1997 Reefs since Columbus. *Coral Reefs* **16(**Suppl.), 23–33. (doi:10.1007/s003380050238.)

Jackson, J. B. C. *et al.* 2001 Historical overfishing and the recent collapse of coastal ecosystems. *Science* **293**, 629–637. (doi:10.1126/science.1063789.)

Johannes, R. E. 1981 *Words of the lagoon: Fishing and marine lore in the Palau district of Micronesia*. Berkeley: University of California Press.

Johannes, R. E., Freeman, M. M. M. & Hamilton, R. J. 2000 Ignore fishers' knowledge and miss the boat. *Fish Fish.* **1**, 257–271.

Kerstitch, A. 1989 *Sea of Cortez marine invertebrates*. Monterey, CA: Sea Challengers.

Kira, G. S. 1999 *The unforgettable sea of Cortez. Baja California's golden age 1947–1977: the life and writings of Ray Cannon*. Torrance, CA: Cortez Publications.

Monteforte, M. & Cariño-Olvera, M. M. 1992 Exploration and evaluation of natural stocks of pearl oyster *Pinctada mazatlánica* and *Pteria sterna* (Bivalvia: Pteridae): La Paz Bay, South Baja California, Mexico. *Ambio* **21**, 314–320.

Morris, A. V., Roberts, C. M. & Hawkins, J. P. 2000 The threatened status of groupers (Epinephelinae). *Biodivers. Conserv.* **9**, 919–942. (doi:10.1023/A:1008996002822.)

Myers, R. A. & Worm, B. 2003 Rapid worldwide depletion of predatory fish communities. *Nature* **423**, 280–283. (doi:10.1038/nature01610.)

Pauly, D. 1995 Anecdotes and the shifting baseline syndrome of fisheries. *Trends Ecol. Evol.* **10**, 430. (doi:10.1016/S0169-5347(00)89171-5.)

Pitcher, T. J. 2001 Fisheries managed to rebuild ecosystems? Reconstructing the past to salvage the future. *Ecol. Appl.* **11**, 601–607.

Poder Ejecutivo Federal 2000 *Carta Nacional Pesquera. Diario oficial de la federación. Organo del gobierno constitucional del gobierno constitucional de los Estados Unidos Mexicanos, Tomo DLXIII, Mexico City, Lunes 28 September 2000* p. 128. Publicada en el Diario Oficial de la Federación.

Reynolds, J. D., Jennings, S. & Dulvy, N. K. 2001 Life history of fishes and population responses to exploitation. In *Conservation of exploited species* (ed. G. G. Mace & J. D. Reynolds), pp. 147–168. Cambridge University Press.

Roberts, C. M. 2003 Our shifting perspectives on the oceans. *Oryx* **37**, 166–177. (doi:10.1017/S0030605303000358.)

Roberts, C. M. *et al.* 2002 Marine biodiversity hotspots and conservation priorities for tropical reefs. *Science* **295**, 1280–1284. (doi:10.1126/science.1067728.)

Roman, J. & Palumbi, S. R. 2003 Whales before whaling in the North Atlantic. *Science* **301**, 508–510. (doi:10.1126/science.1084524.)

Sáenz-Arroyo, A., Roberts, C. M., Torre, J. & Cariño-Olvera, M. M. 2005 Fishers' anecdotes, naturalists' observations and grey reports to reassess marine species at risk: the case of the Gulf grouper in the Gulf of California, México. *Fish Fish* **6**, 121–133.

Sala, E., Aburto-Oropeza, O., Paredes, G., Parra, I., Barrera, J. C. & Dayton, P. K. 2002 A general model for designing networks of marine reserves. *Science* **298**, 1991–1993. (doi:10.1126/science.1075284.)

Shelvocke, G. 1726 *A voyage round the world by way of the great south sea*. London: Cassell & Company. 1928

Thomson, D. A., Findley, L. T. & Kerstitch, A. 2000 *Reef fishes of the Sea of Cortez. The Corrie Herring Hooks Series*. Austin: The University of Texas.

Walker, B. W. 1960 The distribution and affinities of the marine fish and fauna in the Gulf of California. *Syst. Zool.* **9**, 123–133.

Wolff, W. J. 2000 The south-eastern North Sea losses of vertebrate fauna during the past 2000 years. *Biol. Conserv.* **95**, 209–217. (doi:10.1016/S0006-3207(00)00035-5.)

The supplementary Electronic Appendix is available at http://dx.doi.org/10.1098/rspb.2005.3175 or via http://www.journals.royalsoc.ac.uk.