Pauly, D. 2010. The State of Fisheries, p. 118-120 *In:* S.N.S. Sodhi and P.R. Ehrlich (eds.) *Conservation Biology for All.* Oxford University Press, Oxford.

individuals then selective fishing will cause genetic changes in life-history traits such as ages and sizes at maturity (Law 2000). The genetic effects of fishing are increasingly seen as a long-term management issue, but this is not yet managed proactively as short-term regulations tend to merely focus on controlling mortality. However, the damage caused by overfishing extends well beyond the main target species with profound effects on: (i) low-productivity species in mixed fisheries; (ii) non-target species; (iii) food webs; and (iv) the structure of oceanic habitats.

Low-productivity species in mixed fisheries

Many multi-species fisheries are relatively unselective and take a wide range of species that vary in their capacity to withstand elevated mortality. This is particularly true in mixed trawl fisheries where sustainable mortality rates for a productive primary target species are often unsustainable for species that are less productive, such as skates and rays, thereby leading to widespread depletion and, in some cases, regional extinction processes. Conservation measures to protect unproductive species in mixed fisheries are always controversial since fishers targeting more productive species will rarely wish to sacrifice yield in order to spare less productive species.

Bycatches

Most seafood is captured by indiscriminate methods (e.g. gillnetting, trawl netting) that haul in large numbers of incidental captures (termed bycatches) of undesirable species, which numerically may correspond to 25–65% of the total catch. These non-target pelagic species can become entangled or hooked by the same fishing gear, resulting in significant bycatch mortality of many vulnerable fish, reptile, bird and mammal populations, thereby comprising a key management issue for most fishing fleets (Hall *et al.* 2000). For example, over 200 000 loggerhead (*Caretta caretta*) and 50 000 leatherback turtles (*Dermochelys coriacea*) were taken as pelagic longline bycatch in 2000, likely contributing to the 80–95% declines for Pacific loggerhead and leatherback populations over two decades (Lewison *et al.* 2004). While fishing pressure on target species relates to target abundance, fishing pressure on bycatch species is likely insensitive to bycatch abundance (Crowder and Murawski 1998), and may therefore result in "piggyback" extinctions. Bycatches have been the focus of considerable societal concern, often expressed in relation to the welfare of individual animals and the status of their populations. Public concerns over unacceptable levels of mortality of large marine vertebrates (e.g. sea turtles, seabirds, marine mammals, sharks) have therefore led to regional bans on a number of fishing methods and gears, including long drift-nets.

Food webs

Overfishing can create trophic cascades in marine communities that can cause significant declines in species richness, and wholesale changes in coastal food webs resulting from significant reductions in consumer populations due to overfishing (Jackson *et al.* 2001). Predators have a fundamental top-down role in the structure and function of biological communities, and many large marine predators have declined by >90% of their baseline population levels (Pauly *et al.* 1998; Myers and Worm 2003; see Box 6.1). Fishing affects

Box 6.1 The state of fisheries
Daniel Pauly

Industrial, or large-scale and artisanal, or small-scale marine fisheries, generate, at the onset of the 21st century, combined annual catches of 120–140 million tons, with an ex-vessel value of about US$100 billion. This is much higher than officially reported landings (80–90 million tons), which do not account for illegal, unreported and undocumented (IUU) catches (Pauly *et al.* 2002). IUU catches include, for example, the fish discarded by shrimp trawlers (usually 90% of their actual catch), the catch of high sea industrial fleets operating under flags of convenience, and the individually small catch by millions of artisanal fishers (including women and children) in developing countries, which turns out to be very high in the

continues

Box 6.1 (Continued)

aggregate, but still goes unreported by national governments and international agencies.

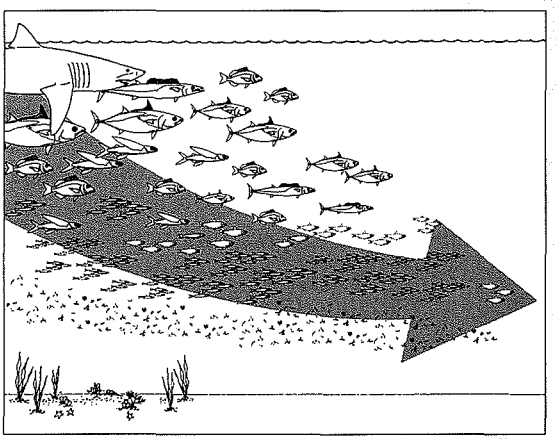
This global catch, which, depending on the source, is either stagnating or slowly declining, is the culmination of the three-pronged expansion of fisheries which occurred following the Second World War: (i) an offshore/depth expansion, resulting from the depletion of shallow-water, inshore stocks (Morato *et al.* 2006); (ii) a geographic expansion, as the fleets of industrialized countries around the North Atlantic and in East Asia, faced with depleted stocks in their home waters, shifted their operations toward lower latitudes, and thence to the southern hemisphere (Pauly *et al.* 2002); and (iii) a taxonomic expansion, i.e. capturing and marketing previously spurned species of smaller fish and invertebrates to replace the diminishing supply of traditionally targeted, larger fish species (Pauly *et al.* 1998; see Box 6.1 Figure).

In the course of these expansions, fishing effort grew enormously, especially that of industrial fleets, which are, overall, 3–4 times larger than required. This is, among other things, a result of the US$30–34 billion they receive annually as government subsidies, which now act to keep fleets afloat that have no fish to exploit (Sumaila *et al.* 2008). In addition to representing a giant waste of economic resources, these overcapitalized fishing fleets have a huge, but long-neglected impact on their target species, on non-targeted species caught as by-catch, and on the marine ecosystems in which all species are embedded. Also, these fleets emit large amounts of carbon dioxide; for example trawlers nowadays often burn several tons of diesel fuel for every ton of fish landed (and of which 80% is water), and their efficiency declines over time because of declining fish stocks (Tyedmers *et al.* 2005).

Besides threatening the food security of numerous developing countries, for example in West Africa, these trends endanger marine biodiversity, and especially the continued existence of the large, long-lived species that have sustained fisheries for centuries (Worm *et al.* 2006).

The good news is that we know in principle how to avoid the overcapitalization of fisheries and the collapse of their underlying stocks. This would involve, besides an abolition of capacity-enhancing subsidies (e.g. tax-free fuel, loan guarantees for boat purchases (Sumaila *et al.* 2008), the creation of networks of large marine protected areas, and the reduction of fishing effort in the remaining exploited areas, mainly through the creation of dedicated access privilege (e.g. for adjacent small scale fisher communities), such as to reduce the "race for fish".

Also, the measures that will have to be taken to mitigate climate change offer the prospect of a reduction of global fleet capacity (via a reduction of their greenhouse gas emissions). This may lead to more attention being paid to small-scale fisheries, so far neglected, but whose adjacency to the resources they exploit, and use of fuel-efficient, mostly passive gear, offers a real prospect for sustainability.



Box 6.1 Figure Schematic representation of the process, now widely known as 'fishing down marine food webs', by which fisheries first target the large fish, then, as these disappear, move on to smaller species of fish and invertebrates, lower in the food web. In the process, the functioning of marine ecosystems is profoundly disrupted, a process aggravated by the destruction of the bottom fauna by trawling and dredging.

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Box 6.1 (Continued)

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predator-prey interactions in the fished community and interactions between fish and other species, including predators of conservation interest such as seabirds and mammals. For example, fisheries can compete for the prey base of seabirds and mammals. Fisheries also produce discards that can provide significant energy subsidies especially for scavenging seabirds, in some cases sustaining hyper-abundant populations. Current understanding of food web effects of overfishing is often too poor to provide consistent and reliable scientific advice.

Habitat structure

Overfishing is a major source of structural disturbance in marine ecosystems. The very act of fishing, particularly with mobile bottom gear, destroys substrates, degrades habitat complexity, and ultimately results in the loss of biodiversity (see Box 4.3). These structural effects are compounded by indirect effects on habitat that occur through removal of ecological or ecosystem engineers (Coleman and Williams 2002). Many fishing gears contact benthic habitats during fishing and habitats such as coral reefs are also affected by changes in food webs. The patchiness of impacts and the interactions between types of gears and habitats are critical to understanding the significance of fishing effects on habitats; different gears have different impacts on the same habitat and different habitats respond differently to the same gear. For some highly-structured habitats such as deep water corals, recovery time is so slow that only no fishing would be realistically sustainable (Roberts *et al.* 2006).

6.5 Managing overexploitation

This chapter has repeatedly illustrated examples of population declines induced by overexploitation even in the face of the laudable goals of implementing conservation measures in the real-world. This section will conclude with some comments about contrasts between theory and practice, and briefly explore some of the most severe problems and management solutions that can minimize the impact of harvesting on the integrity of terrestrial and marine ecosystems.

Unlike many temperate countries where regulatory protocols preventing overexploitation have been developed through a long and repeated history of trial and error based on ecological principles and hard-won field biology, population management prescriptions in the tropics are typically non-existent, unenforceable, and lack the personnel and scientific foundation on which they can be built. The concepts of game wardens, bag limits, no-take areas, hunting or fishing licenses, and duck stamps are completely unfamiliar to the vast majority of tropical subsistence hunters or fishers (see Box 6.2). Yet these resource users are typically among the poorest rungs in society and often rely heavily on wild animal populations as a critical protein component of their diet. In contrast, countries with a strong tradition in fish and wildlife management and carefully regulated harvesting policy in private and public areas, may include sophisticated legislation encompassing bag limits on the age and sex of different target species, as well as restrictions on hunting and fishing seasons and