Chapter 2
The Impacts of Human Activities on Marine Biodiversity

Human impacts have been shown to profoundly modify genetic and species diversity (Palumbi 2001) (Fig. 1.9). The main direct impacts are caused by overexploitation and habitat loss, while indirect effects may result from cascading interactions in the food web (e.g. removing competitors and predators from the system) and the effects of environmental change. Dulvy et al. (2003) reviewing local, regional and global marine extinction, identified "exploitation" and "habitat loss" as being respectively responsible for 55 and 37 % of 133 reported extinctions.

Fishing is the main cause of mortality for numerous fish and invertebrate species. Since growth and reproduction are both size-related and to some extent heritable, size-selective fishing gear puts selection pressure on populations. De facto, the exploited populations will evolve in response to harvesting pressure.

Lower local species richness will not necessarily entail a drop in fisheries productivity. However, if the targeted species are functionally "redundant", the ecological function values may change. This issue has led several authors to call for more research on functional similarities (Collins and Benning 1996). Although species richness does not appear to play a vital role in this case in maintaining ecosystem functions, we should remember than the species which could fulfil new roles when environmental conditions change must already be present. The keystone species concept also applies in the marine environment (Mills et al. 1993).

The evolutionary effects of exploitation by fisheries can be investigated with quantitative genetics. Using a model of population dynamics incorporating quantitative genetics, Law and Rowell (1993) conducted the first assessment of the effects of exploitation on body length in North Sea cod and suggested a small selection response after 40 years of exploitation. Subsequent work on fisheries-induced adaptive change has been extensive, showing continuous shifts towards maturation at earlier ages and at smaller sizes (Heino and Dieckmann 2004). These trends correspond to the outcomes predicted by the theory. Fisheries managers should be aware of this evolutionary change, because it will be hard to reverse and, if properly controlled, could bring about an evolutionary gain in yield (Law 2000).

Human-induced genetic impacts on wild populations can also result from interactions with their domesticated counterparts. Factors that may influence the magnitude, rate and reversibility of genetic responses, shifts in reaction norms and

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reduced plasticity, loss of genetic variability, outbreeding depression and their demographic consequences for wild fishes have been shown in many fish populations (Hutchings and Fraser 2007).

The direct effects of fishing can also influence species diversity at two levels. First, by removing components of populations that may show some genetic differentiation and second, by depleting species that are most vulnerable. Large slow-growing and late-maturing species suffer greater population declines for a given fishing mortality rate, because these attributes are associated with intrinsically lower rates of population growth. An example of collapse in the abundance of intensively fished vulnerable species is that of the common skate *Dipturus batis*, a large ray found in the North-East Atlantic. The case is particularly striking in that overfishing was further exacerbated by the confusion between two taxa. Iglesias et al. (2010) showed recently that the so-called *D. batis* "species" actually corresponds to two distinct species, one of them (*Dipturus flossada*) reaching maturity at about 120 cm in size and the other (*D. intermedia*) at 200 cm. This discovery answers the questions raised by the apparent—and surprising—ability of the skate, a species showing low resilience, to withstand fisheries pressure brought to bear on it (Brander 1981). In fact, the depletion of *D. intermedia*, one of the largest rays in the world, was masked by ongoing catches of *D. flossada,* a smaller and very likely more resilient species, also overfished. In this case, the lack of basic genetic and biological information made it impossible to draw up protection strategies and adequate management measures (Iglesias et al. 2010).

Other important impacts on biodiversity are the effects of species transfer and introduction, which may result in biological invasions (see EU project DAISIE[1]). A prime example is represented by the Mediterranean Sea (Walther et al. 2009; Blondel et al. 2010). To be successful, an invasive species must have ecological, physiological, genetic and morphological characteristics that promote long-distance dispersal of offspring and propagules, rapid colonization rates and high competitive ability (Lambdon et al. 2008). Other human-induced factors like the deballasting of water and sediment by merchant vessels contribute to these invasions and to deteriorating biodiversity.

The impacts of climate change have also been well documented in the marine environment (Walther et al. 2009; Crain et al. 2009; Lejeusne et al. 2009). Those aspects will be discussed in Chap. 3.

Finally, if human pressures lead to sharp drops in the abundance of some species and changes in biological diversity, we can ask what the effect will be on ecosystem stability. While links between diversity and ecosystem stability are an active field of research for terrestrial ecologists, they are little studied in the marine environment (Korobeinikov and Petrovskii 2008; Fig. 2.1).

[1] http://www.europe-aliens.org/.

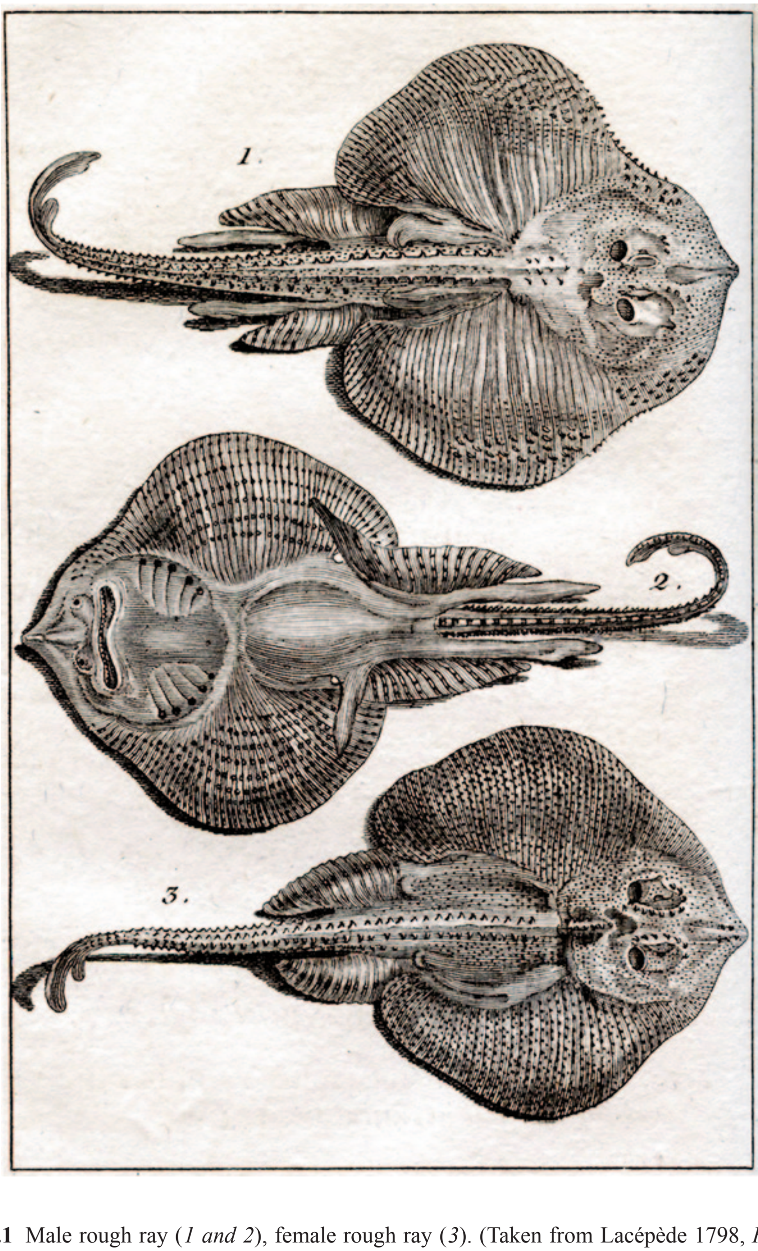

Fig. 2.1 Male rough ray (*1 and 2*), female rough ray (*3*). (Taken from Lacépède 1798, *Histoire naturelle des poissons*, vol. I, plate 5)

The Strategic Value of Research

The main reasons put forward for biodiversity conservation and research typically fall into three categories: (1) *conserving life in the oceans* is a moral and ethical responsibility, seeing the pleasure, wealth and welfare some species secure for people; (2) *species yet to be identified* are potential sources for new drugs, medical treatments and pharmaceuticals (over 15,000 to date), which is especially due to the original and archaic nature of marine biodiversity, providing a rich reservoir of food or genes and models for research; and (3) *organisms contribute to supplying ecosystem services* (Kunin and Lawton 1996; Boeuf 2007), including biological productivity, as well as controlling—or even preventing—the arrival and establishment of invasive species. There are physical, chemical, biological and physiological links between the ocean and public health. A few marine species serving as "biological models" have contributed to major progress being made in the field of life sciences, leading to several Nobel prizes, ranging from the discovery of phagocytosis to anaphylactic shock, the transmission of nerve influxes, molecular bases of memory, discovery of cyclins, organisation of the eye, neurotransmitter membrane receptors for neurotransmission and the bases of the specific immune system. These marine models are quite useful in understanding the origin and function of the mechanisms of human life and sometimes give rise to effective treatments and applications. Thus, studying and protecting marine diversity is crucial for the future of mankind.

Amongst the arguments put forward, moral and ethical aspects and the enrichment of human lives have led some sectors of society to campaign effectively for improved management of some emblematic species. However, these arguments often do little to ensure that millions of lesser known and lower profile species are also sustainably managed. Here, the main scientific inputs to the process are to identify the species concerned, assess trends in their abundance or range of distribution and establish the key factors underpinning these trends, particularly the role of human activities and their drivers. Research must also evaluate how they would respond to alternate management methods.

Assessments of the direct value of genes, species or communities to society, through the value of services they render, often provide economic arguments for the conservation of biodiversity. It is widely considered that such arguments will better influence new policies, since the costs and benefits of management actions can be directly compared (Balmford et al. 2002; CAS, 2009). Moreover, a growing field of research is focusing on the theoretical and practical (economic, social and ecological) implications of using economic incentives in support of biodiversity conservation policy. Conversely, economic incentive measures that are harmful to biodiversity need to be accurately assessed (CDB 2010), as was done on a nationwide scale in 2011 (CAS 2011).

When drawing up scientific advice on uses of biodiversity, advances made by research in understanding its role are especially important. This includes understanding the relationship between biodiversity and the provision of services, as well as (1) *how this relationship is affected* by human impacts and the environment,

Fig. 2.2 Illustrations of gastropods. (Taken from Tryon 1879, *Manual of conchology, structural systematics*, vol. III, plate 62)

(2) *the drivers of human activities* which depend on and impact marine biodiversity, and assessing (3) *the effects of alternate management actions* for biodiversity on the associated services and society.

The scientific inputs needed to describe and manage biodiversity will require collective efforts by scientists who are not necessarily used to working in an interdisciplinary approach. Taxonomists, geneticists and statisticians form the mainstay of contributors to cataloguing biodiversity (and where it is located) and developing tools and methods needed to describe it. Their work will need to be supported by building technical capacity in marine sciences, including the sampling of pelagic and deep water environments. Ecologists will work with geneticists to disentangle the ecological and evolutionary processes accounting for the distribution of biodiversity over space and time. The types and dynamics of links between biodiversity and ecosystem services will be of prime interest to both applied and theoretical ecologists and social scientists and economists. This too must be supported by innovative technological developments. Assessing the links between biodiversity and human and environmental drivers, including historical analysis such as scenarios and their social and economic impacts, will involve physical and ecological sciences as well as social sciences and economics. Likewise, diverse groups of scientists will be needed to support the development of management systems to meet objectives for biodiversity conservation, based on the above-mentioned research (Fig. 2.2).

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