

The Empty Ocean

By Jon Sumbly

Hobart, Australia, 2012.

I once had a conversation with a marine ecologist working on the Wallace Line. I asked her if she was beyond the reach of blast fishing and she said that even there she could always hear it like distant thunder underwater as she did her research. As we talked, I asked her why a Swedish marine ecologist was here, in an extremely remote part of the world, and her reply has stayed with me. She said, 'In Europe we just study how dead the ocean is, but here there is *Life!*' That was twenty years ago and the situation has not improved. Ocean ecosystems are being destroyed, degraded, and heavily altered by human activity.

This is the Sixth Extinction. This is the Anthropocene. We are the apex predator in the ocean. Around the world all parts of the environment are now, as *Science* called it, 'human-dominated ecosystems' (Special section, 1997).

Ocean ecosystems are declining rapidly and many species and ecosystems have declined in the 45-99% range (see Table 1). Over 90% of predatory fish have disappeared globally (Myers and Worm, 2003). Newfound fish populations may well be exhausted by 2020, which means that the serial depletion of fisheries ('boom and bust and move on' fishing) will not continue and a global collapse of fisheries is estimated, at the earliest, by 2048 (Froese and Kesner-Reyes, 2002; Worm et al., 2006), although this has been disputed. The cause of this destruction and decline is easy to identify: Overexploitation. The reasons for this overexploitation and why it still happens is the subject of much interest. Industrial fishing methods are a main driver, but recreational and artisanal fisheries also play a part (McPhee et al., 2002); with the pattern of depletion being scalar, as Worm et al. (2006) found the same pattern from local (recreational and artisanal) to global shelf and oceanic fisheries. Now entire ocean ecosystems are becoming endangered, with coastal and shelf systems the most endangered (Jackson, 2008; Jackson and Jacquet, 2011).

We have sophisticated and large scientific knowledge bases and extensive research and analytical capacity. For example, the EU bases its Common Fisheries Policy on the work done by the International Council for the Exploration of the Seas (ICES) which has over 120 years worth of research data, yet overfishing continues. Globally, there are large and expert fishery research institutions; ICES in Europe, the National Marine and Fisheries Service in the US, in Australia the CSIRO, and Chile has IFOP, to name a few. Yet marine fish populations continue to be overfished, with marine fish abundance declining globally by an average of 38% since 1970 (Hutchings et al., 2010).

Humans have always fished the seas and the first identifiable depletion by overfishing occurred about 125,000 years ago when the giant clam (*Tridacna costata*) disappeared from the Red Sea (Richter et al., 2008). Starting in 11th century Europe, new methods of fishing began to have direct and deleterious effects on ocean ecosystems (Roberts, 2007). This impact accelerated in the late Nineteenth century with the invention of the steam engine, leading to the destruction of whale populations, fisheries, and oyster beds, to name a few. However, the real exploitation and destruction of the global ocean environment began in the 1950s, with the global expansion of trawl and seining fisheries (Fig. 1).

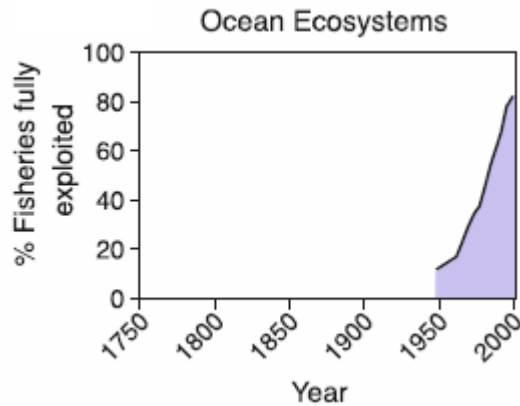


Fig. 1. Percentage of global fisheries either fully exploited, overfished, or collapsed (From; Steffen et al., 2011).

In the late Nineteenth century there was a single oyster bed that covered over 24,000 square kilometres in the North Sea. This 'crusted' the seabed and raised biogenic reefs that were exposed at low tide. These reefs had grown over the centuries and supported a rich and diverse benthic ecosystem of marine plants and animals, including lobsters; which, in turn, supported demersal and pelagic animal populations. Steam-powered trawlers dragged up and destroyed this oyster bed in a couple of decades (Roberts, 2007) with the fisheries starting to collapse soon after (Christensen et al., 2003).

Today most of North Sea benthos is depauperate, with every fishable square kilometre trawled at least twice a year (including wreck sites, like HMS *Victory* (Kingsley, 2009)). The same happened in Chesapeake Bay (USA), where oyster beds filled this large bay and extended over three miles out to sea (Roberts, 2007; Lai and Christensen, 2009). Today there are no wild oyster fisheries, all oysters are brought to market from aquaculture: Oyster populations globally have declined by over 90% (Roberts, 2007; Jackson, 2008).

There are no lack of examples: The depletion of the blue whale from a population known to be once in the hundreds of thousands to, at most, 11,000 today; to the Grand Banks cod, perhaps once the largest aggregation of vertebrate animals in the world, estimated to number over two billion fish in 1960 but was fished down to less than 10% of that population by the early 1990s (Hutchings and Rangeley, 2011); to the critically endangered hawksbill turtle which once had a population of eleven million before being hunted for its shell, today the population is less than 30,000; to post-World War Two Philippines, where the huge number of left-over explosive weapons led to the present blast fishing method that is common in Indonesia and is expanding across the Western Pacific and Indian Oceans; to the late-1960s observation by an American tuna fisher of the relationship between dolphin and tuna (still unexplained, but I tend toward the cooperative hunting hypothesis) led to the purse seining of dolphin to catch the tuna below. Dolphin populations in the Eastern and Western Tropical Pacific have not yet recovered from the effect of this fishing method; to the 1950s observation by an American aquarium owner who found that cyanide he used to kill algae in the tanks also stunned the fish, leading to the present widespread cyanide fishing on coral reefs throughout South East Asia; to the serial depletion of holothurians in southern Papua New Guinea/Torres Strait and the population collapse of the white abalone (*Haliotis sorenseni*) in California (the fishery collapsed within nine years but the decline continued, going from ~20,000 abalone per hectare to about one per hectare within two decades (Malakoff, 1997), which are examples of invertebrate overfishing.

These are just some examples set against a background of general global ocean ecosystem decline caused by trawling, seining, longlining, driftnetting (banned globally since 1992 but still an active fishing method, particularly in the Indian Ocean), pair-trawling, finning and related industrial fishing methods. To catch more of what less is left fishing boats have become bigger with the ‘super-trawler’ appearing more often in global fishing fleets. The *Northern Leader*, a ‘super-longliner’, with an ‘astonishing’ capacity of 76,800 hooks per day is due in the North Pacific in 2013 (Anon, 2012), while the *Albatun Dos* is one of the largest three purse-seine fishing ships operating in the world. The other two vessels (*Albatun Uno* and *Albatun Tres*), are also owned and operated by the same company: Albacora SA. These three ships work the Indian and Pacific Oceans to supply European consumers demand for canned tuna (Fig. 2).

Environmental threats from pollution, loss of habitat, bycatch, illegal fishing and lost fishing equipment compound the problems. These will be briefly outlined below to give a broader picture of the impact of human activities on the ocean environment and that they also complement, or exacerbate, the effects of overfishing.



Fig. 2. The *Albatun Dos*. This 116 metre long, Spanish owned, purse seine vessel can take up to 3,000 tonnes of tuna in a single voyage and is one of the largest vessels of its type; the other two are the *Albatun Uno* and the *Albatun Tres*. The ship was built in 2004 with a € 4.9 million (AU\$ 6.12 million) taxpayers subsidy from the EU; the subsidies for the other two vessels are unknown (Mulvad and Thurston, 2009). (Image: Clipper/CCLic 2009)

Table 1. Percent loss of fauna and flora in different locations. Starting dates are from the beginning of the data time series, except for depletions estimated from the pristine, unexploited condition. SAV* = Submerged aquatic vegetation. (From; Jackson, 2008)

Taxon	Starting date	Location	% loss
Estuaries and coastal seas			
Large whales	Pristine	Global	85%
Small whales	Pristine	Global	59%
Pinnipeds and otters	Pristine	Global	55%
Sirenia	Pristine	Global	90%
Raptors	Pristine	Global	79%
Seabirds	Pristine	Global	57%
Shorebirds	Pristine	Global	61%
Waterfowl/waders	Pristine	Global	58%
Sea turtles	Pristine	Global	87%
Diadromous fish	Pristine	Global	81%
Groundfish	Pristine	Global	62%
Large pelagics	Pristine	Global	74%
Small pelagics	Pristine	Global	45%
Oysters	Pristine	Global	91%
Mussels	Pristine	Global	47%
Crustaceans	Pristine	Global	39%
Other invertebrates	Pristine	Global	49%
Seagrass	Pristine	Global	65%
SAV*	Pristine	Global	48%
Wetlands	Pristine	Global	67%
Large carnivores	Pristine	Global	77%
Small carnivores	Pristine	Global	60%
Large herbivores	Pristine	Global	63%
Small herbivores	Pristine	Global	54%
Suspension feeders	Pristine	Global	68%
Shelf and pelagic fisheries			
Large predatory fishes	1900	N. Atlantic	89%
Atlantic cod	1852	Scotian shelf	96%
Fish 4–16 kg	Pristine	North Sea	97%
Fish 16–66 kg	Pristine	North Sea	99%
Large predatory fish	1950s	Global	90%
Large pelagic predators	1950s	Tropical Pacific	90%
Fishery biomass	1959	Bohai Sea	95%
Coastal and pelagic sharks			
Hammerheads	1986	N.W. Atlantic	89%
White	1986	N.W. Atlantic	79%
Tiger	1986	N.W. Atlantic	65%
<i>Carcharhinus</i> spp.	1986	N.W. Atlantic	61%
Thresher	1986	N.W. Atlantic	80%
Blue	1986	N.W. Atlantic	60%
Mako	1986	N.W. Atlantic	70%
Coral reefs			
Live coral cover	1977	Caribbean	80%
Live coral cover	1977	Caribbean	93%
Live coral cover	1980–1982	Indo-West Pacific	46%
<i>Diadema antillarum</i>	1977	Caribbean	92%
Reef fish density	1977	Caribbean	90%
Green turtle	1700s	Caribbean	>99%
Hawksbill turtle	1700s	Caribbean	>99%
Goliath grouper	1956	Florida Keys	96%
Large carnivores	Pristine	Global	85%
Small carnivores	Pristine	Global	61%
Large herbivores	Pristine	Global	87%
Small herbivores	Pristine	Global	66%
Corals	Pristine	Global	61%
Suspension feeders	Pristine	Global	49%
Seagrasses	Pristine	Global	50%

Bycatch

Under a recently proposed definition; 'Bycatch is catch that is either unused or unmanaged', 40.4% of global trawl catch is bycatch (some 38.5 million tonnes) (Davies et al., 2009).

The authors caution that this should be considered a minimum estimate of total global bycatch as they did not include longlining, gillnetting, pots, traps or artisanal fisheries. In Australia (see Fig 3. A and B), bycatch forms an estimated average of 24.6% of total catch (Kelleher, 2005).

In broad terms bycatch has two main components:

1. Marine species that are caught along with the target species and dumped as they are unwanted by the fishing vessel.
2. Marine species that are not associated with the fishery but are caught by the gear (seabirds, marine mammals, sea turtles, corals, invertebrates, etc.).

There are many subsets of bycatch: High-grading (dumping smaller, less valuable, fish of the target species in expectation of catching bigger fish of the same species); catching the wrong species for the fishing permit; quota discard (in multispecies fishing, if the quota for one species has been reached but not for another species the ship keeps fishing, dumping the fish for which it has reached quota until it reaches the quota(s) for the other species); value discard (via the internet, the ship knows the latest market values and dumps catch for which value has dropped in order to free up storage space for more valuable species); the caught fish are damaged, etc.

Bycatch can affect commercial species, contributing to overfishing. For example, the Argentinian shrimp fishery of 50,000 tonnes annually is estimated to generate 365,000 tonnes of bycatch, of which 30,000-40,000 tonnes is hake, a valuable commercial fish and a fishery that almost collapsed in the late-90s (Davies et al., 2009). Bycatch contributes to the depletion of marine species, the trophic downgrading of the ocean and alteration to the ecosystem function of the ocean (such as trophic cascades; Myers et al., 2007).

Almost half the birds listed on the IUCN Red List as endangered are seabirds with fishing methods the threatening process (Anon, 2007). Bycatch from longlining and trawling is estimated to kill over 100,000 albatross each year (see Fig. 4A) while driftnetting, before it was banned, killed at least 500,000 seabirds each year (Trouwborst, 2008). Pelagic longlining alone killed 200,000 loggerhead turtles and 50,000 leatherback turtles annually (in 2000), with the species declining by 80-95% in the last 20 years (Lewison et al., 2004). With both of these species endangered, the impact is obvious.

A critical element of bycatch, IUU fisheries (see below), and ghost nets (see below) is the effect on endangered species under what is called is 'deathbed conservation' (Parentau, 1998; Kunich, 2005; Trouwborst, 2008). The issue is that most endangered species acts and agreements (like CITES), are essentially reactive, in that human use of a biological resource is 'business as usual' until the target species or an ecologically related species is depleted to the point at which it is at risk of extinction. In terrestrial systems, defining and policing protected habitats and behaviours is easier than at sea.

Marine species generally at risk are usually mobile, crossing national boundaries and the high seas. Conservation measures must then be voluntary and can be ignored by vessels flagged to nations not party to the conservation agreement. Once at sea, fishing vessels can choose not to observe protocols. IUU vessels simply ignore conservation measures. Conservation policy can fail: Tuck (2011), showed that the subAntarctic longline fishery conservation action point of 0.5 birds per 1000 hooks may remain below that point because the population continues to decline, but as far as conservation objectives are concerned the species is surviving. Frazer (1992) questioned the intensive and expensive captive breeding programs for sea turtle, when the turtles are then released into the same environment that is sending the species extinct. In the face of continued global marine capture fishing, conservation of marine endangered species is problematic, or what I call 'IUU conservation': Ineffective, Unmanageable and Unenforceable.

IUU fisheries

Illegal, unreported and unregulated fishing occurs in all marine capture fisheries, either within national control or on the high seas. Typically, an IUU fishing vessel does not follow any management rules or bycatch reduction methods. They will fish on spawning fish populations, juvenile fish, in closed areas or on closed fisheries and follow no quota (Balton, 2004).

Controlling IUU fishing is problematic as vessels can relocate and often reflag, rename or change ownership (Miller, 2004). The use of a flag of convenience is integral to IUU fishing. The activities of IUU fishing can make management of regulated fisheries difficult. If a quota is allocated and IUU fishing is also taking a catch, then the fishery is very likely being overfished. If the regulated fishery reduces quota to try and take into account the IUU fishing, the regulated fishery will suffer and the IUU fishing vessels could simply take advantage of the increase in available fish.

For example, in the CCAMLR area the regulated longlining fishery on toothfish (*Dissostichus* sp.) averaged around 12,000 tonnes per year between 1997 and 2003 (2008/09: 15,783 tonnes; 2009/10 11, 860 tonnes (CCAMLR, 2010)), while the IUU catch was around 7,500 tonnes (2009/10: 1,615 tonnes), giving a total catch 62% higher than the regulated fishery. Over the same period, the seabird bycatch in the regulated fishery declined to about 1000 seabirds per annum, while the IUU bycatch was about an average of 50,000 seabirds (high: 70,000 (1998); low: 20,000 (2003)) (Miller, 2004).

IUU fishing has been estimated to be a major fisheries pressure, contributing to overfishing and ecosystem decline (Coll et al., 2008). Globally, the catch of swordfish and tuna was a reported 680,000 tonnes (in 2000) with the IUU catch an estimated 85,000 tonnes, making the total catch 12.5% more than what one would presume to be the sustainable regulated catch (Lewison et al., 2004). In PNG, IUU fishing is reported to be 14% of legally reported catch value (Williams, 2007). IUU fishing off West Africa is an estimated 40% higher than reported catches (Agnew et al., 2009). This means that 'sustainable' fishing quotas are meaningless in West Africa.

Ghost nets

'Ghost net' is a catchall phrase for abandoned, lost or otherwise discarded fishing gear (ALDFG). The principle is simple, particularly when fishing gear is generally made from durable and non-biodegradable plastics. The term refers to the continued fishing and killing of marine species by trawl nets, gill nets, pots and traps, and other gear types (see Fig. 4B). In Europe there are approximately 7958 nets lost annually resulting in an estimated 209 km of ghost nets every year. Ghost gillnets continue to fish and take about 15% of the normal rates of catch. However, owing to tangling, bundling, and fouling, the average fishing time for ghost nets in the EU is 6-12 months, although ghost nets in the halibut fishery off Greenland can fish for 2-3 years (Macfadyen and Brown, 2007). In Australia, the Carpentaria Ghost Net Program collects beached nets from accessible beaches at an average 2.5 km of net per month (Macfadyen et al., 2009).

Fish traps and pots can also fish for some time after being lost. In Queensland, Australia, the blue swimmer crab (*Portunus pelagicus*) is the target of a commercial pot fishery. Annually about 3000 pots are lost. Pots ghost fish by attracting marine animals into the pot, often trapping them. These die and attract more animals and the cycle continues until the pot degrades or settles into the sediment. In Queensland, traditional pots have been largely replaced over the last decade with trawl-net based mesh pots which are durable and non-biodegradable. The fishers estimate that a lost mesh pot will ghost fish for four to ten years. After accounting for escapement, 10,395 to 41,646 crabs die in these lost pots each year. When the regional SE wind shifts are taken into account, as they greatly increase crab catches, the rate rises to an annual bycatch mortality of 670,866 crabs per year (Campbell and Sumpton, 2009). In the Gulf of Oman, approximately 20% of fish traps are lost per year and retain their capacity to ghost fish with a 95% mortality rate. The mortality rate over a six month period was estimated at 78.36 kg per trap, mainly commercially valuable fish species and cuttlefish (*Sepia* sp.), with the catch declining steeply after then (Al-Masoori et al., 2004).



Fig. 3. A. Bycatch from the Northern Prawn Fishery (NPF), Australia's most lucrative prawn fishery. Bycatch rates have been estimated at up to five kilograms of bycatch species for every kilogram of prawns caught (some arrowed), 97% of NPF bycatch is dumped at sea. Location: off Yorke Island, Gulf of Carpentaria, 2006.

B. Bycatch taken in a research trawl on orange roughy (reddish fish on the right). Bycatch mortality in this fishery is 100%. Location: onboard the *FTV Bluefin* off the East Coast of Tasmania, 2006. (Both images: Stephen McGowan, Australian Maritime College, 2006/Marine Photobank)

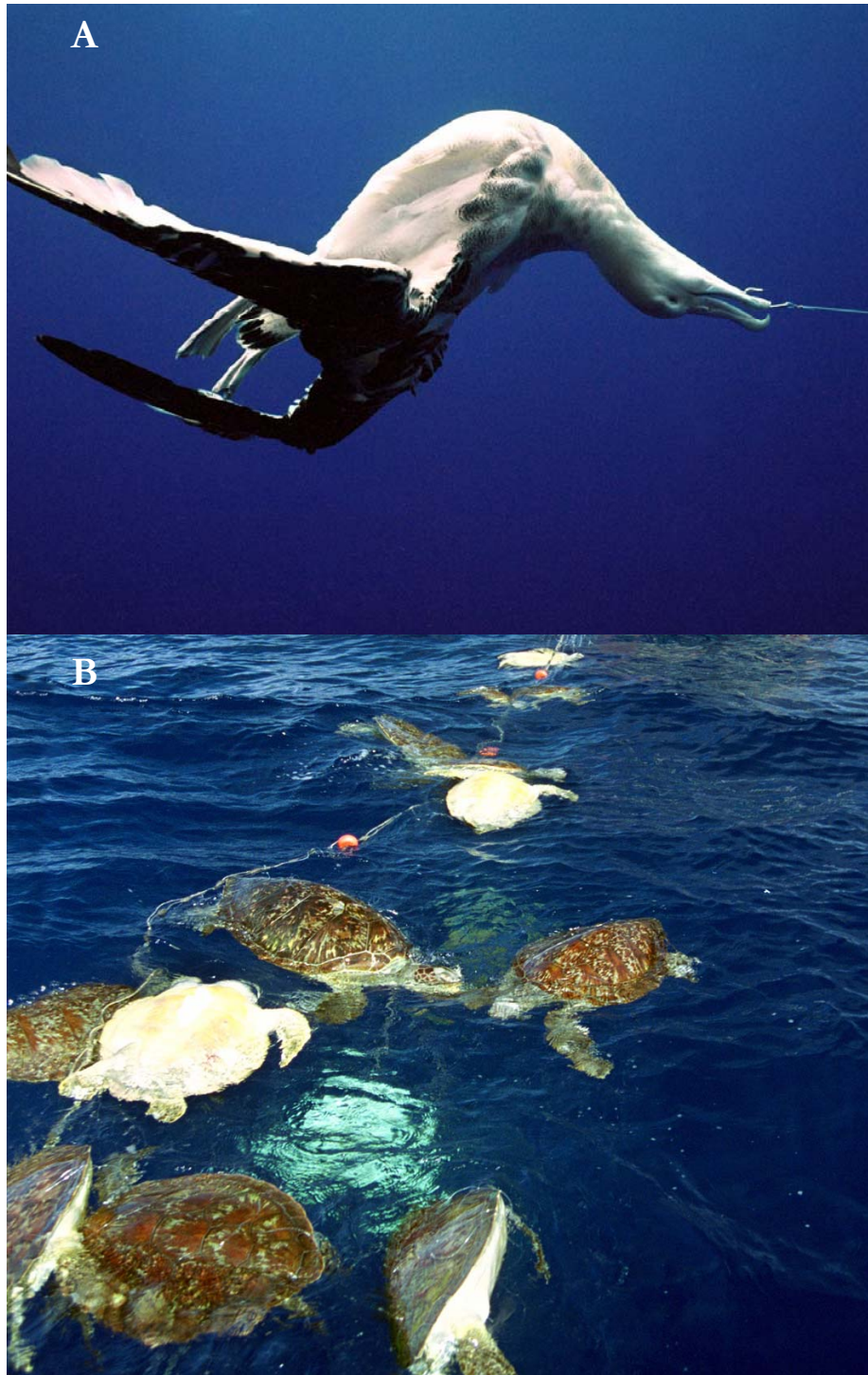


Fig. 4. **A.** An albatross caught and drowned on a pelagic longline hook. Of the 22 species of albatross, two are critically endangered, 19 threatened and one near threatened as the direct result of industrial fishing by longlining (especially in the subAntarctic), and trawling (especially off the coast of West Africa). Location: offshore from Bahia, Brazil, 2005. **B.** A ghost net found at sea carrying 17 drowned sea turtles. Of the seven species of sea turtles, three are endangered and three threatened. Location: offshore Praia do Forte - Mata de são João, Bahia, Brazil, 2005. (Both images: Projeto Tamar Brazil/Marine Photobank)

Pollution

Pollution has a largely hidden but major effect. Sewage and agricultural and industrial runoff causes 'dead zones' where eutrophication has removed oxygen from the water. Chemicals in this global runoff enter the food chain and bioaccumulates to the detriment of marine life by reducing fitness. Pollution enters the deep sea from the cargo ships that sink each year and from at-sea waste disposal, often illegal.

Plastic waste is flushed by river into the ocean, or disposed of into the ocean from ships; it is the largest component of marine debris (Derraik, 2002). This does not biodegrade but breaks down into smaller and smaller particles. These small particles sorb chemical pollutants from the water column or contain their own toxins and are eventually eaten to deliver their toxins to the animal, as well as having no nutrient value. Plastic waste collects on islands and traps and injures wildlife. An estimated 100,000 marine mammals die in the North Pacific each year from plastic entanglement and ingestion.

In the ocean, gyres concentrate plastic waste into patches hundreds of kilometres wide. Moore et al. (2001) sampled the North Pacific central gyre and found 334,271 pieces/km² at the neuston size, which weighed in at 5.177 kg/km². This was six times the mass of plankton but the plankton was five times more abundant. The effect on filter feeding organisms is poorly understood but the implications are that they would be undernourished, poisoned, and lose fitness. Larger pieces are known to kill tens of thousands of seabirds by clogging their digestive tracts and those of their young, which are fed items such as cigarette lighters that have been mistaken for fish. Marine turtles are similarly affected.

Habitat Loss

Habitat loss is occurring across the ocean, from the coast to the abyss. Along with species depletion by fishing, bycatch and IUU fishing, habitat loss is having a profound effect on the ecosystems of the ocean. Anthropogenic habitat disturbance and loss has been happening for millennia, estuaries being one of the most affected coastal habitats owing to the human habit of establishing cities and towns on estuaries and reworking them. Wetlands are drained and mangroves cleared worldwide. In the Adriatic, 75% of species that provide habitat and filtering roles have been removed (Lotze et al., 2010) affecting the entire ecosystem function of that sea. Oceanic seafloor communities and habitats have been greatly altered in the last century, owing to the expansion of trawling worldwide. In the North Sea, where bottom trawling continues throughout the year, large scale changes have been seen. Tillin et al. (2006) found that seafloor filter feeding, attached and larger animals were more abundant in lightly trawled areas but in heavily trawled areas, the ecosystem shifted to mobile animals, scavenger crabs and infauna. Epibenthic flora and fauna do not survive repeated trawling with effects throughout demersal, pelagic and coastal ecosystems.

These effects were seen at the large scale fishery level by Thrush et al. (1998) in Hauraki Gulf, New Zealand; they found that with decreased fishing pressure there was an increase in epifauna, echinoderms and long-lived surface animals as well as an increase in species diversity and abundance. Trawl fishing changes to the seafloor lead to the functional extinction of key species and communities and pose a threat to structural and functional biodiversity on the seafloor and above it, changing the ocean as we know it, leading to the shifting baselines syndrome (Thrush and Dayton, 2002; Jackson and Jacquet, 2011). Deep sea trawl fisheries are rapidly expanding as shelf fisheries decline and these deep sea ecosystems are even more vulnerable to bottom trawling and serial depletion, as these animals typically have slow physiology, long life, and low reproduction rates (Norse et al., 2012). Physiological stress and barotrauma ensures that no organism taken from these depths survive.

People and the Sea

People have always fished the sea and overfishing and species extinction have accompanied this; for example, Steller's sea cow disappeared from its entire range by the early Holocene, surviving on a single island which had not been found by the indigenous peoples. It finally went extinct within three decades after that island was discovered by Europeans in 1741 (Roberts, 2007; Jackson et al., 2001).

From the perspective of the individual, the ocean is vast and the marine life abundant (but vastly less abundant than it was a century ago). The right of people to exploit marine resources has a long history:

And truly by natural right, these be common to all; the air, running water, and the sea, and hence the shores of the sea. Also all rivers and ports are public, so that the right of fishing in a port and in rivers is common to all. And by the law of nations the use of the shore is also public, and in the same manner as the sea itself...Any person is at liberty to place on [the shoreline] a cottage, to which he may retreat, or to dry his nets there, and haul them from the sea...The right of fishing in the sea from the shore belongs to all men...Everyone has a right to build on the shore, or by piles upon the sea, and retain the ownership of the construction so long as it lasts, but when it falls into ruins, the soil reverts to its former status...

Roman Civil Law, Institutes of Justinian, Liber Two, Tract One, Section One.
(cited in Weinstein et al., 2007)

The huge fish schools (cod, herring, pilchard, pollock, sprat, etc.), vast bales of sea turtle, whale pods that crowded the sea to the horizon, the seabird colonies that blackened the sky, oyster beds that stretched out of sight, elvers (young eels) that filled coastal bays and inlets until there seemed to be more elvers than water, cod that could be hauled out just by dropping a basket into the sea, seemed to make the abundance of the ocean inexhaustible. Indeed the famous biologist, T.H. Huxley, declared during the 1883 Royal Commission into the effects of trawling that, 'all the great sea fisheries are inexhaustible' (King, 1995), which was also the title of a popular 1955 book, *The Inexhaustible Sea* (Roberts, 2007). This viewpoint is virtually ingrained in the society's cultural psyche even today; note the numerous fishing programs on television and the popularity of recreational fishing.

The freedom of the seas for fishing, trade and travel, was further ingrained by Grotius' legal idea of *mare liberum* in 1608, codified in the Treaty of Westphalia (1648). The legal concept of 'Freedom of the Seas' continues to this day with the 'open access' nature of the high seas: 'The great void' (Steinberg, 2001). Going to sea is freedom; the sailor can go wherever the wind sets and the riches of the sea are abundant and free to take. This is the generalized romantic view. In reality, there are many international and intergovernmental agreements and rules about how the sea is used; from marine waste disposal to fishing. Yet, globally, fisheries are collapsing and even the European Union has admitted that the Common Fisheries Policy is a failure: Unable to protect fish stocks, provide a sustainable food source, or profitable fisheries with 88% of EU fisheries overfished and 30% of EU fisheries collapsing (Brown, 2011).

Overfishing

Seafood is the most highly traded food internationally (Smith et al., 2010) and overexploitation, as overfishing, is common to the world's oceans (Coll, et al., 2008) despite sophisticated science (Young, 2003). The effects of current and historical overfishing (Jackson et al., 2001) are now beginning to be understood. Hutchings (2000) has found that despite conventional wisdom, populations of overfished species do not necessarily recover quickly, with recovery being on the scale of years. As the apex predator in the ocean, humans are changing the phenotypes of marine species at an extremely rapid rate. This 'harvest selection' is reducing the size of fish and affecting life history traits. This can affect population numbers and dynamics, reduce fecundity, and affect ecological interactions with other organisms in the system as well as modifying the structure and function of the affected ecosystem as a whole (Darimont et al., 2009). Overfishing also distorts ocean ecosystems by 'stripping out' the biomass, and hence energy, of a trophic level and denying this resource to higher trophic levels (Coll et al., 2008).

Fisheries also take the apex consumers resulting in trophic downgrading and the effects of this alter biodiversity, ecosystem dynamics and ripple out into carbon sequestration, disease dynamics, biogeochemical cycles (e.g. iron cycling by whales in the Southern Ocean), invasive species and the persistence and resilience of ecosystems and species (Estes et al., 2011).

Food webs in the open ocean are being altered, affecting the ocean ecosystem (Hinke et al., 2004). At the human level, fish products contribute a global average of at least 15% of human protein consumption (Smith et al., 2010) and that figure is expected to rise with the growing global population. Overfishing is not only the depletion of marine species but the alteration of the whole ocean ecosystems and productivity which, along with the depauperation of the ocean, will have profound effects on human nutrition supply in the next few decades. Fishers are phlegmatic. Jack mackerel populations have plummeted in the Southern Pacific, going from an estimated 30 million tonnes in 1990 to less than three million tonnes today. The world's largest trawlers are now heading south, including the 144 m *Annelies Ilena* (formerly the *Atlantic Dawn*). "It's going fast," Pineda said. "We've got to fish harder before it's all gone." Asked what he would leave to his son, he shrugged: "He'll have to find something else." (Rosenblum and Cabra, 2012).

In the next article I will examine the causes of overfishing and also briefly discuss the broad scale changes to the ocean environment that will alter the ocean for generations to come: Ocean acidification; oxygen depletion; ocean warming; nutrient depletion and the pole-ward migration of ecosystems.

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