

The environmental damage wreaked by modern intensive agricultural and fishing practices is huge. Increasing the pressure on the environment courts catastrophe.

In the 1960s the Club of Rome and other notable commentators such as Paul Ehrlich predicted that the world's rapidly expanding population could not be fed in the near future and that mass starvation may occur. However, such dire predictions were scoffed at by many and subsequently proven wrong in following decades by the Green Revolution with the introduction of high yielding crops. However, these high yields were only possible through the greater associated use of irrigation and fertilizers. Now it appears that this has come at a price, the very high price of environmental degradation that we are now paying:

- **Water contamination and depletion**
- **Green house gas, air pollution and acid rain.**
- **Disturbance of the nitrogen cycle**
- **Soil degradation**
- **Deforestation**
- **Loss of biodiversity**
- **Damage to the marine environment**

Introduction

The recent FAO report entitled ***Livestock's long shadow***, noted *"Directly and indirectly, through grazing and through feedcrop production, the livestock sector occupies about 30 percent of the ice-free terrestrial surface on the planet. In many situations, livestock are a major source of land-based pollution, emitting nutrients and organic matter, pathogens and drug residues into rivers, lakes and coastal seas. Animals and their wastes emit gases, some of which contribute to climate change, as do land-use changes caused by demand for feedgrains and grazing land. Livestock shape entire landscapes and their demands on land for pasture and feedcrop production modify and reduce natural habitats"* (Steinfeld 06).

There has been a progressive encroachment by agriculture into wild habitats causing severe fragmentation and overall loss which along with climate change has increased the species extinction rate to between a 100 and 1000 times that seen in the geological record. The recent Millennium Ecosystem Assessment noted that a third of amphibians, a fifth of mammals and eighth of bird species are now threatened by

extinction in the near future (Steinfeld 06).

Vital statistics of the livestock industry overall (Steinfeld 06):

Class	Effect	Percentage
Economic importance	Contribution to world GDP	1.4
Land	Total of terrestrial surface used for grazing	26%
	Grazing land degraded	20 overall, 70% in dry regions
	Feedcrop land of total arable land	33%
Atmosphere	Contribution to Greenhouse gases in CO ₂ equivalents	18%
	Share of CO ₂ emissions	9%
	Share of methane emissions	37%
	Share of N ₂ O emissions (including feed crops)	65%
Water	Total use including drinking servicing and irrigation of feedcrops.	8%

Resource consumption on a huge scale. High yielding crops are dependent of the use of large amounts of fertilizer, pesticides and water as shown in the following table (Adapted from D'Antonio 01):

World usage	1960	1980	2000
Nitrogen fertilizer Millions of tonnes	11	52	83
Phosphorous containing fertilizers Millions of tonnes	12	21	28
Irrigated land Millions of sq. kilometres	0.14	0.21	0.28

Crop land Millions of sq. kilometres	1.33	1.43	1.54
Pasture land Millions of sq. kilometres	3.07	3.28	3.5
Pesticide trade globally Billions of dollars (1996 dollars)	1.0	7.2	11.1

Water wastage and pollution.

Using vast amounts of water for needless production of animal protein by profit-hungry vertically-integrated multinational agribusinesses is a luxury the world cannot afford. See the section on [water](#).

Pollution of water from livestock production is a huge problem.

While pollution of water from untreated human waste in the developing world is the greater problem, in the developed world, the major source of water pollution is agriculture particularly livestock production. In the US for example, up to 40% of water lakes, rivers and other storage areas is unfit for drinking or recreational use because of pollution from dangerous micro-organisms, pesticides and fertilizer, principally from agriculture. See the section on [animal manure](#). The additional cost of downstream purification of this polluted water is also substantial.

Water pollution from slaughter houses is also very substantial particularly in the developing world. Industrial scale livestock production is usually associated with large scale slaughtering facilities. While the machinery inside such facilities is often imported, the associated waste processing technology isn't with large amounts of material such as rumen content, blood and fat dumped into the environment.

Sediment in water from agriculture is a major pollutant. Annually 25 billion tonnes enters rivers world wide. The livestock sector is one of the major contributors to this, either directly or indirectly from feedcrop production (Steinfeld 06). See below under soil erosion.

Greenhouse gas production, air pollution and acid rain.

Eighteen percent of all greenhouse gas production (in CO₂ equivalents) comes from livestock. This figure includes the effect of pasture degradation and land use (Steinfeld 06).

Livestock production is a large contributor to CO₂ emissions

(Adapted from Steinfeld 06):

Stage	Estimated CO ₂ production In millions of tonnes / year world wide	Notes
Fertilizer for feedcrop production.	41	Production of chemical fertilizers is very energy intensive
Livestock related on-farm fossil fuel use	60	This includes fuel for farm machinery, production of pesticides/herbicides, electricity use and seed production.
Livestock related land use changes	1700	Clearing of forest for pasture or feedcrops, for example, around some 3 million hectares/year in South America.
Livestock related releases from cultivated soils	30	Carbon loss from soil tillage, soil liming.
Releases from livestock related desertification.	100	Mainly related to decreased soil organic matter from vegetataion loss and to some extent above ground loss as well.
Processing related to livestock feed and livestock products	10-50	Energy is used in preparing livestock feed and well as in processing products such as milk pasteurization, cheese making etc.
Transport of livestock products both feed and outputs	Less than 1	This represents only a very small contribution to the overall production.

When land clearance is included, CO₂ emissions from livestock account for about 9% of total anthropogenic CO₂ emissions (2.7 billion tonnes per year out of a total of 31 billion tonnes per year).

Other greenhouse gas emissions from animal production. Worldwide ruminant livestock account for 37% of annual methane emissions and 65 of nitrous oxide (Steinfeld 06). Methane's importance is increased markedly because a little bit of methane goes a long way: every molecule of methane has the same greenhouse effect as that of 23 molecules of carbon dioxide. It has been estimated that methane production world wide from ruminants is around 86 million tonnes from rumens and a further 18 million tonnes from manure (Steinfeld 06). Methane levels have risen more dramatically than CO₂, having more than doubled in the last century from around 800ppm to 1755 ppm in 2004 compared to the 25% increase of CO₂. It must be noted that methane levels over the last few years have been relatively stable related mainly to a reduction of methane production by the drying up of wetlands which has counterbalanced the increasing man made methane emissions (Bousquet 06).

Methane's half life in the atmosphere is relatively short at around 12 years compared CO₂ much of which is retained in the atmosphere for more than 80years (Hanson 06). Because of methane's short life span and its powerful greenhouse gas effect, moves to reduce methane production, particularly by limiting the production from animals, is likely to have a relatively greater effect than efforts to reduce CO₂ in the shorter term. This is a strong argument for moving to a more plant based diet.

Ammonia gas production from manure and urine as well as from fertilizers add greatly to the nitrate pollution of water and subsequent eutrophication. Close up, ammonia gas is unpleasant to breath in, but its distant effects are much worse. Large amounts are produced from animal manure and to a lesser extent from the volatization of chemical fertilizers. Most of the atmospheric ammonia is quickly returned to the earth where it acts as a significant pollutant. Around 47 million tonnes are released into the environment annually from human-related activities with around 65% coming from livestock production (Steinfeld 06). As example, on the Delmarva Peninsula adjacent to Chesapeake Bay in the eastern US, there are 600 million chickens producing around 20,000 tonnes of per year. An estimated 27% of this ends up in the bay (Jacobson 06).

Nitrous oxide (N₂O) is an even more powerful green house gas and substantial amounts come from fertilizers and manure. Nitrous oxide, molecule for molecule, has 200 times the effect of carbon dioxide as a greenhouse gas and in addition is extremely long lived in the atmosphere lasting anything up to 150 years. It also depletes the

stratospheric ozone layer which protects the world from excessive harmful ultraviolet radiation. A doubling of the N₂O would result in a 10% decrease in the ozone layer and a 20% increase of the UV radiation striking the earth. The current increase since the industrial revolution is around 16% (Steinfeld 06). However, it doesn't end there. A lot of this ends up as nitrate pollution in water, causing eutrophication. The largest livestock related source of nitrous oxide is animal manure and world wide it is estimated at 3.69 million tonnes per year (Steinfeld 06).

The overall picture of livestock production in relation to greenhouse gases. These figures include the contribution from land use change (Steinfeld 06):

Gas type	Contribution from livestock in billions of tonnes/year in CO ₂ equivalents	Total anthropogenic contribution in billions of tonnes/year in CO ₂ equivalents
CO ₂	2.7	31
Methane	2.2	5.9
N ₂ O	2.2	3.4
All	7.1	40

Overall livestock production contributes around 18% to total greenhouse gas production. It should be noted that a substantial proportion of this is related to land clearance practices to extend pastures particularly in South America. Controlling this clearance directly by better local regulation or indirectly by reducing the demand for animal products are urgently required.

Nitric oxide (NO) comes mainly from burning fossil fuels but significant amounts also come from the action of soil bacteria on nitrogen containing compounds. This along with nitrogen dioxide, has a number of unwanted effects: increase in lower atmospheric ozone, decrease upper level ozone, photochemical smog and acid rain. See the section on [manure](#).

Smell: an unpleasant neighbour. The smell arising from these huge intensive animal production units is very unpleasant and while not a significant health risk, none-the-less degrade the environment for humans.

Disturbance of the nitrogen cycle: it is being severely damaged by

man made fertilizers and other human activities.

We have doubled the world's nitrogen supply since the invention by Haber and Bosch of artificial nitrogen fixation at the beginning of the 20th century. Recent estimates are as follows (Vitousek 97):

Source of fixed nitrogen	Amount in Millions of tonnes/year
Fertilizers	80
Nitrogen fixing crops: Soya and other legumes	40
Burning fossil fuels	20
Burning forests and other organic materials	40

Fertilizer use to produce animal-based foods is very large (Modified from Jacobson 06).

Food type	Fertilizer kg/ kg of product	Notes
Pork	0.42	This is the highest level since pigs are grain fed for their entire lives.
Beef	0.37	This is a high figure in part because of the relative inefficiency of cattle in converting feed to meat.
Chicken	0.17	
Eggs	0.14	

What is the effect of all this extra nitrogen?

Initially all the extra nitrogen promotes plant growth in many ecosystems and this may have offset the rise of CO₂ in the atmosphere. However, from there on it is mainly negative since only about 50% of the added nitrogen is taken up by crops and livestock with the rest polluting the environment (Vitousek 97):

- Before the massive increase of nitrogen in modern times, most ecosystems had were nitrogen poor. With the large increase, nitrogen responsive plants were favoured over those that were not,

leading to a substantial loss of species and a subsequent degradation of these systems, particularly heaths and grasslands.

- With the progressive increase of nitrogen, many soils become saturated being no longer able to use the excess, leading to the build up of nitrates which then leach into water, taking with them alkaline minerals such calcium, magnesium and potassium causing a loss of productivity. With progressive acidification of these soils, aluminium ions are mobilized producing a toxic mix for many plants.
- Much of the excess ends up in rivers and surrounding seas leading to problems of eutrophication as outlined in the section on [animal manure](#).
- Gases such as nitric oxide and ammonia are dissolved in rain and are eventually converted to nitric acid a significant component of acid rain, especially since sulphur dioxide emissions from power generation have been cut in more recent times.

Soil degradation can arise from a number of processes:

- **Soil erosion from tillage of crops**
- **Soil damage from excess water and nutrients, from pesticides and other chemicals and minerals.**
- **Soil compaction and erosion from hard hooved animals and farm machinery.**
- **The spread of woody weeds in semi-arid and subtropical rangelands.**

The global size of the problem is huge, year 2000 figures (Eswaran 01)

Land Mass	Scale of the problem
Africa	Yield loss from soil erosion ranges 2 to 40%, overall loss 8.2%
Asia	Loss of productivity annually estimated at 36 millions tons of cereal equivalent, valued at \$US5.4 billion by water erosion and 1.8 billion from soil erosion.
North America	In the US, annual cost of erosion from agriculture about \$US44 billion.
The	Globally, the annual loss of 75 billion tons of soil costs at \$US400 billion or approximately \$70 per

World

costs at \$3400 billion or approximately \$70 per person per year world wide.

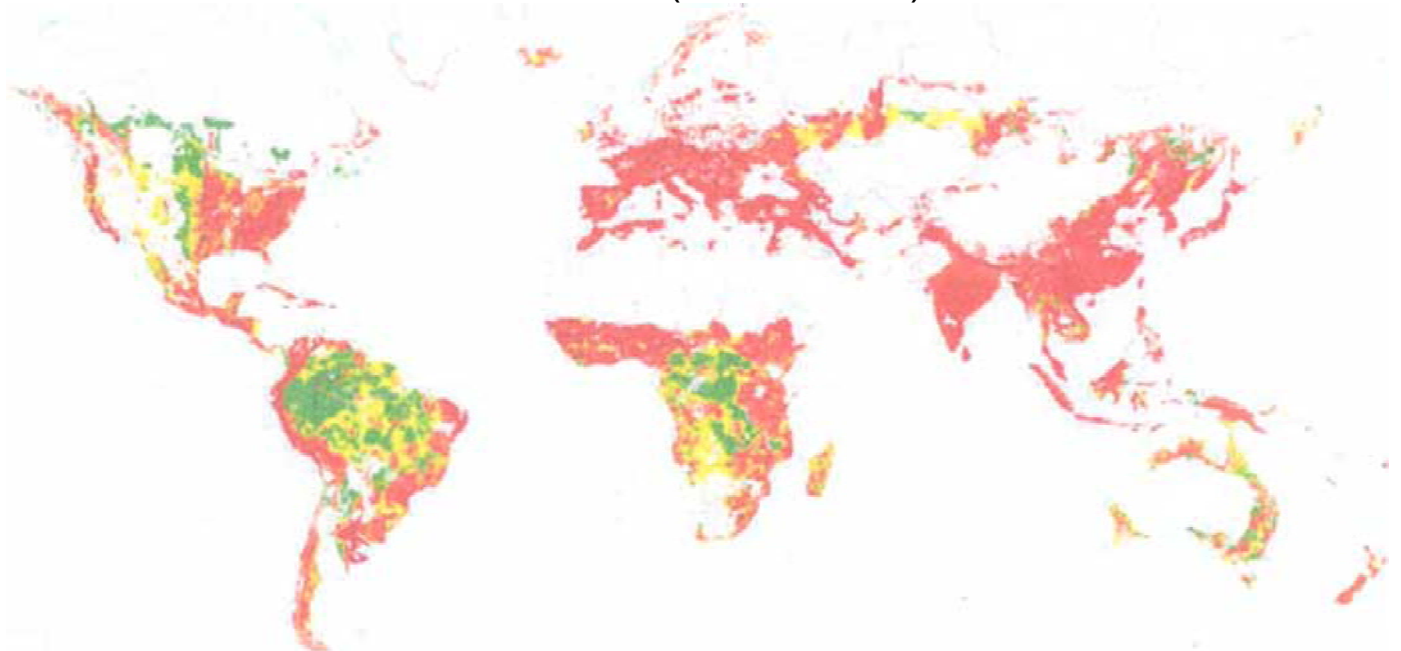
Estimates of the proportion of various land types that have been degraded quoting various studies (Steinfeld 06).

Land type	Asia	Latin America	Africa
Forests and woodlands	Around 33%	15 to 20%	
Pasture	2 million sq. kms.	1.1 million sq. kms.	2.4 million sq. kms.
Agricultural land	One third	One half	Two thirds
Dry land areas	71%	73%	73%

Soil erosion

In the US, 55% of the erosion of crop and pasture land is related to livestock either directly or indirectly from growing feedcrops (Steinfeld 06).

The risk of soil erosion world wide (Steinfeld 06)



The areas with the highest potential are in red, those with the lowest in green and land areas in white were not considered in this analysis.

Yellow and orange are intermediate. As can be seen high risk soil erosion areas dominate the non-desert areas of the world. As noted elsewhere, much of this is related to livestock production.

Soil should be viewed as a non-renewable resource, a resource that we are using up through excessive consumption animal-based foods coupled with unwise farming practices.

Effects of soil erosion (also see the section on [water](#))

- Increased sedimentation of rivers, reservoirs and channels, thus reducing dam capacity and blocking irrigation channels.
- Destruction of aquatic ecosystems in rivers, lakes and seas such as the damage to coral reefs.
- Disruption of the hydraulic characteristics of water flow, leading to increased speed of run off, flooding and reduced water during dry periods.
- Transport of adsorbed agricultural nutrients and pollutants.
- Increased growth of micro-organisms and protection from disinfection.
- Further eutrophication.

Soil loss from tillage of crops. Despite recent advances from the adoption of minimal or no tillage, there are still very substantial losses from erosion. Some crops are associated with greater losses because they supply less ground cover. For example soy and corn grown in rows provides less cover to prevent erosion than compared to small grained crops such as wheat which are not grown in rows. Because of the massive amounts of soy produced in the world today for intensive feed lot operations, this is a very significant problem. Soil erosion not only reduces the productivity of the land but also the run off sediment blocks drainage ditches, fills dams with silt, and pollutes streams and rivers. The problems are directly related to the amount of land under cultivation. That area has been increasing around the world in the last decades (see the above table), much of it related to the increasing use of crops to feed animals rather than being used to feed humans directly. This is very wasteful and in the longer term unsustainable.

Soil erosion increases water loss and wastage. This is probably the most significant effect of all since eroded soils are less absorbent of rain water, where more than 80% of water is lost to excessive run off.
(Pimentel 04)

Soil compaction and erosion from large free-range animals Soil compaction and erosion caused by hard hoofed animals in fragile

landscapes is causing substantial damage. Forage is often concentrated around water sources. Studies in the US rangelands have shown that while these riparian areas represent 1.9% of grazing land, they produce 21% of the forage and 81% of forage consumed by cattle. This concentrates the damage in this fragile zones greatly increasing erosion. Also, compaction of soil stops water penetration leading to increased run off and erosion as well as reducing aquifer replenishment. Lowering the water table then lowers stream water level, increasing the bank height and further increasing erosion from cattle, setting up a vicious cycle (Steinfeld 06).

The importance of biological crusts. Many landscapes used for cattle ranching are semi-arid lands. These usually have biological crusts formed by living organisms such as cyanobacteria, algae, lichens and mosses which protect the surface. Hard hoofed animals readily damage them opening up such landscapes to wind and water erosion (Soilcrust 06). Compaction also damages ant nests which are an important mechanism for carrying organic matter into the subsoil and also for the penetration of water (White 97). Such processes have led to desertification in most continents especially in Australia and Africa. Local water courses are particularly hard hit by trampling, leading to murky water choked with sediment, algae and manure.

Soil compaction also occurs from agricultural machinery. This has been a significant problem in the past but due to better farming methods this has been reduced, but in many parts of the world remains a substantial problem. The heavier the machinery, the greater the problem, not necessarily overcome with dual or balloon tyres. As agriculture has become more industrialized to meet the demands of intensive animal feedlots, machinery has tended to become much bigger for economies of scale, promoting this problem. There are many factors that can moderate this effect but good crop rotation, adding more organic matter to the soil and minimal tillage are effective measures (Compaction 06).

The spread of woody weeds is promoted by cattle grazing. Cattle are selective in what they eat, often eating down the more palatable native plants and leaving the unpalatable small woody trees along with other exotic species. Overgrazing along with competition for water and sunlight reduces ground cover grasses leading to wind and water erosion of the exposed earth. Also cattle often distribute the seeds of these plants which become attached to their hides and the surface damage of their hooves promotes planting of the seeds. Fires which will reduce woody weeds are suppressed in an attempt to maintain pasture

in the shorter term but in the longer term such moves are counterproductive. The spread of woody weeds has caused major degradation of enormous tracts of land in many countries (Steinfeld 06). The only effective measure is to reduce livestock numbers by reducing demand for animal products.

Pollution of soils by heavy metals - the roxarsone story. There has been some concern that heavy metals such as cadmium are being added to the environment through fertilizers. As small amount is added through the use of rock phosphate based fertilizers, but this is probably less important than other processes. Roxarsone is an organic arsenical compound added to chicken feed to prevent coccidial gut infections and hence acts as a general growth promoter. This compound is not absorbed by the chickens and hence there is no significant arsenic contamination of chicken products. However, the compound is passed unchanged in the litter which are then spread onto land for disposal.

What has become apparent in recent times is that there is considerable bioconversion of this compound to inorganic arsenates and arsenites. As roxarsone is water soluble, its potential to spread in ground water is large. Roxarsone is widely used around the world. More than 900 tonnes of it is released into the environment every year in the US. Chicken litter often contains 48mg/kg of arsenic. Land that has been used for such litter disposal has been shown to have substantially higher levels of arsenic. This is a cause of great concern (Cortinas 06).

Many other metals are used in intensive production units. Copper, zinc, selenium, cadmium, cobalt, iron and manganese are various used and much of this ends up as environmental contaminants (Steinfeld 06).

Salinization is a huge problem, particularly in lands where irrigation is used. Up to a third of the world's land is either affected or vulnerable. There are a number of different mechanisms causing salinization of land: evaporation of irrigation water, rising water tables either directly from irrigation or by the removal of trees for cropping/pasture. In rain fed crop lands, build up of salt is usually not a problem since the rain water flushes the salt away. Where water is applied to crops via irrigation, the dissolved salts in the irrigation water are progressively concentrated by the evaporation and transpiration of the applied water. This results in a paradox. Where water is applied by low volume methods such as drip irrigation, no water is available for flushing, the salt builds up. Where large volumes are used, build up of salt is reduced because of flushing (Pimentel 04).

Irrigation water can cause the water table to rise considerably. If the underlying ground has high levels of salt, this is dissolved in the rising water table and brought to the surface, eventually making the ground non-productive. Large areas of Australia, being once an inland sea, suffer from this problem. Finally, the water table can rise because of the removal of trees which keep the water table lower by extracting water which is then lost by transpiration. The rising water table brings with it large amounts of salt (White 97). Run off from these operations takes large amounts of liberated salt leading to rises in salinity of many rivers. In Australia, the Murray River is becoming more and more salty so that cities such as Adelaide closer to its mouth and which draw substantial amounts of drinking water from it, are likely to run into problems in the not too distant future.

Waterlogging from irrigation reduces productivity: water in the wrong place. Up to 60% of the water intended for the plants doesn't reach them. If drainage is not good, this water accumulates in the upper soil levels and once it has risen to root level, productivity drops. As an example 8.5 million hectares of land in India are affected by this, with a reduced yield around 2 million tonnes per annum (Pimentel 04).

Deforestation.

Deforestation has a number of major adverse consequences. The best known is its contribution to increasing green house gases. Loss of habitat and consequent extinction of a significant proportion of the world's fauna is also a major threat. Removal of trees has several other very substantial adverse effects. It increases water run off by as much as 15% and depending on the situation, this may substantially reduce the replenishment of aquifers. In other situations it can have the reverse effect by causing a rise in the subsurface water table leading to salinization.

Huge tracts of land have been cleared in many areas of the world for cropping and grazing. In South America, particularly in Brazil and Argentina, this has been particularly aggressive, with vast areas of land cleared either to grow soya beans to feed intensive animal production or to extend grazing land to supply the hamburger trade. Brazil lost 25,200 sq kilometres of rain forest in 2002, an area roughly 150 kilometres long by 170 kilometres wide. The area devoted to growing soy beans in Latin America more than doubled in the decade to 2004, rising to a massive 39 million hectares. This makes it the largest area for a single crop, dwarfing the 28 million hectares devoted to maize. However, the area of

forest lost to the extension of grazing land in Brazil is even greater than that from crop land expansion (Steinfeld 06). Our animal-based foods are a very poor exchange for the enormous ecological damage associated with feedcrop production and ranching in these regions.

Loss of biodiversity.

Humans have caused a massive expansion in a very limited number of species including ourselves. Less than 20 staple plant species supply the vast majority of plant-based foods and only 14 animal species supply 90% of animal-based foods. When put together, this represents a very substantial proportion of the world's biota leaving much less room for the estimated 14 million species that occupy the world.

Loss or severe degrading of the following habitats has been proceeding rapidly, much of it related to livestock production and aquaculture:

- Forests, which have the greatest overall biodiversity, are currently be cut down to extend pasture for ruminants. As example a further 24 million hectares of forest in the Amazon basin is projected to be converted to grazing land between 2000 and 2010. Much of this expansion is occurring piecemeal fashion leading to extensive fragmentation of habitat, markedly accentuating the problem. It also makes the remnants drier in creasing their vulnerability to fire which is used in the clearing process.

Many other examples of severe pressure on ecosystems can be found in South America: the tropical Andes mountain area, the Brazilian Cerrado region, the eastern Atlantic forests of Brazil, large areas of the neotropical Pampas in Argentina. These areas have enormous diversity which is threatened by this process to largely supply the hamburger and fast food broiler trade: a very poor bargain for the world.

- Wetlands variously drained, filled in or converted to aquaculture. Freshwater ecosystems are by far the most threatened. In the US for example 37% of freshwater fish species, 67% of mussels, 51% of crayfish and 40% of amphibians are either threatened or become extinct.
- Traditional farm areas which have undergone intensification causes a sharp reduction in biodiversity by a number of mechanisms. Remnant vegetation areas such as hedge rows and field edges

have been removed to increase the planting area. In large monocultures of herbicide resistant crops, herbicides eliminate not only weeds but also anything else which in turn eliminates many insect and bird species. Many pastures are planted with single grass species and weeds controlled with herbicides to increase livestock yields, markedly reducing the plant community diversity.

- Traditional farmland which has been abandoned or set aside under the general push for intensification. These lands quite often revert to scrub cover of very low biodiversity rather than regenerating into diverse forest regions. There is a conversion of the previous diverse pasture biota to a much more limited one associated with woody weed invasion.
- Rangelands, particularly the dry and semi-arid marginal lands are extensively damaged by livestock causing significant species loss, through erosion, desertification and woody weed invasion.

Other mechanisms of loss of biodiversity.

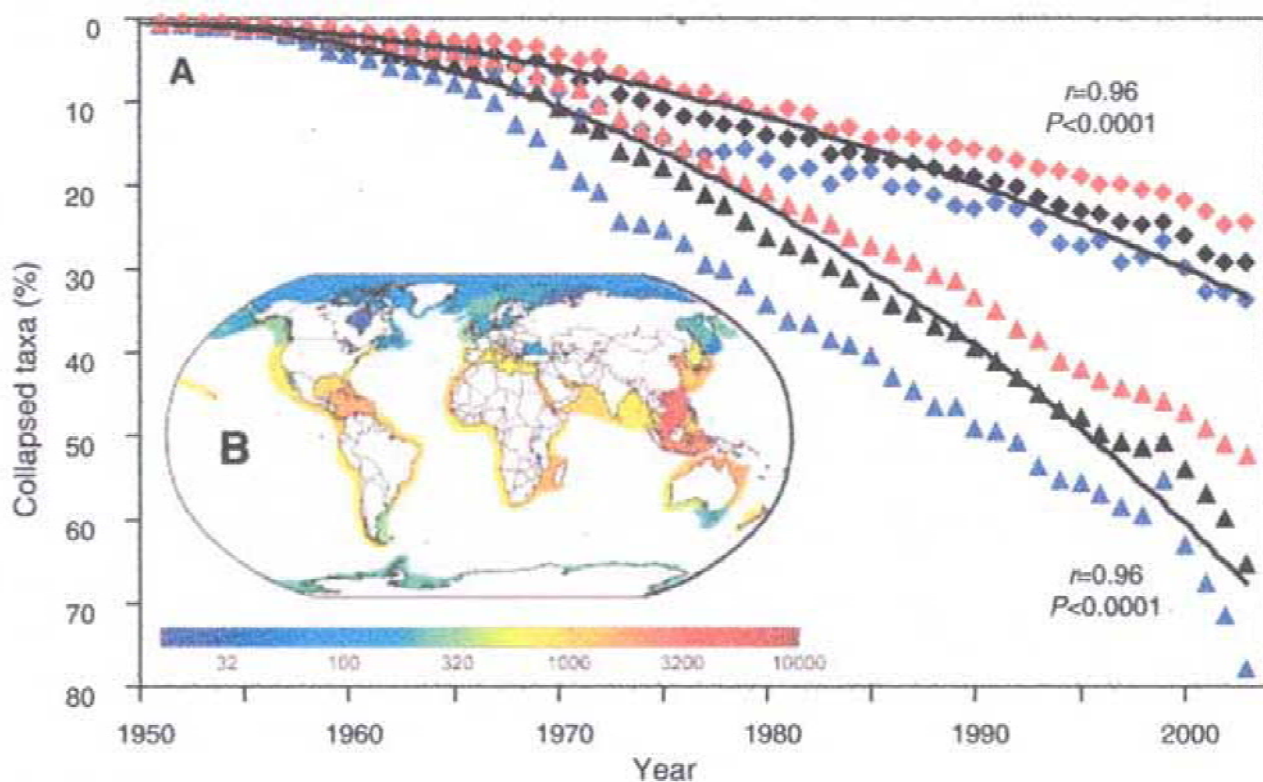
- Competition with wildlife through either predation or competition over food and water, particularly in Africa. In areas of Europe and North America, large predators have been re-introduced leading to conflict with ranch owners.
- Reliance on a very small number of breeds suitable for industrial scale production has led to the loss of a large number of earlier breeds. In Europe, 55% of mammalian breeds and 69% of avian breeds have either become extinct or are endangered. This represents a concerning loss of genetic stock. For example in the US, 90% of milk comes from one breed, Holstein-Friesian and 90% of eggs from White Leghorns (Steinfeld 06). This contraction of the gene pool may have major adverse effects if future living conditions change markedly such as with climate change.
- Pollution particularly of the marine environment has led to marked changes in the pre-existing flora and fauna often associated with algal blooms and toxic dinoflagellates from eutrophication. Also see the section on [dead zones](#). Toxins from algal blooms can affect a very wide range of organisms from shell fish to sea birds to cetaceans. Coral reefs are particularly vulnerable to eutrophication. Eutrophication related zooplankton increase has been the main driver of the massive expansion of jelly fish populations in many areas of the world, causing numerous problems. Acid rain has greatly affected biodiversity in freshwater habitats. Pollution from veterinary medicines such as growth promoters,

hormones, antibiotics and other medicines. Veterinary use of the anti-inflammatory drug diclofenac almost wiped out Indian subcontinent vultures.

Damage to the marine environment. Current fishing practices are:

- **At the limit of their capacity**
- **Damaging the sea bed and injuring birdlife and large marine animals.**
- **With the use of marine aquaculture, further depleting wild fish stocks, polluting the seas and damaging coastal habitats.**

Many fisheries are in steep decline or have been wiped out. Globally, the number of fishery collapses (defined as catches less than 10% or the historic maximum) have been accelerating with 29% of fisheries in large marine ecosystems in this category in 2003. If individual fish taxa are considered, around 65% of species are in this category (Worm 06).



Graph A showing the progressive decline in fish stocks. The top curve represents the yearly rate of numbers of collapsed taxa and the bottom shows the cumulative loss. The insert B shows the worldwide distribution of the number of species, indicating a falling diversity is most regions. (From Worm 06)

The overall catch has declined more slowly because as fishing fleets

having depleted one species they move onto another thus tending to maintain the overall catch. As example, following the collapse of the Canadian cod fishery, the number of crustaceans caught increased substantially. Most fisheries are below their historic maximum catches, for example Canada at 40%, US at 55% and the EU at 60% (Hilborn 03) forcing the large European fleets to move further afield. Worldwide, despite large increases in fishing effort, cumulative yields across all species has declined by 13% since the peak in 1994 (Worm 06).

Some commentators argue that this doesn't necessarily indicate that these fisheries will collapse but instead a new equilibrium will be gained with lower or different catches. This can be seen in the highly exploited Mediterranean (Hilborn 03). However, many disagree with such assessments. For an excellent review of the negative aspects of world wide fisheries, download "Fish Dish: Exposing the unacceptable face of seafood" from the World Wildlife Fund site (WWF 06). If for example the exhortations to eat more fish as part of a healthy diet were put into effect, serious short falls in supply would occur and the temptation to over exploit would increase. Current estimates would indicate that if major conservation programs are not put in place to conserve major marine fish stocks, close to 100% of all fisheries will collapse by the mid 21st century (Worm 06).

Some fishing policies to conserve numbers has had unexpected consequences. Setting size limits in an attempt to maintain populations selectively removes the larger more mature fish. Breeding success has been noted to rise exponentially with size with the largest older fish having a much higher breeding success rate, often orders of magnitude greater. This has been one of the reasons for steep declines in some fish numbers. A solution taken up by some fishery regulators is to establish substantial no-fishing zones, where older and much larger mature breeding stock is left undisturbed allowing their hatchlings radiating out from these zones. (Birkehead 05)(Worm 06).

Many fishing practices are very destructive. Problems relate to the discarding of undersize fish and other unmarketable species which rarely survive the trauma of being caught. Removal of large numbers of a particular type of fish may also cause a permanent alteration in the ecology so that predators previously eaten by the fish now eat the young of that fish. This is thought to be one of the major reasons why cod fisheries have not recovered with an explosion in crab numbers. Added to this is when many new fishing zones are exploited, no consideration is given as to how long these fish take to develop to breeding maturity.

Many fish types take surprisingly long times of decades to reach this stage and are readily threatened by even moderate fishing such as the orange roughy or the Patagonian tooth fish. Finally high demand and high prices have led to the use of cyanide fishing practiced illegally in many parts of SE Asia which lays waste to the whole environment. Often times these people are forced into this situation through desperation because of declining fish stocks associated with poorly regulated industrial fishing.

Exploitation of remote fisheries continues apace with little benefit to the local inhabitants. As example, the fisheries off Kiribati in the Pacific are now being very heavily fished by boats from China, Taiwan, and Europe extracting billions of dollars of fish, but giving a paltry few million to the local community. As an added "bonus", the fleets have bought sexual exploitation and HIV to the local community (Bohane 06). Since the dramatic decline of North Sea fisheries, European government subsidized fleets have spread much further afield, wreaking havoc on coastal fisheries of distant countries. These fleets off the west coast of Africa have significantly reduced the catch of the local fishermen, who have in turn boosted their protein intake from bush meat, leading to the subsequent further alarming decline of many endangered land animals through the bushmeat trade (Brashares 04). Industrial fishing off the coast of Chile has severely affected the local fisheries so that many have now turned to environmentally more damaging aquaculture.

The damage done by bottom trawling has only recently been appreciated. Because no one in the past looked very carefully, the damage done to sea bed habitats was ignored. Recent studies have shown long term damage in places to these fragile habitats and a minority of may recover (Hilborn 03). However, most sustain substantial damage with a reduction of species richness which in turn reduces productivity(Worm 06). Bottom trawling lead to a permanent change in the marine fauna, with scavenger species favoured. This leads to further pressure on other species because of predation on juveniles. Many jurisdictions have imposed controls on this type of fishery but in less well regulated parts of the world, it remains a significant problem.

Injury to wild life has been extensive. This has been widely publicized and public pressure has been placed pressure on some fisheries, many problems remain. The killing of dolphins and large seabirds has been highlighted and while some changes have occurred, much is still to be done. Here are some examples of the massive toll on wildlife (WWF 06):

Fishery	Damage to wildlife
Swordfish longline	<p>Longlines kill huge numbers of mako and blue sharis, making up 68% of the catch of Spanish longliners in the Atlantic.</p> <p>Illegal Moroccan drift netters kill an estimated 100,000 sharks a year in the Mediterranean. Similar figures are seen in other fisheries.</p> <p>Marlin are a large bycatch, and both the white and blue species are threatened with extinction.</p>
Tuna longline	<p>Over 250,000 loggerhead turtles are caught and more than half die. Large numbers of sea birds are killed including highly threatened species of albatross.</p>
Drift netting	<p>Illegal drift netting in European waters as estimated to kill more than 16,000 dolphins a year, many of which are threatened.</p>

Even though there have many advances in aquaculture, the problems of industrial scale farming also apply to aquaculture. It should be noted at the outset, the majority of farmed fish in the world, located predominantly in China, are fresh water vegetarian species and are much more environmentally acceptable. Most of the the table fish favoured in the west are carnivorous. Feeding fish to fish has always seemed wasteful of natural resources, with around 3kg of feed for every kg of farmed salmon. However, with some species fishmeal is being augmented with vegetable protein lowering the pressure on the supply of fish for fishmeal, but this has the negative effect of reducing omega 3 levels. Many of the improvements in food conversion ratios has been because of the increasing proportion of fish oil in feed, but this can alter the flavour of the fish considerably.

The industry and those that advise it feel that fishmeal fisheries are sustainable but many others express doubts. Around 53% of fishmeal world wide is fed to farm animals, 29% to pigs and 24% to poultry (Steinfeld 06). Such a use is a great concern in relation to sustainability. While the proportion used by poultry has fallen in the past two decades, there is still increasing demand from the expanding pig industry. While fish meal only forms a very small proportion of pig feed, it is a highly valued protein input particularly in the early weaned stage of development.

Statistics show that world fishmeal supplies have remained relatively constant for the past 15 years where as farmed fish outputs have

increased three fold in the same period. Part of the explanation for this may be that most of the fish stocks used for fishmeal such as sardines, anchovies and capelin, are close to full exploitation, requiring increasing diversion from animal feed uses. However, there is evidence of illegal fishing to bypass the quotas set by many countries to maintain supply in the face of heavy demand. Significant local problems have arisen in association with these fisheries. Reduction in small fish numbers in Chilean waters in part associated with heavy fishing to supply fish farms has led to a substantial reduction in sea bird numbers. Other major environmental problems are shown in the following table:

Problem associated with fish farm	Comments
Pollution from farms	Eutrophication, in some areas equivalent to the sewage output of large cities can lead to algal blooms and other problems of excessive nutrient levels. Antifouling chemicals, antibiotics and pesticides may cause problems, often being toxic to surrounding wild populations.
Escaped fish	Escapes which occur quite often allowing interbreeding with wild fish populations. Farmed fish are genetically less well adapted to life in the wild and escaped fish so weaken wild populations.
Diseases	They also reduce wild fish numbers by increasing parasite and harmful bacteria numbers which then attack passing wild fish. Major epidemics leading to closure of farms and collapse of wild fish numbers are well documented.
Harm to other wildlife	Large marine creatures such as sharks, seals and dolphins are often attracted farms. They can become entangled in the nets. If they damage the enclosures, they are often deterred by load underwater noise or are killed illegally.
Illegal activities	Fish farms are often used for "laundering" illegally caught wild fish.

For an extensive and balanced review of aquaculture of carnivorous fish see the Seaweb report (Seaweb 03).

Shrimp farming has been associated with the broad scale destruction of mangrove habitats particularly in south east Asia.

This leads to several more problems: the increased vulnerability of these coasts to typhoons and tsunamis, the extensive loss of fish breeding habitat and extensive pollution.

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