2. ESTIMATING THE SIZE OF ENVIRONMENTAL IMPACT

Finding real-life analogs to environmental issues and assessing potential impacts can be fairly straightforward when there is an appropriate frame of reference.

Finland's cultivated lands, traffic network, basic production infrastructure – even its cities – are largely a legacy of development in the 20th century. Not only is Finland's rapid emergence as a technologically advanced society a recent event, so are most of its environmental emissions. In the more populated parts of Europe this development has occurred over a longer time span and has been more intense.

There is extensive experience with environmental impacts associated with human activity. In many cases environmental impacts and risks can be easily assessed in light of decades of accumulated knowledge.

Consider, for example, the well-documented release at the Kaukas pulp mill, owned by the UPM-Kymmene Corporation. During June 2003, untreated waste water was inadvertently released from the mill located in eastern Finland. The release received extensive media coverage and was repeatedly deplored by the national media and environmental bureaucrats as the worst environmental disaster of the pulp and paper industry in decades. Russia, which had routinely taken harsh criticism from Finns about its handling of environmental matters, was suddenly demanding Finland never allow such a mistake to occur again.

The buried lede in newspaper accounts was that the water area strongly affected by the release was limited to just a few square kilometers of the lake and part of the Saimaa Channel. Ironically, the press was also giving coverage that summer to massive blue-green algae blooms covering more than a thousand square kilometers of eutrophied waters in the Gulf of Finland.

Available figures suggest the uncontrolled release from the Kaukas mill lasted less than a week and resulted in an overall additional oxygen demand (chemical oxygen demand and biological oxygen demand, COD + BOD) of about 3,400 tons, or 1.7 % of Finland's total accounted oxygen demand. The release peaked at 560 tons for a single day and the daily average release during June was 90 tons. The maximum daily average permitted at the time was 75 tons in a month.

Examination of existing records and discussions with water-quality experts suggest that just two decades earlier, the total oxygen demand for waste-water releases in Finland was about ten times higher than in 2003. In other words, Finland experienced several decades when the daily discharge from its pulp and paper mills was as high as a week of emissions from the Kaukas pulp mill at the height of its environmental emergency.

Many Finns still remember the days when the water near pulp and paper mills was clouded and foamy. Fish caught in nearby waters often had a funny aftertaste. Although the situation was far worse then, it was never described as a disaster. People went on with their lives and prospered. There are no reports of wide scale permanent damage to the Finnish environment.

Statistics provide an excellent foundation for assessing the relative magnitude of environmental impacts. The drawback is that statistics, as Mark Twain noted, can be manipulated to bend the truth. For example, Worldwatch Institute reports paint a view of the conditions in global environment quite contradictory to Bjorn Lomborg in his book *The Skeptical Environmentalist* /32/.

One approach to resolving these disparate views is to compare the figures used by both camps side by side. Although burdensome, an even better approach is to go back to the original source and make an informed assessment oneself.

Dredging as environmental destruction – mountain or molehill?

Most of us have some idea of what dredging involves. A large scoop or crab digs up the sea bottom, churning up loose sediment and making the water murky. If the bottom is sludgy, the water may smell bad.

Dredging activities are largely associated with the development and upkeep of maritime infrastructure. In the last decade, dredging activity in Finland has been subject to harsh regulation and an object of considerable press interest. Newspaper headlines exploit the popular notion that dredging is a filthy business and a major environmental problem involving hazardous chemicals in the dredging mass threatening marine ecosystems. Yet is this a fair portrayal of reality?

Dredging is basically underwater earthworks. A project to clarify the magnitude of dredging impacts entitled "The impacts and permitting process of harbor and channel projects" was commissioned by the Ministry of Transport and Communications, the Finnish Maritime Administration and major Finnish ports /10/. The general findings included:

- Dredging activity related to ports and channels serving Finland's foreign trade affects a tiny fraction of the sea bottom (annually no more than a few of square kilometers of the 53,000 km^2 of sea bottom in Finnish territory).
- Typically, the amount of suspended solids released into the water during dredging activity is 1–5 % depending on coarseness of the mass and the method used. Most suspended solids settle to the bottom near the dredging site.
- The amount of suspended solids released into the water during dumping is also about 1–5 % depending on mass coarseness and the method used. Again, most suspended solids settle to the bottom near the dumping site. A smaller amount is dispersed, but differences in turbidity or clarity in the water is usually imperceptible from the natural cloudiness of Baltic waters just a few hundred meters from the dumping site.
- There is no regional significance with regard to suspended solids from dredging activities. For example, in the Airisto Sea area in southwestern Finland (volume 4 km^3), dredging and dumping volumes are typically around 100,000 m^3 annually. Dredging and dumping increases the average level of suspended solids in the Airisto waters by about a tenth of a percent during the dredging period.
- Dredging spoils are typically dumped in bottom depressions to prevent the possibility of erosion.
- Dredging activity does not increase the amount of harmful substances in the sea, and disturbs annually perhaps one-hundred-thousandth of the legacy of harmful substances discharged by Finns into the sea.

- In theory, the upper limit for a harmful substance in sediment or the maximum acceptable risk (MAR) level should correspond to 5 % impact on the ecosystem. In other words, if a lake bottom is fully covered with sediment having an upper limit concentration of a harmful substance introduced by human activity, 95 % of the ecosystem is safe. In the sea, in fact, the impact would likely be smaller because of current action flushing the sediment surface.
- The lower limit value is supposed to correspond to a harmless level of chemical substance.
- The average content harmful substances in suspended solids stirred up by dredging activity in Finland is usually lower than in naturally occurring suspended solids in the water mass.

Figure 2.1 shows the impact magnitudes relevant to port and channel construction projects.

Finland's public discourse has extensively dealt with harmful substance levels in dredged sediments. Public attention typically focuses on outlier samples that reach or exceed maximum limit levels, even if they are not representative of the larger sample batch. The outlier figure is then compared against an unofficial guideline recommendation for the harmful substance.

Indeed, no matter what the human activity in the area, some harmful substance content of surface sediments will always exceed background levels. In certain spots, samples taken from the top few centimeters of surface sediment can show significantly higher values than in the sediment only slightly deeper. Moreover, limit values may ignore natural variations in substance content.

For example, the surface sediments in the waters near the town of Tornio at the top of the Gulf of Bothnia typically possess chromium levels in the range of 88–6,700 mg/kg of dry weight. While the area hosts Europe's largest chromium mine, most of the chromium found in the area is introduced by the Kemi and Tornio rivers as the result of natural erosion. In the guideline on dredging and dumping prepared by the Finnish Environment Institute /82/, the lower limit for chromium (guideline value) is 65 mg/kg and the upper limit value is 270 mg/kg of dry weight. Although the sea ecosystem in the sea near Tornio has bottom sediments with chromium content well in excess of allowed limits, no damage has been detected /81/.

Examining the dredging process more closely, we see that a layer about one-meter thick is scooped off the bottom, raised to the surface and deposited in a barge. The mass mixes so that differences in hazardous substance concentrations are equalized. The mass is then dumped back into the sea at the dumping site, further eliminating concentration differences. When the surface layers are removed from the dredging and dumping sites, a biologically active surface layer forms over the virgin dredging mass. The outcome is a nearly pristine bottom at both the dredging and dumping sites (Figure 2.2).

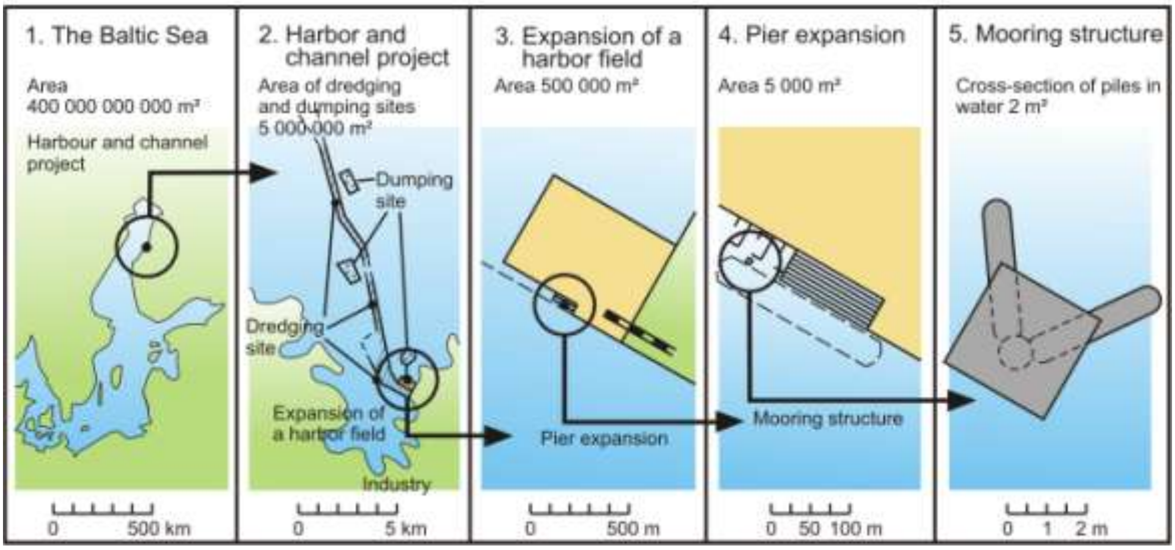
Size of Investment		Mass quantity	
Tiny	< 0,1 million euros	Tiny	<1 000 m³
Very small	0,1 - 1 million euros	Very small	1 000 - 10 000 m³
Small	1 - 10 million euros	Small	10 000 - 100 000 m³
Medium size	10 - 100 million euros	Medium size	100 000 - 1 000 000m³
Large	100 - 1000 million euros	Large	1 000 000 - 10 000 000 m³
Very large	> 1000 million euros	Very large	>10 000 000 m³

Fill or cut area in the bottom		Duration of environmental impact	
Tiny	< 0,1 hectares	Very short	< 1 day
Very small	0,1 - 1 hectares	Short	1 day - 1 month
Small	1 - 10 hectares	Medium	1 month - 1 year
Medium size	10 - 100 hectares	Quite long	1 year - 10 years
Large	100 - 1000 hectares	Long term	10 years - 100 years
Very large	>1000 hectares	Very long term	>100 years

Suspension, sedimentation	Current speed	Erosion on dumping sites
Not detectable	Very weak, < 0,2 m/s	Not detectable
In common range	Weak, 0,2 - 0,5 m/s	Within natural variation
10 x normal	Moderate, 0,5 - 1,0 m/s	Considerably larger than natural
100 x normal	Strong, 1,0 - 3,0 m/s	Significant part of mass will erode
1000 x normal	Very strong, over 3,0 m/s	Major portion of mass will erode

Average amount of harmful compounds in dredged and dumped mass
Minor (under the target value or the background level at the dumping site)
Within the background variation at the dumping site
Dirty (over the target value and background concentrations at the dumping site)
Polluted (over the limit value)
Heavily polluted (one order of magnitude over the limit value)
Very heavily polluted (two or more orders of magnitude over the limit value)

Character of the ecosystem
Insignificant (bottom or harbor area, dumping site, poor or spoiled bottom)
Ordinary
Notable (spawning area, wandering route of the fish)
Quite important (protection area)
Very important (key area for biodiversity or ecosystem)



Figures 2.1. Scales of magnitude considered in international harbor and channel construction projects /10/.

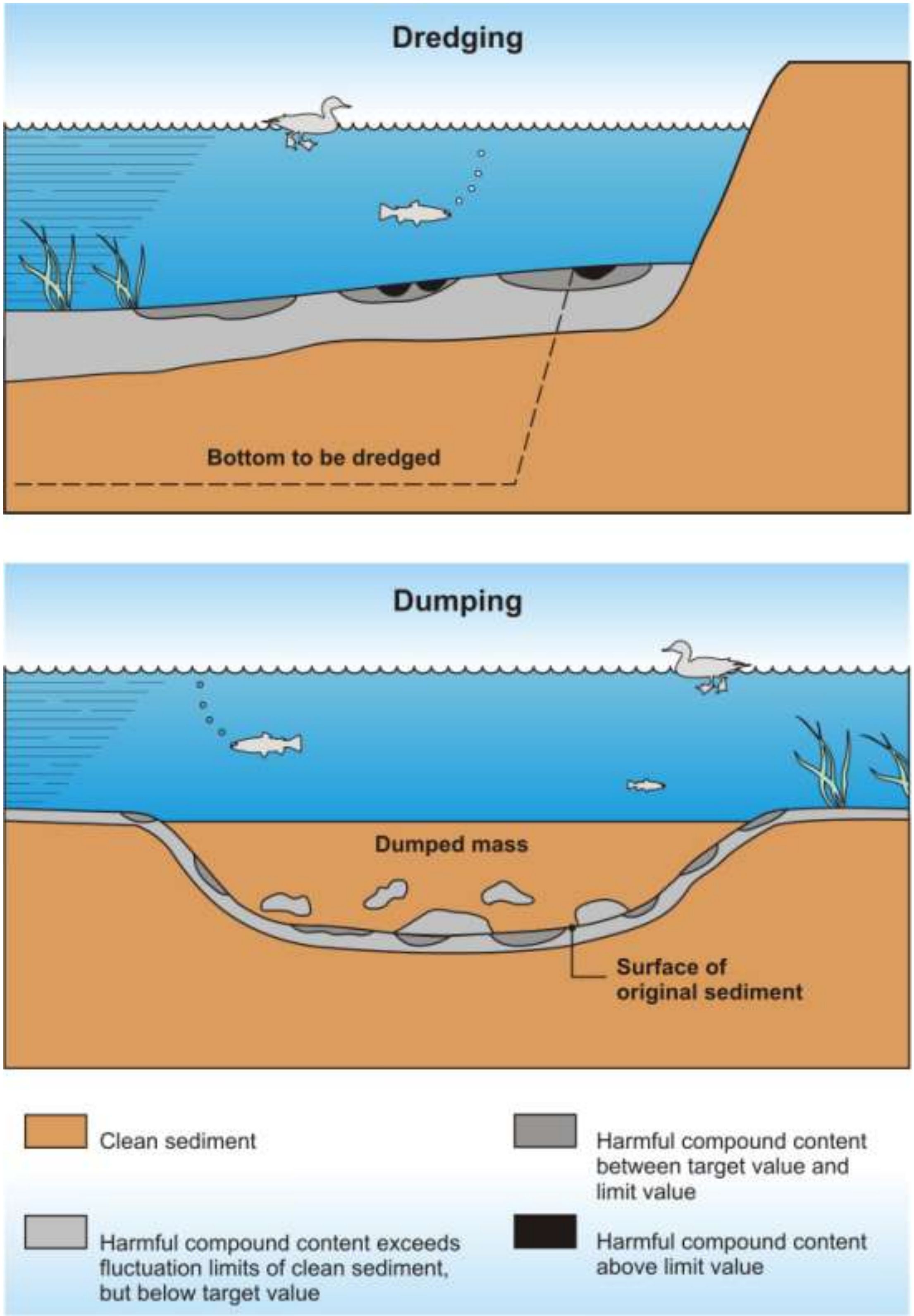


Figure 2.2. Impacts of dredging on the harmful substance content of the biologically active surface layer at the dredging site and the dumping site.

While dredging activity stirs up sediments, storm waves, sea currents, runoff and biological activity generate suspended solids at levels several orders of magnitude more efficiently.

Consider the Gulf of Finland. It has a water volume of about 1,000 km^3 and mean water depth of less than 40 m. The solid material content of water mass in the Gulf of Finland is typically on the order of 2 mg/l or more. Thus, there is about 2 million tons of solid material floating in the Gulf of Finland on any given day. If current velocity is 5 cm/s, the flux of solid material is typically 300 t/(km x day).

Now consider the effects of a powerful storm from the west in the Gulf of Finland. Significant wave height reaches 7.5 m at the mouth of the Gulf of Finland and 4.5 m at the eastern end of the Gulf of Finland. The loosest surface sediments start to erode throughout the Gulf of Finland. In the areas of breaking waves or loosest sediments, solid material content commonly exceeds 1,000 mg/l and may exceed 10,000 mg/l close to the bottom /6, 27, and 79 /.

Based of an order of magnitude estimate using /59, 71, and 78/ the storm easily adds 10 million tons of suspended solids in the water mass of the Gulf of Finland. The flux of solid material typically increases by more than an order of magnitude, and suspension is especially heavy close to the bottom.

The surface sediments in the Gulf of Finland are hardly virgin /30/. The concentrations of cadmium, mercury, TBT and certain other harmful substances commonly exceed the lower limit value used in Finland. However, the lower limit value used in Finland is often a fraction of the value used in other countries for the same substances /26/. In any case, the ecosystems has adjusted to this environment including the varying flux of suspended material, the dynamics of surface sediments and the heavy suspensions near the bottom during disturbed periods.

A one-million ton dredging and dumping project may temporarily add 200 tons of suspended solids into the water mass of Gulf of Finland. Since the content of harmful substances in dredged material tends to be lower or similar to that of the bottom and suspended material floating around, dredging in general poses little, if any, threat to marine life in the Baltic.

The most famous dredging case in Finland involved the construction of the Port of Vuosaari in eastern Helsinki. The project called for transferring cargo handling operations from the southern shore of downtown Helsinki to the remote Vuosaari area in the eastern part of the city. The goal was to get heavy road traffic out of the city center and convert the former harbor areas into residential housing districts. From the start, the project faced opposition from the environmental administration and the media. The permitting alone took over ten years.

During the final phase of the harbor permitting process, a small area with high TBT content was discovered. The site had earlier been directly below a floating repair dock often used to sandblast paint off of ship hulls.

The *Helsingin Sanomat* followed the case for three years. Initial articles remarked on the “sky-high” TBT levels of individual samples and labeled the person in charge of the harbor dredging an environmental criminal. This was followed by a series of articles dealing with the possible impacts of TBT on the environment. Even the EU Commission and the EU Parliament got involved; initiatives were submitted by several environmentally active politicians. Considerable amounts of ink were devoted to publishing the views of concerned letter-writers and journalists.

There were even horror-story articles on TBT content in Vuosaari fish and the possible dangers to human health.

The Ministry of the Environment decided to issue strict unofficial limit values for TBT levels in sediments. Some of the more problematic outlier samples had TBT levels two orders of magnitude larger than the upper limit. In the end, the environmental administration required a massive dredging operation isolated by an extensive dredging curtain and entombment of the TBT-containing mass below the harbor field.

What would have happened if this exceptional dredging project had been implemented using traditional backhoe dredging and dumping of the dredging spoils at sea? This scenario is considered in Appendix 2. Given the years of controversy surrounding this particular dredging operation, the analysis offers some rather sobering findings:

- Dutch studies notes that a standard ocean freighter releases about 0.2 kg of tributyltin a day. Thousands of TBT-painted freighters visited Finnish harbors each year for decades, yet environmental problems from TBT were never detected. Addressing Finland's parliament, former environment minister Jan-Erik Enestam estimated that TBT emissions in Finnish waters were on the order of 20,000 kg a year in the 1970s and 1980s, and that such emissions had been halved by 2004 /9/.
- The Vuosaari dredging mass contained about 100 kg of TBT. In a standard dredging operation, about 10 kg of this would have been stirred up and mixed with seawater. That quantity corresponds to the emissions of a traditional ocean freighter over two months. In other words the suspended amount would have corresponded to the legal emissions of an ocean freighter legally anchored in Vuosaari for two months at the time of construction.
- Dredging does not add TBT to the sea. Nearly all TBT from the dredging would have been covered on the sea bottom at the dumping site, where it would have gradually broken down and vanished over time. The resulting bottom would have been cleaner at both the dredging and dumping sites.
- The organotin content in Vuosaari fish averages 20–50 μg/kg. The European Food Safety Authority (EFSA) estimates that a person can ingest an average of 0.25 micrograms of organotins a day per kilo of body weight without health risk. This limit contains a safety factor of one hundred /51/. Basically, a fairly slender woman could eat 400 grams of Vuosaari fish daily and the health risk would still be smaller than if she drank one glass of wine each month.

The bottom of the Baltic Sea certainly shows signs of human activity, but dredging or other operations generating marginal amounts of suspended solids are not problematic. Indeed, dredging typically yields a cleaner sea bottom. Working in tandem, the Finnish environmental administration and the Helsinki-based mass media have succeeded in making a mountain out of a molehill.

Shifts in natural wealth and diversity

While putting issues into perspective using familiar activities and statistics are helpful in environmental assessment, comparison between different types of environmental impact remains difficult. For example, it is from the above discussion to relate the waste water release from the Kaukas pulp mill to, say, a planned harvesting of timber, an oil spill, or the lifecycle effects of a landfill.

The matter can be approached by examining changes in natural wealth and biodiversity caused by environmental impacts. The relevant parameters here are the relative magnitude of the change, the scope of the area affected, and the duration of the impact.

Working definition: The environmental impact of a particular phenomenon, action or activity can be determined by multiplying the relative intensity, scope, and duration of the impact. Use of a weighting factor for the relative natural value of the impacted area makes comparison with impacts in other areas possible.

The advantage of this approach is that anybody can assess an environmental impact merely by making the required calculations. In many companies and administrative offices, decision-making on even complicated issues is routinely based on similar simple but understandable calculations.

One should note though, that nature in itself is a process of constant change, even if it seems an ecosystem at the local level is fairly stable over the medium term. Life evolves along with shifts in natural conditions and population dynamics. From this point of view the idea of environmental balance is an illusion /20/.

Since the last ice age ended over 10,000 years ago, the average yearly temperature in Finland has fluctuated over a range of several degrees Celsius. During that time, the geographic distribution range of the Common Hazel (*Corylus avellana*) has shifted north and south in Europe across a band over 1,000 km wide. Forest fires, storms and floods have had dramatic effects on local ecosystems over short periods. There have been years when mole populations exploded. Whenever change came, some species prospered at the expense of others.

Since multi-celled animal life became established over 600 million years ago, the geological record suggests that events such as major meteorite impacts, volcano eruptions and ice ages have managed to seriously affect or wipe out large swaths of surface life. Every time, even if it may have taken a few million years, natural wealth and biodiversity has reemerged.

Similarly, natural systems adjust to anthropogenic environmental effects. Small shifts are even difficult to judge as to whether the overall impact was positive or negative. On the other hand, large shifts as a rule lead to degradation of natural wealth and biodiversity in the short run.

Non-linear change is typical of most environmental impacts (Figure 2.3). A tiny change can weaken the living conditions for one species, while improving conditions for another.

Negative short-term effects increasingly dominate as the magnitude of the impact grows, because large changes overwhelm nature's ability to absorb shocks. The loss of a single species can topple an entire ecosystem. Gradually, however, nature reestablishes order in the context of new dynamic ecosystem.

The environmental impact of a given phenomenon, action or activity is difficult to estimate precisely. Ecosystems are sometimes evaluated by deconstructing them into components (mammals, fish, birds, insects, etc.). Natural wealth can be measured in terms of ecosystem biomass and diversity in number of species. To achieve comparability across ecosystems, a weighting factor can be applied to ecosystem components. For example, stocks of fish with high commercial value are distinguished from stocks of fish with low or no commercial value. The relative impact can be estimated by help of changes from the pre-impact situation (Figure 2.3).

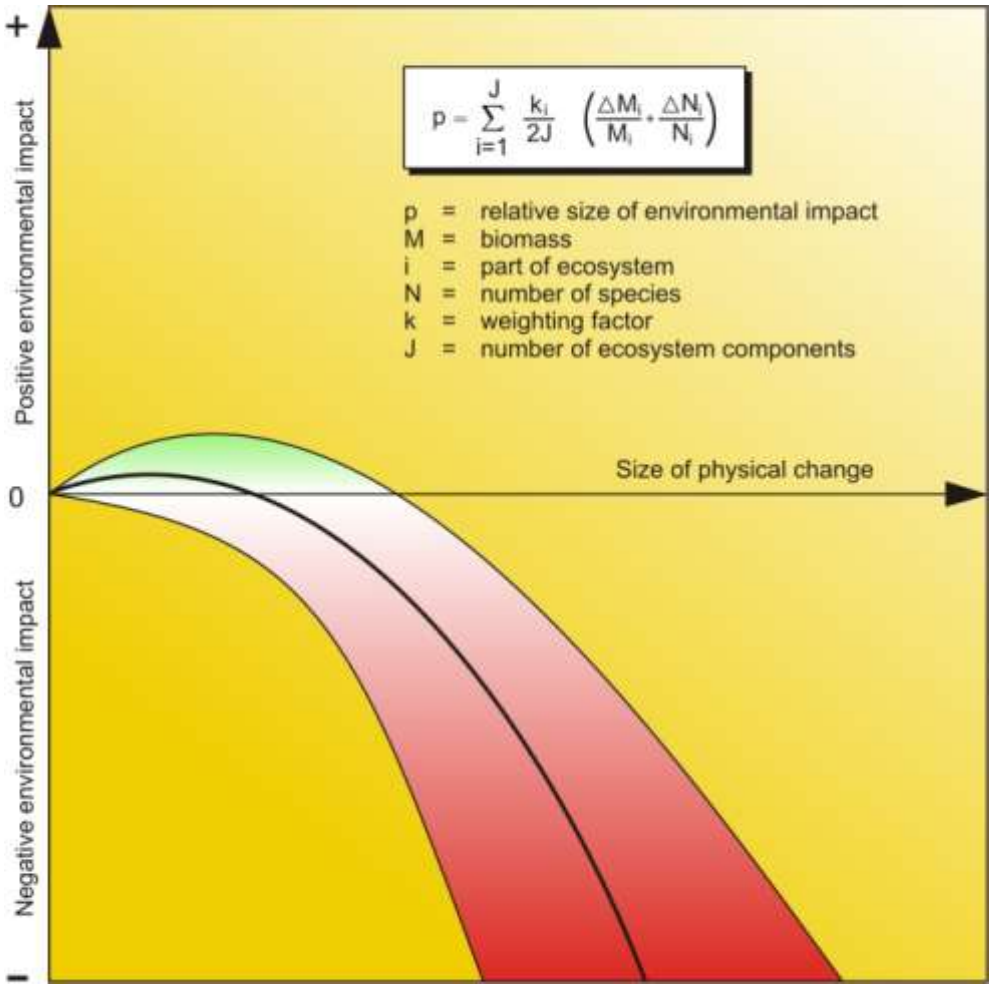


Figure 2.3. Dependency of environmental impact on magnitude of external changes.

The application of weighting factors is slightly problematic in practice as multiple valuations are involved. One needs to keep in mind the theoretical motives for applying weighting factors – the goal is not an exact figure but a rough estimate of the magnitude of the impact. As long as the nature of the impact is clear, one can make a usable assessment.

Figure 2.4 presents typical magnitude estimates of environmental impacts from various human modifications of the natural environment. Clearly, when a grove of trees is cut and replaced with a storage yard, the natural wealth of the area is diminished. Even so, some species can benefit from the change; for example, the warm updraft from the asphalt in the late afternoon draws insects into the airspace above the yard, creating feeding opportunities for swallows.

While natural diversity is generally impoverished by field-clearing and monoculture, the relative size of the impact is location-specific and depends on the site's original condition and the surrounding environment. If a largely forested area is opened up with a field, it could even increase biodiversity in the area.

City-building has typically been considered highly destructive of natural wealth and biodiversity. In contrast, in residential suburbs gardens and parks can largely compensate for the natural wealth and biodiversity lost through urban construction, parking lots and other infrastructure.

It is not always easy to anticipate the scope of impact of a given phenomenon, action, or activity. The strength of the impact varies across parts of the primary impact area, and may be reflected outside the primary impact area as various external factors interact.

A field, for example, influences the ecosystem of the surrounding forest and vice versa. Biodiversity is particularly rich in the transition zone. The distinguishing of how strongly particular areas are affected improves the accuracy of impact magnitude estimation.

The duration of impacts from various phenomena and actions vary greatly in nature. Nature has the ability to recover even from large environmental changes (e.g. revegetation after forest fires, breakdown or sedimentation of hazardous substances) and to adjust to changes in the ecosystem.

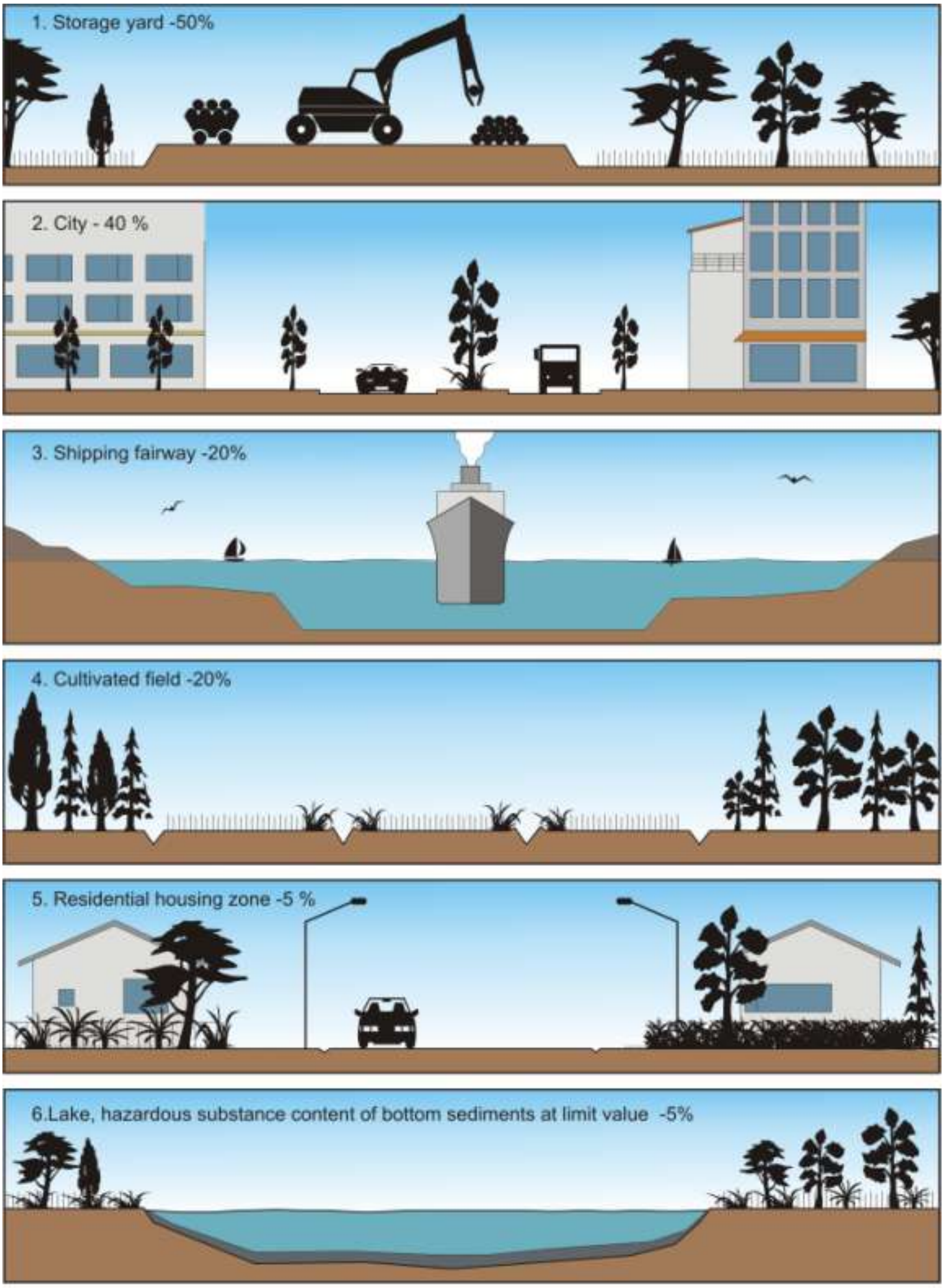


Figure 2.4. The relative intensity of impacts of human activity on various environments.

The time frames of various environmental impacts are described in Figure 2.5. In **Situation a)**, the environmental impact lasts essential as long as the physical event. This type of effect (e.g. noise and artificial lighting) is common at worksites. This category also includes small one-time emissions into water or the atmosphere.

Situation b) involves an immediate shock to the ecosystem and long recovery such as a large oil spill in Finland's southern archipelago. The direct impacts are the despoiling of shorelines and death of water birds. The impact on the local ecosystem may also be cumulative. It can also reflect to the coastal areas of the Arctic Ocean and the North Sea by reducing the number of migrating birds. Recovery of the immediate local ecosystem to its former state can take a long time.

Situation c) shows the life arc of a typical construction footprint. Site preparation and construction activity, for example, typically have larger environmental impacts than the much longer period when the structure or facility is in use. At the end of the facility's lifecycle, landscaping and other remedial measures can be applied to bring the site back to an environmental condition even better than originally.

Situation d) highlights cumulative environmental impacts that persist at a high level long after the physical cause of the impact is gone. The phenomena described here include the climate change and ozone layer depletion.

We do not necessarily ascribe the same value to all areas for their natural wealth and biodiversity. For example, the Amazon rain forest or the Ruissalo natural park area near Turku could be considered more important per surface area unit that land in the mid-Sahara or open sea in the mid-Atlantic. A weighting factor for a specific area allows for recognition of its ecological significance, including the presence of endangered species and links to larger ecosystems such as resting and feeding grounds for migrating geese or turtle breeding grounds.

If the weighting factor for a specific area is increased, the weighting factor for other areas should be decreased correspondingly. This allows for calculation of the relative natural significance of individual areas. The overall equivalent surface area, e.g. the Earth's surface, remains constant. When a weighting factor is applied, it naturally is based in accordance with the overall situation, and should not be applied capriciously.

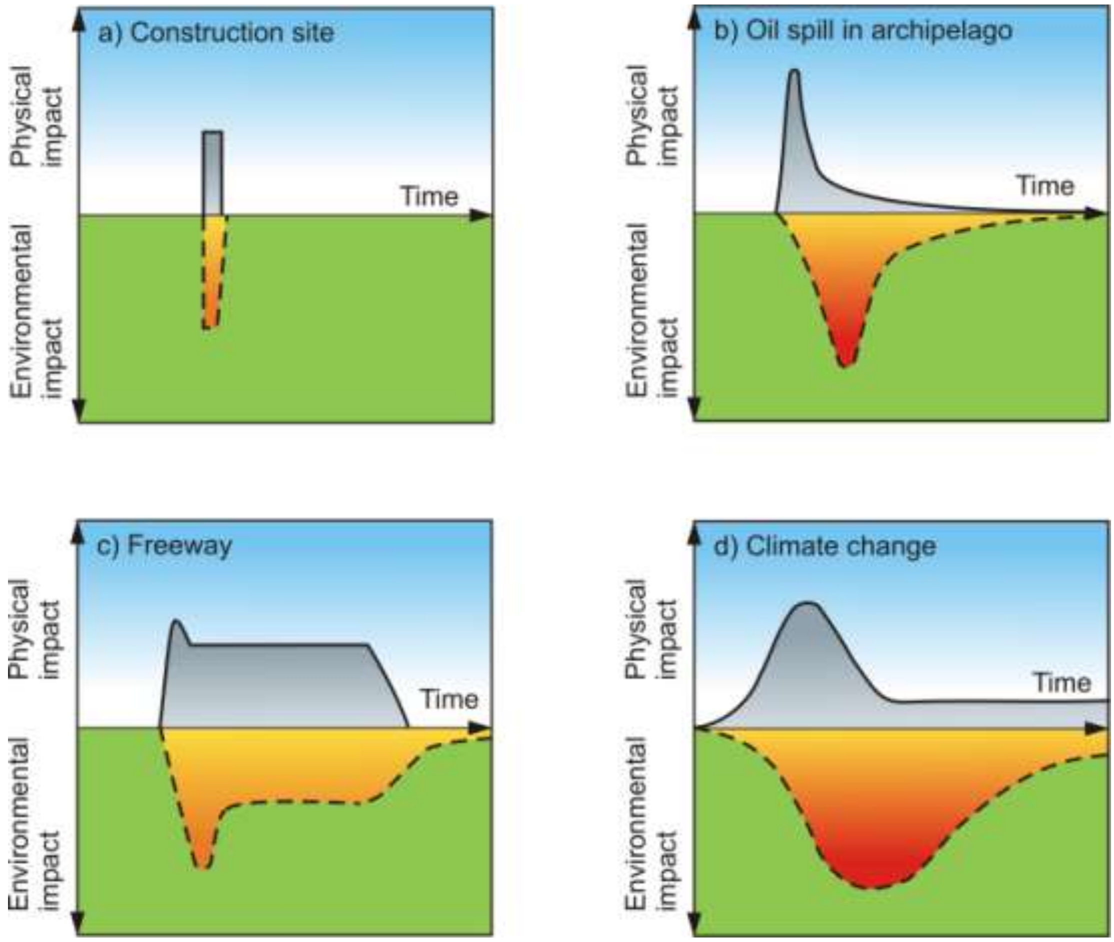


Figure 2.5. Attenuation of physical and environmental impacts in hypothetical situations.

Open-ended environmental impact scale

Equipped with the means for estimating environmental impact, we can now rank them by size. Figure 2.6 places environmental impacts from various phenomena, actions, and activities on a logarithmic (exponential) scale similar to the Richter scale of earthquake activity. When new impacts are ranked alongside familiar impacts, their relative significance becomes easy to assess.

Environmental impact is organized in ten- and thousand-fold increments on the scale. Thus, if the base level is one meter, then the thousand-fold increase would be one kilometer. A million-fold increase would be a million kilometers, or roughly the distance from the Earth to the Moon and back.

In the following examples, the approach is visualized for a dredging operation. Appendix 3 provides detailed explanations of how the values for the examples in the Figure 2.6 were calculated. The reader is encouraged to recalculate these reference points and other examples using independent information to get a feel for this proposed method and its accuracy.

Figure 2.6 shows the huge range of differences in the possible magnitudes of environmental impact. The impact of fossil fuel use is quite substantial, matched only by a major military conflict. Widely discussed activities such as landfills, in contrast, are shown to have relatively tiny impacts.

The UN's Intergovernmental Panel on Climate Change (IPCC) estimated that the average global temperature will increase between 1.4°C and 5.8°C in the next one hundred years if nothing in done to control greenhouse gas emissions. Besides higher temperatures, climate change is predicted to cause more violent hurricanes and storms, as well as shifts in precipitation patterns and amounts. Consequences of global warming include the melting of sea ice, permafrost layers and glaciers, a rise in sea level, and local changes in farming conditions. This is dealt with more extensively in reference /25/.

We use the IPCC scenario for a rise in the average global temperature of 3°C in our calculation (see Appendix 3). It is good to remember that the history of environmental science has been replete with theories and hypotheses that conveniently reinforced the prevailing social order or political regime. Despite widespread support for these views, they were eventually replaced with a new scientific paradigm /3/.

For example, less than 400 years ago, Galileo was put under house arrest for publishing his *Dialogue Concerning the Two Chief World Systems* because he ostensibly mocked the Catholic Church's case for the Aristotelian view that the Earth was the center of the universe. Today, few of us cling to a geocentric view of the universe, but it was once a controversy.

A number of respected scientists have challenged the assumptions underlying the IPCC scenarios. Some argue that the impact of carbon dioxide emissions on climate is negligible, while others claim the IPCC has been overly cautious and that the emerging risks to the global climate may be worse than projected. Researchers disagree as to whether the current temperature rise is human induced or not, and if there is a human contribution, how much. While we work forward based on the IPCC predictions we should remain open to all sides of this scientific discussion and even be willing to fund research that appears to be politically incorrect.

In many cases, human activity can have not only social and economic, but clear environmental benefits. Those should be included in an environmental impact assessment. Sample efficiency calculations connected to cutting greenhouse gas emissions are provided in Appendix 4.

The positive impacts of the proposed Vuotos reservoir and hydroelectric plants, for example, are estimated to be an order of magnitude greater than the negative environmental impacts noted in Figure 2.6. We now have an important question to make. What is the point of using the habitat directive to block this ecologically beneficial, economic and locally supported project when the environmental values that the directive is supposed to protect in Vuotos are destroyed anyway by uncontrolled global warming?

This calls into question the rationality of many European Union environmental policies from treating waste and marginally problematic soils with massive fuel-consuming operations to decade-long permitting processes in projects that cut greenhouse gas emissions.

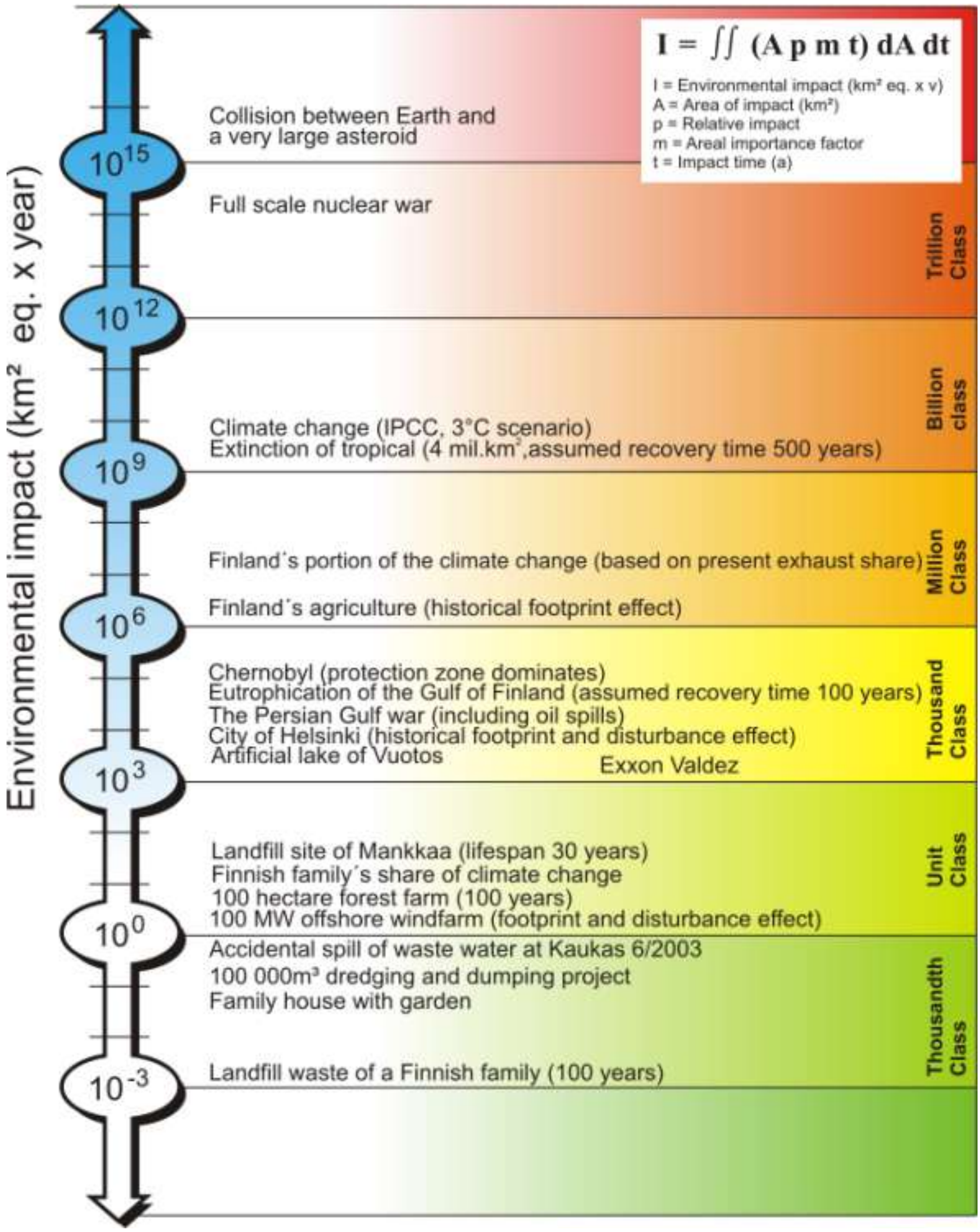


Figure 2.6. The open ended environmental impact scale showing the relative impact of various natural and man-made events and activities.

Case: 100,000 m^3 dredging and dumping project

Here, we consider a fairly large dredging and dumping project along the Finnish coast. Most of the 100,000 m^3 mass to be dredged is fine sediment. The average harmful substance content in the mass is less or similar to levels found in surface sediments at the dredging and dumping sites and in suspended solids in the area.

The project's footprint effect is assumed to cover the 6-hectare dredging site and a 10-hectare dumping site that takes into account dispersal of the dredged spoils in the water. The relative environmental impact at the dredging and dumping sites is initially assumed to be 25% (we have the water mass, sea bottom, and air to consider). The ecological weighting factor for the water area is assumed to be 1.5, used here for shallow waters. The ecological condition of the bottom is expected to recover linearly over two years (initial recovery is fast, but full recovery takes longer). The footprint effect from the dredging and dumping would be:

$$V = - (0.06 + 0.10)\ km^2 \times 0.25 \times 1.5 \times 0.5 \times 2\ years = - 0.06\ km^2\ eq. \times year$$

The added cloudiness and disturbance associated with the dredging and dumping operation is assumed to have an environmental impact extending over 15 hectares around the dredging site and 30 hectares around the dumping site. The relative environmental impact is conservatively assumed to be 30 %. This includes the effect of driving off fish, which simply increases their numbers elsewhere. The weighting factor is again 1.5 and the duration of the impact is essentially the same as the length of the dredging operation, i.e. three months.

The clouding and disturbance effect is:

$$V = - (0.15 + 0.30)\ km^2 \times 0.3 \times 1.5 \times 0.25\ years = - 0.05\ km^2\ eq. \times year$$

The operation's local environmental impact value would thus be - 0.11 km^2 eq. x year. Harmful substances are a minor component in this case.

The environmental impacts of human activity

The annual environmental impacts from a company, public-sector organization, or even a domestic household's daily activities, can be described in terms of square-kilometer equivalent. This is easy to determine as long as the impacts are nearly linear. Problems arise, however, when considering cumulative impacts and non-linearities. The matter can be handled with similar simplifications as in the calculation of climate change impacts in Appendices 3 and 4.

Below is a case summary of the environmental impacts from operations at a fairly large port in southwestern Finland, including the effects of sea traffic in the harbor area. The harbor has been subjected to rigorous permitting processes and monitoring programs connected to its development and operational impacts. The environmental effects of harbors, sea traffic, and construction of harbor structures are detailed in a separate appendix of reference /10/.

Case: Square-kilometer equivalent comparison of annual environmental impacts of port operations and related sea traffic

Port activities

Carbon dioxide emissions from energy use	- 3.6 km² eq.
Harbor fields and channel areas, footprint effect	- 2.0 km² eq.
Dredging and dumping activities	- 0.1 km² eq.

General impacts of sea traffic and port activities

Water supply and management waste water from ships	- 0.2 km² eq.
Garbage services for ships	- 0.1 km² eq.

Environmental impacts from navigation in the harbor area

Carbon dioxide emissions	- 18 km² eq.
Nitrogen oxide and sulfur dioxide emissions	- 1.0 km² eq.
Tributyltin emissions from foreign ships (now eliminated by international treaty)	- 0.1 km² eq.
Other effects, total (risk of accident, erosion caused by sea traffic, etc.)	- 0.2 km² eq.

Scale of impact (see Table 2.1):

Comparison of environmental impacts of port activities with other common activities:

Harbor activities (1,500 employees)	- 0.004 km² eq./employee
Finnish commercial agriculture (50,000 employees)	- 0.1 km² eq./ employee
Finnish forest industry (50,000 employees)	- 0.25 km² eq./ employee

On the basis of this analysis, the best and most cost-effective way to reduce environmental impacts is to improve the efficiency of service for scheduled line vessels. If line vessels can balance traffic delays by more efficient cargo handling and service in port, fuel consumption will be reduced (a large ship uses 50% more fuel per nautical mile at full speed than at its optimum speed). Carbon dioxide emissions are reduced as well as sulfur and nitrogen oxide emissions.

Eco-balance

The term “eco-balance” is used here to compare a given area’s current environmental wealth and biodiversity against the original situation before, say, industrialization or a population explosion.

It is usually quite easy to identify the main phenomena or actions affecting an ecosystem. The scope and intensity of the impact itself, as well as the scope and intensity of the change, can be estimated using the above described method. We take Finland as an example.

Finland is a sparsely populated and industrially sophisticated country with 5 million people. Population growth is minimal and even set to decline in coming years. Emissions of hazardous compounds have fallen significantly over recent decades. This is reflected in improvements in air and water quality.

Out of Finland’s total land area of 337,000 km^2, some 170,000 km^2 is commercial forests and 20,000 km^2 cultivated fields. Populated areas account for about 6,000 km^2 and the national road network covers about 1,000 km^2.

Over 10 % of the land surface in Finland is protected under various programs. Restrictions and guidelines are designed to reduce the impact of human activity in protected areas. Zoning options are also limited.

Changes in the wealth and diversity of Finland’s natural heritage have been fairly minor in the past century. Even as certain species have vanished from Finland, they have been replaced by new species. Some changes are the result of natural fluctuations in populations; some the result of changed conditions (e.g. development of new agricultural and forestry practices).

Table 2.1 provides the estimated eco-balance and its rate of change for Finland. Weighting factors for particular areas have not been included. This estimate indicates that the eco-balance in most areas is close to the original. At present, the overall direction of change is positive.

It is possible to make several conclusions from these calculations. Forestry, agriculture, and other human activities are largely responsible for the legacy of fractured ecosystems and somewhat degraded water supplies. On the other hand, these activities have been the basis for the social and economic development of Finland. The situation has largely stabilized.

Construction of new city areas, along with the building of roads and highways, while often central to environmental disputes, exert only a minor impact on eco-balance. Often these changes are zero-sum. As eco-balance deteriorates in an expanding urban area, it improves elsewhere through depopulation of rural areas and the abandonment of farmland.

Harmful substances central to the public debate (heavy metals, TBT, PCBs, etc.) are estimated to have minor impacts on eco-balance. The largest problems by far are caused by phosphorus and nitrogen compounds used in fertilizers getting into water systems and sulfur and nitrogen compounds released into the atmosphere.

Emissions resulting from industrial accidents in the process industry have received extensive press. Yet, the small oil spills at the Naantali oil refinery and the waste water releases from the Kaukas pulp mill are miniscule in comparison to the amount of emissions released under permit. The widely published emergencies and conflicts, therefore, seem to be more issues of minor nuisance and quality of process management than ecology.

Climate change has begun to manifest itself as a rise in Finland's average annual temperature. For the past 15 years, winters have tended to be mild and fairly short. The number of bird species seen in Finland tends to increase in warm years. Warmer weather promotes eutrophication effects in water bodies.

Although the strengthening of the greenhouse effect does not appear in the national eco-balance, it has the potential to disrupt Finland's eco-balance far more than Finland's entire legacy of human activity. The conifer forests of Southern Finland could well disappear, higher sea level would reduce Finland's surface area, and the wetlands of the Bay of Liminka (a Mecca for birdwatchers), would vanish. Changes in precipitation would induce profound changes in natural hydrological systems.

The environmental problems in some other countries differ in type and scale from those in Finland. The calculation of eco-balances elsewhere in the world would add some perspective here.

The environmental problems facing certain populations in Africa are discussed for example in reference /18/. Exploding populations may force people to seek sustenance in new areas, so more trees are felled and burned. Land is cultivated for a few years until it is no longer fertile. Livestock grazing removes the remaining plant life and the land is left barren. Erosion from wind and rain causes desertification. The richness and diversity of nature is lost from a wide area and some species are threatened with extinction. In the end, the collapsing carrying capacity of the land and the booming human population collide with tragic consequences.

In many industrializing and industrialized countries, environmental pollution has reached the point where its affects both the natural world and human life. The depletion of fresh water supplies has led to severe shortages of irrigation water across vast areas /70/. Aggressive commercial fishing practice has caused the collapse of fish stocks. Constraints on local living conditions, such as poor access to fresh water, have led to military conflicts and the breakup of societies. In extreme cases the result has been a vicious downward spiral of social, economic and environmental hardship.

Eco-balance calculations help in identifying the most cost-effective approaches to remediation of the environment. In the case of the Finnish environment, elimination of sulfur in fuels used in Baltic Sea traffic and investment in more waste-water treatment facilities for the City of St. Petersburg are excellent remedies. Changes in the structure of energy production would also help fight climate change as long as it is part of coordinated international efforts.

Getting results in developing countries may require different methods such as greater investment in education and birth control /56/.

Factors	VALUE CALCULATION	ECO-BALANCE	COMMENTS	RATE OF CHANGE	COMMENTS
Footprint effects					
- Forestry	100 000 km^2 x 0% - 100 000 km^2 x 5%	- 5000km^2	If a half of forests are cultivated and the other half are old, the impact is ~0	+50 km^2/v	• Methods of forestry are getting better. • Increase in wood volume • Forests are being protected
- Farming	10 000 km^2 x 0% - 10 000km^2 x 20%	- 2000 km^2	Richness of nature and biodiversity decreases only in areas, where farming dominates	+ 20 km^2/v	• Spatial programs increase richness of nature and biodiversity
- Roads and channels	-126 000 km x 0,012 km x 50% 0,3 (16 000 km x 0,1 km x 20%)	~ - 850 km^2		± 0	
- Cities and villages	6000 km^2 x 20%	~ - 1200 km^2	In cities the impact is big, in suburbs the impact is small	- 10 km^2/v	• Suburbs are growing
- Others (industrial and ware-house areas, land fills etc.)	2000 km^2 x 20%	~ - 400 km^2		± 0	• New areas have been developed, but environmental standard´s have improved
- Human disturbance effects (modern part), shattering, accidents and catastrophes	- 307 000km^2 x 1% - 85 000 km^2 x 1%	~ - 4000 km^2		± 0	
Impact of harmful compounds in nature (heavy metals, poisonous compounds etc.)					
- Land environment	-20 km^2 x 5% -0,3 x 305 000 km^2 x 0,1%	- 100 km^2	It is difficult to estimate the stress effects	+ 2 km^2/v	• Emissions have decreased significantly harmful compounds in nature get covered and disintegrate
- Water environment	-200 km^2 x 2% -0,1 x 53 000 km^2 x 0,2% -0,2 x 32 000 x 0,1%	- 200 km^2	It is extremely difficult to estimate the stress effects	+ 8 km^2/v	• Emissions have decreased significantly harmful compounds in nature get covered and disintegrate
Eutrophication					
- Land environment	+ 0,5 x 305 000 km^2 x 10%	+ 10 000 km^2	At least biomass has increased	+ 200 km^2/v	• The amount of nitrogen is getting smaller
- Water environment	-0,2 x 32 000 x 10% - 0,2 x 53 000 x 10%	- 2 000 km^2	Powerful eutrophication and loss of oxygen reduce biodiversity	± 0 km^2/v	• Eutrophication of the gulf of Finland increases, quality of inland waters is getting better
Acidification					
- Land environment	-0,1 x 305 000 km^2 x 2%	~ - 1500 km^2	A difficult and unaccurate estimation	+10 km^2/v	• Acid precipitation has reduced
- Water environment	-0,2 x 32 000 km^2 x 5%	~ - 300 km^2		+10 km^2/v	• Water quality in lakes, rivers and seas iss improving. Acid precipitation has reduced.
The greenhouse effect		+ 0	The rising of average temperature may have enriched Finland´s nature for some time	± 0	• It is difficult to estimate whether the sum of current effects is positive or negative
Ozone layer depletion		± 0	Apparent impacts can not be observed in nature	± 0	• The ozone layer is getting currently thinner, but current Impacts can not be quantified
		- 6000 km^2 (-1,5 %)		+ 300 km/v (+0,08 %/v)	

Table 2.1. A calculation estimating Finnish eco-balances and rates of change.

Dealing with risk and threats

Even the best-available technology can malfunction. It is important to analyze worst-case situations and study outlier scenarios and note their potential environmental impact. Such analysis is a standard part of any robust risk management scheme. The quantity of environmental risk is probability of occurrence multiplied by materialized environmental impact estimate.

Preparation of magnitude estimates for known environmental risks is straight-forward. For example, the amount and flows of tanker traffic in the Gulf of Finland can be simulated, so the probability of various types of tanker accidents can be determined. This approach can also be used in calculating types of environmental damage, their magnitude, probabilities and the possibilities of preventing them. Such analysis is useful in effectively allocating resources to prevention and risk-fighting measures.

Environmental risks for most traditional industries, i.e. the day-to-day and cumulative risks of most heavy industries are already quite explicit. This is probably also true for the environmental risks associated with production of nuclear energy in Finland. Experts say that recent design and technical improvements preclude the possibility of a run-away situation at a Finnish nuclear reactor causing anything close to the damage of the Chernobyl accident.

We also have centuries of experience in the use of tar. No significant problems have emerged from this legacy. Thus, the European Union’s recent campaign to ban the use of tar seems a bit far fetched.

In contrast, the risks associates with new processes or innovations are often underestimated or even unimagined /13/. For example, the depletion of the ozone layer by CFC compounds came as a complete surprise to regulators and CFC users alike. Fortunately, the problem was understood and appropriate measures were taken in time.

An accident in a frontier industry in biotechnology or biochemistry could well carry ghoulish risks. At the same time, we should keep in mind that horror stories appealing to our basic fears resonate well with the media. They are endlessly repeated even as serious experts note the stories groundless.

We can try to deal with new risks by classifying new branches of technology according to their risks, and then applying appropriate limitations and safety measures to their development. The problem is non-trivial as they often require rethinking of traditional values such as scientific independence and unfettered competition – not to mention possible ethical issues.

There is still considerable uncertainty surrounding the extent and rate of global climate change. Scientists participating in the IPCC studies, however, have concluded that their ball-park predictions have a fairly high degree of reliability. Moreover, the potential for environmental destruction is huge and may manifest itself in surprising ways such as a weakening of the Gulf Stream.

Thus, we need to be rational and take preventive measures to reduce risks and continue to modify our behavior as new information from the IPCC and other independent and critical sources comes in. If we wait for scientific certainty, the cost of dealing with the realized environmental risk will already be too high.

Perhaps the largest environmental risks are associated with development of human society and the accompanied social processes. Although it has been just six decades from World War II, we Western Europeans have become accustomed to peaceful existence and high standard of living. Our lives are just now so comfortable that many of us do not consider such risks.

The population explosion, combined with the decline in regional living conditions, carries the seeds of military conflict. Risk is further enhanced when terrorism and fanaticism are added to the mix. Broad economic collapse in Europe could lead to reckless behavior. Europe is not isolated from the risks of military conflicts that involve also extensive environmental destruction.

Chain-reaction scenarios suggest some of the most dreadful images of environmental destruction. The combination of Western dependence on fossil fuels, climate change, and the spread of weapons of mass destruction, is quite explosive in international politics. If farming conditions in our planet’s bread-basket regions are impaired by climate change, nuclear threats become more realistic and terrorism starts to find a wider audience. The risk of a major military conflict grows. Global warming could be followed by a nuclear winter.

A rapid reduction in our reliance on fossil fuels would help in managing such risks.

Use and limits of presented method

The above discussion considered a method for assessing the impact of a given phenomenon, action, or activity on natural wealth and biodiversity. While imprecise, the method makes it easy to assess the magnitude of an environmental impact in terms of a spatial equivalent (e.g. square kilometers) over time (e.g. years).

Ideally, estimates of environmental impact would involve the use of several analysts versed in evaluating the magnitude of environmental impact in combination with at least two independent experts in the type of environmental impact involved. Consideration of the nature of the problem and its various dimensions would be performed first, and then the magnitude calculation was made.

Practicality dictates that those making calculations independently establish a basic framework that includes familiar reference points that can be related to derived values. In this way, no aspect of an impact is unnecessarily exaggerated.

The method is not well-suited to all types of impacts considered environmental including:

- landscape impacts;
- impacts on cultural heritage;
- impacts on recreational use of an area;
- odors, noise, or other nuisances that interfere with the use and enjoyment of land;
- impacts on human health;

These matters are largely covered by existing legislation. Several public agencies are charged with monitoring and administering them.

There is also the issue of endangered species, which the method can treat only by a weighting factor. Here we should bear in mind that while human activities may cause extinction of some species, evolution is also a natural process.

Establishing protected areas does not necessarily assure the well being of threatened species or habitats. Many species are given added protection by naming them endangered and providing them extra protection at the expense of human activities. This naturally skews natural competition by granting special status to threatened species and habitats over other species and places.

It would be quite valuable if legislation and standards could make the distinction as to whether a species is threatened globally (e.g. all tigers) or if it is threatened in an area at the edge of its traditional domain (e.g. flying squirrel in Finland). Species living at the edge of their traditional range may often appear and vanish for entirely natural reasons. One could also reconsider the need of protecting isolated populations of common species.

There is also a need to identify species declared threatened by politically guided administrative decision without a proper scientific basis (e.g. the sea beetle *Macroplea pubipennis* in Finland). Finally, separate treatment should be given to occurrences of non-resident species (e.g. harbor porpoise, North American mink), and highly destructive pests society would prefer to eliminate altogether (e.g. pine sawfly, smallpox).

Our planet is home to an estimated 1.6 million species of vertebrates, mollusks, crustaceans, insects and vascular plants /32/. The total number of species is estimated to range from 5 to 15 million in /35/.We have only the slightest notion of how many kinds of micro-organisms might exist.

The depletion of resources is another factor that the method does not take into account. For example, the Earth’s most accessible oil and gas deposits are likely to be depleted in this century. Of course, this does not mean that our planet will run out of energy sources. Exploiting other energy sources will require further technological advances to make them more economically accessible.

We should also make ourselves be aware of the various measures of environmental impact that have been developed. A range of ecological, economic and social indicators suggested for quantifying sustainable development are described in references /8/ and /43/.

While there are no perfect measures of environmental impact, there is a tendency to choose methods and pick up results to support a desired conclusion. Thus, one should always consider the basis and then ask honestly what the result is telling about the real world.

Human emotions and interests play a huge role in the prioritization of environmental issues. This can be seen in legislation, in the actions of public officials, in the media and even in judicial rulings. Indeed, no approach including this one can claim to be fully objective. Impact assessments are often inaccurate and leave room for interpretation. Feelings and bias can also influence expert assessments. This is the topic we consider next.