Pier Vellinga

Dredging in a Changing Environment

Abstract

Human growth in the last two centuries has been exponential. The question is how long can this continue without interfering with other species and nature itself. This is a source of many studies and is one of the greatest concerns of society in general and therefore of industry as well. As we continue to apply our human expertise to "improving" nature, political decision-making becomes an ever-increasingly important element. But as regards the management, use and protection of nature, political and industrial roles are often experienced as erratic and irrational to the actors involved.

Globalisation raises concerns about growing disparities in income at the national and international levels and a further degradation of the quality of life support systems, such as biological diversity and the global climate. These are issues that concern all of us.

This paper explains the concept of Coevolution which ensures benefits, both for the human species and ecosystems and natural habitats in design, operation and staffing; and the "Triple P Performance" principle, i.e. Profit, Planet and People as a guideline for modern companies to create legitimacy for growth amongst clients, shareholders, employees and society at large.

The paper was the keynote address at the CEDA Dredging Day, "Dredging Seen, Perspectives from the Outside Looking In", in Amsterdam, November 15, 2001 and first appeared in its proceedings. It is reprinted here in an adapted form with permission from the author and the Central Dredging Association.

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Introduction: Environment as an Issue

The human species is colonising the earth in a successful way. Our ancestors felt vulnerable with regard to the forces of nature and they felt dependent on the gifts of nature. It is not surprising that nature is a major focus in all early religions: Amon Ra, Gaia, Wodan and so on.

Over the last 10,000 years the human species has grown rapidly in comparison with the 3 million years before. Over the last 200 years the growth in numbers has been exponential. The main reasons for growth are:

- progress in the capabilities to exploit nature through the domestication of plants and animals;
- progress in understanding the relationships between water quality and public health; and
- progress in protecting ourselves from the forces of nature.

Still, every now and then people ask themselves: how long can a species grow exponentially in numbers, in particular when such growth comes with the increasing

Figure 1. Man-made wetlands: a way in which the human species tries to restore a natural environment and protect nature against the loss of other species.

loss of other species? This question together with the history of being very vulnerable to the forces of nature makes our species presently rather insecure in dealing with nature. It should not be surprising therefore that political decision-making regarding the management, use and protection of nature is often seen as erratic and irrational to the actors involved.

The decision-making process about gas exploration in the Waddenzee in the north of the Netherlands is a typical example. Another example with interesting spin-off for the construction firms is the use of tunnels to avoid interference with the landscape. This article will try to shed some light on the various ways our species deals and can deal with nature (Figure 1).

Different Cultural Perspectives on the Values of Nature

The perspective of people regarding nature is dependent on the conditions they are in, and such perspectives change over time as one can imagine. Still, there are some remarkably consistent differences amongst people and cultures even within Europe.

Tacitus already described the habits of German tribes regarding rituals and nature. In the Germanic culture nature is considered holy (see *Landscape and Memory* by Simon Schama). This religious attitude with regard to nature can presently be recognised in the "Fundi" movement of the German NGOs when it comes to environmental issues. In the debate about genetically modified organisms (GMOs), the naturalness of reproduction and the holiness thereof is a central theme.

In the Roman and Gallic tradition nature is culture: nature is particularly valuable once humans have transformed it into a park landscape or into food. This attitude can be recognised in the Italian and French landscapes and also in the present political debates regarding farming systems and related land use management as part of the food culture in France. In the debate about the introduction of GMOs in France, the protection of the farming system and the related landscape and food culture is the central theme (Figure 2).

In the Anglo-Saxon tradition nature is there for use. The United Kingdom always had a tradition of free access to nature through its pathways. The Anglo-Saxon tradition is one of pragmatic use of natural resources. Regarding the GMO debate it is not completely clear, unless the USA approach is illustrative where there is little or no opposition to genetic modification.

All those involved in dredging and in reshaping the earth's surface and sediment flows in one way or another may ask themselves the question, to what extent do you recognise the cultural differences in Europe and/or elsewhere in the world when it comes to important human interference in the natural systems.

There are some parallels. German environmental research institutes were the first to include the number of tonnes of excavation and removal of soil material in the set of indicators for material intensity of the economy. This so-called MIPS indicator (Material Input per Unit of Service) is a measure to describe the environmental burden of a certain activity. It has been developed by the Wuppertal Institute and includes soil excavation and removal, even if the environmental effect is negligible.

Experts in the USA, UK and the Netherlands are hesitant to adopt the German approach. However, the discussion in the Netherlands regarding a green tax on the excavation and removal of soil including dredged spoil irrespective of its environmental quality and in respect to the environmental burden, illustrates that Fundi approaches can also be found in the Netherlands. Green taxes in themselves are a proper instrument for environmental management, but there should be a clear relation to environmental effects. The Roman, Gallic and Anglo-Saxon cultures will probably not immediately embrace such a green tax on soil removal unless there is clear environmental stress involved.

From Perspectives to Attitude: Views on Dealing with Nature

A view on nature can be defined as a philosophical opinion on how to deal with nature. This opinion includes both an objective concerning nature and a strategy to reach this objective. Societal views on nature as they are empirically encountered can be classified into three main streams on the basis of their objectives, whilst their implied strategies allow for some refinements.

Three main views that have been identified concern (Ruijgrok and Vellinga, 1999) (Figure 3):
- The Conservation view;
- The Development view;
- The Functional view.

Conservation view

The Conservation view is mainly concerned with the objective of conserving and restoring existing natural sites according to an historical reference situation. Whether these have been obtained by human interventions or not is not an issue here. What matters is the protection of the nature remaining today. The protection of today's nature can be realised in two ways:

1. Through keeping one's hands off existing nature. This strategy is opposed to human influence on the natural surroundings. The belief is that human intervention always reduces the naturalness of an ecosystem. Naturalness is defined as the extent to which nature is free from human interventions. The best way to conserve nature is not to touch it and to rely on the natural restoration capacity of ecosystems.

Figure 2. In the Gallic tradition, nature is particularly valuable once humans have transformed it into food as can be seen in this French landscape of neatly planted vineyards.

	Conservation		Development	Functional	
Criteria	**Hands off**	**Classic**	**Development**	**Coevolution**	**Nature Building**
1. Trade off ecology and economy	Priority on ecology	Priority on conserving natural and cultural sites	Priority on Naturalness	Careful trade off to maximize social welfare and natural qualities	Priority on economy
2. Active human intervention	No influence allowed	Activities to conserve species	Actions to stimulate/enable natural processes	Only if it creates win-win situations	Steering natural processes by engineering techniques

Figure 3. Criteria for basic views on nature.

2. Through maintenance and isolation of existing natural and cultural landscapes, aimed at protecting rare species and unique cultural and historical elements. Active human intervention is considered necessary since nature cannot defend itself against the threats from society. Intervention activities such as fencing and mowing are done to maintain diversity and rarity of species.

The Conservation view is a reactive/defensive attitude as a response to rapid industrialisation and related land use changes. As such, it may become counterproductive. Productive measures aimed at preserving diversity and rarity of species can especially reduce natural dynamics (for example succession possibilities). This gives rise to the question whether or not nature is served through such measures.

Development view

In the Development view both protection of existing nature and the development of new natural sites are the main objectives. Driven by the desire to enhance naturalness and wilderness, room for natural processes and diversity of systems instead of species are core issues of this view. Natural processes and dynamics are restored by stimulative actions with relatively uncontrolled spontaneous end results.

There are a number of ways to reach these objectives:

1. Reducing maintenance whenever possible to give natural processes a chance, such as managed retreat;
2. Undoing previous interventions, such as the opening of enclosed sea arms; and/or
3. The creation of abiotic conditions, which will reactivate natural processes, such as dune formation with the initial aid of sand screens.

Whether it is a reduction of maintenance, the undoing of interventions or the creation of physical conditions, they are all aimed at the enhancement of naturalness. This can be realised when connections are made between existing nature; ecological networks or corridors are stimulated since they help to enhance natural resilience of ecosystems. Basically, stimulative interventions are driven by the desire to provide more room for nature rather than by the desire to realise utility for society.

An important argument supporting the Development view is that merely conserving existing natural sites is not adequate. Increasing the quantity and quality of nature requires ecological networks and room for natural processes in addition to protection and isolation.

The creation of corridors and space for processes requires stimulative interventions in a society in which every piece of land is increasingly being used for human activities; neither protective isolation nor simply keeping one's hands off nature is sufficient to secure nature and natural dynamics.

Functional view

According to the Functional view, nature derives its value directly from the welfare functions it performs for society. This does not mean that nature cannot have an intrinsic value according to this view, but it will only have one if humans find it important for some reason. The objective of this view is maximisation of

social welfare derived from nature. This welfare can be derived through both direct (resource extraction) and indirect (regulation processes) use, but also through the social preferences attached to its mere existence.

Because nature is supposed to serve social preferences, which vary amongst interest groups, one can define a whole spectrum of strategies to realise the objective of welfare generations. Two examples of this spectrum are:

1. Realising social welfare through constructing nature according to human wishes. Since naturalness is supposed to be an illusion, one can control and construct nature to meet social demands with the help of civil engineering. Humans can destroy nature through technology, but people can also create favourable conditions for nature by means of technology. Nature can be man made and abiotic conditions do not pose restrictions since these can be adjusted too. This approach is referred to as the "Nature Building" approach.
2. Realising social preferences through a sustainable use of nature; only user functions that do not seriously damage the natural system are allowed, such as nature friendly forms of recreation and sustainable forms of harvest. Though naturalness is considered desirable here, it does not exclude human activities, since humans are also part of nature. A balanced interaction between nature and society is advocated. Both society and nature are allowed to change and to inflict change upon each other as long as neither of them suffers serious damage, threatening its existence; it is a matter of mutual benefit. The term "Coevolution" is used here to describe this interpretation of the Functional view.

The Functional view is based on the principle that separation between ecology and economy will neither be favourable to nature nor to society in the long run, since the two are interdependent. Sustainable use of nature will be beneficial to both nature and society. Opposition to this interdependency is simply not realistic.

Figure 4. The port of Rotterdam: New plans for the extension of the port are an example of the "Functional Coevolution" view in which both the economy and ecology benefit.

Period	Policy aim	View on nature
1950 - 1970	Protecting existing nature	Conservation
1970 - 1995	Developing a national ecological network	Development
1995 - 2000	Call for interaction of economy and ecology	Tentative → Failure Coevolution → Success
2000 - future	Application of balanced trade offs between ecology and economy	Coevolution

Figure 5. Policies for nature.

A critical argument against the Functional view is that it requires operational instruments and legislation to ensure a balanced trade off so that nature is protected against the "tragedy of the commons". Examples of the functional Coevolution view are natural reserves in which certain types of recreation are allowed. Recent examples of how the Functional view can be operationalised is the Dutch plan "Growing with the Sea" and the World Wildlife Fund vision regarding the extension of the Port of Rotterdam, in such a way that both the economy and the ecology benefit (Figure 4).

The three main views of Conservation, Development and Functionality are more than just theoretical concepts. In practice they can be used to explain:

- motivations of economic interest groups concerning their way of dealing with nature;
- developments in national policies and decision-making practice in the fields of nature protection and coastal zone management;
- the way in which nature is valued and accounted for in public decision-making.

Views and Public Policies

In order to find out whether the views can also explain trends in public policies, this section presents a brief review of the Dutch policies for nature protection and coastal zone management.

Figure 6. Policies for Coastal Zones.

Period	Policy aim	View
1950 - 1970	Single sector flood protection	No view on nature
1970 - 1990	Double criterion of protection and environmental neutrality	Nature Building
2000 - future	Multifunctional use of coastal space and resources; 'Growing with the Sea'	Coevolution

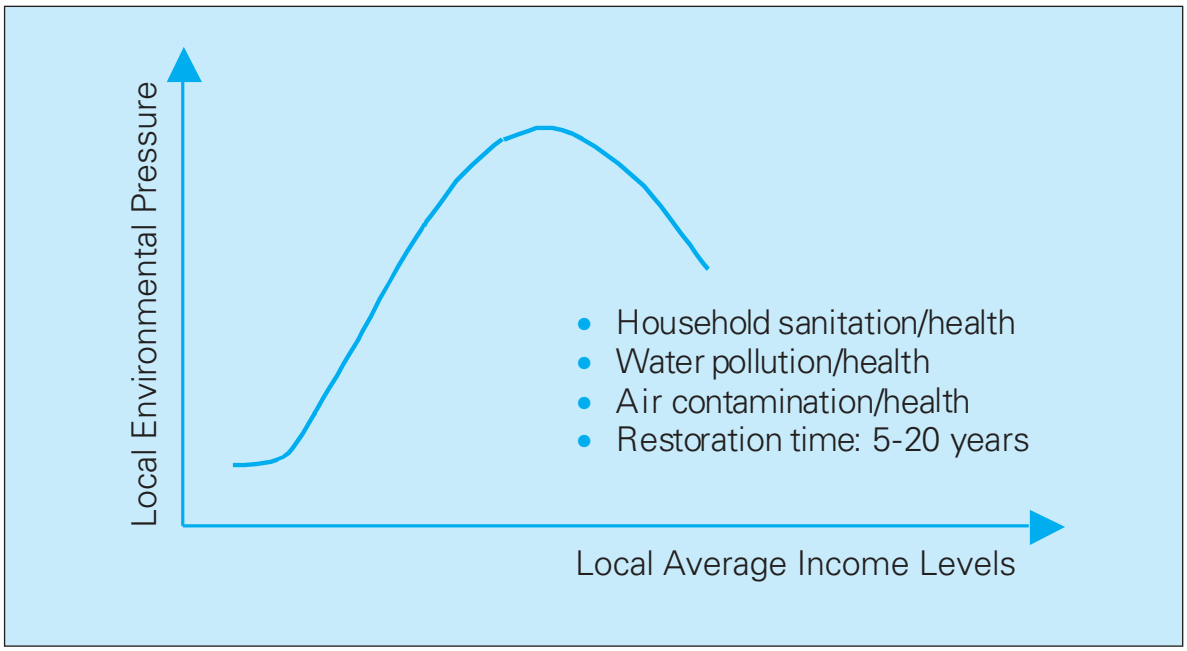
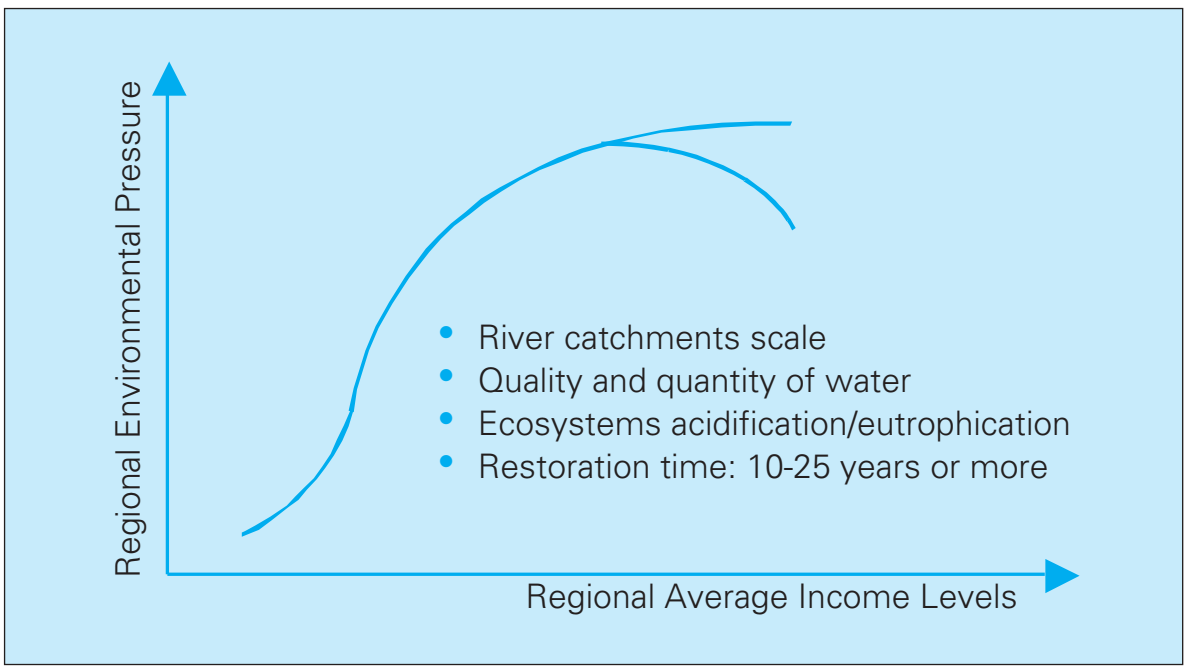


Figure 7. Local Average Income Levels and Environmental Pressure.

In the Dutch policies for the natural environment (Figure 5), one can see a clear development in the lines of thinking starting from a Conservation approach, continuing with a Development approach, and recently the first attempts have been made towards an enlightened version of the Functional approach: Coevolution.

When looking at the Dutch policies for coastal protection (Figure 6), a similar outcome but an opposite starting point can be discerned. Starting from a single sector civil engineering approach of flood protection until the beginning of the 1970s, increasing awareness of environmental impacts of coastal protection works led to the adoption of the double criteria of flood protection and environmental neutrality. At this stage the aim was to minimise environmental impacts of coastal defence measures. This approach was applied up until the early 1990s. In these first two stages the coastal zone was not considered as nature, but merely as an accumulation of (physical) defence capital.

Figure 8. Regional Average Income Levels and Environmental Pressure.



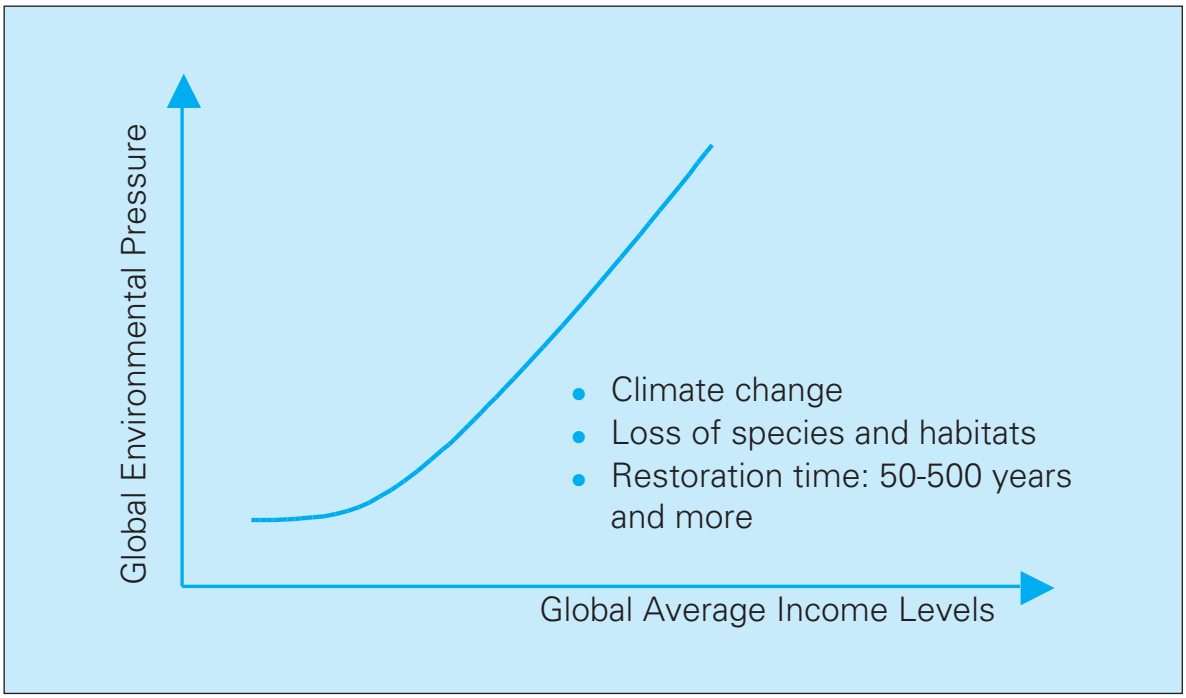


Figure 9. Global Average Income Levels and Environmental Pressure.

Only recently the view has been adopted that coastal defence and nature development can go hand in hand. Both policies in the field of nature and coastal protection have shifted towards the Coevolution approach.

Whether Coevolution will become the dominating philosophy for both coast and nature largely depends on the availability of trade-off instruments and legal arrangements necessary to implement the concept of Coevolution. The legislation of the concept of compensation in the EU–habitat directive may be a starting point.

Globalisation, Economic Growth and the Environment

Many governments and international corporations promote the further opening of global markets as a way to enhance development and income levels worldwide. However, the present rate of globalisation raises concerns about growing disparities in income at the national and international levels and a further degradation of the quality of life support systems, such as biological diversity and the global climate. The challenge that global environmental issues pose to the relationship between environment and development can be illustrated on local, regional and global scales, each with its specific environmental problems.

Local Average Income Levels and Environmental Pressure

Figure 7 (Local Average Income Levels and Environmental Pressure) reflects empirical evidence that people tend to solve their local environmental problems as income increases. Growing income levels can be correlated with an improvement in the quality of the local environment.

Many cities and countries in the industrialised part of the world have experienced the situation represented by this curve, whilst cities in developing countries can still be located on the ascending segment of the curve. The rationale behind the curve is that, as income levels rise and local environmental and health problems become manifest, there are driving forces and financial means to introduce technologies and regulations (incentives and institutions) that reduce pollution and protect the health of the population.

Two critical factors leading to success can be identified:
- People take measures when they actually see that their health is affected.
- Costs and benefits play out at the same (local/national) level.

Regional Average Income Levels and Environmental Pressure

A similar curve (see Figure 8, Regional Average Income Levels and Environmental Pressure) can be developed for environmental problems at a regional level, such as acidification and water quantity/quality issues on the scale of river catchments. There is less evidence that people address these problems successfully as income levels go up. An important reason for this is that industrial and agricultural activities higher up in river catchments (upstream and/or upwind) benefit from pollution and overuse of water and pollution of air, whilst downstream and downwind people and nations experience the negative impacts.

Another reason for continued environmental degradation, as income levels go up, is the time delay between the act of polluting and the effect of pollution downstream. Examples of regions and environmental problems exist, where the curve drops sharply, but this is not a general empirical finding. For most regions of the world the evolution of the curve is not yet clear.

Global Average Income Levels and Environmental Pressure

A curve (see Figure 9, Global Average Income Levels and Environmental Pressure) can also be developed for global environmental problems such as climate change and loss of species and habitats. Empirical data illustrate that there is no income-related levelling-off point when we look at the relationship between income and emissions of greenhouse gases caused by consumption. Income levels (including the consumption of imported goods) correlate with energy use, and present-day energy use is coupled to CO_2 emissions. Similarly, the space we use for our activities (housing, transport, recreation) grows in a linear fashion to income, at the expense of natural habitats.

A critical feature of global environmental change is the time scale of biophysical response. The climate responds to changes in the concentration of greenhouse gasses at a time scale of decades to centuries or even longer. The loss of species including their habitats is considered irreversible in a human time frame.

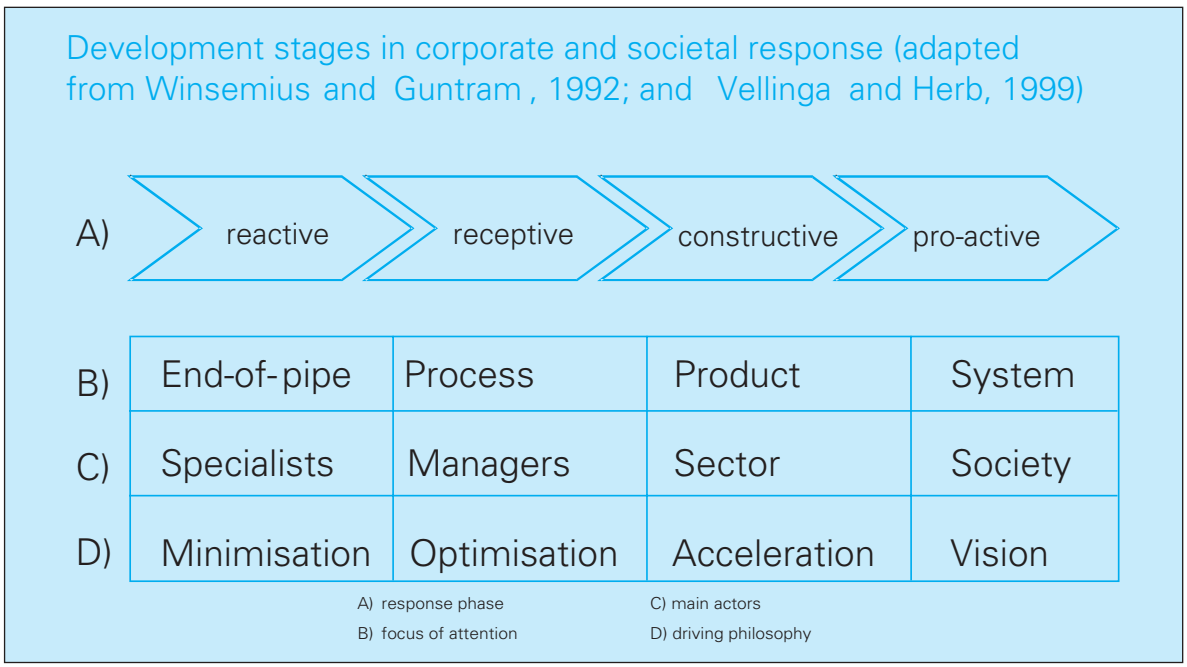
From the above observations it is clear that global environmental change poses an unprecedented challenge to society and requires a proactive approach. To avoid irreversible, high impact changes, society must act before the effects of environmental change become visible. How can research help in clarifying the issues at stake? Certainly a better understanding of the interaction between social and natural systems is required.

From "End-of-Pipe" to Systems Innovation

Guidance for the future may be found in analysing trends in societal response to environmental problems over the last 40 years. Figure 10 (from McKinsey and Company, Winsemius and Guntram, 1992) presents a number of stages of societal response to environmental problems (as quoted from Winsemius and Guntram):

1. "*Reactive response*
   The onset of government policy-making is generally met with a primarily defensive approach. Companies, and especially their sector organisations, dig in exaggerated. They tend to adopt a posture of loyal citizens: 'We will do what is legally required, but we don't like it'. Generally assigning the responsibility to staff specialists, usually as an extension to the Health & Safety departments, they implement the prescribed end-of-pipe solutions consisting of add-on features to the existing facilities whilst all the time trying to minimise their response and the costs thereof.

Figure 10. Development stages in corporate and societal respons (adapted from Winsemius and Guntram, 1992; and Vellinga and Herb, 1999).



2. "*Receptive response*
   Gaining experience and becoming more comfortable with the new responsibilities, companies shift to an attitude of 'Okay, if we have to do it, let's be smart about it'. Line development is now made responsible – within the boundaries of the current business – for developing solutions that meet the criteria set by the government in the most efficient manner. Most solutions will still involve optimising the existing production configurations although they will often include some process redesign.

3. "*Constructive response*
   A limited number of companies have begun to look beyond the boundaries of their current business to find more fundamental answers to the environmental questions. In more advanced countries, stimulated by government intervention, industries have developed so-called 'cradle-to-grave' approaches where they accept responsibility for their product even after it has been sold. As a result, the traditional delivery chains in, for instance, the packaging or automotive industries are changing rapidly. Companies are also starting new cooperations with suppliers, customers, and, especially, competitors to facilitate joint objectives, such as waste collection and recycling, 'green' product labelling or contractual agreements ('convenants') with governments that establish new environmental objectives. Moreover, existing approaches can often no longer meet much tighter targets, necessitating industrial players to strive for technological and/or organisational quantum leaps.

4. "*Proactive response*
   Very few companies have reached this phase yet. Still, the contours of the response pattern can be sketched by looking at the policy development in leading countries and at the role specific companies play. Increasingly, companies will internalise the environmental challenge as an element of quality management. To meet the challenge and, at the same time, focus on the needs of their customers. They will optimise their own functioning and especially their value proposition (i.e., products plus services at a given cost). Companies and industry sectors will pool their resources with those of governments, scientific institutions and often environmental issues that can pass the 3E-test.

   "The challenge of bridging interests and cultures among players of great diversity is considerable. Leaders in government and business, as well as in the environmental organisations and scientific institutions must generate a vision that can serve as a reference for all workers in their organisations.

   "Within industry, this vision must inspire the full internalisation of the environmental challenge throughout a company. Top management must take the lead in defining far-reaching but understandable goals – DuPont and Asea Brown Boveri, for instance, talk about 'zero emissions' – that stretch the organisation to look beyond the horizon of today's concerns – for instance, 'We are responsible for tomorrow's laws'. However, building on the experience of the first three stages, this long-term vision also must drive the medium-term strategy that in turn can be build on in practical short-term action plans".

A Typical Dredging Example of the Four Stages of Response

How do port authorities address the environmental aspects of dredging?

Reaction phase:
"It is not really contaminated" or, the pollutants are not really hazardous to our health and ecosystems. But if required, we will do some measurements. And the most contaminated material? We will leave it where it is".

Reception phase:
"OK, if we have to do it let's be smart about it, we minimise dredging and we define several classes of pollution. For the most polluted part of it: just dig a hole or create storage basins such as in the Great Lakes and in Rotterdam" (Figure 11).

Constructive phase:
"Recycling and re-use of dredged sediment for brick making or whatever and separating the contaminants from the sediments" (Figure 12). Thus new products are developed.

Vision phase:
"Reduce at the source and make the producers of the contamination liable, let them pay for your problems, they are *their* problems, join the environmental movement in the London Convention". In this phase new coalitions develop, such as a coalition of Port Authorities and Greenpeace and Friends of the Earth. They are your friends when it comes to reduction of polluted dredged material.

Moving from "end-of-pipe" and efficiency measures (from 1960 onwards) to green products and systems innovation (from 1990 onwards) reflects a societal development from reactive to proactive environmental policies.

A transformation to more sustainable systems is only partially a matter of technology. Economic, socio-cultural and institutional changes play an equally important role. Transformation can only be successful when societal and technological changes are mutually reinforcing at different levels, as illustrated in Figure 13.

Figure 11. The Slufter, a confined storage basin for dredged materials near Rotterdam.

This includes the micro scale (niches), the meso scale (regimes) and the macro scale (landscapes) (see Kemp *et al.*, 2000).

Industrial Transformation, a system change, is usually initiated as the result of a local or national innovation, serving as a technological and/or institutional "niche market". When an innovation fits into a regime change that occurs at a regional or continental scale, the innovation is reinforced. When, at the international level, socio-cultural changes occur that favour a new way of behaviour, the system innovation can be absorbed at the global level.

Implications for the Sector

Going from the more generic issues about environment and development, we now examine what this means to the sector.

Coevolution

Coevolution is attractive from the perspective of continued activity of the sector, but this requires a deeper understanding of the ecological processes: how to

Figure 12. Synthetic bricks made from dredged materials, Hamburg, Germany.

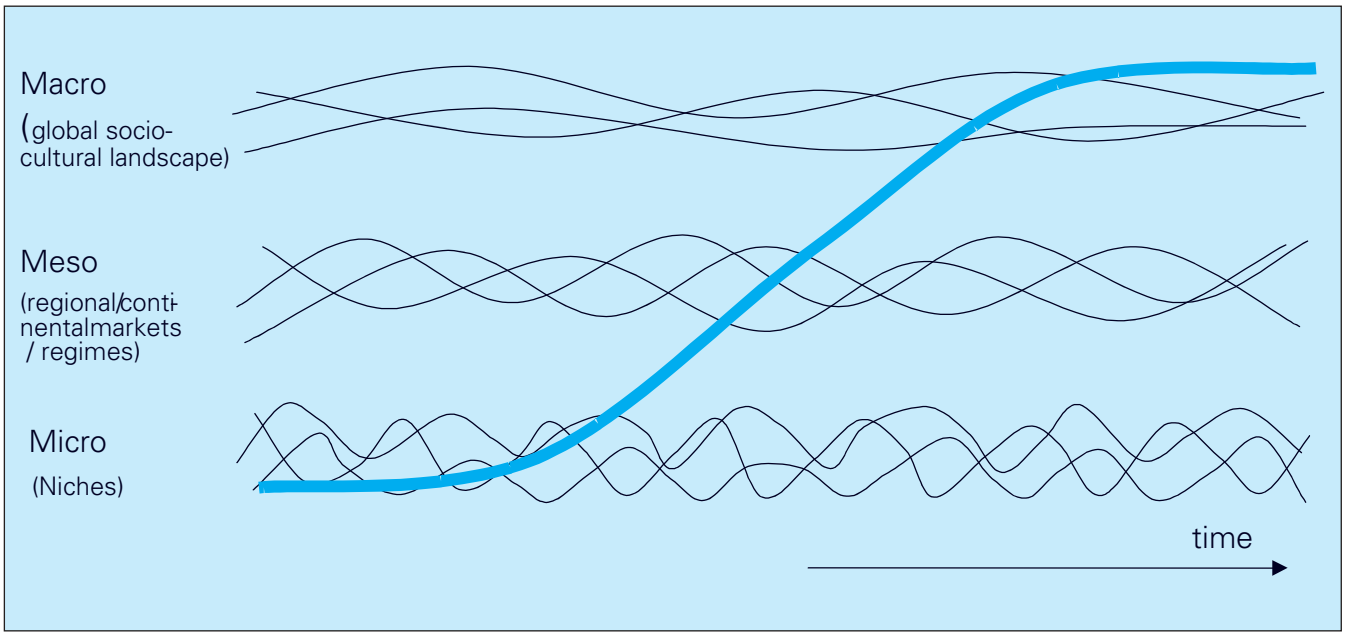


Figure 13. Industrial Transformation occurs through mutually reinforcing technological and societal changes at micro, meso and macro scales (Kemp et al., 2000).

interact with nature instead of how to beat nature should be the slogan. The WWF plans for the extension of the Rotterdam Maasvlakte are a beautiful example of what can be achieved.

This requires the introduction of ecological expertise in the traditional engineering companies towards eco-engineering. Eco-engineering as much as possible in line with natural systems can help to find solutions supported by more people and decision-makers. Moreover, such projects and schemes are often scientifically and engineering-wise more challenging than many of the traditional engineering solutions.

Triple P Performance

Socially more responsive behaviour of companies will help to create trust and thus work for companies. Triple P performance with a balanced focus on Profit, Planet and People could help to make companies more attractive for employees, for shareholders and for clients.

Sustainability concerns

Strategic anticipation of future markets as triggered by sustainability concerns. The major environmental concerns relevant for the dredging industry are:

a) *Climate change*: how to deal with changing rainfall and run-off patterns requiring adjustments in river, canal, sewage and dike systems and how to deal with changing sea level and storm-surge conditions in estuaries and open coasts; how to contribute to a transition of the energy system: wind power at sea; new gas fields at deeper water; CO_2-underground storage; new energy networks (piping systems); new harbours for the shipment of biomass and possibly LNG and in the longer future H_2.

b) *Loss of natural habitats in particular in the coastal zone*: how to initiate and develop schemes of combined land use changes and reclamation in the spirit of Coevolution with benefits for the transport sector, for urban development, for industrial siting on the one hand and benefits for recreation for natural habitats and for bioremediation on the other.

c) *Water*: what can the sector contribute to the solution of the multitude of water related problems now and in the future? Water recharge and water storage will become increasingly important as demand grows, scarcity increases and the climate becomes less predictable. Water transport systems are likely to become more important as well as seawater desalination facilities.

d) *Pollution and polluted soils and dredging material:* are important now, but major changes in the ways to deal with dredged sediment may be ahead. Reduction at source has gained ground; the emphasis is changing from chemicals concentration as a criterion to biological effects as a criterion for controlled dredging, dumping and storing; a river basin and adjacent seas integrated analysis of environmental effects may well change the predominant policy views on how to deal with the sediments accumulating in harbour basins and shipping channels.

Figure 14. The challenge for the dredging industry is to operate in the spirit of Coevolution with benefits for transportation, shipping, recreation and the natural environment.

Conclusion

Many companies may already be aware of some of the information presented here. However, how many companies have experts on staff who have an understanding of biology and ecology of intertidal systems, mangrove forests, coral reefs, sea grass systems?

The challenge for dredging professionals is not only the project but also how to meet the needs of people in the field of shelter, transport, water, natural habitats, whilst enhancing the quality of natural systems and biological diversity. The real challenge is to contribute to society whilst ensuring profit and continuation for the firm (Figure 14).

This implies that:

- Adhering to the concept of social-natural systems Coevolution with ensured benefits, both for the human species and ecosystems and natural habitats in design, operation and staffing;
- Triple P performance as the bottom line for the company: Profit, Planet and People as a way to create legitimacy for growth amongst clients, shareholders, employees and society at large.

Hopefully these ideas on an overall conceptual approach and on some foreseeable priorities and changes relevant for the dredging sector will stimulate thoughts and innovation capabilities.

Errata

In the March issue of *Terra et Aqua*, page 8, the caption by Figure 4 was incorrectly printed. It should read: "Figure 4. Experimental setup for the ecotoxicity experiments with the algae P. Tricornutum (courtesy of M. Vangneluwe)".

Our excuses.