## ESTUARY MANAGEMENT

Many of the issues identified in the Introduction highlight the need for a strategic framework for estuarine planning and management activities (Figure 2.1). This chapter:

- Provides the context for much of the work seeking to identify change, providing an explanation for several drivers;
- Discusses the importance of strategic estuarine management and regulation, and the need for considering sustainable development of an estuary;
- Provides information on ways in which a management framework can be developed to integrate legislation, human impact, natural variability and system response;
- Identifies frameworks developed for the purpose stated above.

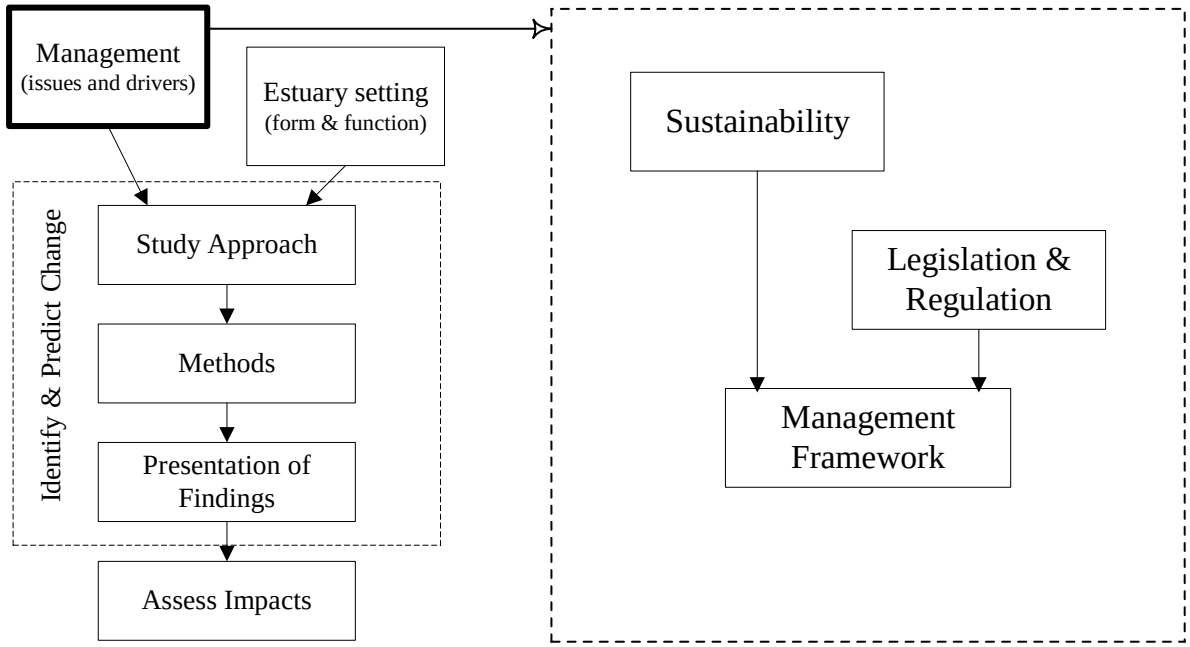


**Figure 2.1 Flow diagram illustrating the process of estuarine management**

### The Need for Strategic Management

The nature conservation importance of estuaries has already been noted and within the UK, this is reflected in the fact that some 76% of the area in estuaries has some form of European nature conservation designation[1] (Townend, 1997). Estuaries are also highly productive and play an important role in the food chain. At the same time, conurbations that have developed alongside estuaries are often low lying and prone to flooding. The defences that now protect these areas inevitably constrain the estuary and, in the face of sea level rise, potentially limit the way in which the estuary can respond. Equally, as a trading nation, 84%[2] of UK imports and exports pass through ports in estuaries (Townend, 1995). Continued growth, the development of shipping and the greater emphasis being placed on short-sea shipping to improve the inter-modal transport balance mean that there are pressures for ports to expand and develop new facilities. As with flood defence this has the potential to constrain the future evolution of the natural estuary system.

1 European sites comprise Special Protection Areas for birds and Special Areas of Conservation for habitats and species.

2 By tonnage.

The problem is made more complicated by the very nature of estuary systems. Within an estuary, form and process are inextricably linked and there are no obvious dependent and independent variables, or clear cause-effect hierarchies. For example, although the size and shape of an estuary channel is a response to tidal processes, the tidal discharge is itself dependent on the channel morphology, since this determines the tidal prism[3]. This interdependence means that changes in one part of the system can cause responses elsewhere in the estuary. It follows that a strategic approach to estuary management must consider the estuary as a whole, managed within the spatial context of river/estuary/sea.

Changes such as reclamation, dredging and the removal of flood storage areas by the introduction of flood defences, all alter the dynamics of the system. Ironically schemes to protect fresh water habitats at the margin of estuaries are progressively having the same effect. Many of these anthropogenic changes can be likened to various geological features that occur within estuary basins (such as variations in the underlying bed formation, some areas being relatively soft and erodible and other areas being hard and more resistant). Both serve to apply constraints on how the estuary can evolve. As the estuary adjusts to these various constraints, particular features within the estuary, such as the extent or position of intertidal, saltmarsh, sandbanks, etc, will also change. It is important to recognise that the estuary will adjust to the imposed constraints, both natural and anthropogenic. Consequently there is little point in seeking to define what the "natural" estuary system would look like. The central question for management is, rather, whether any changes that are imposed will alter particular estuary features, that **we** value, in a way that **we** consider unacceptable?

### Sustainable Development

This inevitably leads to the question of sustainability and some determination of what we are seeking to sustain. The guiding principle stated in the Bruntland Commission's report (WCED, 1987), is now well known and succinctly encapsulates the ultimate objective:

> "*We must meet the needs of the present generation without compromising the ability of future generations to meet their own needs*"

Put simply it is a case of passing the baton in a relay race, always mindful of the fact that if you drop the baton you are disqualified from the race!

There are of course many perspectives on how this can be achieved. One common way of summarising the different views is in terms of ecological, social and economic systems (Steeley, 1995). Thus ecological sustainability relates to maintaining biodiversity (McCann, 2000), social sustainability seeks to improve the lot of the majority whilst maintaining political stability (Young, 1990) and economic sustainability concerns maintaining (ideally growth of) local, national and world economies (Schumacher, 1974; Perrings *et al*., 1997).

The socio-political initiatives, which led to the four main agreements at the Earth Summit in Rio[4], have in many senses been paralleled by similar shifts in outlook within the scientific community. This change in outlook was hinted at by Prigogine (1980) and was elegantly summarised by Sherman (2000), as set out in Table 2.1.

[3] The volume of water that moves in and out on each tide.

[4] The Rio declaration on environment and development; the framework convention on climate change; the convention on biological diversity; and Agenda 21.

Systems that are complex, non-linear and continually adapting to changes in their environment are now central to scientific thinking. This in turn is progressively being reflected in the approach to policy formulation and management and is particularly appropriate when working in a coastal or estuarine context because of the highly dynamic nature of these systems.

**Table 2.1 New outlook in socio-political initiatives**

| *Old view* | | *New view* |
|---|---|---|
| Focus on species | ➔ | Ecosystems |
| Single scale | ➔ | Multiple scales |
| Short term response | ➔ | Long term change |
| Humans outside system | ➔ | Humans integral |
| Resource exploitation | ➔ | Sustain productivity |
| Management intervention | ➔ | Adaptation |

Source: (Sherman, 2000)

### Legislation and Regulation

In general, legislation seeks to regulate specific activities or operations. In some countries these are grouped in a way that recognises the integrity of a geographic region (e.g. the coastal zone), whereas elsewhere the approach tends to be sectoral. An example of the former is the two acts in the US specific to estuaries, namely the Estuary Protection Act (1968) and the Estuary Restoration Act (2000). However, the more typical approach is sectoral, where the range of activities regulated with respect to estuaries is likely to include:

- Flood defence works, construction of hard defences and managed realignment;
- Habitat creation, including foreshore recharge;
- Disposal of dredged material;
- Maintenance, capital and aggregate dredging;
- Construction;
- Expansion of existing port facilities, or new port development;
- Reclamation;
- Vessel traffic, navigation issues;
- Marina development, harbour expansion, slipway development;
- Pipelines, outfalls, intakes, freshwater abstraction;
- Bridge development;
- Barrier / barrage development, alteration of position of tidal limit;
- Generation of tidal power, wind power;
- Development on floodplains;
- Removal of structures;
- Fisheries, trawling; and
- Recreational use.

These are no different to the range of issues recognised to be components of Coastal Zone Management (CZM), for which there is now a substantial literature. This provides a useful introduction to how government policy drives legislation and establishes the framework and obligations that the various institutions have to implement (Townend, 1994). The type of institutional framework adopted varies from one country to another (UNOETB, 1982; Salm & Clark, 1984; Carter, 1988; Sorensen & McCreary, 1990; Vallega, 1992) ranging from complete state control to non-existent or speculation led management, as described in Table 2.2. Even within Europe, there is a diverse range of national laws affecting the management of the coast, where the source of the common law (Roman, Scandinavian or German) and

public ownership of the shore and sea bed are characteristic features, but still vary between countries (Gibson, 1999).

A particular characteristic is the frequent distinction between laws that apply to the land and those that apply to the sea, which often hinders the adoption of an integrated approach. Most coastal (including estuaries) planning law is concerned with land use whereas the sea is treated as a national resource and administered by central government (Gibson, 1999). In a similar vein, the laws are typically sectoral, reflecting divisions similar to those listed above, and again this can be difficult to accommodate in an integrated approach.

**Table 2.2 Variation in institutional frameworks (Townend, 1994)**

| Decision Making Process | Government Framework | Voluntary Framework |
|---|---|---|
| Centralised Decision Making | All embracing legislation with a statutory coastal zone and specific decision making agencies. | Voluntary or non-governmental organisations (ngo's) and pressure groups police coastal management practice. |
| | Lead agency established to co-ordinate individual agencies that have a responsibility for activities or resources in the coastal zone. | |
| | Coastal zone recognised but not established as a statutory zone with agencies directed to co-ordinate activities through the planning process, in order to take account of coastal zone needs. | |
| | Inter-agency co-ordination at national and local level, often through co-ordinating councils or commissions. In many cases these have no statutory or executive decision making powers. | |
| Devolved Decision Making | Coastal zone not recognised in legislation and individual agencies make decisions without any formal framework for co-operation. | Voluntary or non-governmental organisations (ngo's) actively involved in practical coastal management (often supported by pressure groups) |

One important complication that applies to coasts and estuaries is the interplay of different tiers of legislation. There are a range of treaties and conventions established at an international level that define the laws of the sea (UNCLOS[5]) and control such things as pollution (MARPOL[6]) and fisheries (ICES[7]). These work in conjunction with laws drawn up at a supra-national or federal level. Thus there are European Directives and Regulations that apply to the member states of the European Union (e.g. Habitats Directive, 1992 and Water Framework Directive, 2000), much as federal legislation applies to the states that

5 United Nations Conference on the Law of the Sea.
6 Convention for the prevention of pollution of the sea from ships.
7 International Council for the Exploration of the Seas.

make up the United States (e.g. Coastal Zone Management Act, 1972). There are then national or state laws that that provide more specific controls and, sometimes, local byelaws to take account of local circumstances.

Legislation to a large degree determines the management questions relevant to estuaries, including planning and consents procedures. When preparing development proposals or examining options to adapt to ongoing natural changes, it is important to have a sound appreciation of the legislation and regulation that is likely to apply and hence govern what is currently permissible (versus what would require some change to the institutional framework; a notoriously time consuming and difficult process). These can usefully be drawn together to provide an overview of the relevant legislation, as was done in the EMPHASYS project (Cottle *et al.*, 2000), and updated within the EstSim project (ABPmer, 2007).

The EMPHASYS review of the legislation pertinent to estuaries was updated for the EstSim project in light of the rapidity at which some legislation changes and new EU directives become significant and / or are transposed into UK law.

Future changes to legislation that will be relevant to estuary management include the UK Marine Bill White Paper, the draft Climate Change Bill and the Heritage Protection White Paper, both issued for consultation in March 2007; the Planning Reform White Paper and the Energy White Paper, both issued for consultation in May 2007, and in February 2007 Natural England issued advice to the Government for legislation providing improved access to the coast of England. In Wales, the Welsh Assembly Government announced its plans in June 2006 to improve public access to the Welsh coastline.

EU Directives that may have an impact on coastal and estuarine management in the future include the Environmental Liability Directive (Directive 2004/35/EC), which is defined as 'environmental liability with regard to the prevention and remedying of environmental damage'. This Directive must be transposed into UK law during 2008. The Directive is aimed at the prevention and remedying of environment damage, specifically damage to habitats and species protected by EC law, damage to water resources, and land contamination which presents a threat to human health. It would apply only to damage from incidents occurring after it comes into force and is based on the polluter pays principle, i.e. polluters should bear the cost of remediation of the damage they cause to the environment, or of measures to prevent imminent threat of damage.

Within estuaries, legislation influences management decisions being made at a number of stages; it overarches the assessment process and provides context to the decision-making process. For example, if the activity falls under the Strategic Assessment Directive, a Strategic Environment Assessment (SEA) will be triggered at the outset of a plan or project. Therefore the legislative context must be considered throughout the management process; once the nature, scale and extent of change have been determined, legislation can then be considered with specific reference to the parameters affected.

Legislation relevant to morphological change in estuaries can be divided into three categories:

- Legislation regulating an activity or operation within an estuary system that modifies existing physical processes;
- Legislation regulating operations that may result in the construction or removal of features that are part of the morphological estuary system; and

- Legislation protecting or conserving morphological features or the processes that maintain such features, either as features in their own right or as part of the system that requires their functioning.

Some legislation underpins all others, including the Strategic Environment Assessment Directive 2001/42/EC mentioned above, and the proposed Marine Bill, released as a Government White Paper in March of this year (Defra, 2007). Also relevant is the Water Framework Directive (WFD), which came into force in 2000 and is in the process of being implemented in England and Wales, by the competent authority, the Environment Agency. Legislation can place considerable constraints on activities within estuaries, and provide a constantly changing impact on management of estuaries. Some legislation affects all sectors, such as the SEA Directive and Habitats Directive, whereas some legislation is applicable to limited activities or sectors within the estuary. However, there is a move towards more holistic estuary management both within existing and new legislation.

### Management Framework

The dynamic nature of the coastal environment requires an adaptive approach in management frameworks. This approach has led to frameworks being proposed, which are modelled on a cycle with a continuous feedback process. This has been thoroughly explored from a theoretical perspective in relation to sea management (Vallega, 1992) and much of this can be adapted for use in estuaries. In an institutional context, the pressure-state-impact-response model has been suggested as a means of identifying key issues for environmental management (Figure 2.2) (Turner *et al.*, 1998).

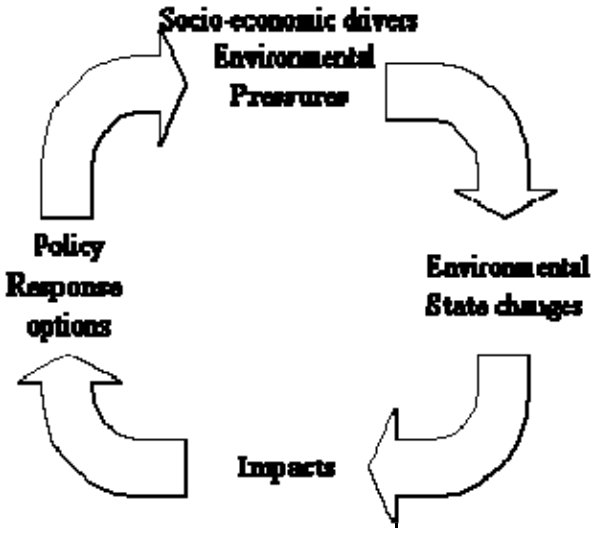


**Figure 2.2 P-S-I-R model (after Turner et al., 1998)**

Nested within this high level framework, more specific frameworks have been proposed to address some of the issues found on the coast (Townend, 1990; Townend, 1992; Capobianco *et al.,* 1999) and in estuaries (Barham, 1997; Pontee & Townend, 1999b; Townend, 2002)[8]. For instance, when considering the morphological response of an estuary, it is possible to consider two approaches, Figure 2.3; Townend (2002) considered

[8] See Framework for estuary shoreline management plans, ABPmer, 2003.

that there are two parallel strands for the assessment of management actions; one strand which considers the resource to be developed or protected and requires the estuary as a whole to be included; and a second strand which considers how the estuary reacts to changes and how this might impact on user interests within the estuary.

The EstSim project found that management actions by estuary users may be at the strategic level, such as the development of a CHaMP, or at the local level, such as the location and impacts of a land-drainage outfall. There are a variety of estuary management questions or actions that can be relevant to the whole estuary or to separate components of the estuary, depending on the manager and their interests (ABPmer, 2007).

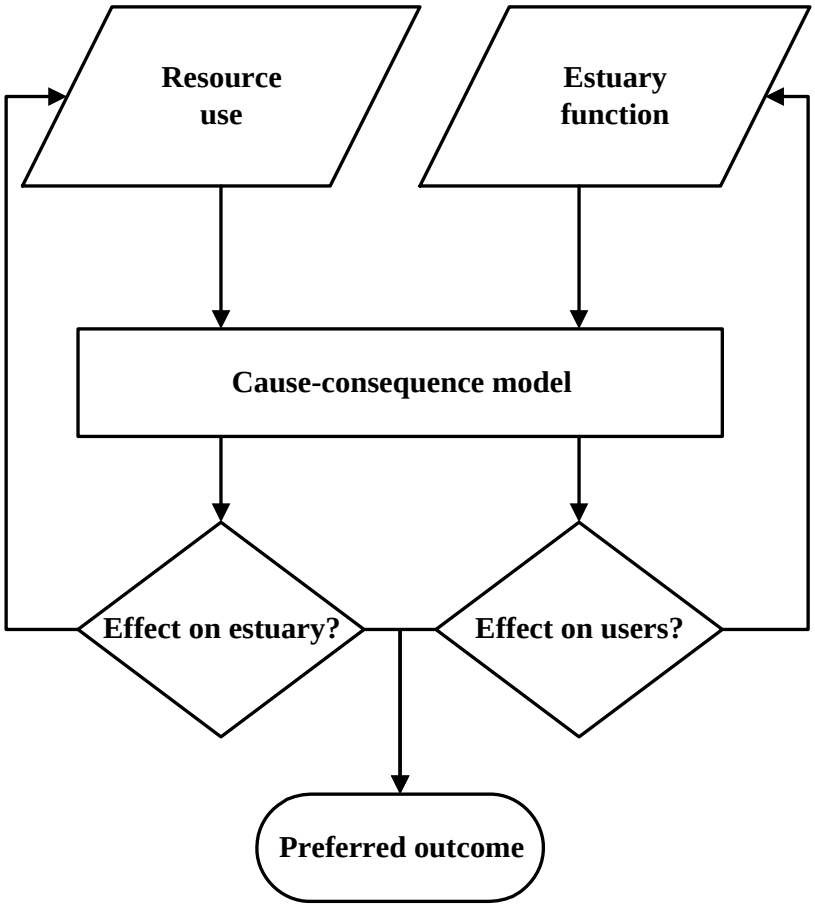


**Figure 2.3 Parallel strands for the assessment of management actions**

An end-user consultation exercise carried out within the EstSim project resulted in a series of management questions, presented here:

General legislative questions:

- How will each of the proposed and adopted legislative measures impact on existing uses and activities within an estuary? (Here proposed and adopted legislative measures include, for example, the WFD, Floods Directive);
- What impact will there be on estuary morphology as a result of above?

The Floods Directive has been set up in order to limit damage to human health, the environment and infrastructure caused by flooding. The directive has been set up so that each member state will adopt a long-term planning framework in order to reduce flood risk. Part of the approach includes assessing the risk of flooding and creating flood risk maps.

Specific questions relating to climate change:

- How will climate change affect forcing factors, including tidal range, storm intensity and frequency, wave heights and direction, within an estuary?
- How will climate change affect existing uses and activities within an estuary?
- How will climate change affect the individual estuary components?
  - e.g. for ports, how will access to docks be affected?
  - What impact will there be on habitats?
  - What changes will there be to sedimentation patterns and supply?

Specific management questions, related to an activity and legislation:

- How will an activity affect the ecological status of an estuary (under the WFD)?
- How will an activity affect sedimentation patterns / habitats (under the Habitats Regulations, WFD, Floods Directive)?
- How will an activity affect flood risk (under the Floods Directive)?
- What will the cumulative impacts be of activities within the estuary (under the SEA Directive, WFD)?

These main issues can be thought of under the Drivers – Pressures – State – Impact – Response framework, where a management question to be tested will affect the Response of the estuary. Table 2.3 effectively interprets the information derived from the questions above in terms of the Drivers – Pressures – State – Impact – Response framework (Socio-Economic Modelling) to derive a series of management question scenarios, under the three main drivers for estuary management currently: climate change, flood and coastal erosion risk management and development pressures. Each of these drivers has a pressure or limiting factor in the form of the relevant legislation or planning process, including the Habitats Regulations, SMPs, the WFD and the SEA Directive.

The state under each scenario can be thought of as the geomorphic state of the whole estuary, or of certain components, such as the habitat area. The impacts are those that the driver and pressure exert on the state, for example, the impact of sea level rise on habitats designated under the Habitats Regulations within an estuary; the response of the estuary to a SMP policy such as 'hold the line', or the impact on the estuary system of a development, such as a barrage or bridge.

The system response can be predicted using the approach encapsulated in the cause-consequence model in Figure 2.4, which refers to a process of identifying causes of change at a number of spatial and temporal scales, determining the system response, and hence predicting the consequences, again at various spatial and temporal scales. Presently, there is no one model that provides the response component. Rather, there are a whole range of analytical and numerical tools that collectively provide a basis for making an assessment (Pontee & Townend, 1999a; EMPHASYS Consortium, 2000)[9]. The limitations of this tool box and in particular the ability to inform the management process is one of the key drivers for further research (Townend, 2002).

[9] See Cause-consequence model, ABPmer, 2003.

**Table 2.3 Estuary Management under the DPSIR framework**

| Driver | Pressures | State | Impact | Response |
|---|---|---|---|---|
| Climate Change | Habitats Regulations | Habitat area / balance. | Impact of sea level rise on designated habitats | Recreate or protect habitats through management of the estuary |
| Climate Change | Habitats Regulations Flood Risk | State of individual estuary components. | Sensitivities of each component of estuary system | Manage / monitor change in estuary components. |
| Flood and coastal erosion risk management | Chosen Shoreline Management Plan policies, (Habitats Regulations) | Estuary geomorphic state, habitat area / balance, sedimentation / erosion. | Response of estuary to the SMP policies | Manage estuary in line with appropriate policies and monitor; review policies as required. |
| Development: individual impacts | WFD[10], consenting / licensing process | Estuary geomorphic state, habitat area / balance, sedimentation / erosion. | Impact on system as a result of development / ability of system to respond. | Control development within estuary in line with policies and legislation. |
| Development: cumulative impacts | SEA Directive | Estuary geomorphic state, habitat area / balance, sedimentation / erosion. | Cumulative impact on system as a result of multiple developments. | Control development within estuary in line with policies and legislation. |

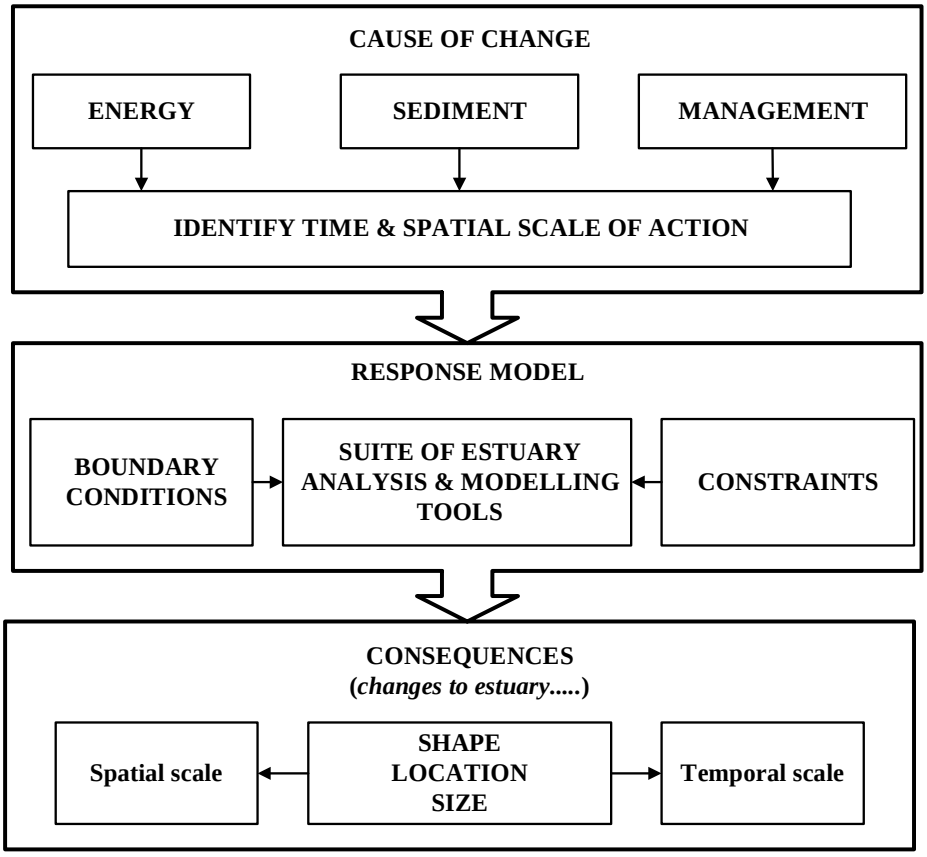


**Figure 2.4 Cause-consequence model for morphological response in an estuary**

[10] Water Framework Directive.

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## ANNEX: Some Comments on Sustainability and its Scientific Context

As noted in the main text, there are many different perspectives of sustainability, reflecting the interaction of ecological, social and economic systems within the universal environment. Each individual system has established ways of operating. The parts that make up a particular system are able to interact and each system has a means of passing *information* or *capital* to successors. In an ecological system, reproduction is used to ensure that genetic information is passed from one generation to the next. Similarly, societies use communication to convey information and this also enables good "ideas" and knowledge (memes[11]) to be passed on. Economic systems also transfer information and assets, giving

[11] The concept that ideas evolve in the same way as genes (Dawkins, 1989).

rise to trade between individuals, companies and nations. Hence each of these systems has a form of capital, be it genes in the ecosystem, memes in a society, or assets within an economy.

Each of these systems makes use of the environment and indeed consumes some of the inherent resources of that environment (sunlight, minerals, etc). There is therefore a complex web of feedback loops within individual systems and between the systems (Figure A.1). Overlaps between each of the systems represent shared objectives, such as conservation (socio-ecology), farming (eco-ecology) and employment (socio-economy). Sustainability will be maximised by seeking to maximise the degree of overlap between the systems.

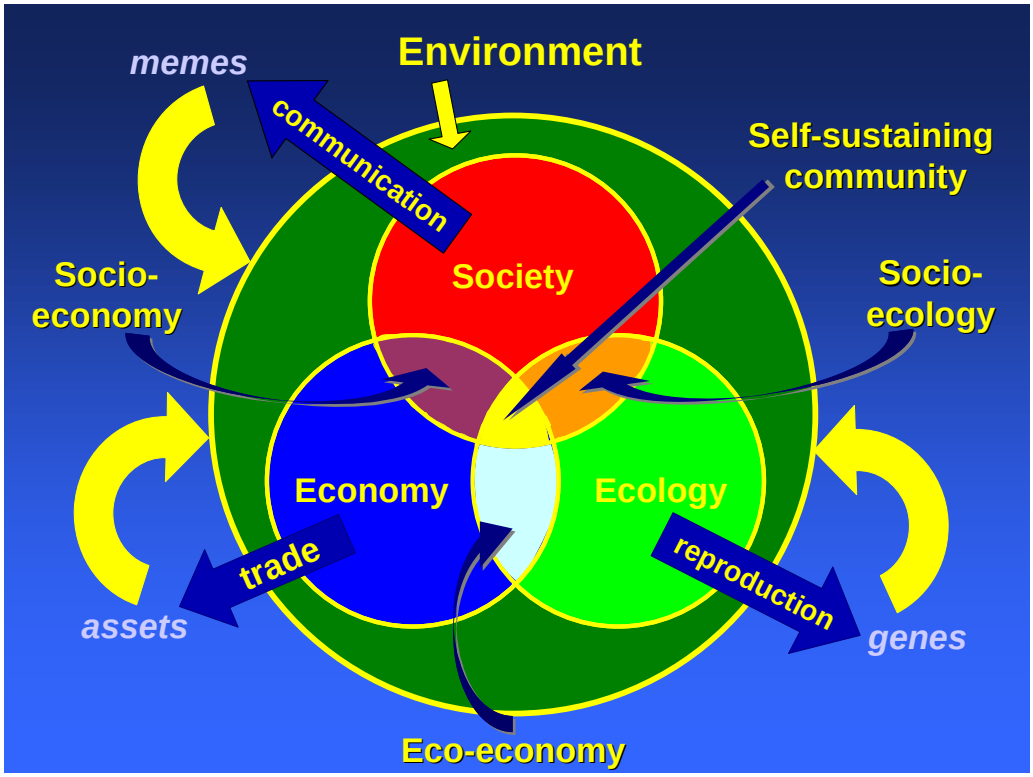


**Figure A.1 Feedback loops in the components of sustainability**

In terms of maintaining a constant capital, Turner has argued that **weak** sustainability is the simple sum of these components and allows unlimited substitution between systems (Turner *et al*., 1998). In contrast, **strong** sustainability requires the natural capital of the ecological system to be maintained, whilst at the same time maintaining the sum of the whole.

It is worth noting that each of these systems is driven by the short-term need to survive. This may give rise to internal conflicts, leading to individual losses (e.g. the collapse of a business), or external conflicts causing losses in one of the other systems (e.g. over exploitation of a resource). What is more, long-term survival is no guarantee of sustainability. For instance the collapse of a business may result in a more sustainable business taking its place, or it may be one component of the demise of an industry. The same is true within ecosystems and societies. Consequently it is essential to recognise that there are a range of spatial and temporal scales implicit in any given view of sustainability.

It may be tempting to assume that the sum of local actions equals the global whole. This reflects cultural heritage and in particular the dominant influence of Newtonian thought for some 300 or more years. Classical dynamics implies that given a definition of the system at some point in time, the past, present and future would be predictable. If nothing else this suggests that science provides only a view of the world "illusions" must always be sought. Newtonian physics underpins determinism, which has of course given rise to much of what supports modern technological lives, but suggests nothing about the irreversible nature of so many processes. It has man as an external observer to an idealised system. In recent decades this has begun to be unravelled as irreversible non-equilibrium processes are explored. The observer is now an integral part of the system, Figure A.2. The system exists due to random fluctuations giving rise to irreversible changes and the creation of what Prigogine (1980) called dissipative structures, (to reflect the juxtaposition of order and dissipation of energy). The observer, and life in general, are just such dissipative structures. Elsewhere these have been called complex adaptive systems, to draw attention to the tendency of systems to become more complex whilst adapting to the surroundings. The simple leads to the complex. This in turn produces diversity, which provides a greater opportunity for systems individually or collectively to adapt to change (Gell-Mann, 1995).

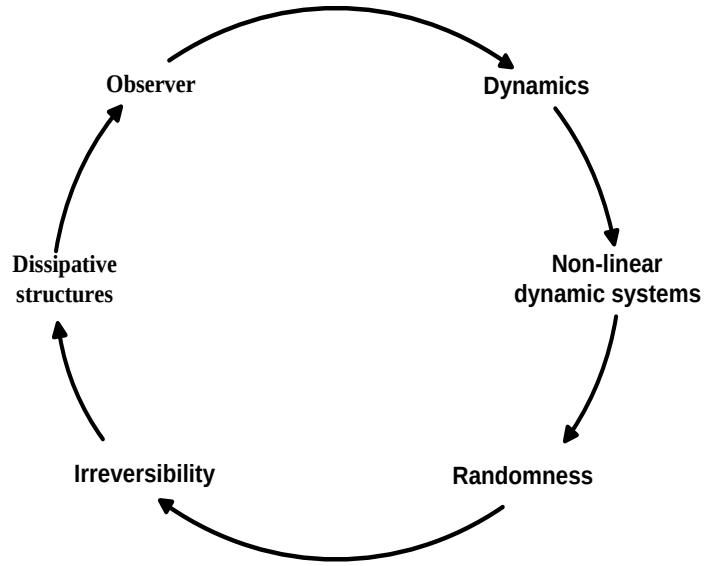


**Figure A.2 Observer as integral to the natural system (after Prigogine, 1980)**

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