# Estuaries

**Scottish estuaries are important resources for wildlife and humans, but are under pressure from human activity and climate change.**

## Summary

Estuaries are important transport routes and many contain ports and harbours, which attract industry and large centres of population, they also provide valuable habitats and breeding grounds for fish and birds. In the past, waste water, generated by people and industry, flowed untreated into industrialised estuaries causing serious pollution. Legislation has improved effluent treatment and this has resulted in better water quality; however, sediments in some estuaries remain contaminated as a result of past discharges. Important estuarine habitats have been lost in industrialised estuaries as a result of land reclamation, construction of ports, harbours and sea defences, and canalisation. Agricultural inputs of nitrogen are a cause for concern in some estuaries in rural areas.

## Introduction

Estuaries are the transition zone between rivers and the sea. The water in estuaries becomes increasingly saline as freshwater mixes with seawater. The degree of mixing between fresh and seawater varies as freshwater floats on top of seawater unless mixing is physically promoted by wind and tidally driven currents. Mixing varies from stratified (salt wedge and Fjord type estuaries) through partially mixed to well mixed, depending on the tidal range and exposure (Figure 1). Scotland's predominantly low-lying east coast is dominated by the three major firths and their adjacent estuaries - the Forth, Tay and Moray. The west coast, however, is quite different, characterised by a highly indented landscape with long narrow fjordic sea lochs and the two major estuaries of the Solway and the Clyde.

The Clyde estuary is an example of a stratified estuary whereas East coast estuaries are usually partially mixed or well mixed. Animals and plants living in estuaries have adapted to cope with the changes in salinity and depth of water, which occur on a diurnal basis with the ebb and flow of the tide.

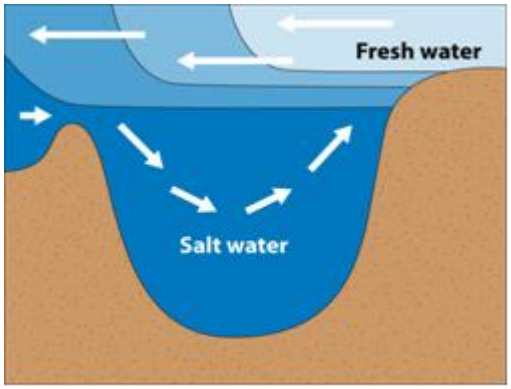
Sometimes estuaries contain saline lagoons, these water bodies are often barely connected to the sea and considered by many to be a halfway house between freshwater lochs and the sea.

In Scotland, there are 50 estuarine water bodies, including nine saline lagoons, covering an area of ~1000 $km^2$. These range in size from 0.0027 $km^2$ (the Pond Cottage lagoon in the Firth of Forth) to the 300 $km^2$ Solway estuary.

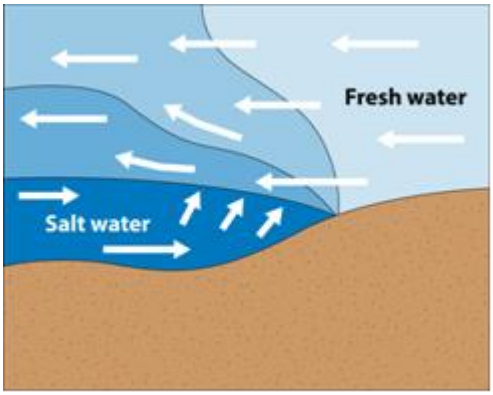
Most large conurbations in Scotland are located on estuaries. As a result, these estuaries receive large volumes of treated sewage and industrial waste water. The impact of waste water discharges on water quality depends on the volume of water, and the degree of mixing and flushing in the estuary. Estuaries with relatively large freshwater inputs compared to their volume are well flushed.

Estuaries are often bounded by organic-rich mudflats and salt marshes. These are important habitats as they provide an abundant food supply for fish and wading birds. Migratory water fowl from further north are attracted to Scottish estuaries by the milder weather. Over half a million waterbirds winter in Scotland, feeding on these estuarine mud and sandflats. Many Scottish estuaries are protected to preserve these habitats where they are of national or international importance.

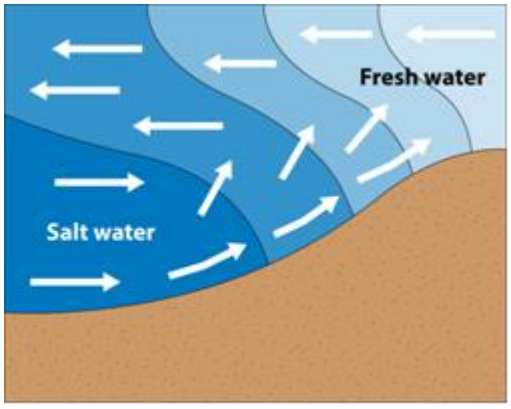
**Figure 1:** Types of estuaries.



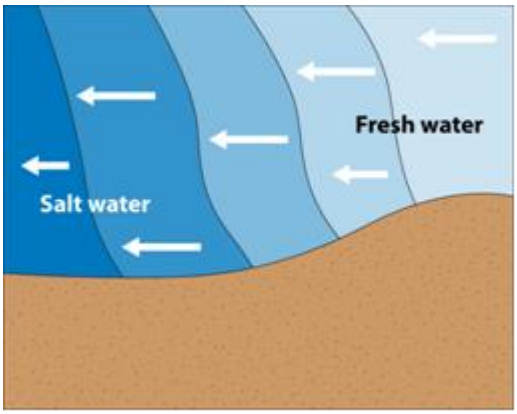

**Fjord Type**




**Salt Wedge**




**Partially Mixed**




**Well Mixed**

## Description of estuaries

The conditions of estuaries are classified using the WFD classification scheme. High status estuaries show very little human alteration from undisturbed conditions, with good status estuaries having only low levels of human alteration. Moderate, poor and bad status estuaries show progressively more impact from human activities. More details on the classification scheme can be found in the 2008 State of the water environment report, and the scheme is explained further in the Policy Statement on the Water Environment and Water Services (Scotland) Act 2003.

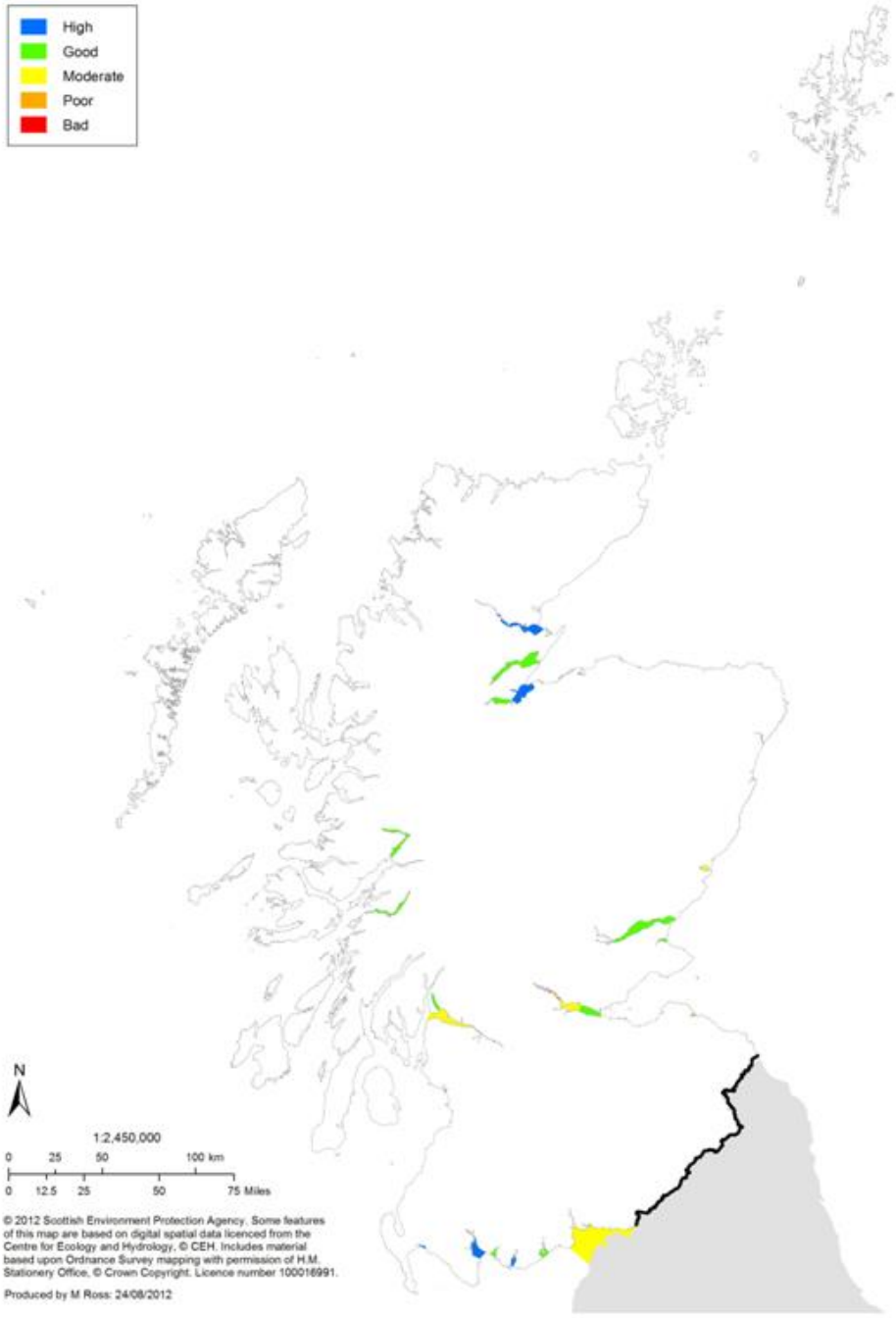
To be in a good condition, our waters need to be clean and free of pollutants at concentrations that would harm the water plants and animals they support, have minimal changes to their habitats and tidal regime and not be adversely affected by invasive non-native species.

Overall, just over half of our estuaries are at high or good status (Table 1 and Figure 2).

**Table 1**: Classification of Scotland's estuaries.

| Indicator | Status | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | High | | Good | | Moderate | | Poor | | Bad | |
| | Area ($km^2$) | Area (%) | Area ($km^2$) | Area (%) | Area ($km^2$) | Area (%) | Area ($km^2$) | Area (%) | Area ($km^2$) | Area (%) |
| Overall status/ potential | 181.29 | 18.3 | 371.24 | 37.4 | 430.23 | 43.3 | 9.67 | 1.0 | 0 | 0 |
| Water quality | 259.98 | 26.2 | 292.54 | 29.5 | 439.90 | 44.3 | 0 | 0 | 0 | 0 |
| Bed and shores | 779.08 | 78.5 | 104.36 | 10.5 | 108.99 | 11.0 | 0 | 0 | 0 | 0 |

**Figure 1:** Overall status of estuaries 2009



## Water quality

Just under half of the area of our estuaries is at less than good status because of the presence of relatively high concentrations of nutrients, in the form of dissolved inorganic nitrogen.. The Solway estuary, the Montrose basin and the Ythan estuary are all at moderate status because of high nutrient inputs from agriculture. Montrose basin and the Ythan estuary are small East Coast estuaries but the Solway accounts for 30% of the total area of estuaries in Scotland.

Although a rich nutrient supply makes our estuaries productive, an excessive nutrient supply can upset the balance of the ecosystem, leading to eutrophication. Excessive input of nutrients accelerates the growth of algae and other water plants. Mats of green algae in the Montrose basin and the Ythan estuary are symptoms of nutrient enrichment.

The decay of plants at the end of the growing season may cause oxygen depletion. Plants and animals need sufficient oxygen to survive and the number of species found decreases at lower oxygen levels. Aquatic animals can also be starved of oxygen as a result of the breakdown of organic matter in waste water discharges (e.g. in sewage), using up oxygen as it decays.

Most estuaries are at good or high status for dissolved oxygen, but the Clyde and upper Forth estuaries are downgraded because of low oxygen levels. Both these estuaries receive relatively large inputs of organic matter from waste water discharges. The sediments in both estuaries are enriched with organic matter from previously untreated discharges, and this contributes to the current problem.

Substances discharged into the environment in waste water that impact wildlife and accumulate in the environment are considered to be hazardous. The WFD sets environmental standards for hazardous substances in waters, and discharges are controlled to ensure that these standards are met. The concentrations of hazardous substances in the waters of our estuaries are within national and international standards, and the WFD classification for these substances indicates that they do not pose a threat to wildlife. Many hazardous substances bind to organic matter in sediments and fatty tissue in animals. Hazardous substances attached to sediments can remain for many years, and hazardous substances in animals can accumulate through the food chain leading to relatively high concentrations in top predators. Contaminants in sediments and mussels in the Forth and Clyde estuaries are relatively high, largely as a result of historical discharges. There is evidence that contaminant concentrations in mussels are decreasing, although the concentrations in sediments have not decreased to the same extent.

The population of sediment-dwelling animals in both intertidal and subtidal sediments in the Forth estuary has gradually become more varied over the last decade; an indication that the sediments are recovering from contamination resulting from previously untreated discharges.

## Habitats

Most estuaries in Scotland have been modified to some extent by building sea defences, reclaiming land, construction of ports and harbours and dredging, although only seven of our 50 estuaries are at lower than good status as a result of changes to their shores and the sea bed.

This land claim (taking land to build on or to construct sea defences and ports) has resulted in the loss of areas of mudflats and salt marshes. These areas are rich food sources for fish and bird life, and important nursery and overwintering habitats for many fish species. The loss of habitat leads to a loss of fish, which ultimately impacts higher in the food web, on animals such as seals and dolphins. In the Forth estuary, land claim has led to the loss of 24% of natural fish habitats, which equates to a 40% reduction in fish food supply.

Commercial fishing for shellfish such as prawns and scallops, and commercial dredging to maintain navigation, may damage fish breeding grounds and sea bed habitat in some areas.

## Non-native species

Although not yet reflected in our classification data, the Significant Water Management Issues report estimated that more than 20% of Scotland's estuaries are at risk of failing to meet environmental objectives because of the presence of invasive non-native (alien) species. Some marine non-native species are widespread in Scotland. They can cause serious problems to the environment and the economy by outcompeting native species and smothering other creatures. Examples include the carpet sea squirt, which smothers the sea bed, and wireweed which forms floating mats that can become entangled in propellers.

# Pressures affecting estuaries

## Waste water

Large volumes of waste water (treated sewage and industrial effluent) are discharged to estuaries.

Waste water can contain:

- **organic matter such as sewage** – which can accumulate in sediments and remove oxygen from the water. Organic enrichment of sediments causes an increase in abundance of opportunistic species and a decrease in diversity;
- **nutrients** – which, in excess quantities, stimulate the growth of algal mats in intertidal areas. These mats smother the sediment, preventing colonisation by sediment dwelling organisms which are an important food source for wading birds;
- **hazardous substances** – which can impact on the diversity and abundance of plants and animals. Some substances can cause disruption to the endocrine system, resulting in changes to the sexual characteristics of organisms and development disorders.

## Diffuse pollution

Diffuse pollution arises from activities across a catchment, and cannot be linked to a specific discharge. It includes inputs from:

- agriculture – nutrients, sediments, pesticides and organic matter washed off the land into water courses;
- urban – pollutants washed off roads into storm drains and sewage overflows;
- oil spills from shipping and recreational craft;
- anti-fouling treatments (applied to boats to prevent the nuisance growth of organisms);
- dredging and dumping of spoil.

## Habitat changes

Estuaries are modified by:

- construction of ports and harbours;
- construction of sea defences;
- dredging;
- canalisation;
- land claim.

## Climate change

There is a lot of uncertainty about the impacts of climate change on estuaries and the impacts on estuaries have not been evaluated. The potential changes in the coastal environment resulting from climate change were identified in the Climate Change Risk Assessment for Scotland published in January 2012. The risks were identified as:

- changes in erosion and accretion rates leading to the loss of important habitats, especially where landward migration is constrained by sea defences;
- changes in species migration patterns;
- saline intrusion into freshwater areas and aquifers may lead to a change in the ecology and impact on economic resources;
- changes in composition and range of shallow marine habitats;
- increases in nutrient and contaminant inputs resulting from an increase in run-off from land. This may lead to an increase in eutrophication and pollution of estuaries.

## Water abstraction

There are 20 water abstractions from Scottish estuaries, the majority of which use the water for cooling. Biocides are added to cooling water to prevent the growth of weeds and invertebrates such as mussels and barnacles. Cooling water is also screened to remove sediment, weeds and fish that could block the pipes. The use of biocides is regulated to prevent any impact when it is returned to the estuary; however, the removal of fish may have a significant impact. It has been estimated that nearly 12.5 million fish, weighing ~75 tonnes, were trapped on the cooling water screens of Longannet Power Station in $1999_1$. A fish return system is being installed at Longannet to reduce mortality and return all fish (alive and dead) to the estuary to reduce the impact on the estuarine ecosystem.

## Noise

Underwater noise in estuaries is generated by dredging, shipping and construction. Many marine mammals, fish and some shellfish communicate by sound. Human-generated noise is thought to interrupt their ability to communicate and may injure or even kill wildlife. There is currently not enough evidence on the extent of noise disturbance, nor of the impacts of noise on wildlife.

## Dredging

Dumping of material on the sea bed is regulated by Marine Scotland, which issues licences under the Marine (Scotland) Act 2010. Dumping at sea has progressively reduced since the 1980s as bans were imposed on the dumping of radioactive wastes (1982), colliery mine stone (1995) and sewage sludge (1998). Only the disposal of dredged material from ports, harbours and marinas is currently allowed.

The Clyde, Forth, Tay and Dee estuaries are regularly dredged to maintain navigable channels for shipping, and the Tay estuary is dredged to remove sand for commercial use. The Forth and Tay estuaries contain licensed dump sites for dredged material. Dredging can directly harm sea bed communities (by the action of dredging) and can pose a contamination risk, with the re-suspension of contaminants contained in the sediment, or their deposition at the dumping site of the dredged material.

## Non-native species

Non-native species can be introduced by visiting ships and recreational craft (either attached to the hull, or in ballast water), floating litter and by aquaculture (either escape of the farmed species, or, more commonly, unintentional introduction alongside the farmed species). Non-native species can significantly alter the ecology of our native communities, as well as causing problems for shipping and aquaculture.

## Litter

Litter is unsightly and can cause harm to wildlife by ingestion or entanglement. Litter can arise from several sources, including:

- being dropped by the public;
- sewage-related debris (such as cotton buds);
- discarded fishing gear;
- being dumped at sea (deliberately or washed overboard from ships).

There are currently no systematic data on the presence of litter in estuaries but it is known to be widespread on the shore and the sea bed. Most litter is plastic, this slowly degrades into micro-particles, and can be found throughout Scotland's seas.

## Reference

[1] Greenwood MFD. (2008) Fish mortality by impingement on the cooling-water intake screens of Britain's largest direct-cooled power-station. *Marine Pollution Bulletin* 56, 723–739.

## Consequences of a change in estuaries

Estuaries provide a variety of benefits; these benefits can be categorised into the ecosystem services provided (for a description of ecosystem services, read the benefits from nature topic). Damaging estuarine ecosystems can damage or even destroy the benefits received from them.

Damaging estuaries can result in the loss of obvious benefits (e.g. their use for transport and cooling water for electricity generation), as well as less directly linked benefits such as the tourism income resulting from appreciation of a healthy environment, the capacity of estuaries to store large water volumes (increasing the risk of flooding) and their role as nursery and overwintering grounds for commercially important fish species.

## Response by society

Water quality in estuaries has improved over the years as a result of improvements to effluent treatment prompted by legislation such as the Dangerous Substances Directive (74/464/EEC) and the Urban waste water treatment directive (97/271/EEC).

The WFD, which was enacted in Scotland in 2003 as the Water Environment and Water Services Act, placed greater emphasis on the ecology of our water environment and for the first time allowed for the regulation of engineering works, which can cause damage to habitats.

Planned improvements to the status of estuaries to be achieved through the WFD are shown in Table 2 and discussed in the river basin management plan. River basin planning is a collaborative approach to managing and improving the environment, and offers opportunities for more effective co-ordination between partners. Actions needed to improve the quality of estuaries to good environmental status are detailed in individual Water Body Data Sheets. Overall, the objective is for 99% of our estuaries to be at good or high status/potential by 2027.

**Table 2:** Planned improvements to the status of estuaries to be achieved through the WFD.

| | Estuary area ($km^2$) | | |
|---|---|---|---|
| **Overall status/potential** | **2015** | **2021** | **2027** |
| High | 217 | 217 | 217 |
| Good | 336 | 336 | 767 |
| Moderate | 430 | 430 | 9 |
| Poor | 10 | 10 | 0 |
| Bad | 0 | 0 | 0 |
| **Total** | **992** | **992** | **992** |
| **Proportion of total at good or better status (%)** | **56** | **56** | **99** |

Diffuse inputs of nitrates from agriculture are regulated by the Nitrates Directive (91/676/EEC). Areas where the nitrate concentration in groundwater is high are designated as Nitrate Vulnerable Zones. Action programmes are put in place to reduce the inputs of nitrates from agriculture in these areas. The catchments of the Solway estuary, the Montrose basin and the Ythan estuary all contain Nitrate Vulnerable Zones. Sources of nitrate to the River South Esk, which drains into the Montrose Basin and the River Ythan, are also being studied as part of SEPA's Diffuse Pollution Monitoring programme. This programme aims to reduce diffuse pollution through encouraging best practice.

The Oslo and Paris Commission (OSPAR) has been working to reduce inputs of hazardous substances to the marine environment for over 20 years through regulation of industries and phasing out the use of some substances, for example:

- **polychlorinated Biphenyls** – UK sales stopped in 1986;
- **brominated Flame Retardants** – use banned in 2004;
- **tri-butyl-tin** – use banned on all boats in 2008.

Although these have been banned, they can still be detected in some parts of the environment, due to their persistence and their continued release from materials made using them.

SEPA uses Controlled Activity Regulations to regulate the discharge of hazardous substances, and policy 61 outlines the controls on the discharges of these substances.

Sustainable Drainage Systems measures are encouraged to reduce diffuse inputs of contaminants in urban areas.

The loss of habitat due to land claim is difficult to rectify and may not be economically viable. There are some small scale projects involving breaching sea defences to restore intertidal habitats.

- Black Devon Wetland (Forth Estuary);
- Skinflats (Forth Estuary);
- Nigg Bay (Cromarty Firth).

The RSPB are planning a larger scale project to restore a network of intertidal habitats in the Forth estuary.

These projects will restore intertidal habitat, which encourages wildlife and reduces flooding by increasing the amount of water held back in the wetlands.