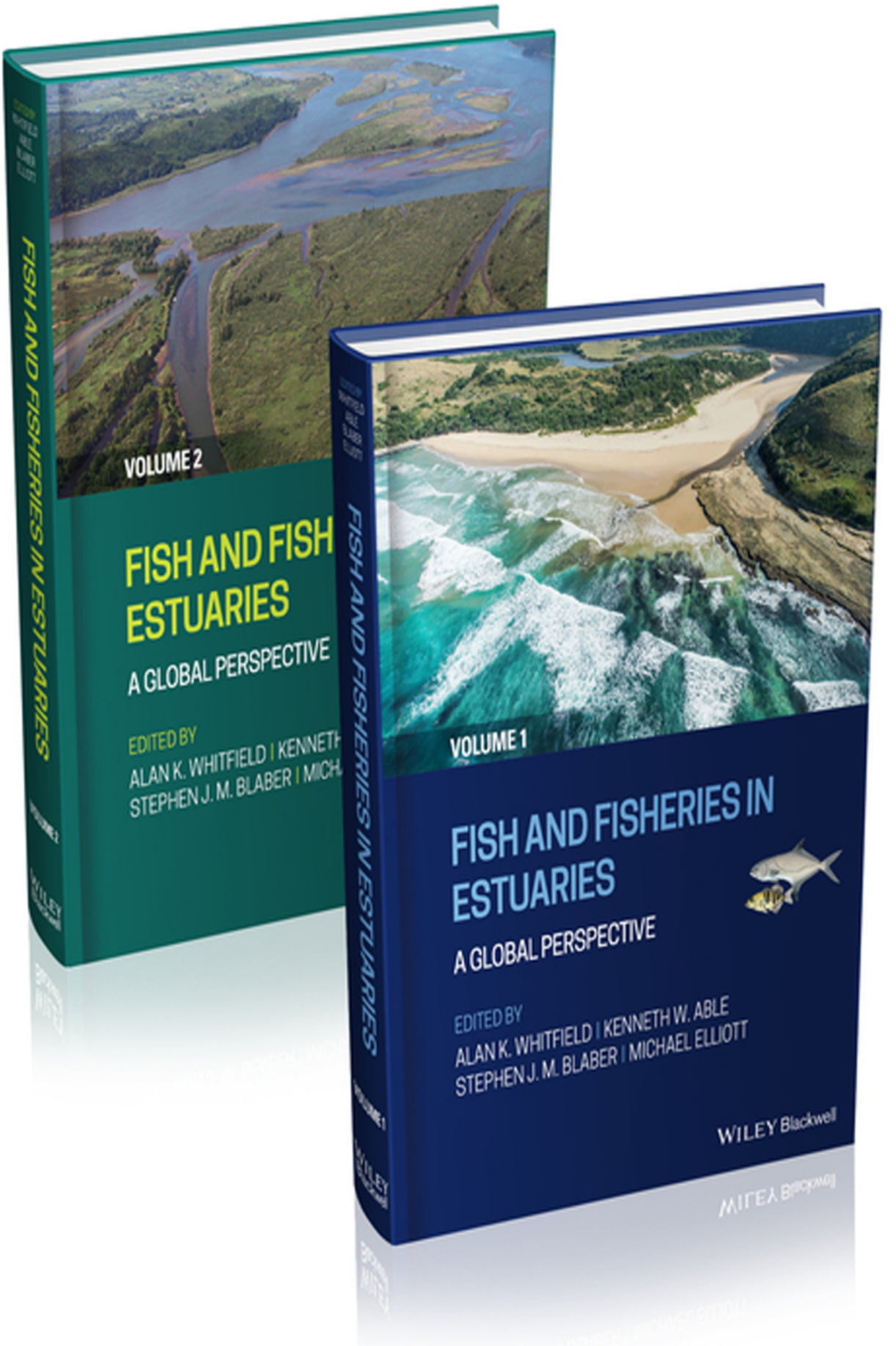
FISH AND FISHERIES IN ESTUARIES
VOLUME 2
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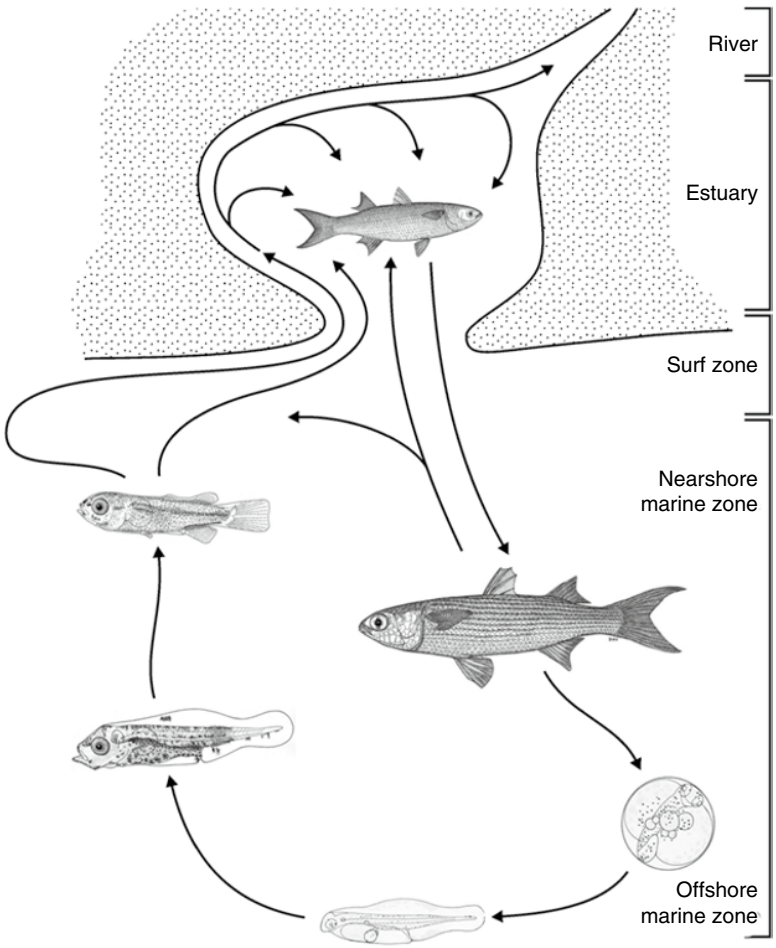
Fish and Fisheries in Estuaries: A Global Perspective


River
Estuary
Surf zone
Nearshore marine zone
Offshore marine zone

Fish and Fisheries in Estuaries

A Global Perspective

Volume 1

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We dedicate this book to our offspring; Alan's grandchildren Brendan and Rory Stones; Ken's children Nathan, Colin and Peter Able; Steve's children Lucy, Gail and Helen Blaber; and Mike's grandchildren Olly, Dylan and Mycah Elliott. We sincerely hope that they will be able to enjoy well-conserved estuaries and fish stocks, and that the number of healthy systems with an abundance and rich diversity of fish will continue to grow in the decades to come.

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Preface

Throughout the world, estuaries are perhaps the type of water body most intimately associated with humans. The reasons for this have been stated often but emphasize sites for harbours, fishing, industrial, and residential development. In addition, since all estuaries represent a meeting place between river and sea, the availability of catchment freshwater supplies are vital for developing and maintaining life in and around these systems.

Coastal communities by their very nature have strong maritime traditions, with estuaries giving ready access to the sea and have therefore been important in human history. Consequently, it is no surprise that many of the world's megacities have developed on estuaries, with residents frequently identifying themselves in relation to their estuary. Our close connection with estuaries has also led to a great deal of interest in the fish stocks, both for food and pleasure – for exploitation, commercial and recreational, and for aesthetic reasons.

However, the importance of estuaries and coasts has also given rise to what we are calling 'the triple whammy' – the increase in industrialisation and urbanisation, the increased use of resources such as food, space and water, and the decreased resistance and resilience to global events such as climate change. Indeed, climate change and the accompanying sea-level rise is already starting to have major impacts on estuaries, fishes and people living along the coast. This close association, particularly in relation with food security and burgeoning human populations, has therefore given urgent impetus to research into maintaining the viability of fish populations in the face of both fishing and other pressures, especially habitat degradation.

The widespread recognition of the value of biodiversity, enshrined in a number of international treaties (e.g. the 1992 Convention on Biodiversity) to which most countries are signatories, has encouraged the documentation of the very diverse estuarine fish faunas, as well as the setting up of protected areas, driving rehabilitation, and the enactment of conservation laws. From a research perspective, the emphasis has shifted from the vitally important tasks of documenting estuarine fish faunas, as well as their often unique biology and life histories, to trying to ameliorate or at least record, all the negative anthropogenic effects on the fishes and their environment, and to achieve a balance between exploitation and conservation. We have learnt that we need to understand not only the structure of the systems but especially the functioning. Perhaps more than other ecosystems, in order to understand and protect estuaries, we need to consider connectivity and what happens in the adjoining areas at sea and in freshwaters. To reach this balance, a good understanding of the fishes and all their interrelationships, including that with humans, are obviously required.

This book seeks to document all aspects of fishes in estuaries from a global perspective. Its genesis was about 10 years ago when Wiley Blackwell, the publishers of two books on tropical and temperate estuarine fishes, suggested that the authors get together and produce an overall volume. Given the rapid increases in knowledge, it was soon realised that this task required a larger multi-author and multi-national approach than the previous volumes, and by involving estuarine ichthyological specialists from many fields. Hence, the present volume – which consists of 13 chapters plus 2 appendices, representing the best efforts of 52 authors to bring together in one book our current state of knowledge of the fish and fisheries in the myriad of estuaries throughout the world.

Alan Whitfield, South Africa
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Mike Elliott, UK

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Chapter 1
Introduction

Alan K. Whitfield, Kenneth W. Able, Stephen J.M. Blaber, and Michael Elliott

1.1 Scope of the book

Estuaries are transitional water bodies that represent the meeting place between rivers or land-based freshwater run-off and the sea. Within this system and its associated catchment and marine areas, there is a set of ecotones, i.e. gradations between the different systems (Basset et al. 2013). These ecotones cover the freshwater-estuary, estuary-marine, surface-water column-bed (vertical) and estuary to the sides (lateral) of systems. Each of these ecotones cover a gradation or even an abrupt change in environmental characteristics. This in turn creates ecoclines, the gradients of change on the biotic and environmental variables. The horizontal ecocline between the freshwater and marine fish components associated with estuaries is often steep (Whitfield et al. 2012). In contrast, the ecocline in fish assemblages between the estuary and the marine environment is usually more gradual (Chaves et al. 2018) and may even extend a considerable distance into the sea (McHugh 1967, Araújo et al. 2002). In some cases, these two different ecoclines may overlap within a single region of an estuary, e.g. in the Thames system there were overlapping gradients for freshwater species from the river to the mid-estuary region, and for marine species, the gradient was from the sea to the mid-estuary (Attrill & Rundle 2002).

Although the environmental (physico-chemical) transition from the sea through the estuary and into the river catchment or watershed may appear gradual (Table 1.1, Basset et al. 2013), the changes between these different aquatic environments represent, for many fish species, major potential barriers (Blaber 1991, Martino & Able 2003), which can be likened to the obstacles facing labyrinthodonts making the transition from water to land! Thus, the assumption that most freshwater and marine fish species have relatively free access to the abundant and diverse food resources and habitats provided by estuaries is a fallacy that is not supported by ichthyological studies that traverse these ecosystem boundaries or transition zones (Barletta et al. 2008).

All fish species have a set of well-defined tolerances to environmental characteristics, and those tolerances may remain constant or change during their lifecycles, for example the ability by some taxa to live for part of their lives in the sea, estuary or catchment. Most fish species, especially those which have life cycles closely tied to either rivers or the sea, are generally confined to those particular aquatic environments and seldom stray into estuaries (Whitfield et al. 2017). However, those taxa that are able, because of their tolerances, to traverse the ecological divisions have access to highly productive waters that provide ideal nurseries and adult feeding grounds for a variety of fish trophic groups (Elliott & Hemingway 2008).

Fish and Fisheries in Estuaries: A Global Perspective, Volume I, First Edition. Edited by Alan K. Whitfield, Kenneth W. Able, Stephen J.M. Blaber, and Michael Elliott.

Table 1.1 Geographic divisions, salinity ranges and zones (Venice System) and the approximate distribution of different categories of ichthyofauna found in a 'generalized' estuary (modified from an estuarine invertebrate concept published by Carriker 1967).

Estuary divisions	Salinity ranges	Salinity zones	Fishes and approximate distribution range within estuaries
River reaches	<0.5	Limnetic	Anadromous migrants; Freshwater taxa
Estuary head	0.5–5	Oligohaline	
Upper reaches	5–18	Mesohaline	
Middle reaches	18–25	Polyhaline	Estuarine residents
Lower reaches	25–30	Polyhaline	
Estuary mouth	30–40	Euhaline	Stenohaline marine taxa; Euryhaline marine taxa; Catadromous migrants

There is little doubt that the highly variable and sometimes widely fluctuating physico-chemical conditions in estuaries are a challenge to many marine or freshwater fish species that would otherwise make extensive use of these systems (Haedrich 1983, Cowan et al. 2013). However, those taxa that are euryoecious (i.e. a wide ability for various variables, including euryhaline for salinity and eurythermal for temperature) and eurytopic have been able to exploit estuaries and have the benefit of occupying one of the most productive natural aquatic ecosystems on the planet (Day et al. 2013). This gave rise to the idea of the stress-subsidy phenomenon in which a highly variable environment is stressful for those species not able to tolerate the conditions but a subsidy for those able to tolerate the varying conditions, and thus thrive (Elliott & Quintino 2019).

Some marine species have become so closely associated with estuarine systems that they are termed 'estuary dependent', especially in terms of nursery area use by the juveniles (Miller et al. 1984). This term has been widely and often loosely used to refer to a wide range of fish species that are found in estuaries (Able 2005). In reality, there is a cline in the association by fish taxa found in estuaries (Figure 1.1), ranging from those species that are completely dependent on estuaries for at least part or all of their life cycle, to those fish that are most abundant in either marine or freshwater environments and only use estuaries opportunistically to varying degrees (Elliott et al. 2007, Potter et al. 2015, Whitfield 2020).

The occupation of an estuary by a particular fish species depends on the availability of a suitable niche for that species. As an initial model, Figure 1.2 summarises the way in which a niche is produced and then occupied by fishes within estuaries, but it also illustrates that most of the driving variables are prone to anthropogenic impacts from a variety of sources. The nature and extent of these impacts feature in a number of chapters within this book (see Chapters 6–11 in particular) and highlight the major role that humans play in determining the future of estuarine fish assemblages going forward. In reality, the full range of abiotic and biotic drivers of fish assemblage structure is very complex and diverse, with a simplified depiction of known factors influencing southern African fish communities being shown in

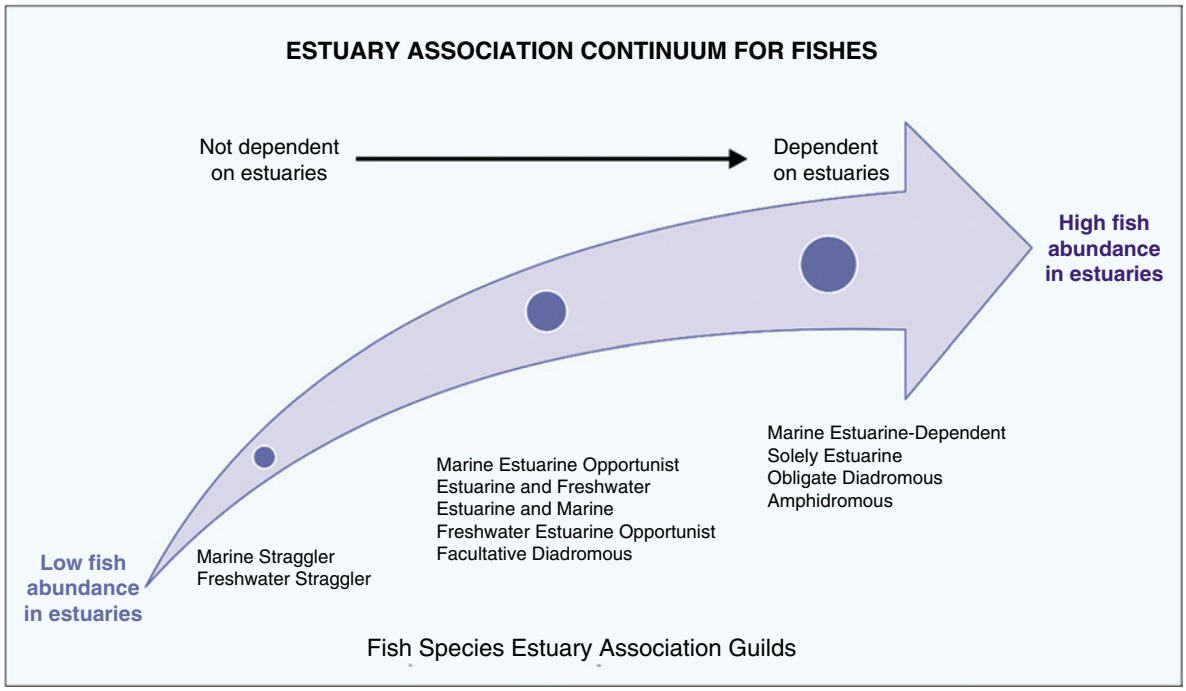

Figure 1.1 Diagrammatic representation of the gradual change in the level of estuary association by fish guilds not dependent on estuaries (lower left) to those completely dependent on estuaries (upper right) (after Whitfield 2020).

Figure 1.3. Despite having worked on some of these drivers for several decades, it would be true to say that, in many instances, our current understanding of the detailed influences on estuarine fish communities is still in its infancy.

1.2 Reasons why this synthesis is important

Anthropogenic impacts on estuarine morphology and hydrodynamics are significant and widespread. Human modifications of riverine flow (e.g. major dams) and estuarine morphology (e.g. canalization) have the ability to substantially modify or completely disrupt natural ecoclines between catchments and the sea (de Groot 2002). These aspects then give rise to important and fundamental questions (Box 1.1).

Box 1.1

To what extent are human developments and activities transforming estuaries into systems that even eurytopic fish species will find difficult to colonise?

Have certain systems already reached that tipping point and been switched into habitats that are not able to support viable estuarine fish assemblages?

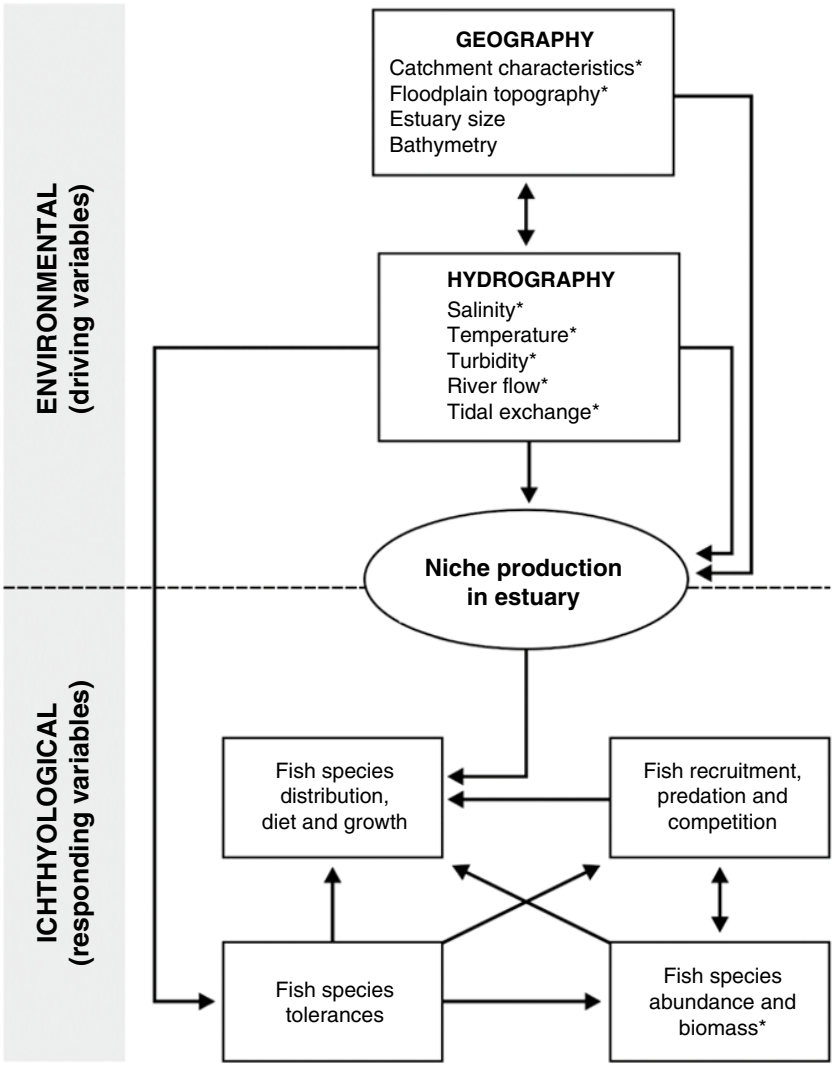

Figure 1.2 Interactions between selected environmental and fish variables in estuaries. An asterisk denotes those variables that are often influenced by anthropogenic activities (modified from Whitfield & Elliott 2002).

Evidence from estuaries such as the Mersey and Thames (UK) suggest that we have had such situations arise in the past due to gross mismanagement, particularly in terms of sewage, industrial and agricultural waste inputs, but that recovery of estuarine fish populations is possible when the degradation process is reversed (Jones 2006, Elliott & Hemingway 2008). Indeed, the Thames lost virtually its entire fish community through gross sewage pollution up to the 1960s but has since recovered to now carry more than 120 species.

Estuaries have recently been characterised as being exposed to a 'triple whammy' of threats – of increasing industrialisation and urbanisation, of increasing use or loss of resources (such as space, energy and biological materials such as fisheries) and of the increased threats of climate change including sea-level rise, acidification and invasive species (Elliott et al. 2019). Whilst this has led to the declining levels of natural estuarine ecosystem functioning which is a characteristic of many estuaries around the world, there are