# APPENDIX E

# SPECIALIST REPORT ON FISH

## DRAFT SPECIALIST REPORT ON THE FISH OF THE ORANGE RIVER ESTUARY

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### Introduction & background

This specialist report reviews the available information on the fish fauna of the Orange River Estuary as part of the Rapid Resource Directed Measures (RDM) assessment of the system.

The Orange River is 2 173 km long with a catchment, excluding the dry areas of Namibia, of 549 000 km in extent that drains approximately 47 % of South Africa (CSIR in prep.). Along with the Berg and Olifants it is one of only three large rivers entering the sea on the arid west coast. Similarly to the Berg and Olifants estuaries, the Orange Estuary falls within a winter rainfall zone with a mean rainfall of 40 mm per annum. Unlike the other two estuaries, most of the catchment falls within the summer rainfall zone with a mean precipitation of 415 mm per annum (CSIR in prep.)

Tidal intrusion extends as far as the Ernest Oppenheimer Bridge approximately 10 km upstream. Surface water area of the estuary is estimated at 600 ha whereas the entire wetland area including saltmarsh and floodplain is approximately 2 000 ha (Van Niekerk *et al*. 2003). Historically the Orange Estuary was a temporarily open / closed system closing briefly during low flow periods and / or the build up of the berm through storm conditions in the winter months. However, the Orange is one of the most regulated rivers on this planet with over fifteen major impoundments and numerous inter-basin transfer schemes (Snaddon et al. 1999). Hydro power releases during the winter months have elevated flows to such an extent that mouth closure seldom, if ever, occurs and seawater intrusion is severely limited. During summer, flood events that reset the system and inundated saltmarsh and floodplain, have been greatly reduced. In turn, most of the spring and early summer floods are captured by the upstream dams with the result that mouth closure, previously a winter event is now more likely to occur in the early wet season. In all, elevated winter flows, reduced summer flows and a shift in mouth closure events amount to a seasonal reversal of the abiotic drivers in the Orange River Estuary.

Despite the above, the Orange remains a freshwater dominated estuary for most of the year and the fish assemblage is expected to comprise estuarine-dependent and freshwater species tolerant of low salinities. In turn, given the biogeographical trend of decreasing species richness from east to west on the South African coast, the paucity of estuaries on the west coast and the vast distances between them, the fish assemblage of the Orange Estuary is likely to be small.

Fish of the Orange River Estuary have been reported on in Brown (1959), Day (1981), DWAF (1986), Morant & O'Callaghan (1990), Harrison (1997) and Seaman & van As (1998). Most of these studies seemed to have been based on the preconception that the Orange had a paucity of fish species and that there was little if no community structure or fish assemblage that was typically estuarine. Consequently, with the exception of the latter two studies, all the rest comprised anecdotal evidence or a few opportunistic seines or gillnet sets in the mouth region with little or no quantification of catches.

Harrison (1997) sampled the lower 6 km of the estuary quantifying adult small and juvenile fish but the study lacked in that it did not extend far enough upstream. Seaman & Van As (1998) sampled from the mouth to Brandkaros 35 km upstream but used almost entirely gillnets targeted on large fish and ignored the two main "tenets" of estuarine studies by failing to quantify or even mention the juvenile component of the fish assemblage or nursery function of the system. Cambray (1984) sampled the lower 1000 km of the Orange River intensively, including the estuary. Importantly, he found estuarine species, namely southern mullet *L. richardsonii*, approximately 100 km from the mouth.

**Importance of the estuary to fish**

The benefits provided by estuaries to fish are well documented and include high productivity, low predation, low salinities and refuge from adverse conditions in the marine environment such as low temperature or oxygen levels, all factors which contribute to more rapid growth and/or reduced mortalities (Potter *et al*. 1990, Whitfield & Marais 1999). As a result, many South African fish species are either partially or entirely dependent on estuaries to complete all or part of their lifecycle (Wallace *et al*. 1984). The life history characteristics of most of South Africa's estuarine fish are known. This allows the fish recorded from the Orange River Estuary to be classified into the five major categories of estuarine-dependence suggested by Whitfield (1994) (Table 1).

Twenty-nine species of fish representing 14 families have been recorded from the Orange Estuary (Brown 1959, Day 1981, Cambray 1984, DWAF 1986, Morant & O'Callaghan 1990, Harrison 1997 & Seaman & van As 1998) (Table 2). Three of these, the estuarine round herring (*Gilchristella aestuaria*), barehead goby (*Caffrogobius nudiceps*) and klipvis (probably *Clinus superciliosus*) live and breed in estuaries but the latter two also have marine breeding populations. Three species, white steenbras (*Lithognathus lithognathus*), leervis (*Lichia amia*) and the facultative catadromous flathead mullet (*Mugil cephalus*) are dependent on estuaries for at least their first year of life whereas another two, elf (*Pomatomus saltatrix*) and harder (*Liza richardsonii*) are partially estuarine dependent. Six species such as west coast steenbras (*Lithognathus aureti*) and silver kob (*Argyrosomus inodorus*) are marine species that occasionally venture into estuaries whereas 14, such as largemouth yellowfish (*Labeobarbus kimberleyensis*), river sardine (*Mesobola brevianalis*) and the introduced carp (*Cyprinus carpio*) are euryhaline freshwater species whose penetration into the estuary is determined by salinity tolerance. One catadromous species the longfin eel *Anguilla mossambica* has been recorded from the Orange River near Kakamas and it is assumed that recruitment occurred through the estuary notwithstanding the (more likely) possibility that it entered the system through one of the inter-basin transfer schemes that connect the catchment with rivers on the east coast. Overall, 31 % of the fish species recorded from the Orange Estuary are either partially or completely dependent on estuaries for their survival, 21 % are marine and 48 % freshwater in origin.

Two species of kob, silver kob *Argyrosomus inodorus* and Angolan kob *A. coronus* are known from the Orange Estuary, the latter only been caught by anglers in the mouth region. Interestingly, on the east coast of South Africa dusky kob (A. *japonicus*) are dependent on estuarine nursery areas whereas *A. inodorus* seldom if ever ventures into estuaries. On the west coast however, *A. inodorus* frequently (&

**Table 1.** The five major categories of fishes which utilize South African estuaries (After Whitfield 1994)

| Categories | Description of categories |
|---|---|
| **I** | Estuarine species which breed in southern African estuaries. Further divided into:<br>**Ia**. Resident species which have not been recorded spawning in the marine or freshwater environment<br>**Ib**. Resident species which also have marine or freshwater breeding populations. |
| **II** | Euryhaline marine species which usually breed at sea with the juveniles showing varying degrees of dependence on southern African estuaries. Further divided into:<br>**IIa**. Juveniles dependent on estuaries as nursery areas.<br>**IIb**. Juveniles occur mainly in estuaries but are also found at sea.<br>**IIc**. Juveniles occur in estuaries but are usually more abundant at sea |
| **III** | Marine species which occur in estuaries in small numbers but are not dependent on these systems |
| **IV** | Euryhaline freshwater species, whose penetration into estuaries is determined by salinity tolerance. Includes some species which may breed in both freshwater and estuarine systems. |
| **V** | Catadromous species which use estuaries as transit routes between the marine and freshwater environments. Further divided into:<br>**Va**. Obligate catadromous species which require a freshwater phase in their development<br>**Vb**. Facultative catadromous species which do not require a freshwater phase in their development |

predictably) occurs in the Berg, Olifants and Orange Estuaries whereas *A. coronus* is predominantly caught on the beaches immediately adjacent to their mouths only having been recorded in estuaries during low oxygen conditions in the sea (Lamberth unpublished data). Therefore, *A. inodorus* may show some degree of estuarine dependence on the west coast of South Africa. All three of the kob species mentioned prefer turbid waters such as that in the Orange Estuary. Further, towards the edge of the range of *A. inodorus*, *A. coronus* becomes the dominant kob species in the Kunene River Estuary over 1 500 km to the north.

Comparisons with other estuaries and biogeographical regions are difficult because the data collected in the Orange Estuary, and consequently the relative contribution of each estuarine-dependence category, varies according to the gear used in each study and the distance sampled from the mouth. Overall, species that breed in estuaries and / or estuarine residents comprise 10-22 % of the Orange Estuary fish fauna as compared to 26-27 % for the Berg and Olifants estuaries (400 - 500 km to the south) and 4-25 % for estuaries on the south, east and KwaZulu-Natal coasts (Bennett 1994, Lamberth & Whitfield 1997). Entirely estuarine dependent species comprise 24-33 % of the Orange Estuary fish fauna comparing well with the 26, 25-54, 22 and 9 % recorded for the west, south, east and KwaZulu-Natal coasts respectively (Bennett 1994, Lamberth & Whitfield 1997, Harrison 1997, 1999). Partially estuarine dependent species comprise 7- 22 % of the Orange fish fauna, which is lower than the 29-40 % for the Berg and Olifants and 18-27 % for estuaries from Cape Point to KwaZulu-Natal (Bennett 1994, Lamberth & Whitfield 1997). Non estuarine dependent marine species comprise 21 % of the species recorded but at least two of these, *A. inodorus* and *L. aureti*, occur predictably according to season and weather conditions as opposed to being vagrants that occur randomly.

**Table 2.** A list of all species recorded in the Orange / Gariep Estuary by (a) Harrison 1997, (b) Day 1981, (c) Seaman & Van As 1998, (d) Cambray 1984, (e) Brown 1959, (f) DWAF 1986 and (g) Morant & O' Callaghan 1990. The species are classified into five major categories of estuarine-dependence as suggested by Whitfield 1994, Table 1. Species recorded by anglers marked with an asterisk *.

| Family | Species | Common name | Dependence category | Recorded by | % Samples reported |
|---|---|---|---|---|---|
| Anguillidae | *Anguilla mossambica* | Longfin eel | Va | f * | 14 |
| Austroglanididae | *Austroglanis sclateri* | Rock catfish | IV | d | 14 |
| Carangidae | *Lichia amia* | Leervis | IIa | c | 14 |
| Cichlidae | *Oreochromis mossambicus* | Mozambique tilapia | IV | a,c,d,g | 57 |
| | *Pseudocrenilabris philander* | Southern mouthbrooder | IV | a,c,d | 43 |
| | *Tilapia sparrmanii* | Banded tilapia | IV | d | 14 |
| Clariidae | *Clarias gariepinus* | Sharptooth catfish | IV | c,d,g | 43 |
| Clinidae | *Clinus* sp. | Klipvis | Ib | f | 14 |
| Clupeidae | *Gilchristella aestuaria* | Estuarine round-herring | Ia | a,c | 29 |
| | *Sardinops occellatus* | Sardine | III | a | 14 |
| Cyprinidae | *Barbus hospes* | Namaqua barb | IV | d | 14 |
| | *Barbus paludinosus* | Straightfin barb | IV | c,d | 29 |
| | *Barbus trimaculatus* | Threespot barb | IV | d | 14 |
| | *Cyprinus carpio* | Carp | IV | c | 29 |
| | *Labeo capensis* | Orange River mudfish | IV | c,d | 29 |
| | *Labeo umbratus* | Moggel | IV | g | 14 |
| | *Labeobarbus aeneus* | Smallmouth yellowfish | IV | a,b,c,d,g | 71 |
| | *Labeobarbus kimberleyensis* | Largemouth yellowish | IV | c,d | 43 |
| | *Mesobola brevianalis* | River sardine | IV | c,d | 29 |
| Gobiidae | *Caffrogobius nudiceps* | Barehead goby | Ib | a | 14 |
| Mugilidae | *Liza richardsonii* | Southern mullet / harder | IIc | a,b,c,d,e,f,g | 100 |
| | *Mugil cephalus* | Flathead mullet | IIa | a,b,c,e | 57 |
| Pomatomidae | *Pomatomus saltatrix* | Elf | IIc | c | 14 |
| Rajidae | *Raja* spp. | Skates | III | g | 14 |
| Sciaenidae | *Argyrosomus coronus* | Kob | III | * | |
| | *Argyrosomus inodorus* | Silver kob | III | a,b,c,g | 57 |
| Sparidae | *Diplodus cervinus* | Wildeperd / zebra | III | c | 14 |
| | *Lithognathus aureti* | West coast steenbras | III | * | |
| | *Lithognathus lithognathus* | White steenbras | IIa | b,c,g | 43 |

Based on their distributional ranges, 22 (76 %) of the fish recorded in the Orange River Estuary are southern African endemics, 11 estuarine or marine, 11 freshwater in origin (Smith and Heemstra 1986, Skelton 1993). Maree *et al* (2003) rank the Orange Estuary at number 62 out of a total of 248 South African estuaries with regards to it's importance to fish. In terms of the fish importance score outlined in the RDM methods, the Orange Estuary has a biodiversity and overall importance score of 60%, which places it within the 2$^{de}$ quintile of all estuaries in South Africa (Taljaard *et al*. 2003). The Orange is one of only three large estuaries of a total of nine on the west coast and, excluding Verlorenvlei, provides 20 % of the estuarine area available to fish (Turpie *et al*. 2002, Lamberth & Turpie 2003). Its importance lies in its size and its situation in a region where there are only a few isolated estuaries spaced hundreds of kilometres apart (Bennett 1994). If the Orange were to lose its estuarine function, the likely result would be a range shrinkage of completely estuarine dependent species by at least 400 km southwards to the Olifants Estuary.

Also important to consider is that the Orange Estuary may be a crucial component of the linkage or exchange between South African and Angolan stocks of at least two estuarine dependent or associated species. Current speculation is that the South African stocks of elf (*Pomatomus saltatrix)*, and perhaps leervis (*L. amia)*, are not necessarily one stock each, but two. It's generally accepted that both these species spawn off KwaZulu-Natal with the larvae and juveniles dispersing southwards and westwards to estuaries throughout the coastline. However, there are also Angolan stocks of these species which may disperse southwards during El Nino years when Namibian waters are warmer and upwelling events less frequent. The Orange and other estuaries on the west coast may provide the warm water refuge when summer upwelling resumes. A similar process is thought to drive the southwards migration of *A. coronus* which, although not recruiting to estuaries, is almost exclusively caught in the turbid warm water cells that occur close to shore in St Helena, Donkin's and other small bays along the west coast.

**Spatial & temporal distribution & abundance**

Catches in the Orange Estuary are fairly seasonal with the highest being in the spring (Table 3). This is likely to be a combination of new recruits entering the system, marine species remaining before salinities are "diluted" and freshwater species moving downstream in response to the first wet season flows. Winter catches are the lowest comprising a few (7) estuarine, marine and freshwater species tolerant of high salinities. Catches in the winter months are dominated by the partially estuarine dependent *L. richardsonii* whereas those in the spring, summer and autumn months are mostly the latter species plus roughly equivalent numbers of the freshwater *Labeobarbus aeneus*, *Labeo capensis* and *Oreochromis mossambicus*. Overall, *L. richardsonii* (81 %) dominates the total catch followed by *L. aeneus* (7 %) and *M. cephalus* (4 %).

Interestingly, spring catches reported by Harrison (1997) and Seaman & Van As (1998) bear absolutely no resemblance even though both samples were taken in September 1993 (Table 3). Much of this discrepancy is probably due to Seaman & Van As using predominantly gillnets and sampling 35 km upstream whereas Harrison sampled in the lower 10 km using gillnets and seines, the latter to sample the small and juvenile fish component more thoroughly. In turn, Harrison's visit was during mouth closure whereas the tidal variation in salinity reported by Seaman & Van As suggest that the mouth was open during their visit.. The presence of at least two size classes of *L. richardsonii* corresponding to 0-1 year-old and 2 year-old fish suggests that the Orange Estuary is being utilized as a nursery for this species (Harrison 1997). Similarly, various size classes of *Gilchristella aestuaria* indicate that the estuary is supporting a viable population of this species. The non estuarine-dependent pilchard (*Sardinops sagax*) and *A. inodorous* were both captured during mouth closure suggesting that they easily survive these events. Salinity ranges were well within their tolerance levels, bottom salinity ranging from 29 ppt near the mouth to 16 ppt 6 km upstream. *S. sagax* has been recorded in a salinities less than 10 ppt, 40 km from the mouth of the Berg Estuary whereas *A. inodorous* has been recorded in salinities of less than 5 ppt 10 km upstream in the Olifants Estuary (Lamberth unpublished data).

**Table 3.** Species composition (%), total catch and occurrence (%) in seine and gillnet samples in the Orange / Gariep Estuary during the period autumn 1993 – summer 1994 (after Harrison (1997) and Seaman & Van As (1998). The latter did not distinguish between seine & gillnet samples but the majority of the catch was by gillnets.

| | Autumn 1993 – Summer 1994 (Seaman & Van As) | | | | | | Spring 1993 (Harrison) | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | % Catch | | | | TOTAL | % Occurrence | % Catch | | TOTAL | % Occurrence | |
| | Autumn | Winter | Spring | Summer | | | gillnet | seine | | | |
| *Liza richardsonii* | 15.07 | 60.85 | 26.73 | 26.53 | 678 | 58.33 | 48.00 | 97.33 | 8442 | 85.71 | **9120** |
| *Labeobarbus aeneus* | 15.07 | 17.45 | 16.04 | 34.81 | 512 | 54.17 | 48.95 | 0.37 | 288 | 23.81 | **800** |
| *Mugil cephalus* | 7.88 | 13.19 | 26.21 | 17.83 | 478 | 62.50 | | 0.01 | 1 | 4.76 | **479** |
| *Labeo capensis* | 21.58 | 3.40 | 12.09 | 10.27 | 281 | 37.50 | | | | | **281** |
| *Oreochromis mossambicus* | 14.73 | 3.40 | 11.92 | 2.28 | 203 | 58.33 | 2.48 | 0.02 | 15 | 19.05 | **218** |
| *Gilchristella aestuaria* | | | | 0.14 | 1 | 4.17 | | 2.16 | 182 | 19.05 | **183** |
| *Mesobola brevianalis* | 14.73 | | 3.68 | | 85 | 12.50 | | | | | **85** |
| *Labeobarbus kimberleyensis* | 2.40 | 1.28 | 1.14 | 2.14 | 38 | 45.83 | | | | | **38** |
| *Pomatomus saltatrix* | 1.71 | | | 3.57 | 30 | 20.83 | | | | | **30** |
| *Pseudocrenilabris philander* | 3.08 | | 0.88 | | 19 | 16.67 | | 0.07 | 6 | 19.05 | **25** |
| *Clarias gariepinus* | 3.08 | | 0.88 | 0.71 | 24 | 25.00 | | | | | **24** |
| *Lithognathus lithognathus* | | | 0.35 | 1.43 | 14 | 8.33 | | | | | **14** |
| *Argyrosomus inodorus* | | 0.43 | | 0.14 | 2 | 8.33 | 0.38 | | 2 | 9.52 | **4** |
| *Caffrogobius nudiceps* | | | | | | | | 0.04 | 3 | 9.52 | **3** |
| *Barbus paludinosus* | | | 0.09 | | 1 | 4.17 | | | | | **1** |
| *Cyprinus carpio* | 0.34 | | | | 1 | 4.17 | | | | | **1** |
| *Diplodus cervinus* | 0.34 | | | | 1 | 4.17 | | | | | **1** |
| *Lichia amia* | | | | 0.14 | 1 | 4.17 | | | | | **1** |
| *Sardinops sagax* | | | | | | | 0.19 | | 1 | 4.76 | **1** |
| **Number of species** | **12** | **7** | **11** | **12** | **17** | | **5** | **7** | **9** | | **19** |
| **Total number of fish** | **292** | **235** | **1141** | **701** | **2369** | | **525** | **8415** | **8940** | | **11309** |

Upstream distribution of the species caught during autumn-winter and spring-summer was largely a function of the estuarine-dependence category to which they belong (Fig 1). Distribution and abundance of *Mugil cephalus*, a category IIa, facultative catadromous species that ventures far into freshwater, did not vary much between winter and summer. In both seasons there were three areas of "high density" these being the 1-2 km, the REI zone 5-10 km and the freshwater reaches 35 km from the mouth respectively. *Lithognathus lithognathus* and *Lichia amia* both category IIa species dependent on estuaries for their first year of life were caught exclusively in the first kilometre and only during summer. This suggests that, despite summer flows being high, these two species may recruit during spring and remain throughout the year without being flushed from the system. Adults are also likely to enter the estuary during summer to escape cold upwelling events in the sea. Temperature differences between sea and estuary are often in the region of 10 ºC during summer.

*Liza richardsonii*, a category IIc species shows an upstream shift during the winter months probably in response to saltwater intrusion and expansion of the REI zone (Figure 1). During summer, higher flows see them concentrated nearer the river mouth with much of the population likely to be continuously

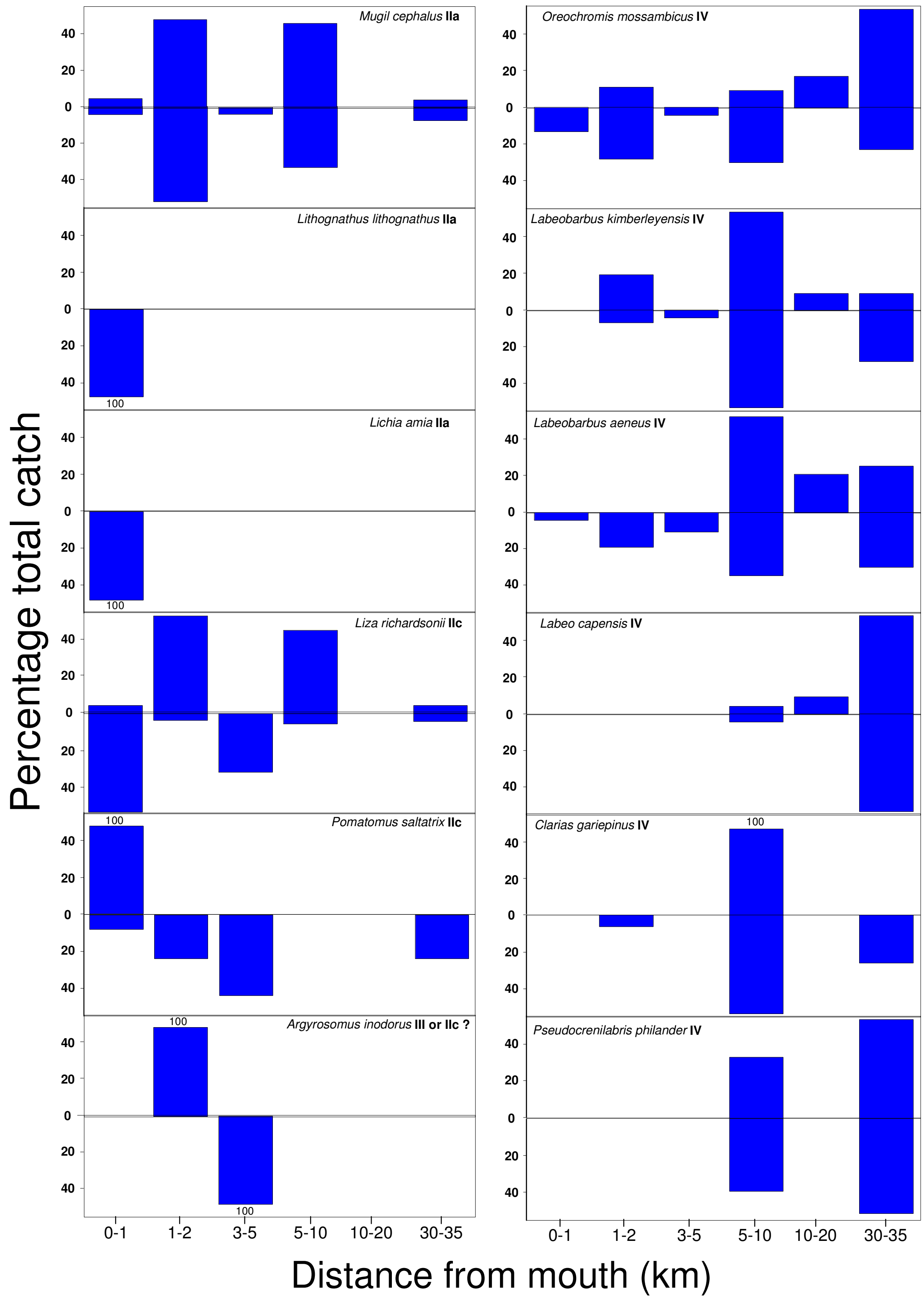


**Fig. 1.** Percentage of total catch from the mouth of the Orange River Estuary to Brandkaros 35 km upstream during Autumn-Winter 1993 and spring-summer 1993-1994. Winter catches are shown above, and summer catches below, each axis. Species arranged in order of their estuarine dependence category (Table 1). Note that the distance axis is not continuous. (Data after Seaman & Van As 1998).

moving between the estuary and adjacent surf-zone with the tides. Densities within the estuary are also likely to increase in response to upwelling events. This species also ventures far upstream with a few individuals caught in both summer and winter 35 km and even over 100 km from the mouth (Cambray 1984). The response of *Pomatomus saltatrix* (category IIc) during summer high flows is unexpected. During winter, all catches were made in the lower 1 km of estuary whereas in summer they were caught at most sites and well into the freshwater reaches. Catches were represented by at least two, perhaps three, year classes of 150-300 mm and 350-400 mm respectively. These are similar to those recorded in the Berg and Olifants Estuaries where the commercial "bycatch" of *P. saltatrix* amounts to approximately 120 t per annum mostly during the summer months. This suggests that, despite the elevated summer flows in the Orange, recruitment of *P. saltatrix* follows similar patterns to that of the Berg and Olifants Estuaries the latter which fall entirely into a winter rainfall zone experiencing summer low flows. *Argyrosomus inodorus*, a category III marine species also shows a slight upstream shift during the summer which, although data are limited, may be another indication that it shows some degree of estuarine dependence on the west coast.

Category IV freshwater species such as *O. mossambicus*, *L. kimberleyensis* and *L. aeneus* showed a downstream shift into the estuary during the summer months and higher flows although the bulk of their populations remained above the REI zone during both seasons. *O. mossambicus* and *L. kimberleyensis* appear to be more tolerant of high salinities with both being found in the lower 2 km during winter. *O. mossambicus* has been known to survive in salinities in excess of 100 ppt and often takes advantage of adverse conditions such as poor water quality and low oxygen by moving into areas from which other fish have been excluded.

**Assessment of the present day**

On the whole, the current fish assemblage and the presence of estuarine residents and juveniles of estuarine dependent species such as *G. aestuaria*, *C. nudiceps*, *L. richardsonii* and *P. saltatrix* suggests that the Orange Estuary functions as a viable nursery area and refuge for juvenile and adult estuarine fish though perhaps not as well as under natural conditions. Historically, it was likely that estuarine and freshwater fish escaped floods and high flows by either swimming upstream or moving onto the inundated floodplain and saltmarshes. Nowadays obstructions such as the dykes and causeway have removed much of this temporary refuge and the chances of being flushed from the system are higher and may even occur at slightly lower flows. Reduced inundation of the marginal and channel areas of the saltmarsh are also likely to have seen a reduction in habitat and numbers of benthic species such as the goby *Caffrogobius nudiceps*. Higher flows in the winter months may have reduced the residence time and / or numbers of marine and estuarine dependent species entering the system whereas lower flows during the summer months may have seen fewer fish escaping cold upwelling events in the sea. Higher winter flows are also likely to have resulted in the freshwater species persisting in the estuary throughout winter whereas previously they would have moved back into the upper reaches in response to increased salinity.

The fish community is typical of a freshwater dominated and temporarily open / closed estuarine system comprising a relatively small group of species such as *L. richardsonii*, *G. aestuaria* and *L. amia* that are tolerant of low salinities and of being cut off from the sea for extended periods. Available habitat is not confined to the tidal influence but extends into the freshwater reaches as evidenced by *P. saltatrix* and *L. richardsonii* being recorded at 35 km and 150 km from the mouth respectively.

On a cautionary note, comparing present and reference conditions there appears to have been an almost complete (75 %) seasonal reversal in flows from the reference to the present state with marine conditions dominating in previously freshwater months and *vice versa*. The impact that this has had on recruitment, migratory or spawning cues is unknown but may have resulted in a decline in abundance or the loss of some species from the system.

**Importance of the estuary to fishers**

The value of estuarine fisheries and estuary contribution to marine fisheries on the west coast is in the region of R 18 million per annum of which R 3 million (17 %) can be attributed to the Orange Estuary (Lamberth & Turpie 2003). Although recreational angling is the dominant fishing method, cast-netting and a moderate level of illegal gillnetting take place within the Orange River Estuary. Under the Marine Living Resources Act of 1998, no commercial linefishing is permitted within estuaries.

The estuarine line-fishery comprises recreational shore-angling and limited recreational boat fishing. The boats used range from small dinghies to ski-boats of 6 m in length. Based on angler densities on the adjacent shorelines and angler and boat counts in the Berg and Olifants estuaries, there may be up to 0.12 anglers per km of estuary or a maximum of 4 400 angler-days per year expended in west coast estuaries from the Berg River northwards (Lamberth & Turpie 2003). The gear used ranges from handlines to fishing rods of various shapes and sizes including fly-fishing. All the effort is currently recreational although approximately 14 % of these anglers admit to selling part of their catch (Lamberth 1996).

An estimated 14 t of marine line-fish are caught annually from estuaries on the west coast, one ton (7 %) from the Orange Estuary. Recreational anglers catch a further 0.1 t of harders (Liza richardsonii) using cast-nets as well as an unknown quantity of frehwater fish. .The bulk of the Orange Estuary linefish catch comprises silver kob (*A. inodorus*), Angolan kob (*A. coronus*), white steenbras (*L. lithognathus*), west coast steenbras (*L. aureti*) and elf (*P.saltatrix*). Of these, the stocks of *A. inodorus* and *L. lithognathus* are collapsed and those of *P.saltatrix* and *L. aureti* overexploited. Estuarine fish stocks cannot be considered as discrete and in isolation from the marine environment. The current status of estuarine stocks is largely a reflection of the nationwide decline that has occurred for most line-fish species. In all, the associated yields are not sustainable with the current levels of effort.

There are currently no commercial gill or seine-net permits issued for the Orange Estuary. The Olifants Estuary has 45 gillnet permit holders whereas the Berg River gillnet fishery has been closed since early

2003. Illegal gillnetting in the Orange Estuary catches an estimated 5-10 t per annum, 80 % *L. richardsonii* and 20 % mainly *M. cephalus*, *P. saltatrix*, *A. inodorus* and various freshwater species.

**Freshwater flows and fish in the marine environment**

The possible importance of Orange River outflows to the marine environment cannot be ignored. River flows influence marine fish and fisheries directly and indirectly through the export of nutrients, sediment and detritus. Nutrient supply stimulates production of phytoplankton and zooplankton, and ultimately, the larval, juvenile and adult fish that depend on them as a food source. Detritus may be broken down into useful nutrients, serve as a substrate for micro-flora and fauna or be consumed directly by detritivorous fish and invertebrates. Sediment export replenishes the nearshore habitats that are continuously eroded by oceanic currents and also provides a refuge for many fish by increasing turbidity. Turbidity also tends to increase the catchability of many species, especially the larger individuals that move into the turbid environment in search of concentrated prey. Freshwater flows (and associated plumes) also provide cues for the migration of estuarine-dependent juvenile and adult fish into and out of the estuarine environment. The strength of these cues will ultimately dictate how many individuals of these species recruit into the marine fisheries. From a fisheries perspective, altered freshwater flows and consequently any of the above variables, can cause changes in catch composition, resource base (e.g. demersal vs pelagic fish abundance), fleet structure, the spatial and temporal distribution of effort and ultimately the economic value of the fishery concerned.

From an Orange River perspective, frequent upwelling events in the sea during the summer months make it unlikely that nutrients are ever limiting or that nutrient export from the catchment is a significant part of that available, except perhaps immediately in the adjacent surf-zone. Sediment and detrital export may be important to detrivores (e.g. *L. richardsonii*) as well as to species that may require a specific sediment habitat type be it for foraging, spawning nursery area (e.g. Soles & other flatfish species). In turn, summer outflows result in warm turbid areas adjacent to the mouth that are favoured by *A. inodorus* and other species finding refuge from cold upwelled water.

Linking freshwater outflows and perceived fluctuations in fish abundance are difficult in that there are numerous other variables (e.g. current & wind direction) that respond to the same weather patterns that determine rainfall and ultimately flow. However, a cursory look at biomass estimates from demersal trawl surveys on the west coast indicates a possible positive correlation between biomass and Orange River outflow. The biomass of St Joseph Shark (*Callorhynchus capensis*), tongue sole (*Cynoglossus zanzibarensis*) and Cape gurnard (*Cheilidonichthyes capensis*) fluctuate with river outflow and peak in flood years. The biomass of *Callorhynchus capensis* was treble the mean during the flood or high flow years of 1988, 1997 and 2000.

**Monitoring requirements**

Current knowledge on the fish of the Orange Estuary is dismal, much based on hearsay and anecdotal evidence. The Orange Estuary needs to be sampled quarterly over at least one year to account for the seasons followed by another year covering summer and winter. Seine-nets to sample small and juvenile fish and gillnets to sample adults are the appropriate gear. Monofilament gill nets should comprise at least 3 different mesh sizes within the range of 40-150 mm stretched mesh. Seine nets should be 30 m long, 1.7 m deep with a 15 mm bar mesh in the wings and a 5 mm bar mesh in the purse. All species in the catch should be identified, counted and measured in total length. Given the uncertainty as to the dominant food sources and the possible seasonal changes in them, a representative sample should be retained for stomach content analysis. Salinity, temperature, turbidity and if possible oxygen need to be recorded at each sampling site.

The Orange Estuary needs to be sampled from the mouth to Brandkaros 35 km upstream. Samples in the estuary proper up until the Ernst Oppenheimer Bridge (10 km) should be 1 km apart thereafter at 2 km intervals to Brandkaros covering all habitat types (sand, channel, saltmarsh etc). This gives 23 sites in total. Given the evident links between the estuary and adjacent surfzone, it would also be advisable to sample the surf-zone with the seine-net, to at least 1 km either side of the mouth. All the salinity regimes must be covered. These typically include: Fresh (representative of river), 0 – 10 ppt, 10 – 20 ppt and 20 – 35 ppt.

## ADDITIONAL DATA

Additional data are being collected by the Ministry of Fisheries and Marine Resources, Namibia on the lower Orange River, but could not be incorporated in to this summary due to time constraints. However it is necessary that future studies incorporate this crucial data set in its overall assessment.

Data are available from:

**The Permanent Secretary**
Ministry of Fisheries and Marine Resources
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Windhoek
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