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T.F. Næsje[1], A.R. Childs[2], P.D. Cowley[3], E.B. Thorstad[1], F. Økland[1],
S. Weerts[4] and P. Buthelezi[4]

[1] Norwegian Institute for Nature Research (NINA), Tungasletta 2, NO-7485 Trondheim, Norway

[2] Department of Ichthyology and Fisheries Science (DIFS), Rhodes University, P.O. Box 94, Grahamstown 6140, South Africa

[3] South African Institute for Aquatic Biodiversity (SAIAB), Private Bag 1015, Grahamstown, South Africa

[4] Zoology Department, University of Zululand, Private Bag X1001, KwaDlangezwa 3886, South Africa

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ADDRESS TO CONTACT

Dr Paul D. Cowley	Dr Tor F. Næsje
SAIAB	NINA
Private bag 1015	Tungasletta 2
Grahamstown 6140	NO-7485 Torndheim
SOUTH AFRICA	NORWAY
Tel: +27 46 603 5805	Tel: +47 73 80 14 00
Fax: +27 46 622 2403	Fax: +47 73 80 14 01
p.cowley@ru.ac.za	tor.naesje@nina.no
http://www.saiab.ru.ac.za	http://www.nina.no

Great Fish Estuary Programme:

Behaviour and management of important estuarine fishery species

A project within the South Africa / Norway Programme on Research Cooperation

The aim of the programme is to investigate the movement behaviour, migrations and habitat use of important estuarine fishery species (spotted grunter and dusky kob) and local exploitation from fisheries to contribute to the development of a sustainable utilisation strategy.

Background

The utilisation of estuarine fish resources plays a major role in the local economy and food supply in many parts of South Africa. Many fish species that spend parts of their life in estuaries, such as the spotted grunter (*Pomadasys commersonnii*) and dusky kob (*Argyrosomus japonicus*), are exploited for both food (subsistence and small scale fisheries) and recreation. Such estuarine species may also form an important component of commercial coastal fisheries. Due to the poor status of many of the estuarine associated fish stocks, the sustainability of these fisheries is in question. It is therefore urgent to develop sound management practices based on adequate knowledge of the migratory behaviour, population biology, and habitat use of the targeted species.

Project purpose

The purpose of this project is to investigate the movement behaviour of two of South Africa's most important estuarine fishery species, the spotted grunter and dusky kob, the exploitation of these species in estuaries and its implications for management. The movements and activity patterns of the spotted grunter and dusky kob are recorded by making use of acoustic telemetry methods, while the fisheries data are collected using structured visual surveys and on-sight direct contact roving creel (interview) surveys. Results from the project will contribute significantly to ensure sustainable utilization of these heavily targeted species.

Specific objectives

- Describe the movement behaviour of spotted grunter and dusky kob within the Great Fish River estuary and to describe behavioural responses to anomalous natural events and anthropogenic influences
- Describe habitat utilization of spotted grunter and dusky kob within the estuary,
- Establish the periodicity and duration of the fishes' movements between the estuary and the sea,
- Describe spatial and temporal trends in catch and effort by the different fishery sectors.

Ultimate objectives

- Collate fishery statistics, fishing areas and angler catch data with the observed daily and seasonal movement trends of the fish species in order to assess the species susceptibility to local depletion
- Explore the effectiveness and consequences of different management measures such as bag limits, minimum legal sizes, estuarine protected areas, and effort restriction as appropriate conservation strategies for the fish species
- Assist in developing a sustainable exploitation strategy for the different fishery sectors (subsistence, recreational, commercial) and develop recommendations to assist with the overall management of spotted grunter and dusky kob stocks

Methods

Telemetry enabled us to track the behaviour of individual fish by means of acoustic transmitters attached to the fish. The fish could be continuously tracked for reasonable periods of time, up to a year or longer depending on the setup of the transmitters. Each tag transmitted coded signals on a fixed frequency, allowing for simultaneous tracking of several individual fish. The transmitted coded signals were retrieved by either stationary receivers positioned in the estuary, or by a hand held receiver. In this study spotted grunter and dusky kob were tagged with surgically implanted transmitters in the Great Fish River estuary. Their movements and habitat utilization were monitored during both summer and winter. The stationary receivers monitored the fish continuously for as long as they were in the estuary, while the hand held hydrophone was used to monitor the individuals more intensively on shorter time scales.

Aspects of the recreational and subsistence fisheries in the estuary were studied both while manually tracking the fish from a boat and by on-site direct-contact roving creel surveys (interview surveys) conducted on foot on the shore. Observations of number of lines in the water, the number of fishers, classification of anglers (recreational or subsistence), whether they were fishing from land or boat, and their position were done while manually tracking the fish. Information on demographics, resource use sector, area use, catch, and effort were obtained through rowing creel surveys.

Funding and project partners

The following institutions collaborate on the project: the South African Institute for Aquatic Biodiversity (SAIAB), the Norwegian Institute for Nature Research (NINA), Rhodes University, and University of Zululand. It is the intent of the collaborating institutions that the project and relationships established should form the basis for long-term collaborative links between South African and Norwegian scientists and institutions.

The projects were funded by the South Africa / Norway Programme on Research Cooperation (National Research Foundation of South Africa, and the Research Council of Norway), the South African Institute for Aquatic Biodiversity (SAIAB), the Norwegian Institute for Nature Research (NINA), and East Cape Estuaries Management Programme (Marine and Coastal Management). We would like to thank these institutions for their financial support.

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Dr Paul Cowley
Project leader South Africa
SAIAB
Private Bag 1015
Grahamstown
South Africa
(E-mail: P.Cowley@ru.ac.za)

Dr Tor F. Naesje
Project leader Norway
NINA
Tungasletta 2
NO-7485 Trondheim
Norway
(E-mail: tor.naesje@nina.no)

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Abstract

Næsje, T.F., Childs, A.R., Cowley, P.D., Thorstad, E.B., Økland, F., Weerts, S., and Buthelezi, P. 2005. Movements and area use by small spotted grunter (*Pomadasys commersonnii*) in the Great Fish Estuary (South Africa): implication for management. - NINA Report 55. 46 pp.

The purpose of this project in the Great Fish Estuary, South Africa, was to investigate the movements and area use of small spotted grunter, being legally undersized to retain in fisheries, in relation to the different fisheries exploiting this species and size-group. Fish movements and area use of spotted grunter in the estuary were studied using acoustic telemetry, while the information on the fisheries in the estuary was collected through visual registration of fishing activity,

Data collection
Twenty spotted grunter (mean TL = 336 mm; min TL = 263 mm; max TL = 387 mm) were tagged by means of surgical implantation of acoustic transmitters, and released in the Great Fish Estuary in January. Two telemetric methods were used to monitor spotted grunter movements. Fish positions were recorded, firstly, by manual tracking to monitor non-continuous high resolution spatial data for 48 days. Secondly, four automated data logging receivers were used to continuously monitor the presence of individual fish within an omni-directional range. Every time a fish was located while manually tracking, measurements of water depth at the fish position, surface and bottom salinity, temperature, turbidity and surface current velocity were taken. In addition, the same physico-chemical parameters were taken daily at eight fixed stations along the estuary.

Aspects of the fisheries operating on the estuary were examined during the manual tracking surveys. The following data were collected: number of lines in the water, number of fishers, fishery sector (recreational or subsistence), whether they were fishing from shore or boat, and their location in the estuary.

Movements between river, estuary and sea
Six fish (30 %) were resident in the estuary and confirmed to be there every day during the 48 days of manual tracking. Two fish (10 %) were mainly resident in the estuarine environment, but had one or two short trips to sea during the manual tracking period, and each trip lasted for only a day. Eleven spotted grunters (55 %), however, left the estuary during manually tracking and remained in the marine environment for the rest of the study period. Ten of these 11 fish left the estuary between 11 and 29 days after being tagged. The fish spent on average 66 % of the 48 days of manual tracking in the estuary, while being the rest of the time in the marine environment. The differences in movements to sea could not be linked to fish size within the studied body length interval (26–39 cm total length).

Movements within the estuary
The average distance from each positional fix in the estuary to the catch site of individual fish ranged from 0.07 km to 6.5 km. The mean for all fish was 1.5 km. While in the estuary, more than fifty percent of the fish (11 individuals) were on average located less than 1 km from their respective catch sites. There was no significant relationship between the average distance moved from the catch site and the number of positional fixes of individual fish.

The average distance moved by each spotted grunter between positional fixes varied from 0.06 km to 2.7 km. The distance moved between each fix, however, varied considerably for each individual. Six fish moved on average less than 0.5 km between fixes, 3 fish between 0.6 and 1.0 km, 8 fish between 1.1 km and 1.5 km, 2 fish between 1.6 km and 2.0 km, while one fish moved more than 2.6 km. Mean distance for all individuals were 1.0 km. There was no significant relationship between the body lengths of the fish and the average distance moved between positional fixes.

Physico-chemical parameters and fish positions
Various environmental parameters were recorded at eight fixed stations spread out along the estuary. The parameters studied (depth, salinity, temperature and turbidity) all varied at each station and also among the eight sampling stations.

The majority of positional fixes of spotted grunter (78 %) were located at depths between 1 and 2 m, while only 9 % were located at depths < 1m, and the remainder (14 %) at depths > 2 m. Spotted grunters were euryhaline and found in most salinities as the bottom salinity at the fish positions varied from 0 to 36 ‰, with a mean of 22 ‰. Most fish positions (68 %) were in either the euhaline range (36 % in > 30.0 ‰) or polyhaline range (32 % in 18.0 – 29.9 ‰). The spotted grunters were found in water temperatures varying between 17 °C and 31 °C (bottom temperature). The highest percentage, 37 %, of the fish observations were in water temperatures of 22 – 23 °C. The spotted grunters were located in water with turbidities varying from 6 FTU to 567 FTU. Most positional fixes (55 %), however, were found in water with 20 to 100 FTU.

Due to the high correlation between the environmental parameters, it was difficult to address the impact of the specific variables on the distribution of spotted grunters. However, we could study the combined effects of the variables expressed through one of the variables. The bottom salinity in the estuary was used as an index of the distribution of seawater in the estuary, and indicated that individual fish tended to be situated further upriver from the river mouth on days when salinity was high.

Fish distribution and area use
Most of the tagged fish were positioned in the lower part of the estuary, as 70 % of the positional fixes were within the first 3 km, and 89 % of the positions were within the first 6 km. Approximately half (49 %) of the total observations were recorded between 1.0 and 1.5 km from the mouth of estuary. The total length of the estuary used by individual fish ranged from 0.2 km to 12.0 km, while the mean area used by all the fish was 4.9 km. The majority of fish (15 individuals) utilized an area of 3.2 – 7.1 km of the estuary, while three fish used less and two fish more. There was no significant relationship between the body lengths of the fish and the maximum distances between the positional fixes, i.e. the area of estuary used.

Fisher composition and area use
The total number of lines recorded over the study period in February and March 2003 was 1441. Subsistence fishers, all fishing from shore, accounted for most fishing lines used (73 %), while recreational fishers accounted for the rest (27 %), of which 17 % were fishing from the shore and 10 % from a boat. Within the estuary (ca. 11 km), 93 % of the lines were recorded within the first 6 km from the mouth of the estuary, of which 80 % were recorded within the first 3 km. Almost 1/3 of the fishing effort was recorded between 1.0 and 1.5 km from the mouth.

Distribution of spotted grunter and fishers
There was a significant relationship between the distribution of fish and the distribution of subsistence fishers. There were, however, no relationship between the distribution of fish and neither the recreational shore anglers nor the recreational boat anglers.

Management implications
Spotted grunter was the most important fish species caught in the fisheries in the estuary constituting 54 % of the total catch. This study has shown that the implementation of the currently legislated management measures in the middle and upper reaches of the estuary would have had little effect on the fish populations as both the fish and fishers were mainly located in the lower one third of the estuary. An over-exploitation of the juvenile spotted grunter population might be best controlled by establishing a protected area. If a no-fishing zone is to be implemented on the Great Fish Estuary it should be established in the lower reaches as this area represented a high use area by fish and fishers.

Contents

1 Introduction

Estuaries are productive ecosystems that provide numerous fishery opportunities and food for people. In South Africa, temporarily resident estuarine fish populations are exploited for both food, mainly subsistence, and recreation. Little is known about the status of estuarine fisheries, but it is widely believed that they have contributed to the over-exploitation of several species, which are also important components of other coastal fisheries (Griffiths 1997, Wood *et al.* 2003). Due to the paucity of information regarding estuarine fishing and its impacts, sustainable utilisation and effective management of the resources are currently impossible. At a national workshop on estuaries, it was noted that realistic exploitation strategies need to be developed for all estuarine living resources, and that the concept of ecological sustainability needs to be understood and accepted by all user groups (Boyd *et al.* 2000).

The Great Fish Estuary in the Eastern Cape Province once formed the boundary between South Africa and the former Ciskei homeland. The region is economically depressed with high unemployment rates, estimated to approximately 60 % (SA census data), resulting in a high dependence on coastal and estuarine fishery resources for food and income. Subsistence fishers were only recognised as a formal sector for the first time in 1998 (Marine Living Resources Act). These fishers generally consist of the historically disadvantaged people who use low technology gear to catch fish, predominantly for their own consumption. The same fish species, however, are also the popular targets of local and visiting recreational anglers. Subsistence fishing effort is usually less than recreational fishing effort, with the exception of the rural Great Fish River and Keiskamma River estuaries, where subsistence fishers are permanent dwellers (Cowley *et al.* 2004).

Due to the poor stock status of many estuarine fishery resources, the potential for growth and development of the subsistence sector appears to be limited (Lamberth and Turpie 2003). According to Lamberth and Turpie (2003), 14 of the 80 utilised estuary-associated species found along the South African coastline are considered over-exploited, including the spotted grunter (*Pomadasys commersonnii*) and the dusky kob (*Argyrosomus japonicus*) which are South Africa's two most important estuarine fishery species. Branch *et al.* (2002) stated that enthusiasm for granting new entrants rights to subsistence or commercial resources must be tempered with the reality that many resources are already over-exploited, and that there is no room for expansion. Linefish, for example, are severely over-exploited (Hutchings and Lamberth 2002).

The two most important fishery species in the Great Fish Estuary, spotted grunter and dusky kob, utilise estuaries as nursery areas for varying lengths of time and are vulnerable to local depletion during this period. For example, Griffiths (1997) revealed that due to a high rate of juvenile mortality throughout its distributional range, the spawner biomass per recruit (SB/R) ratio for dusky kob has been reduced to between 1.0 and 4.5% of the pristine value. In a recent assessment of recreational angling in Eastern Cape estuaries, Pradevand and Baird (2002) indicated that spotted grunter and dusky kob were the most targeted species, either individually or in combination, in all eight of the studied estuaries.

Since 1992, spotted grunter has been a de-commercialised species (i.e. the species may not be sold). This is primarily because of its inshore distribution and estuarine dependence, and hence greater vulnerability to exploitation relative to other, more marine species (Fennessy 2000).

The aims of this study were to investigate the movements and area use of small spotted grunter, being legally undersized to retain in fisheries, in relation to the different fisheries exploiting this species and size-group. Fish movements and area use of spotted grunter in the Great Fish Estuary were studied using acoustic telemetry, while the information on the fisheries in the estuary was collected through visual registration of fishing activity,

2 Study area

2.1 Site description

Main access to the Great Fish Estuary (**Figure 1**) is via the coastal road (R72), and the estuary is situated approximately 30 km north-east of Port Alfred. A gravel road accesses the estuary on the west bank through the Great Fish Wetlands Reserve. The area is currently controlled by the Ndlambe Municipality and provides ablution facilities for day visitors and overnight campers. A small residential settlement (also within the Wetlands Reserve) consisting of "holiday shack" homes is located close to the western bank in the region of the estuary mouth. This settlement is under the management control of the Ndlambe Municipality via a land lease agreement with the homeowners (Cowley and Daniel 2001).

Access to the estuary can be gained on the eastern bank via the Fish River Diner and Caravan Park. Camping, caravanning and ablution facilities are here available to paying visitors (Cowley and Daniel 2001). This property is privately run through a long-term lease agreement. Above the Fish River Diner and Caravan Park, the only access to the eastern side of the estuary is possible by foot, boat or via a rough vehicle track over a privately owned farm. On the western bank access to the water's edge can also be gained via the Kap River Reserve, where overnight accommodation is available by bookings only (Cowley and Daniel 2001).

2.2 Great Fish River catchment

The 650 km long Great Fish River enters the Indian Ocean approximately half way between Port Elizabeth and East London at 33° 29' 28"S and 27° 13' 06" E, drains a catchment area of approximately 30300 km^2 with mean annual runoff of 525×10^6 m^3/yr (Vorwerk *et al.* 2001) (**Figure 1**). The estuary mouth is permanently open and possibly maintained by enhanced freshwater inputs from an inter-basin transfer system located in the Orange River (Vorwerk *et al.* 2003). This inter-basin scheme also accounts for continuous nutrient inputs and, hence, elevated phytoplankton production. The main channel in the mouth region of the estuary is approximately 30 m wide and is restricted by the presence of extensive sand banks (Cowley and Daniel 2001). Following flood events, however, the main channel can be up to 200 m wide.

The estuary is mostly shallow, ranging between 1 m and 2 m (mean 1.4 m), except for some areas in the lower and upper reaches that have depths of up to 3 and 6 m respectively (Cowley and Daniel 2001). The estuary is highly influenced by the tide with a tidal prism of 1.6×10^6 m^3 (Allanson and Read 1987).

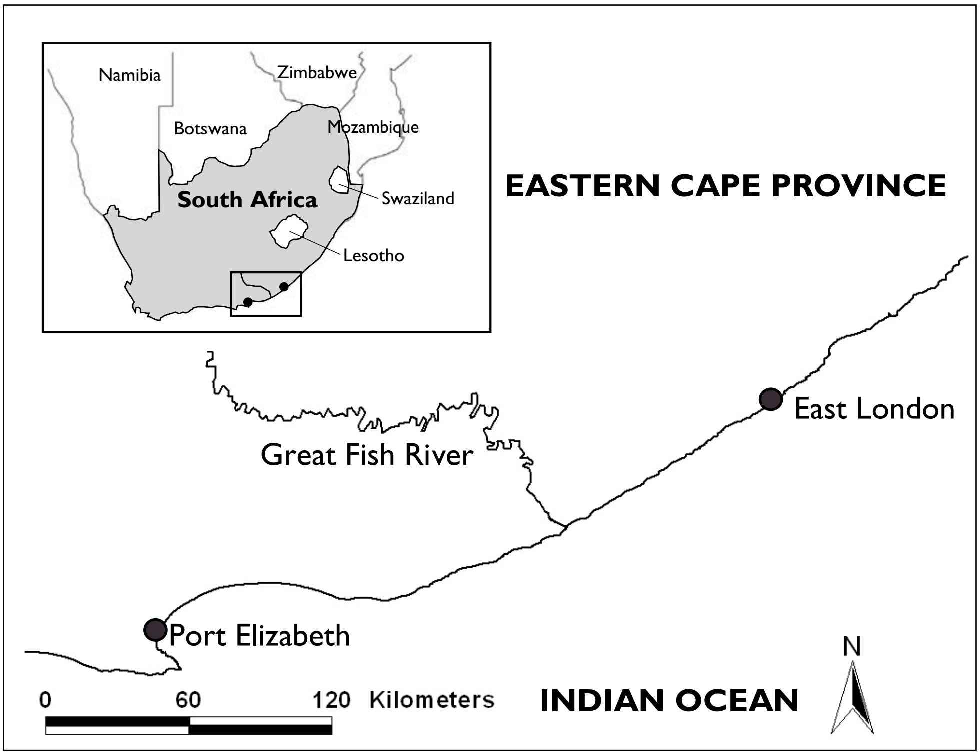


***Figure 1**. Map of Southern Africa (insert) showing the location of the Great Fish River, situated half way between Port Elizabeth and East London in the Eastern Cape Province of South Africa.*

This study was mainly confined to the estuarine environment of the Great Fish River, up to approximately 12 km from the mouth. The surface area of the estuary was approximately 1.0 km^2.

Most of the catchment area is used for agricultural activities consisting mainly of livestock ranching (cattle, sheep and goats), while some of the low-lying floodplain areas along the banks of the river and the estuary have been cultivated (mostly maize). In addition, some arable lands in the high lying coastal region are cultivated with pineapple crops.

2.3 Important fauna elements

South African estuaries are characterized by a relatively low ichthyofaunal diversity but high abundance of individual taxa with wide tolerance to the fluctuating environmental conditions (Whitfield 1998).

A total of 55 species from 28 families have been recorded from the Great Fish Estuary (**Appendix 1**). The ichthyofauna is typical of a permanently open estuary, dominated by marine migrant fish species. According to Whitfield *et al.* (1994), the most abundant fish species in the Great Fish Estuary are the estuarine spawning roundherring (*Gilchristella aestuaria*), prison goby (*Caffrogobius gilchristi*) and speckled sandgoby (*Psammogobius knysnaensis*). Although the marine fish component is dominated by mugilids, especially southern mullet (*Liza richardsonii*), groovy mullet (*Liza dumerilii*) and flathead mullet (*Mugil cephalus*), a number of other species such as spotted grunter (*Pomadysys commersonni*) and dusky kob (*Argyrosomus japonicus*) are common (**Appendix 1**). Four exotic freshwater fish species have been recorded in the estuary, namely the Mozambique tilapia (*Oreochromis mossambicus*), carp (*Cyprinus carpio*), the sharptooth catfish (*Clarius gariepinus*) and smallmouth yellowfish (Barbus aeneus) (Whitfield *et al.* 1994, Vorwerk 2002).

Due to the high freshwater inputs, the estuary is highly productive supporting a high biomass of planktonic organisms, mud prawns (*Upogebia africana*) populations on the large mudbanks on either sides of the estuary, and sand prawn (*Callianassa krausii*) populations on the large sand banks in the mouth region.

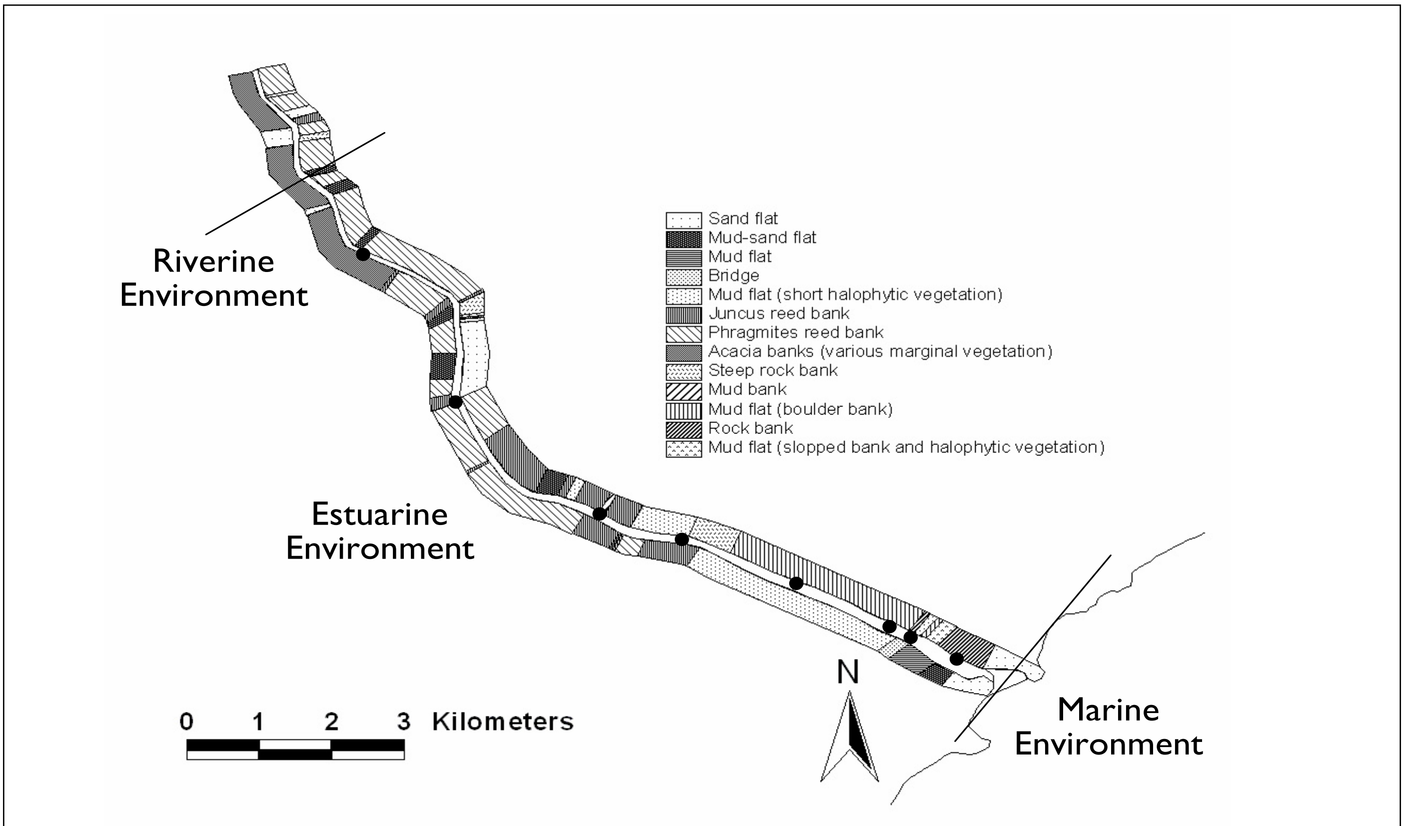


***Figure 2**. Shoreline vegetation of the Great Fish Estuary as registered in 2002. Dots indicate the position of the eight fixed stations where environmental parameters were sampled during the study between February and March 2003. The lines indicate the length of the estuary.*

2.3 Riparian vegetation

The estuary is riverine in appearance, with few intertidal mud flats or salt marshes (**Figure 2**). There are few submerged macrophytes, probably due to the water being very turbid. Reeds and sedges do occur intermittently along the banks, covering a total of 16.6 ha (Colloty 2000). The eastern bank of the lower and middle reaches of the estuary consists mainly of coastal bushveld and mud/boulder banks (**Figure 2**). Most of the western bank is encompassed in either the Kap River Reserve or the Great Fish Wetlands Reserve, which include short halophylic vegetation and phragmites reeds. Phragmitis rees also lines the eastern banks in the upper part of the estuary.

2.4 Physico-chemical parameters

Water temperatures in the estuary have small seasonal and longitudinal variation (Allanson and Read 1987, Whitfield 1994). Vorwerk *et al.* (2003) noticed the seasonal variability in water temperatures to be more pronounced in the upper reaches, with the sea having a moderating influence on the mouth region. Due to a persistent freshwater input, the estuary has a strong axial salinity gradient between the mouth and the head reaches (Withfield *et al.* 1994).

The estuary water is very turbid with a high load of fluvially dominated sediments (Grange *et al.* 2000). Deposition of sediments is the major geomorphological process in the estuary during non-flood periods, resulting in most of the bottom being covered in a thick layer of unconsolidated mud, which is prone to erosion when flooding occurs (Reddering and Esterhuysen 1982). Sediment originates mainly from the catchment area, with marine sediments seldom penetrating beyond the first kilometre from the mouth. Sand is deposited in the upper reaches during periods of high flow, whereas low flow results in mud deposition.

2.5 Great Fish Estuarine fisheries

The estuary supports large subsistence and recreational line fisheries. Recreational fishers fish from boats and from shore, while subsistence fishers are restricted to the shore. Spotted grunter and dusky kob are currently managed by way of bag limits (five fish per person per day) and size restrictions (40 cm total length is the minimum fish size that can be kept).

The Great Fish estuarine fisheries were studied from October 2003 to September 2004 (Potts *et al.* 2005). According to Potts *et al.* (2005) the species composition in the fishers' catch comprised of twelve species. Spotted grunter (*Pomadasys commersonnii*) dominated the catches in terms of number and mass (54 % and 59 %, respectively), followed by dusky kob (*Argyrosomus japonicus*) (19 % and 20 %) and white seabarbel (*Galeichthys feliceps*) (23 % and 17 %). In both numbers and mass, subsistence fishers captured most spotted grunter (59 % and 65 %) and white seabarbel (45 % and 45 %), but recreational boat fishers captured the most dusky kob (51 % and 24 %). A substantial part of the catch were undersized as 29 % of the retained spotted grunter, 55 % of the dusky kob and 73 % of the white steenbras were below the legal size limit. Most fishers failed to capture fish during a single day outing as 70 % did not catch a spotted grunter and 82 % a dusky kob. The bag limit for spotted grunter was exceeded on 3.2 % of the fishers outings, while the bag limit for dusky kob was exceeded on 0.6 %. For further description of the fisheries please see Potts *et al.* (2005).

3 Materials and methods

3.1 Physico-chemical parameters

Physico-chemical parameters from surface and bottom waters were sampled at eight fixed stations allocated along the estuary (**Figure 3**). The following environmental parameters were measured: Salinity (refractometer), temperature (digital thermometer), and turbidity (Hanna 93703 turbidimeter). At each station, water samples were taken from 10-15 cm below the surface and 30 cm from the bottom. Water sampling took place in conjunction with the manual tracking, i.e. daily from 7 February to 22 February and 9 March to 24 March, 2003, and every third day from 25 February to 7 March, 2003, starting in the mouth region. Samples were collected at approximately the same time of the day at each station. Hence, the whole tidal cycle; neap and spring as well as low and high tide, was represented in the samples taken at each station during the study. Water depth was also recorded at each station at the time of sampling (**Table 1**).

Based on the mean bottom salinities recorded at the fixed stations, the euhaline (30.0 – 39.9 ‰) and polyhaline (18.0 – 29.9 ‰) regions were restricted to relative small areas, ca. 0 - 1.2 km and ca. 1.2 – 2.5 km, respectively, in the lower reaches of the estuary. While the mesohaline region (5.0 – 17.9 ‰) occupied most of the middle part (ca. 2.5 – 6.3 km), and oligohaline region (0.5 – 4.9 ‰) most of the upper part (ca. 6.3 – 11.5 km) of the estuary (**Figure 3**).

3.2 Tagging of fish

The transmitter tags used in this study (V8SC-2L-R256 coded pingers, VEMCO Ltd, Halifax, Canada), with an expected battery life of 112 days, were 8.5 mm in diameter, 28 mm in length and weighted approximately 3.1 g in water. These coded transmitters (69 kHz) emitted unique acoustic pulse trains randomly every 5-15 seconds.

Twenty spotted grunter (mean TL = 336 mm; min TL = 263 mm; max TL = 387 mm) were tagged by mean of surgical implantation, and released in the Great

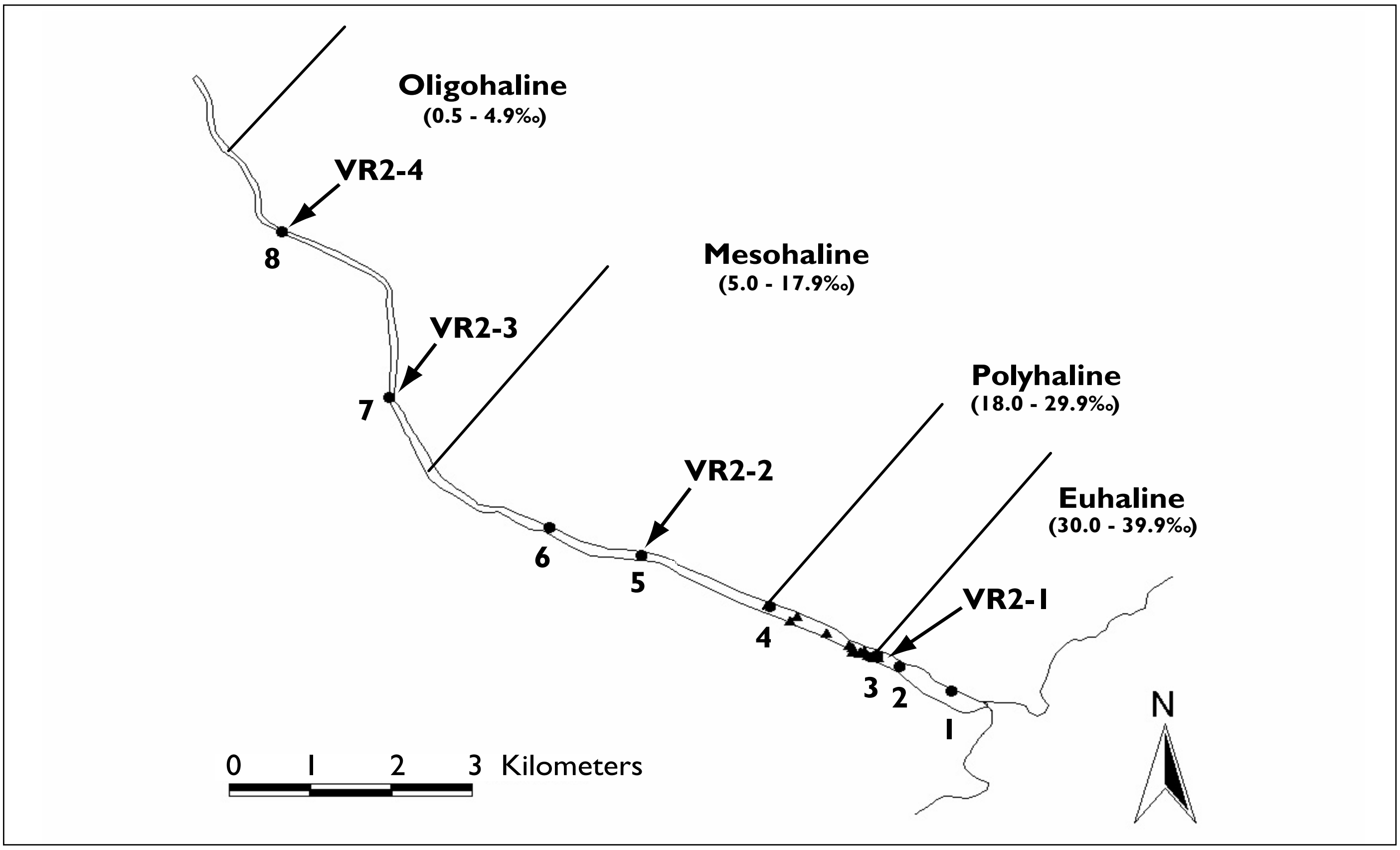


***Figure 3**. The salinity regions of the Great Fish Estuary according to Venice system based on mean bottom salinities at the fixed stations (numbered 1-8). Arrows indicate the positions of the automated data logging stations (VR2 1 to 4). Dots indicate the position of the fix stations where environmental parameters were sampled, while triangles indicate the catch and release sites for the 20 tagged spotted grunter.*

Table 1. Location (distance from estuary mouth), average depth with standard deviation, and minimum and maximum depth at the eight physico-chemical stations along the Great Fish Estuary sampled from 7 February to 24 March 2003.

Station	Distance from mouth (km)?	Average depth (m)	Standard deviation	Minimum depth (m)	Maximum depth (m)
1	0.4	1.6	±0.3	1.0	2.2
2	1.0	2.9	±0.4	1.9	3.4
3	1.2	1.9	±0.3	1.3	2.4
4	2.5	1.0	±0.2	0.5	1.5
5	4.0	1.2	±0.4	0.6	2.0
6	5.0	1.6	±0.3	1.0	2.3
7	7.6	3.8	±1.1	2.6	6.2
8	10.3	3.6	±0.7	2.4	5.2

Table 2. Transmitter code, body lengths , tagging date, number of positions manually recorded, average number of days between fixes, and last date manually tracked for the spotted grunter tagged with acoustic transmitters in the Great Fish Estuary in January and February 2003.

Fish code	Fork length (mm)	Total length (mm)	Tagging date	Number of fixes manual tracking	Average number of days between fixes	Date last manually tracked
20	297	317	21/01/03	25	1.5	16/03/03
21	307	334	21/01/03	34	1.3	23/03/03
22	271	297	01/02/03	20	1.4	06/03/03
23	354	380	01/02/03	36	1.3	24/03/03
24	304	330	01/02/03	18	1.2	28/02/03
25	284	313	01/02/03	19	1.3	03/03/03
26	291	314	01/02/03	35	1.3	24/03/03
27	300	328	01/02/03	12	1.0	18/02/03
28	354	382	01/02/03	34	1.4	24/03/03
29	346	377	27/01/03	36	1.3	24/03/03
30	282	308	01/02/03	36	1.3	24/03/03
31	330	357	27/01/03	12	2.7	09/03/03
32	293	318	01/02/03	36	1.3	24/03/03
33	300	329	27/01/03	13	2.5	09/03/03
34	256	263	21/01/03	8	1.4	17/02/03
35	330	357	27/01/03	8	1.4	17/02/03
36	358	387	27/01/03	15	1.4	28/02/03
37	344	363	21/01/03	23	1.8	23/03/03
38	296	319	26/01/03	12	1.3	21/02/03

Fish Estuary between 21 January and 1 February 2003 (**Figure 3** and **Table 2**). Based on information from Webb (2002), the fish tagged were between 3 and 5 years old. The fish were caught with rod and line using mud prawn (*Upogebia africana*) or sand prawn (*Callianassa krausii*) as bait. Surgery took place on site on a 4.3 m boat. After capture, the fish was immediately placed in a 50 litre container with estuary water containing 2-phenoxy ethanol (approximately 1.0 ml per 1 l water). Once anaesthetized, the fish was measured to the nearest millimetre and placed ventral side up in a wet towel on v-shaped high density foam. During surgery, the gills were continuously flushed with estuarine water. A 15 - 20 mm incision was made along the ventral surface posterior to the pelvic girdle. The transmitter was carefully inserted into the body cavity. The incision was closed using two independent silk sutures (2/0 Ethicon). The dura-

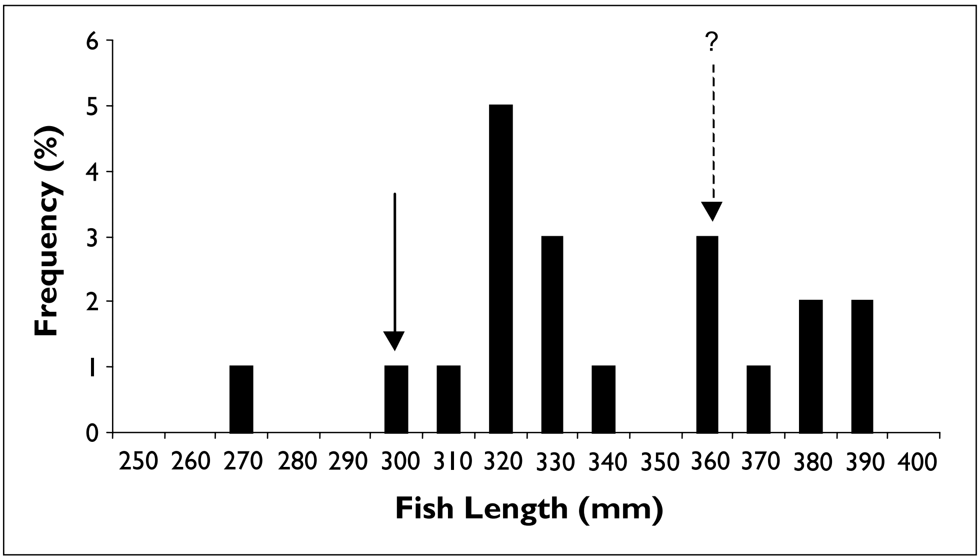


Figure 4. Length distribution of the 20 acoustically tagged spotted grunter in Great Fish Estuary in February 2003. Solid arrow indicates length of 50% maturity for male spotted grunter in KwaZulu Natal and Great Fish Estuary (Wallace 1975b, Webb 2002). Dashed arrow indicates length at 50% maturity for female spotted grunter in KwaZulu Natal (Wallace, 1975b). Questions mark illustrates that the length of 50 % maturity of females in Great Fish Estuary is not known.

tion of the surgical implant was on average 2 min 48 sec (range 2 min 21 sec - 3 min 26 sec), after which the fish was placed in a recovery bath. Once the fish was in a stable upright position and swimming, it was released into the estuary at the catch site. The duration of the entire surgical process, from the time when the fish was placed in the anaesthetic bath to the time it was released into the estuary, was on average 17 min (range 8 min - 41 min), with the exception of one fish that was kept longer in the recovery bath for observation (total time of surgical process and recovery 1 h 27 min).

According to Wallace (1975b) spotted grunters from KwaZulu-Natal attain 50 % sexual maturity at lengths of 300 mm (TL) for males and 360 mm (TL) for females. Similarly, Webb (2002) found that males in the South Eastern Cape attained 50 % maturity at 305 mm TL. Although it is not possible to externally sex spotted grunter, it is possible that not all the spotted grunter tagged during this study were immature (**Figure 4**). However, all fish were under the legal size limit for fisheries (< 400 mm TL).

3.3 Tracking of fish

Two telemetric methods were used to monitor spotted grunter movements. Fish positions were recorded, firstly by manual tracking using a VEMCO VR60 (VEMCO Ltd, Halifax, Canada) receiver linked to a directional hydrophone to monitor non-continuous high resolution spatial data. Secondly, four VEMCO VR2 automated data logging receivers, were used to continuously monitor the presence of individual fish within an omni-directional range. The VR2 receiver is a submersible, single channel receiver, which identifies coded transmitters, and is designed to collect long-term data. The information was downloaded from the VR2s in the field using a notebook computer.

Manual tracking

Manual tracking was conducted from a 4.2 m motorized boat. Tracking took place between January and March 2003, in the form of two 16 day sampling periods with daily tracking, and an interim period of 16 days, where fish were tracked every third day. The sampling periods were 7 - 22 February (daily), 25 February - 9 March (every third day) and 9 - 24 March (daily). The daily route tracked was standardized doing a return trip that started at the mouth of the estuary and turning at the head region of the estuary (13 km from the mouth). Tracking started at the same time every day (09h00). Furthermore, the two 16-day sampling periods were standardized according to the moon phase, so that tracking was conducted over two semi-lunar cycles, with each 16 day period beginning 2 days prior to the first quarter (waxing) moon, and the last day of tracking commence at the waning moon. When a tagged fish was located, positional fixes were taken using a handheld GPS (Garmin 12).

Every time a fish was located while manually tracking, measurements of water depth at fish position, surface and bottom salinity, temperature, turbidity and surface current velocity were taken. The spotted grunter is a benthic feeder, and the bottom values of the physico-chemical parameters were used to describe the environment at the fish positions.

Automated logging stations

The four automated logging receivers (VR2's) were situated along the total length of the estuary at intervals of 1.0, 3.7, 7.6 and 10.3 km from the mouth (**Figure 3**). They were deployed at the following dates in 2003: VR2–1: 12 February, VR2–2: 8 March, VR2–3: 21 January, and VR2–4: 22 January.

Range testing revealed that the reception range of each automated logging station varied between 310 – 600 m. However, under periods of adverse conditions (high winds, strong wave actions a.s.o.) could have been considerably less. The lowermost automated logging station (VR2-1) could not be situated in the estuary mouth due to the strong currents and wave actions in this area, which in periods reduced the reception range drastically. Since the transmitters had a life expectancy of 112 days, the automated logging stations were removed from the estuary on 16 April 2003.

Assumptions with regard to positioning of fish

Data collected from the automated logging stations and the manual tracking provided information to describe the proportion of time spotted grunter spent in the freshwater, estuarine or marine environments during the study period. The lower most automated logging station (VR2-1) was situated 1 km from the mouth of the estuary, while the uppermost data logger (VR2-4) was in the transition zone between the estuarine and riverine environments (**Figure 3**).

In order to describe the proportion of time spent in the different environments we made use of the following assumptions with regard to the daily whereabouts of each fish:

i) The fish was in the estuary if it was logged by one or more VR2s and/or by manual tracking.

ii) The fish was in the riverine environment if it was not located by manual tracking, but was last recorded on the uppermost automated logging station (VR2-4).

iii) The fish was in the marine environment (at sea) if it was not located in the river or estuary by manually tracking, and was last recorded on the automated logging station closest to the mouth (VR2-1). Furthermore, if a fish was not located by manual tracking on two or more consecutive days, and not recorded on the automated loggers, but later located in the estuary, it was assumed to have been at sea.

It is important to note that it was possible, under certain conditions, for fish have passed the lower most automated logging station without being recorded due to reduced reception range or code collisions. Missing fish, therefore, either went to sea or was caught by a fisher in the lower reaches of the estuary. The former was confirmed if the fish was later located in the estuary. The probability of being captured was considered less likely because of a reward incentive to fishers returning a transmitter and an angler awareness campaign among the fishers.

3.4 Fishery data

Aspects of the fisheries operating on the estuary were examined during the manual tracking surveys. The following data were collected: number of lines in the water, number of fishers, fishery sector (recreational or subsistence), whether they were fishing from shore or boat, and their location in the estuary (using a GPS). The fishery study was conducted during the manual tracking of acoustically tagged fish in the estuary.

The mouth area of Great Fish Estuary.

Clear seawater pushing into the mouth of Great Fish Estuary.

Upper part of the Great Fish Estuary.

Recreational boat-fishing in the lower part of the Great Fish Estuary.

Recreational fishers in the caravan park at the mouth of Great Fish Estuary.

Subsistence fisher with a nice handful of spotted grunter.

Subsistence fishers with a nights catch of spotted grunter.

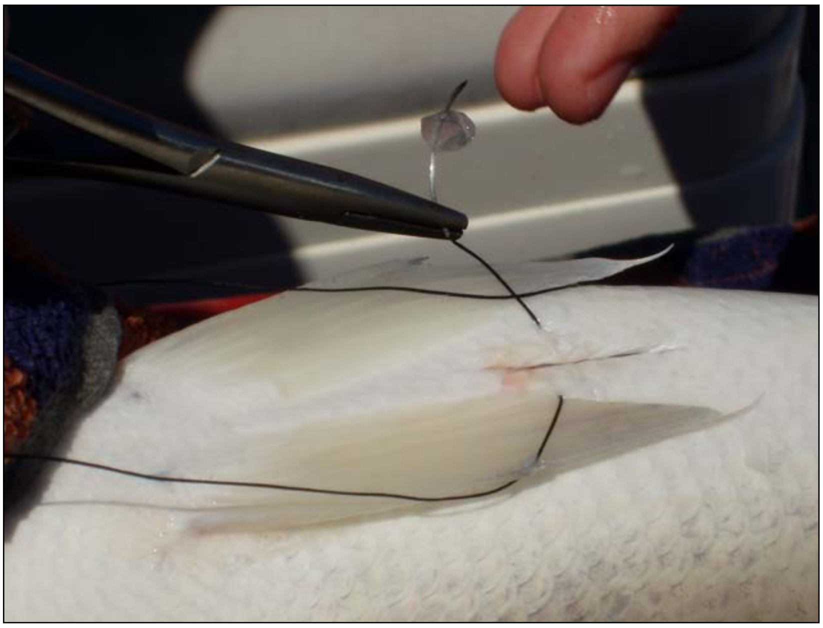
All the tagged spotted grunter were caught by rod and line.

The fish were released at the catch site after recovery.

Implantation of the transmitter took place in the boat at the catch site.

Implantation of transmitter after anaesthetization of the fish.

Closing of the incision.



The incision was closed with two sutures.

Manual tracking with directional hydrophone.

Automated data logger being placed in the upper part of the estuary.

Downloading of fish data from an automated data logger.

4 Results

4.1 Movement patterns

Six fish (30 %) were resident in the estuary and confirmed to be in the estuary every day (**Table 3** and **Figure 5**). One fish (code 23) was last recorded during the last day of manual tracking 24 March, while the remaining two were last recorded 13 April on the lowermost automated logging station. The logging stations were removed from the estuary on 16 April and two fish (code 29 and 32) were still in the estuary on that date.

Two fish (10 %) were mainly resident in the estuarine environment, but had one or two short trips to sea during the manual tracking period (**Table 4** and **Figure 5**). Each trip lasted for only one day. However, both these fish, however, left the estuary permanently at the end of March or beginning of April before the automated logging station was removed from the estuary.

Eleven spotted grunters (55 %) left the estuary and ventured into the marine environment and stayed there for the rest of the study period (**Table 5** and **Figure 5**). This movement was confirmed by the automated logging station deployed closest to the mouth and by manual tracking data. Within this group, 10 of the 11 fish left the estuary between 11 and 29 days after being tagged. The remaining individual (code 37) left the estuary after 45 days.

Two fish, code 25 and 31, most probably left the estuary for the marine environment. The fish with code 25 was last recorded on the lower most automated logging station (VR2-1), but later on the same day manually recorded above this station, while the fish with code 31 was last recorded on logging station VR2-2. Hence, there was a chance that these fish were caught in the estuary without being reported.

One fish (2.5 %) spent time both in the marine, estuarine and riverine environments and was last recorded on the uppermost automated logging station (VR2–4). It is therefore most likely that it went further up river and stayed there until the transmitter battery failed or, despite very low fishing effort, might have been caught in the riverine environment (**Table 6** and **Figure 5**).

Based on these findings we can categorize the various movement patters as follows:

1) **Estuary resident:** Fish that remained in the estuary and never went to sea during the study period.
2) **Occasional marine movements:** Fish that were in the estuary at the end of the study period, but had occasionally visited the marine environment.
3) **Marine movements:** Fish that frequented the sea during the study period and confirmed to be in the marine environment at the end of the study.
4) **Riverine movements:** Fish that frequented the freshwater environment and ultimately remained above the upper most automated logging station at the end of the study period.

Table 3. *Details of the six spotted grunters that were estuarine residents in the Great Fish Estuary between 7 February and 24 March 2003. The table shows fish code, date last recorded and how it was last recorded (last recorded by). The automated logging stations were taken out on 16 April 2003.*

Fish code	Date last recorded	Last recorded by
23	24/03	Manually tracking
26	13/04	Logging station (VR2-1)
29	Still in estuary 16/04	Logging station (VR2-1)
30	Still in estuary 6/04	Logging station (VR2-1)
32	Still in estuary 16/04	Logging station (VR2-1)
39	13/04	Logging station (VR2-1)

***Table 4 .** Details of the two spotted grunters that had occasional marine movements from the Great Fish Estuary between 7 February and 24 March 2003. The table shows fish code, date last recorded by automated logging stations, date last recorded by manually tracking, number of trips to sea, and total number of days at sea. Figures in brackets denote number of days the fish were missed for one day only while manually tracking, but not confirmed to be in the sea.*

Fish code	Date last recorded by automated logging	Date last recorded by manual tracking	Number of trips to the sea	Total number of days at sea
21	02/04/03 (VR2-1)	23/03/03	2	2
28	25/03/03 (VR2-1)	24/03/03	1 (2)	1 (2)

***Table 5.** Details of the eleven spotted grunters that had marine movements from the Great Fish Estuary between 7 February and 24 March 2003. The table shows fish code, date last recorded on automated logging stations, date last recorded by manual tracking, number of return trips to sea before permanently leaving the estuary, total number of days at sea with one or more returns to the estuary, number of days at sea after permanently leaving the estuary, and total number of days spent at sea. Figures in brackets denotes number of days the fish were missed for one day only while manually tracking, but not confirmed to be in the sea.*

Fish code	Date last recorded by automated logging	Date last recorded by manual tracking	Number of return trips to sea	Total number of days at sea with returns	Total number of days at sea after perm. left	Total number of days at sea
22	07/03 VR2-1	06/03			16	16
24	01/03 VR2-1	28/02			18	18
25	03/03 VR2-1	03/03			17	17
27	19/02 VR2-1	18/02			24	24
31	10/03 VR2-2	09/03	3 (5)	7 (9)	15	22 (24)
33	09/03 VR2-1	09/03	1 (2)	7 (8)	15	22 (23)
34	17/02 VR2-1	17/02	1 (2)	2 (3)	25	27 (28)
35	18/02 VR2-1	17/02	1	3	25	28
36	24/02 VR2-1	25/02	1(2)	2 (3)	18	20 (21)
37	23/03 VR2-1	23/03	5	12	1	13
38	23/02 VR2-1	21/02	1 (2)	2 (3)	21	23 (24)

***Table 6.** Details of the one spotted grunter that had riverine movements from the Great Fish Estuary between 7 February and 24 March 2003. The table shows fish code, date last recorded by automated logging stations, date last recorded by manual tracking, total number of days at sea with return to the estuary, and total number of days spent at sea.*

Fish code	Date last recorded by automated	Date last recorded by manual logging	Number of return trips to sea tracking	Total number of days at sea with returns	Total number of days at sea
20	10/03 VR2-4	16/03 above VR2-4	1	1	1

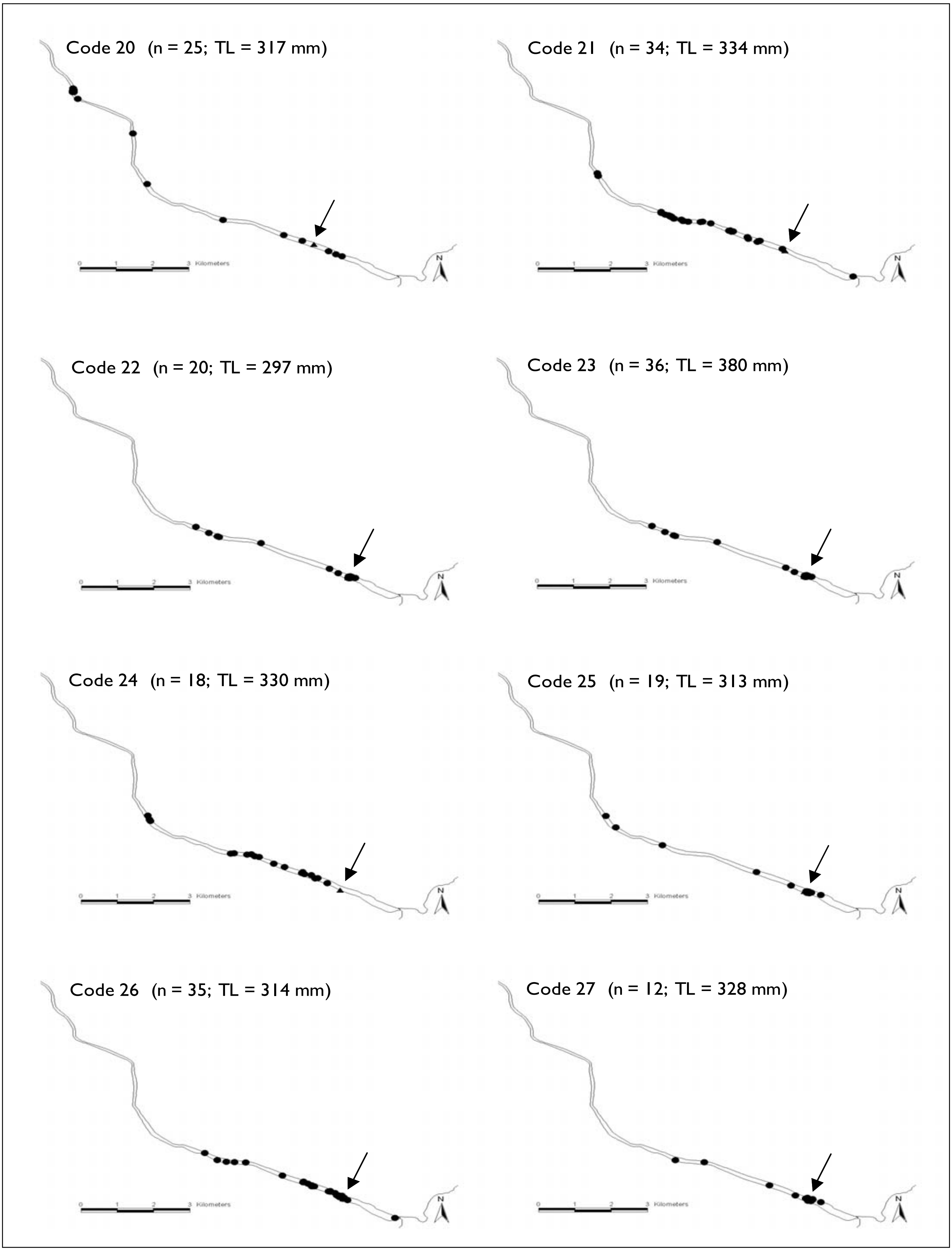


Figure 5*. Individual positional fixes of the 20 acoustically tagged spotted grunters in Great Fish Estuary recorded with manual tracking between 7 February and 24 March 2003. The arrow and triangle indicate the catch and release site of the fish. n = the number of positional fixes, TL = the total length of the fish.*

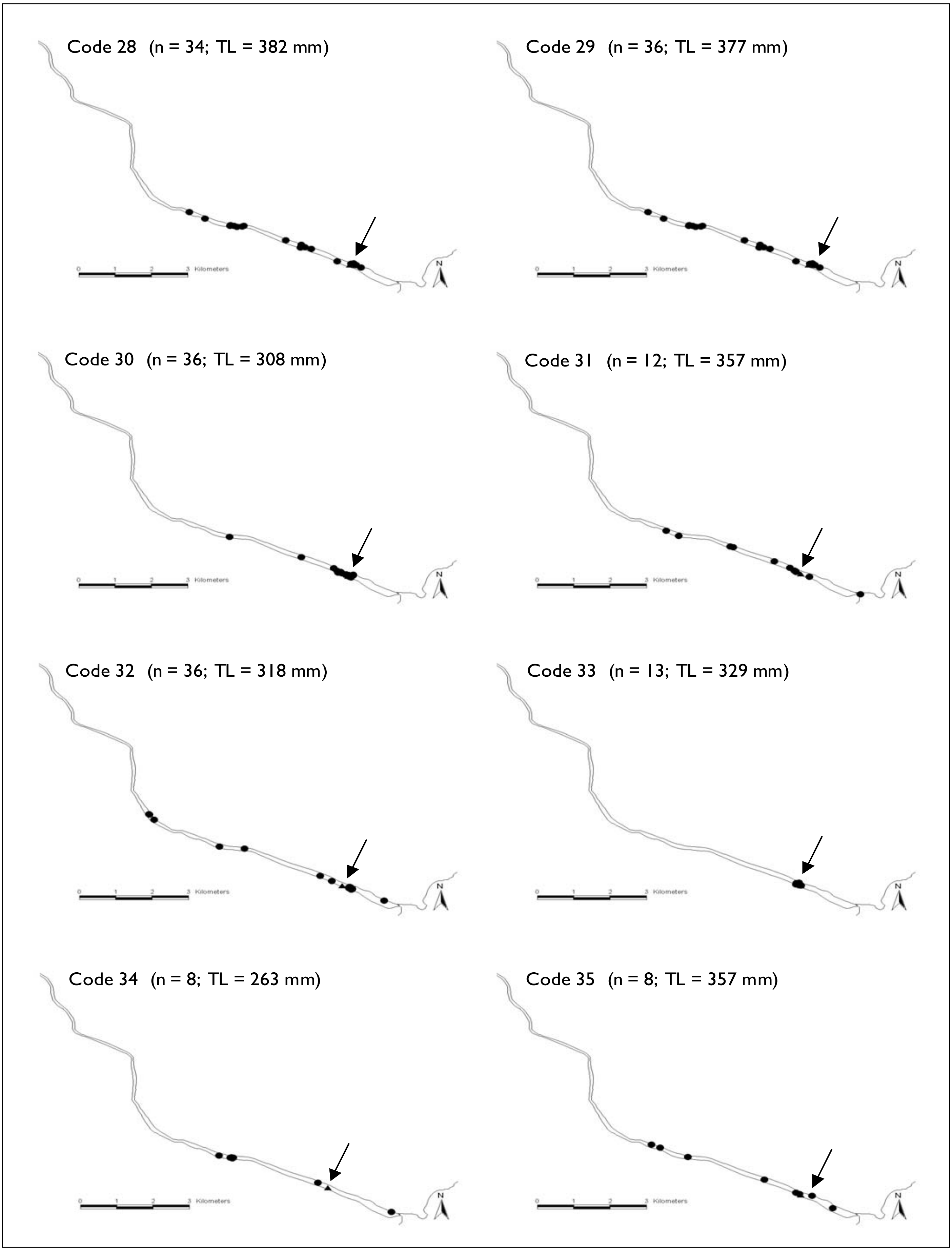


Figure 5 (continued)*. Individual positional fixes of the 20 acoustically tagged spotted grunters in Great Fish Estuary recorded with manual tracking between 7 February and 24 March 2003. The arrow and triangle indicate the catch and release site of the fish. n = the number of positional fixes, TL = the total length of the fish.*

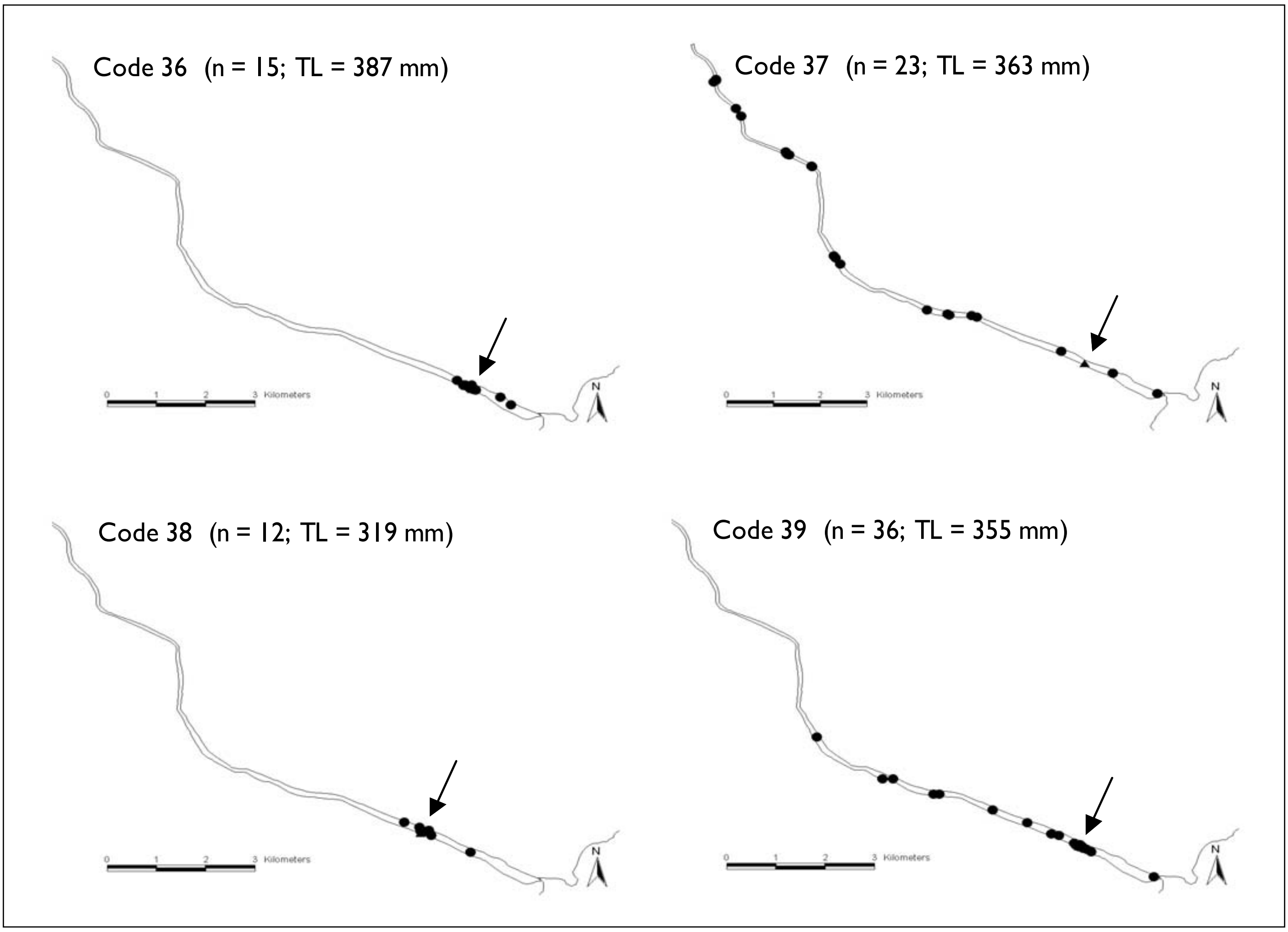


Figure 5 (continued)*. Individual positional fixes of the 20 acoustically tagged spotted grunters in Great Fish Estuary recorded with manual tracking between 7 February and 24 March 2003. The arrow and triangle indicate the catch and release site of the fish. n = the number of positional fixes, TL = the total length of the fish.*

4.2 Estuarine residency

The number of position fixes obtained for individual spotted grunter varied (range: 8 – 36), as well as the number of days between each fix, and the movement pattern within the estuary and between the estuary and the sea (**Table 2**, **Figure 5** and **6**).

Based on data obtained from manual tracking and the stationary listening stations, we calculated the proportion of time each fish spent in the estuary or at sea during the manual tracking period (7 February to 24 March 2003). When excluding the one fish that was lost in the riverine environment (uncertain fate), the rest of the fish (n = 19) spent 66 % of the 48 days of manual tracking in the estuary, while being the rest of the time in the marine environment (**Figure 6**). If excluding the two fish that might have been caught in the estuary, the rest of the fish spent 68 % of the period with manual tracking in the estuary.

Altogether 50 % of the fish made return-trips to the sea, and the number of return trips for individual fish ranged from 0 to 5 (mean 0.8). Nine fish made return trips before permanently leaving, while 4 fish left the estuary permanently on their first trip to sea (**Table 4** and **5**). On average, the fish that permanently left the estuary spent 92 % of their time in the estuarine environment before leaving permanently.

There was no significant relationship between the body lengths of the fish and the time spent in the estuary (total number of fish positions) for each fish ($P = 0.30$; $R^2 = 0.06$). Hence, movements to sea could not be linked to fish size within the studied length interval (26 – 39 cm total length).

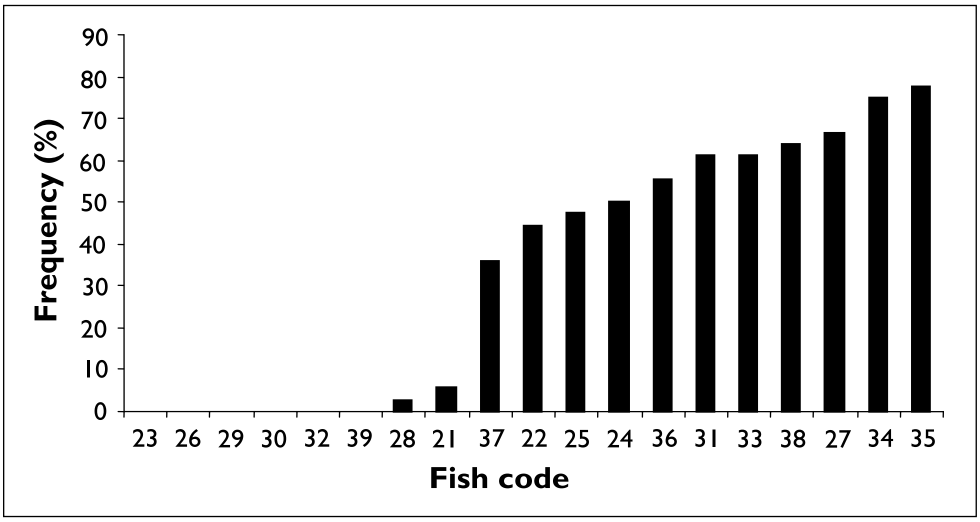


***Figure 6**. The percentage of time (days) each spotted grunter (codes 21 – 39) spent at sea between 7 February and 24 March 2003.*

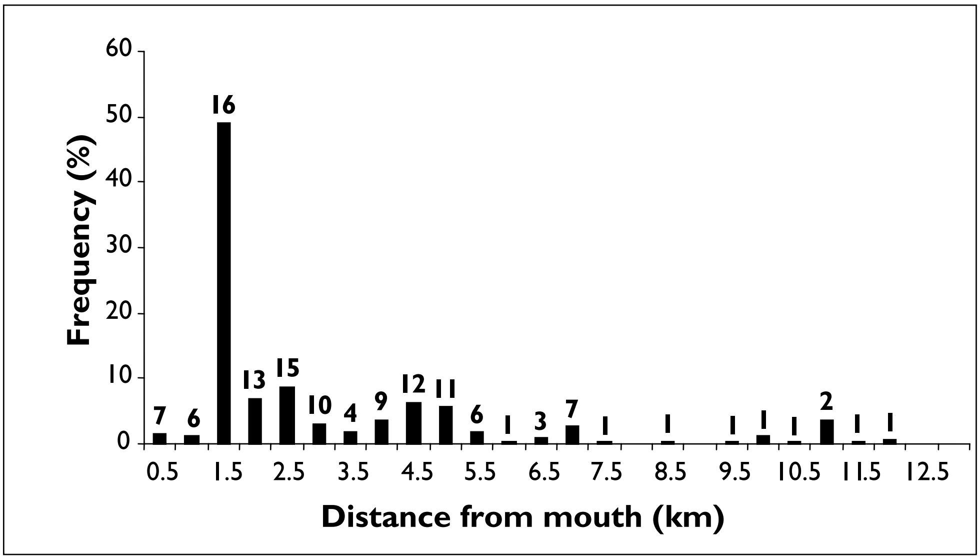


***Figure 7**. The percentage frequency of positional fixes of spotted grunter (n = 468) per 500 m zones within the Great Fish Estuary between 7 February and 24 March 2003. Numbers above the bars indicate number of individuals recorded within each zone.*

4.3 Movements in the estuary

Distribution

Most (70 %) of the positional fixes were recorded within the lower part of the estuary (first 3 km) (**Figure 7** and **Figure 8**). While 89 % of the positions were recorded within the first 6 km. Approximately half (49 %) of the total observations were recorded between 1.0 and 1.5 km from the mouth of estuary.

The upper-most automated data logging station (VR2) confirmed that very few fish entered the riverine environment (> 10.3 km from the mouth). Only four individuals were recorded on this VR2 (code 20, 21, 34, and 37), while only two of these fish, code 20 (17 fixes) and 37 (5 fixes) were manually tracked above the upper-most VR2.

Distance between positional fixes

There was no significant correlation between distance moved between consecutive positional fixes and the number of days between these fixes for most (17) fish. Three individuals (codes 20, 23 and 30), did however, show a significant correlation between distance moved and the numbers of days gone between consecutive fixes were taken. Two of these (codes 23 and 30) had a week coefficient of determinations (linear regression, P = 0.04, R^2 = 0.13; and, P = 0.05, R^2 = 0.11, respectively). While for fish with code 20, the riverine migrant that was lost, the distances between fixes were longer when it was positioned every third day than daily (P = 0.004, R^2 = 0.33). For the pooled data set there were no significant relationship between number of days between fixes and distance moved between the corresponding positional fixes (log transformed) (linear regression, P = 0.26, R^2 = 0.003).

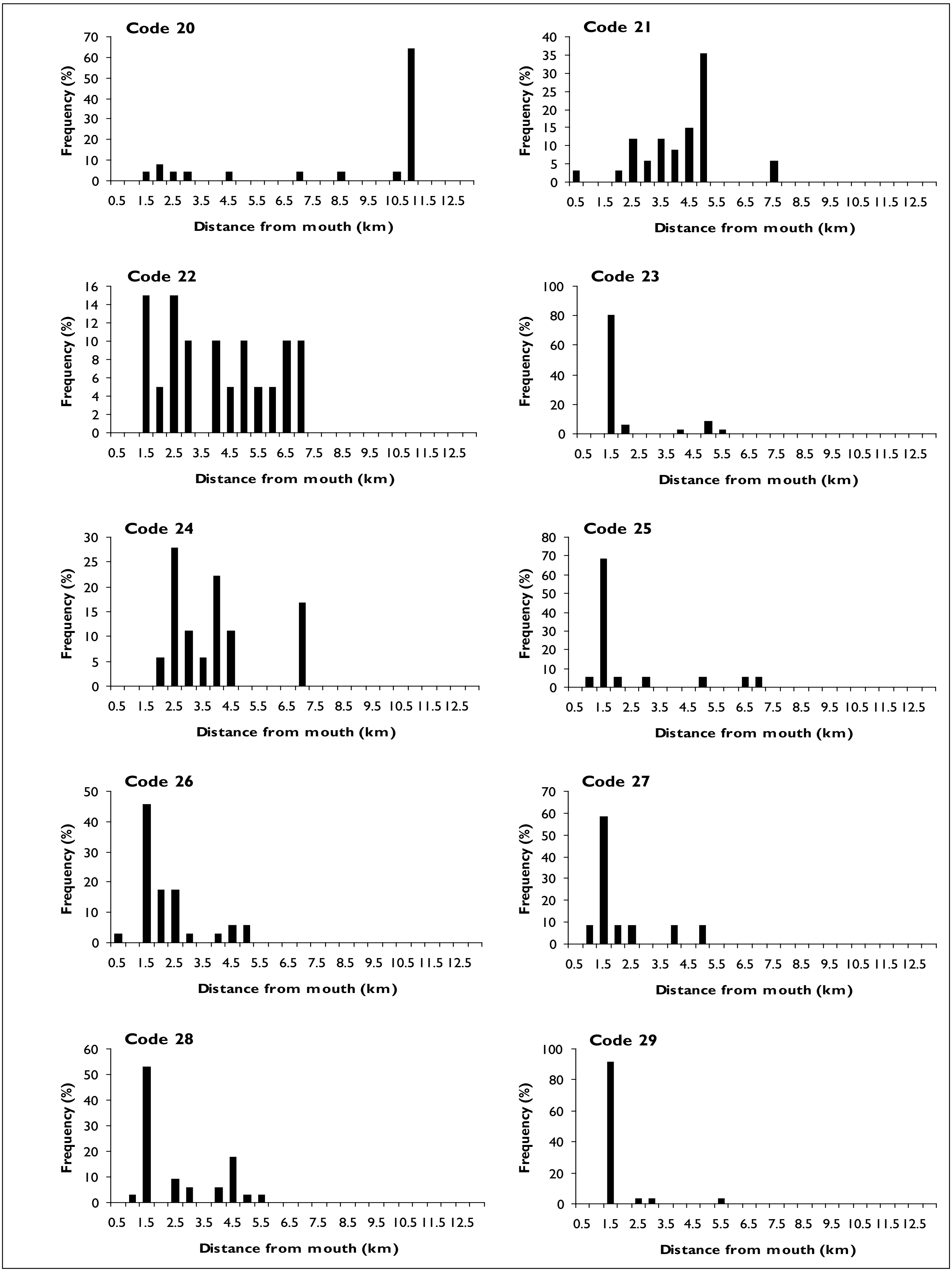


***Figure 8**. Distribution of the positional fixes within 500 m zones of each of the 20 tagged spotted grunters in Great Fish Estuary beteen 7 February and 24 March 2003.*

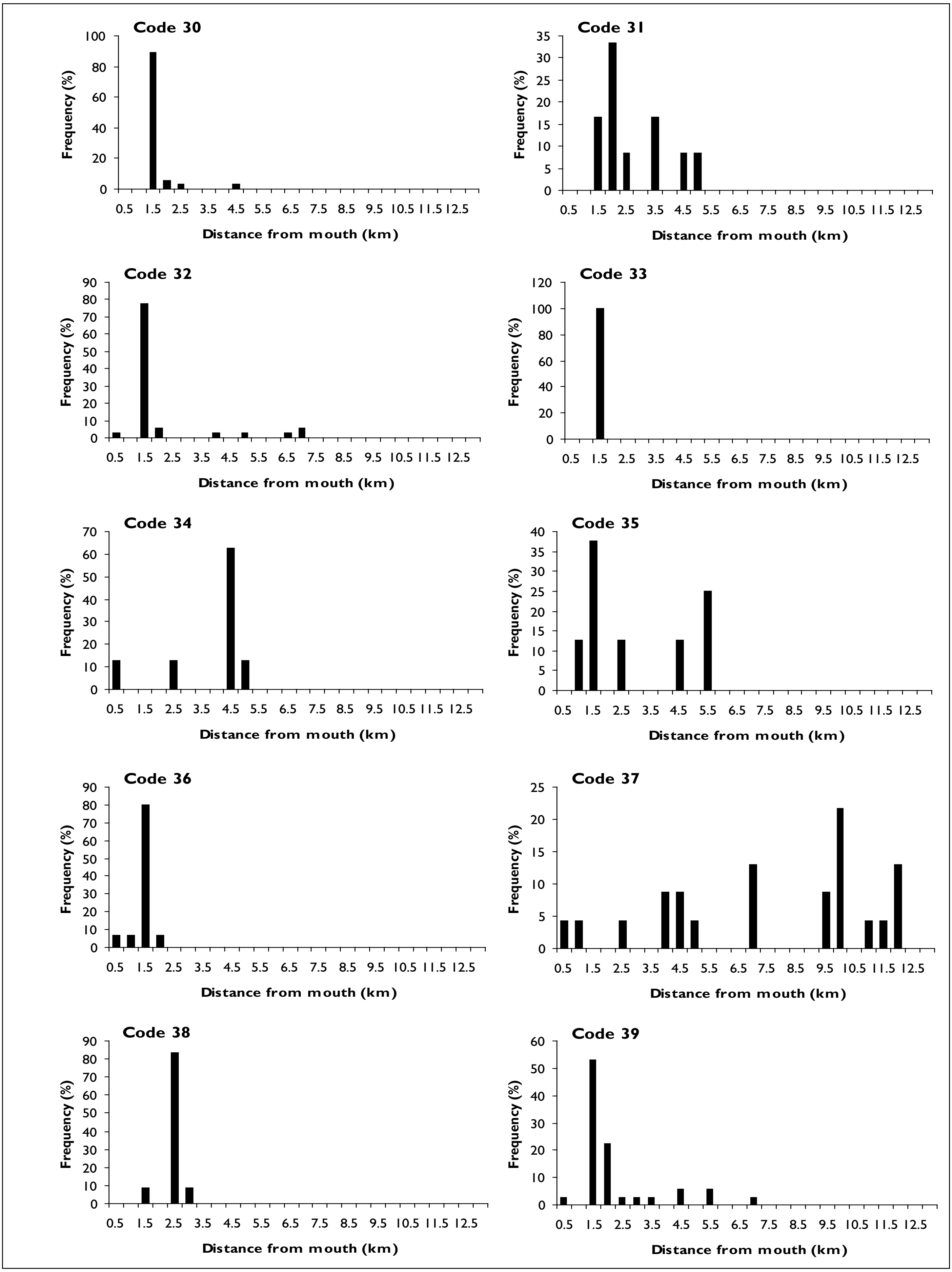


***Figure 8 (continued)**. Distribution of the positional fixes within 500 m zones of each of the 20 tagged spotted grunters in Great Fish Estuary beteen 7 February and 24 March 2003.*

The average distance moved between positional fixes for each spotted grunter varied from 0.06 km (SD: ± 0.04) to 2.67 km (SD: ± 2.76) (**Figure 9**). The average distance moved between consecutive fixes varied considerably for individual fish. Six fish moved on average less than 0.5 km between fixes, 3 fish between 0.6 and 1.0 km, 8 fish between 1.1 km and 1.5 km, 2 fish between 1.6 km and 2.0 km, while one fish moved more than 2.6 km. Mean distance for all individuals were 1.01 km (SD: ± 0.65 km) (**Figure 9**). Further more, there was no significant relationship between the body lengths of the fish and the average distance moved between positional fixes (linear regression: P = 0.87; R^2 = 0.002).

Area use

The total area used (length of the estuary) by individual fish was taken as the distance between the furthermost position fixes recorded during manual tracking. The length of estuary used ranged from 0.15 km to 11.99 km (mean 4.93 km, SD: ± 2.70 km) (**Figure 10**). The majority of fish (15 individuals) utilised an area of 3.2 – 7.1 km of the estuary, while three fish used less and two fish more.

There was no significant relationship between the body lengths of the fish and the maximum distances between the positional fixes, i.e. the area of estuary used (linear regression: P = 0.91, R^2 = 0.001), nor between the number of fixes and the distance between the furthermost fixes (P = 0.23, R^2 = 0.08).

Fidelity to catch site

Fidelity to catch site was assessed by calculating the average distance from each fix in the estuary to the catch site. The average distance moved from the catch site (ADMC) for each fish ranged from 0.07 km (SD: ± 0.04) to 6.45 km (SD: ± 3.34) (**Figure 11**). The mean for all fish was 1.49 km (SD: ± 2.32 km). While in the estuary, more than fifty percent of the fish (11 individuals) were on average located less than 1 km from their respective catch sites (**Figure 11**).

There was, however, no significant relationship between the average distance moved from the catch site (log transformed) and the number of positional fixes (linear regression: P = 0.87, R^2 = 0.002). Furthermore, there was no significant relationship between the average distance between each fix and the catch site (log transformed) and fish length (P = 0.37, R^2 = 0.05).

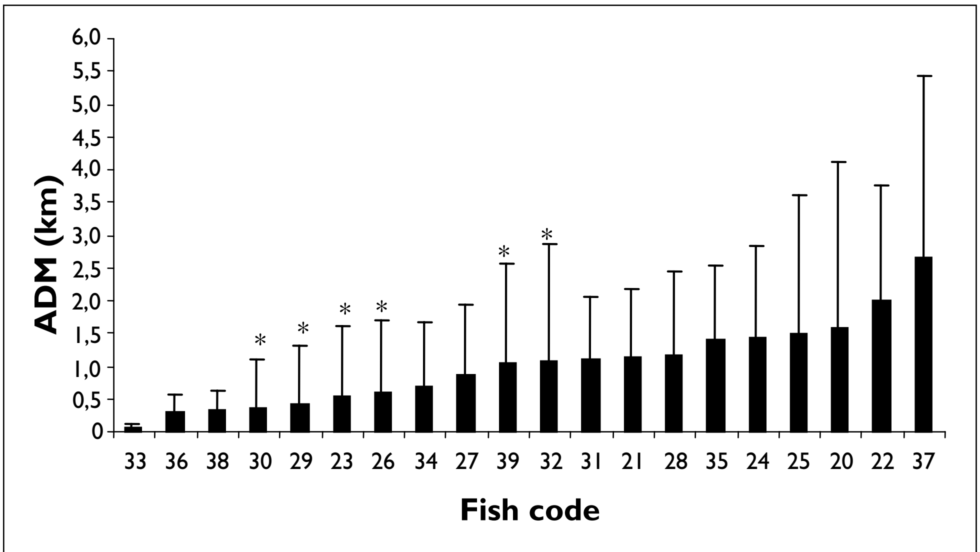


Figure 9*. The average distance moved (ADM ± SD) between consecutive positional fixes for the 20 spotted grunter tagged (codes 20 – 39) in the Great Fish Estuary between 7 February and 24 March 2003. Asterisks indicate the estuary resident fish that did not move into the sea during the period of manual tracking.*

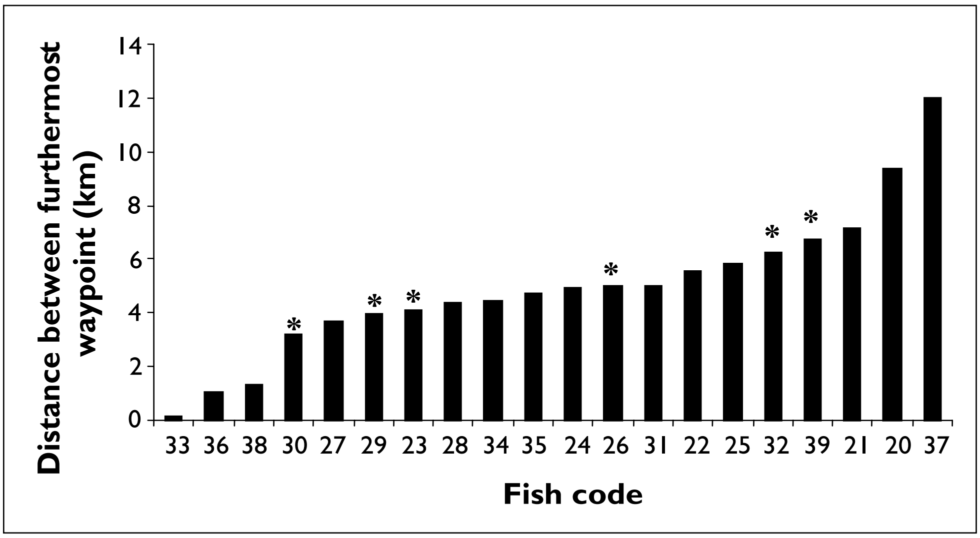


***Figure 10**. The distance between furthermost fixes for each of the tagged spotted grunter (codes 20 - 39) in the Great Fish Estuary between 7 February and 24 March 2003. Asterisks indicate the estuary resident fish that did not move into the sea during the period of manual tracking.*

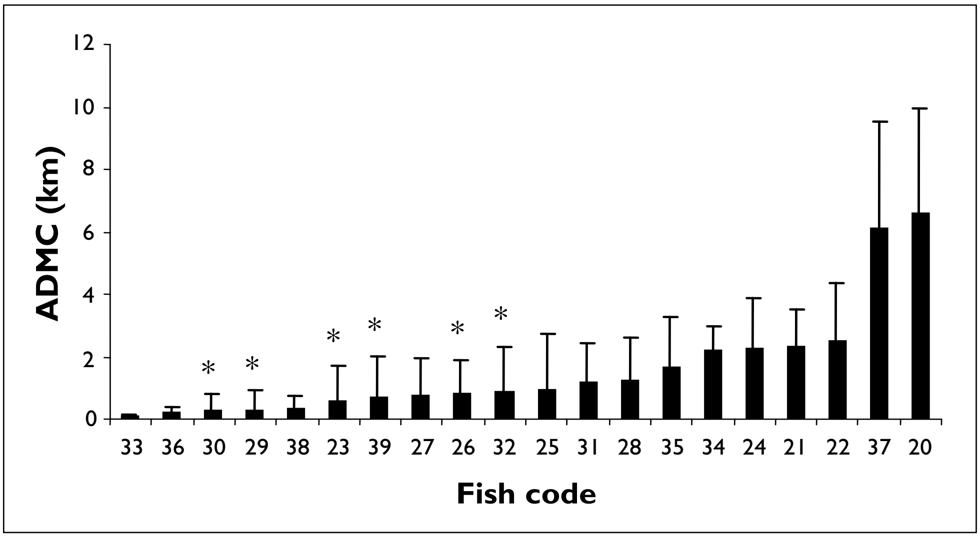


***Figure 11**. The average distance moved from the catch site (ADMC ± SD) for each of the tagged spotted grunter (codes 20 - 39) in the Great Fish Estuary between 7 February and 24 March 2003. Asterisks indicate the estuary resident fish that did not move into the sea during the period of manual tracking.*

4.4 Physico-chemical parameters and fish positions

Various environmental parameters were recorded at eight fixed stations spread out along the estuary. The parameters measured, namely depth, salinity, temperature and turbidity, all varied at each station and also among the eight sampling stations (One-Way ANOVA, all Ps < 0.01).

Depth

Five of the fixed sampling stations (1, 3, 4, 5, and 6) had an average depth of 1 to 2 m, being 1.6, 1.9, 1.0, 1.2, and 1.6 m, respectively (**Table 2** and **Figure 3**). However, there are certain deep areas in the lower and upper reaches, as shown by stations 2, 7, and 8 having average depths of 2.9, 3.8, and 3.6 m, respectively.

The majority of positional fixes of spotted grunter (77.6 %) were located at depths between 1 and 2 m, while only 8.6 % were located at depths < 1m, and the remainder (13.8 %) at depths > 2 m (**Figure 12**).

Salinity

The surface salinity profile of the estuary with oligohaline (0.5 – 4.9 ‰) conditions often extended into the lower reaches of the estuary, reflects the high levels of freshwater input (**Figure 3**). During our study the mean bottom salinity at the uppermost station, 10.3 km from the mouth of the estuary, was 0.4 ‰ (range: 0 – 3 ‰), confirming that this station was lying in the transition zone between the estuary and riverine environment (**Figure 13**). The mean bottom salinity at the stations 0.4, 1.0, and 1.2 km from the mouth were high and similar, being 31.5, 33.0, and 30.4 ‰, respectively. However, the mean surface salinity at these stations differed considerably being 22.7, 17.5, and 12.9 ‰, respectively.

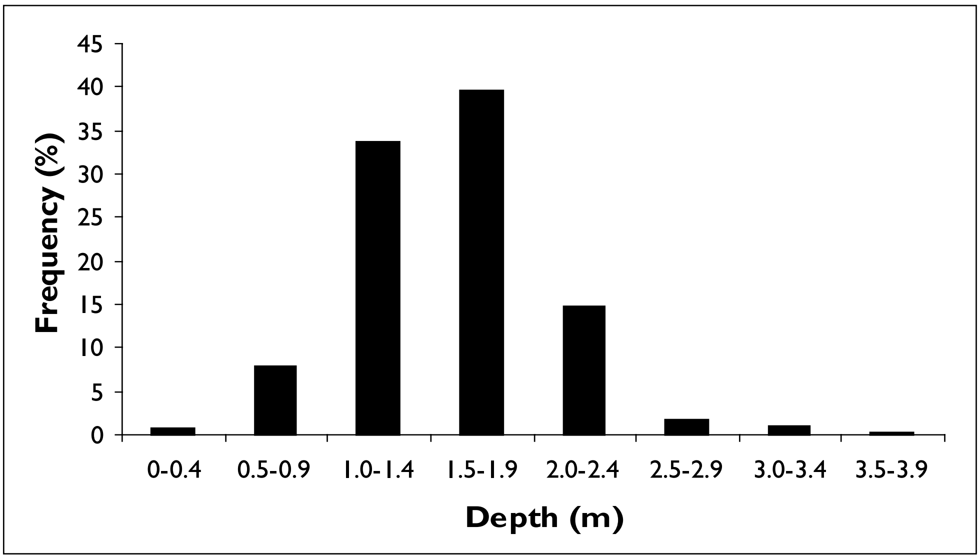


***Figure 12**. The water depth (frequency in percent) where the acoustically tagged spotted grunter were positioned in the Great Fish Estuary between 7 February and 24 March 2003.*

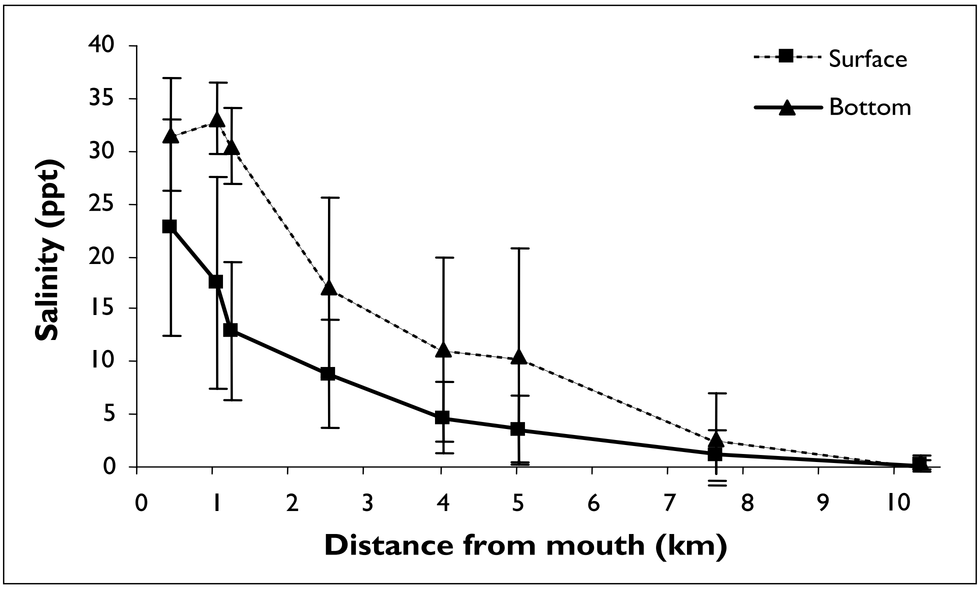


***Figure 13**. Mean surface and bottom salinity (±SD) at the 8 fixed stations in relation to the stations distance from the mouth of the Great Fish Estuary. Measurements were taken every day fish were manually tracked between 7 February and 24 March 2003.*

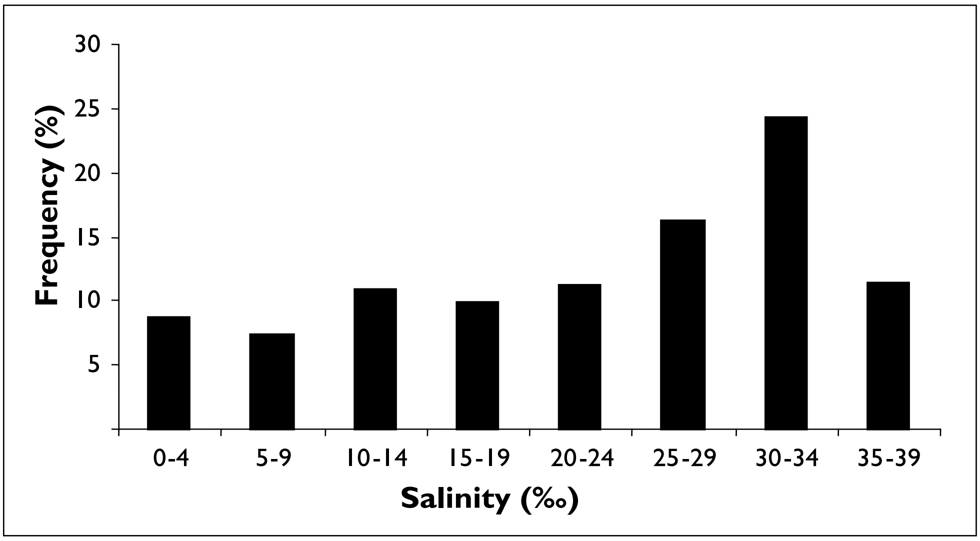


***Figure 14**. The salinity (frequency in percent) where the 20 tagged spotted grunter were positioned in the Great Fish Estuary between 7 February and 24 March 2003.*

Spotted grunters were euryhaline and found in most salinities i.e. the bottom salinity at the fish positions varied from 0 to 36 ‰, with a mean of 22.1 ‰ (**Figure 14**). Most fish positions (68 %) were in either the euhaline range (36 % in > 30.0 ‰) or polyhaline range (32 % in 18.0 – 29.9 ‰), while 24 % of fish observations were in the mesohaline range (5.0 – 17.9 ‰), and 8.8 % in the oligohaline range (0.5 – 4.9 ‰) (**Figure 3** and **14**).

Temperature

During our study the average bottom water temperatures at the fixed stations were lowest in the lower part of the estuary and highest in the upper part, varying between 20.3 °C at station 1 (range: 15.2 – 23.6 °C) and 26.0 °C at station 8 (range: 20.2 – 29.5 °C) (**Figure 15**). The relative temperature difference between surface and bottom temperatures, however, varied as the average surface temperature could be up to 2.9 °C colder and 8.3 °C warmer than the bottom temperature at our sampling stations.

The spotted grunters were found in water temperatures (bottom temperature) varying between 17.3 °C and 30.5 °C (**Figure 16**). The highest percentage, 37 %, of the fish observations were in water temperatures of 22 - 23 °C, while 26 % were in warmer water (24 - 25 °C, and 28 % were in cooler water (< 22 °C). Only 9.7 % of observations were in water temperatures higher than 26 °C.

Turbidity

The turbidity in the estuary varied considerably among the fixed stations, but there were only minor differences between surface and bottom layers in the same area (**Figure 17**). The average turbidity was lowest in the lower part of the estuary (stations 1 - 3), varying between 38 FTU (range: 12 – 80 FTU) at station 1 to 72 FTU (range 28 – 125 FTU) at station 3. Station 4 (2.5 km upriver) was in a transitional zone with average 163 FTU (range: 54 – 440 FTU), while the average turbidity was high or very high in the middle and upper part of the estuary, at stations 5 to 8, varying between 293 FTU (range 190 – 755 FTU) at station 8 and 318 FTU (range: 181 – 762 FTU) at station 7.

The spotted grunters were located in water with turbidities varying from 6 FTU to 567 FTU. Most positional fixes (55 %), however, were found in water with 20 to 100 FTU and in the lower part of the estuary (**Figure 18**). Only 1.1 % of fixes were in water with less than 20 FTU.

Effects of environmental parameters combined

All the environmental parameters studied (viz. depth, salinity, temperature and turbidity) were significantly correlated (**Table 7**). Strongest negative correlations were between salinity and temperature as well as between salinity and turbidity, while the strongest positive correlation was between temperature and turbidity (**Table 7**, all Pearson's r > - 0.50). Due to the high correlation between the environmental parameters it is difficult to address the impact of the specific variables on the distribution of spotted grunters. However, we can study the combined effects of the variables expressed through one of the variables.

Table 7. *Correlation (Pearson's r) between the environmental parameters surface salinity (Sal S), bottom salinity (Sal B), surface temperature (Temp S), bottom temperature (Temp B), surface turbidity (Turb S), bottom turbidity (Turb B), and depth sampled at the eight fixed stations in Great Fish Estuary from 7 February to 24 March 2003.*

	Sal S	Sal B	Temp S	Temp B	Turb S	Turb B	Depth
Sal S	1.000	0.611 P < 0.01	*- 0.592* P < 0.01	*- 0.343* P < 0.01	*- 0.655* P < 0.01	*- 0.531* P < 0.01	0.334 P < 0.01
Sal B	0.611 P < 0.01	1.000	*- 0.403* P < 0.01	*- 0.612* P < 0.01	*- 0.606* P < 0.01	*- 0.556* P < 0.01	0.425 P < 0.01
Temp S	*- 0.591* P < 0.01	*- 0.403* P < 0.01	1.000	0.715 P < 0.01	0.551 P < 0.01	0.552 P < 0.01	*- 0.212* P < 0.01
Temp B	*- 0.343* P < 0.01	*- 0.612* P < 0.01	0.715 P < 0.01	1.000	0.517 P < 0.01	0.501 P < 0.01	*- 0.205* P < 0.01
Turb S	*- 0.655* P < 0.01	*- 0.606* P < 0.01	0.552 P < 0.01	0.517 P < 0.01	1.000	0.770 P < 0.01	*- 0.277* P < 0.01
Turb B	*- 0.531* P < 0.01	*- 0.556* P < 0.01	0.523 P < 0.01	0.501 P < 0.01	0.770 P < 0.01	1.000	*- 0.244* P < 0.01
Depth	0.334 P < 0.01	0.425 P < 0.01	*- 0.212* P < 0.01	*- 0.205* P < 0.01	*- 0.277* P < 0.01	*- 0.244* P < 0.01	1.000

Since both temperature and turbidity were negatively correlated with salinity, we choose salinity as an explanatory variable representing the highly correlated group of variables. The salinity of the estuarine water is also an indicator of the marine influx into the estuary. Spotted grunters are bottom feeder. We therefore used the bottom salinity to explain the distribution of spotted grunters within the estuary.

If spotted grunters prefer water with relatively high salinity, as indicated by the bottom salinities at most positional fixes (**Figure 14**), one would expect the fish to be distributed further from the river mouth on days when marine water is distributed higher up in the estuary e.g. due to spring tide. The bottom salinity measured at station 6 situated (5 km from the mouth) was used as an index of the distribution

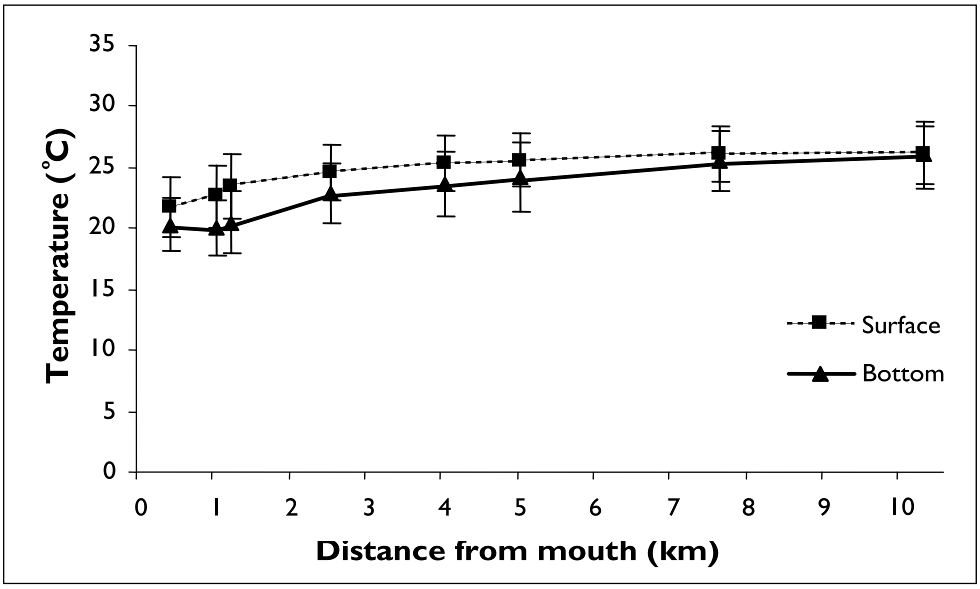


***Figure 15**. Mean surface and bottom temperature (±SD) at the 8 fixed stations in relation to the stations distance from the mouth of the Great Fish Estuary. Measurements were taken every day fish were manually tracked between 7 February and 24 March 2003.*

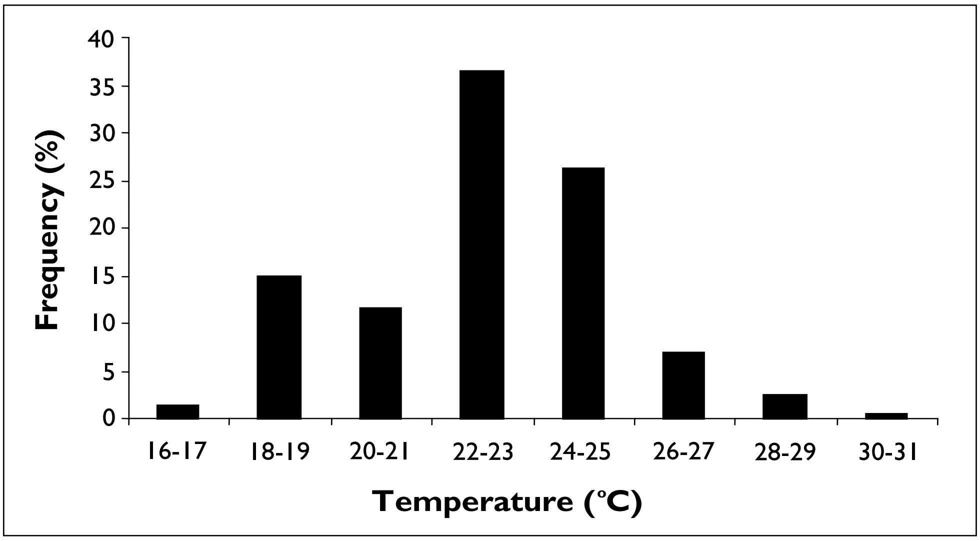


***Figure 16**. The water temperature (frequency in percent) where the acoustically tagged spotted grunter were positioned in the Great Fish Estuary between 7 February and 24 March 2003.*

***Table 8.** Spearman rank correlation coefficients (r) between the bottom salinity at station 6 (5 km upstream from the river mouth) and distance from the river mouth for individual spotted grunters. N = number of fixes on days when salinity on station 6 was measured. Only fish with observations on 10 days or more are presented.*

Code	20	21	22	23	24	25	26	28	29	30	32	33	37	39
r	0.64	0.69	0.49	-0.27	0.35	0.74	0.45	0.33	0.005	0.05	0.25	-0.11	0.18	0.52
N	19	26	12	28	10	11	27	26	28	28	28	10	20	28
P	0.004	<0.001	0.11	0.17	0.33	0.01	0.018	0.1	0.98	0.81	0.21	0.76	0.46	0.005

of seawater in the estuary. Salinity at this station varied between 0 and 30 ‰, and could therefore best describe the variation in salinity among the fixed stations. Individual fish tended to be situated further upriver from the river mouth on days when salinity at station 6 was high (**Table 8**). For 12 of 14 individual fish (the number of fish with 10 or more registrations at station 6) there was a positive correlation (5 significant) between salinity at station 6 and distance from the river mouth. This is significantly more positive values than expected if the fish were randomly distributed independent of the salinity in the estuary (binomial test, P = 0.013).

Another approach to addressing the same hypothesis is to examine the distribution of all fish with regard to variation in salinity. There was a significant positive correlation between the mean distance from the river mouth for all fish and the salinity at station 6 (**Figure 19**), showing that fish were distributed further upriver on days with high influx of marine water. In **Figure 19** only days with observations of 10 or more fish is included, if we also include days when fewer fish are observed the spearman rank correlation coefficient is reduced from 0.84, n = 20, P < 0.001 to 0.57, n = 28, P = 0.002. Whether this positive correlation was caused by preference for salinity, temperature, turbidity, depth or some unmeasured variable is, however, difficult to address due to the high correlation among the variables.

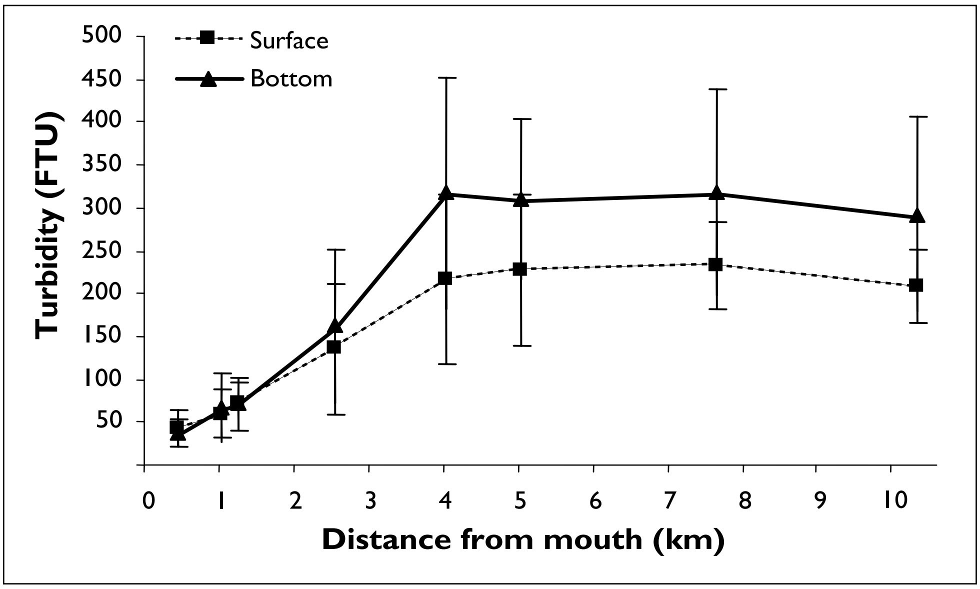


***Figure 17**. Mean surface and bottom turbidity (±SD) at the 8 fixed stations in relation to the stations distance from the mouth of the Great Fish Estuary. Measurements were taken every day fish were manually tracked between 7 February and 24 March 2003.*

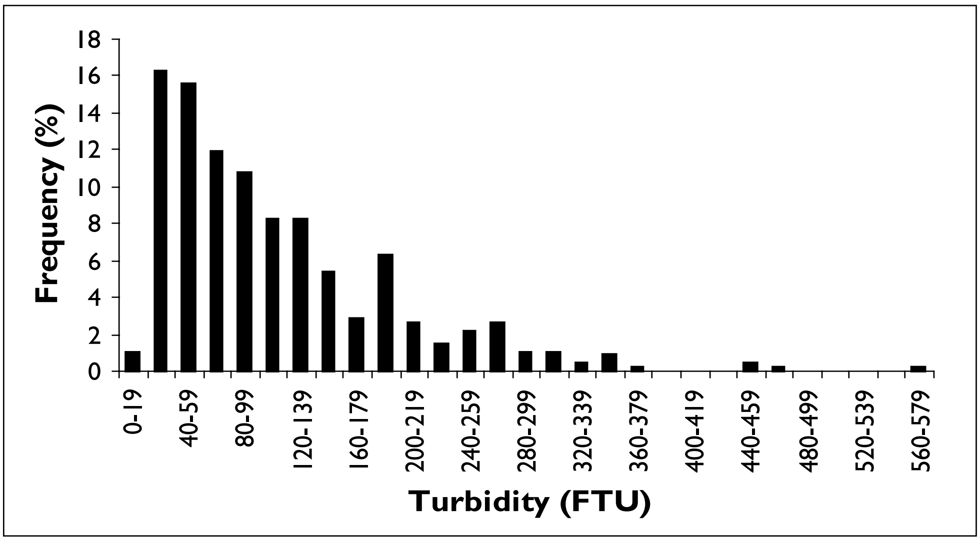


***Figure 18**. The turbidity (frequency in percent) where the acoustically tagged spotted grunter were positioned in the Great Fish Estuary between 7 February and 24 March 2003.*

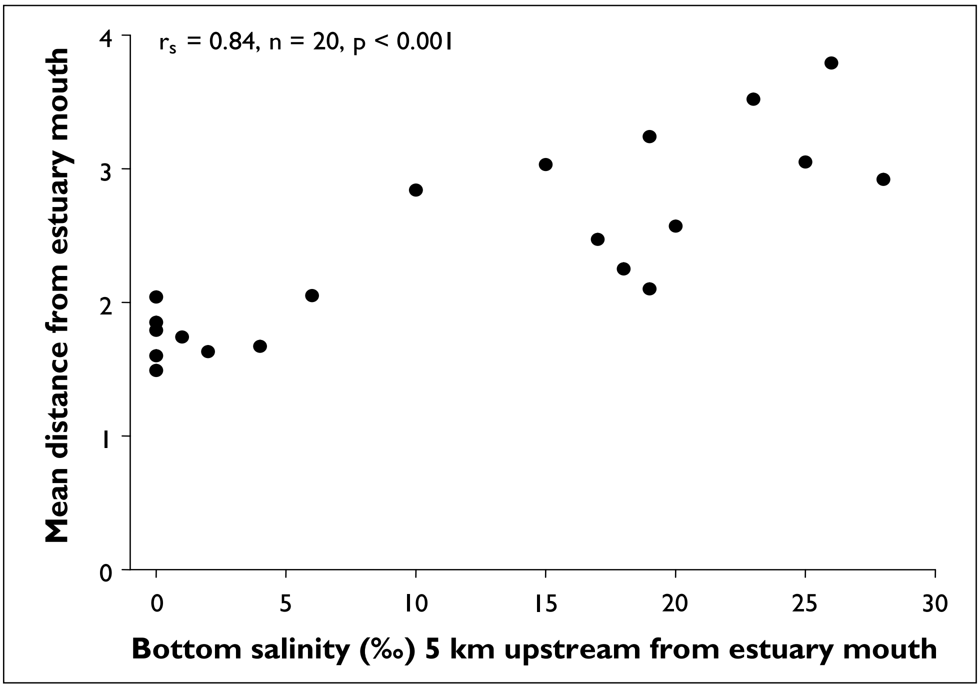


Figure 19*. Mean distance of the position of tagged spotted grunters plotted against the salinity measured near the bottom 5 km upstream from the estuary mouth. Mean distance is the daily means of the positions of all fish located. Only days with observations of 10 or more fish are included.*

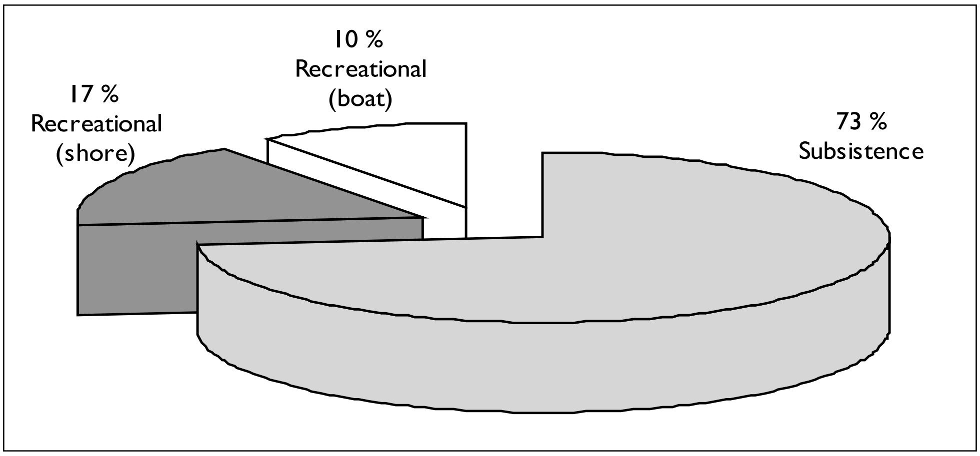


Figure 20*. Proportion of fishing effort (lines in the water) by subsistence, recreational shore and recreational boat fishers in the Great Fish Estuary between 7 February and 24 March 2003.*

4.5 Fisher distribution in estuary

All fishing activity registered on the estuary was by people fishing with rod and line, either from land or boat. As individual fishers often used more than one rod and/or hand line, fishing effort was recorded as number of lines used. The total number of lines recorded over the study period was 1441. The proportion of fishers using rods within the subsistence sector was 73 %, while it was 96 % in the recreational sector. Subsistence fishers, all fishing from shore, accounted for most lines (73 %), while recreational fishers accounted for the rest (27 %), of which 17 % were fishing from the shore and 10 % from a boat (**Figure 20**).

Within the 10.5 km of the estuary surveyed during this study, 93 % of the lines were recorded within the first 6 km of the estuary, of which 80 % were recorded within the first 3 km of the estuary (**Figure 21**). Almost 1/3 (28 %) of the fishing effort was recorded between 1.0 and 1.5 km from the mouth of the estuary.

Of the 66 boats recorded during the study period, nine (14 %) were moving and not included in our analysis as they were not fishing when encountered. Recreational boat anglers were recorded fishing from the mouth of the estuary to 7.5 km upriver (**Figure 22**). Within this area, 99 % of boat fishing effort occurred within the first 6 km of the estuary, of which 67 % were within the first 3 km of the estuary (**Table 9**). Although more than a third of the boat fishing effort occurred within the first 500 m of the estuary, the remaining effort was more evenly distributed.

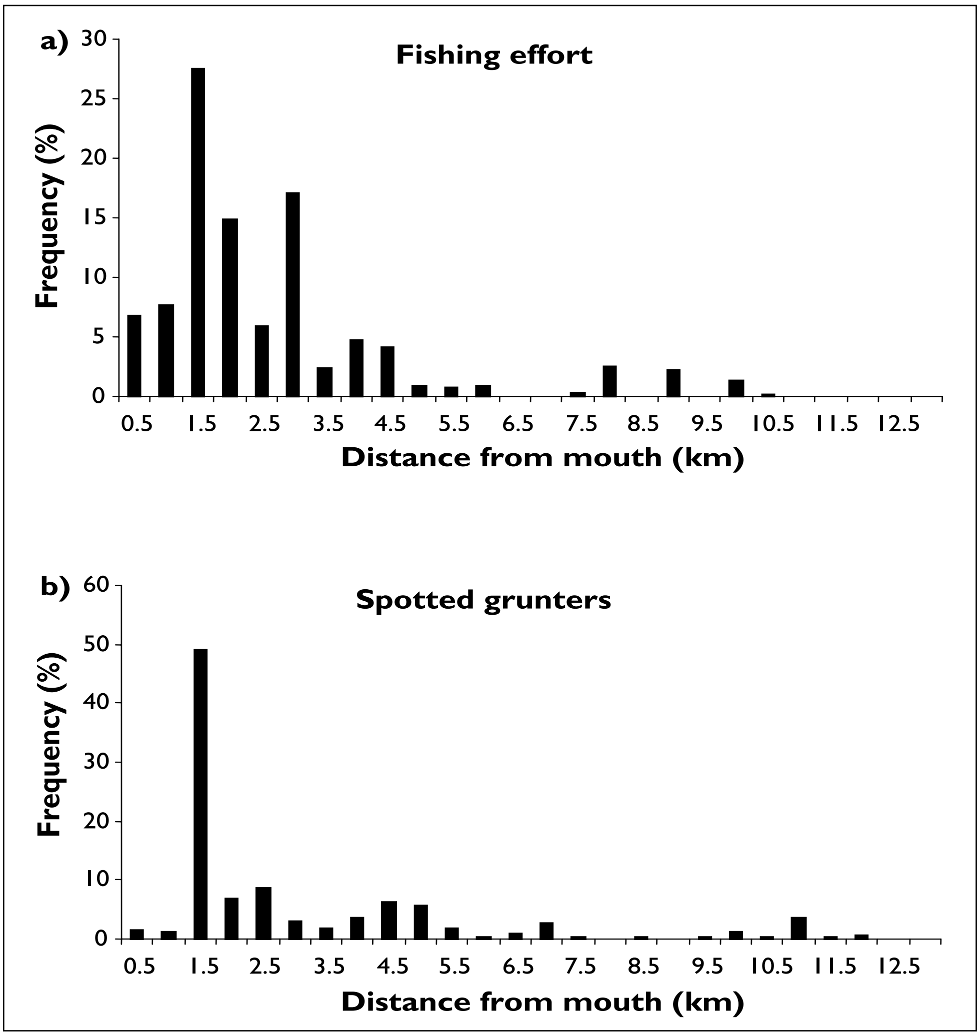


Figure 21*. The distribution of a) angler effort (total number of lines in water) for all fishing sectors and b) tagged spotted grunter in 500 m zones from the mouth of the estuary between 7 February and 24 March 2003.*

Table 9. *Distribution of tagged spotted grunter and the different groups of fishers within the first 3 and 6 km of Great Fish Estuary in February and March 2003.*

	First 3 km of estuary	First 6 km of estuary
Fish Distribution	70 %	89 %
Angler Distribution	80 %	93 %
Subsistence	78 %	91 %
Recreational (shore)	94 %	100 %
Recreational (boat)	67 %	99 %

Recreational shore anglers were mainly recorded (94 %) within 1.5 km of the estuary mouth with little effort (n = 14 lines) recorded further up in the estuary (**Figure 22**). Most of the effort was recorded around the road bridge as 39 % of the lines in water were observed within 500 m below the bridge, and 40 % within 500 m above the bridge.

The shore-based subsistence fishing effort was recorded from the mouth to 10.5 km upriver (**Figure 22**). Ninety-one percent of all observations, however, were recorded within the first 6 km of the estuary, of which 78 % of all observations were recorded within the first 3 km of the estuary (**Table 9**).

There was a significant relationship between the distribution of fish, expressed by the number of manually recorded fish positions per 2.5 km length of estuary, and the distribution of subsistence fishermen along the estuary (linear regression, P = 0.013, R^2 = 0.21). There was, however, no relationship between the distribution of fish and neither the recreational shore anglers (P = 0.60, R^2 = 0.04) nor the recreational boat anglers (P = 0.94, R^2 = 0.001).

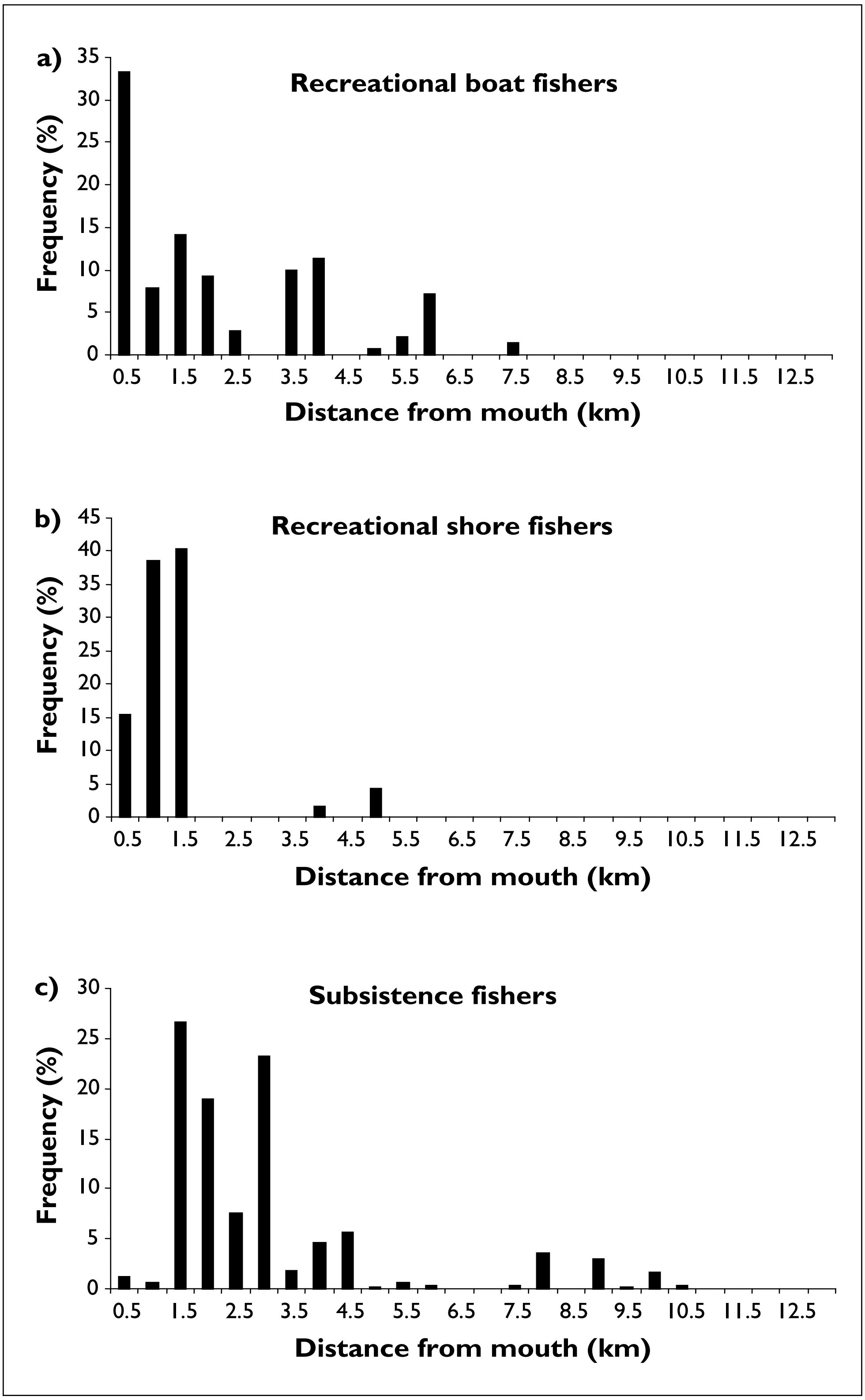


***Figure 22**. Distribution of fishing effort (total number lines in the water) divided into groups of a) recreational boat fishers, b) recreational shore fishers, and c) subsistence fishers all fishing from the shore between 7 February and 24 March 2003. The effort is sorted in 500 m zones from the mouth of the Great Fish Estuary.*

5 Discussion

Movements between river, estuary and sea

The spotted grunter is an Indian Ocean coastal species with a distribution in temperate, sub-tropical and tropical waters extending from India to False Bay in South Africa (Smith and Heemstra 2003). In South Africa the species is particularly abundant in KwaZulu-Natal and Transkei, being less abundant towards the south (van der Westhuizen and Marais 1977, Blaber 1981, Day *et al.* 1981). According to this, our study area in the Great Fish Estuary is in the southern part of the species main distributional range.

Twenty small spotted grunter (26 – 39 cm in total length) were manually tracked for 48 days in the Great Fish Estuary in February and March 2003. In addition to manual tracking, movements between the main riverine, estuarine and marine environments were monitored by four stationary automated logging stations.

The behaviour and movement patters varied considerably among individuals. During the study period, fish movements were categorised into four groups: Estuary residents, occasional marine migrants, marine migrants, and riverine migrants. More than half of the fish (55 %, n = 11) were classed as marine migrants, i.e. were fish that were in the sea at the end of our study. However, 30 % of the fish (n = 6) stayed in the estuary during the entire manual tracking period. Only 10 % (n = 2) were classified as occasional marine migrants, i.e. fish with seaward return movements but were in the estuary at the end of the study, and 5 % (n = 1) were riverine migrants, i.e. stayed in the river or caught just prior to the end of the study.

The spotted grunter is a marine spawning estuarine-dependent species (Wallace and van der Elst, 1975). Early juveniles (20-30 mm TL) recruit into estuaries where they make use of the nutrient rich environment as a feeding and nursery ground. The estuarine dependent phase, which lasts for at least the first year of life, is followed by a movement back into the marine environment. The spotted grunter reaches sexual maturity at approximately 2-3 years of age at 30-40 cm total body length (Wallace 1975b, Wallace and Schleyer 1979, Day *et al.* 1981, Webb 2002).

The studied fish spent on average a considerable amount of time (66 %) at sea during the 48 day study. On average each all the fish had 0.8 (min. 0 – max. 5) return trips to sea before they emigrated. However, there was a large individual variation, as only nine fish made return trips before leaving and six fish never went to sea. The fish, however, spent on average 92 % of their time in the estuary before they left the estuary permanently.

The observed behavioural patterns may be linked to sexual maturation and spawning migration. According to Webb (2002), who studied growth of spotted grunter in Great Fish Estuary, length-at-age varies considerably between individuals. Based on body length, the ages of the tagged fish in this study most probably were between three and five years old. There is, however, considerable overlap between age classes, and the studied individuals could have been younger (2 year) or older (6 or 7 years).

Small spotted grunter cannot be externally sexed nor the maturity stage determined. Therefore the sex or maturity state could not be substantiated. Male and female grunter attain 50 % maturity at approximately 30 and 36 cm (TL), respectively (Wallace 1975b, Webb 2002). Two (10 %) of the studied fish were smaller than 30 cm, while as much as 15 fish (75 %) were smaller than 36 cm. It is therefore likely that the studied fish consisted of both immature and mature fish of possibly both sexes.

Little is known about the reproductive biology of spotted grunter apart from the work of Wallace (1975b) from KwaZulu-Natal and Webb (2002) in Great Fish Estuary. Spawning takes place off the KwaZulu-Natal coastline (Wallace 1975b, Wallace and van der Elst 1975, Connell 1996, Harris and Cyrus 1997, Harris and Cyrus 1999), and no studies have indicated elsewhere (see Webb 2002). The primary spawning season is suggested to be from September to December, but extending until February (Wallace 1975b). Due to the lack of evidence that spawning occurs outside of KwaZulu-Natal it has been suggested that all South African spotted grunters comprise a stock (conf. Webb 2002). The present study was conducted just after the suggested spawning season. However, it is unknown whether marine migrants in our study were sexually mature or maturing individuals leaving or preparing to leave the estuary to spawn in spring-summer of 2003-2004, four to five months later.

There is, however, evidence to suggest that fish return to or use the estuary for a prolonged period of time. Two of the spotted grunters which left the estuary during this study were caught by anglers in the estuary in January and July 2004, respectively, and three other fish that were resident in the estuary during this study were recorded in the estuary when the automated logging stations were later again deployed in October 2003 (Cowley *et al.* unpublished data). The documented presence of 25 % of the fish in the estuary 12 to 24 months after being tagged, suggest that the fish display residency behavior to the Great Fish Estuary. These findings are supported by conventional tagging studies compiled by Bullen and Mann (2000 and 2004) indicating that tagged spotted grunters are largely resident to certain estuaries. The majority of the recaptured fish (> 80 %, both reports) were caught in close proximity to the initial release site (< 3 km). However, some of the recaptured fish also showed fairly extensive movements in excess of 50 km.

Based on this study it is evident that a significant proportion of the fish in the studied size category (26 – 39 cm) spend time at sea during late summer and autumn. Such information may have management implications for example for estimation of the estuarine stock size and fisheries regulations as bag limits.

Movements within the estuary

Movements within the estuary were characterized by high variability, and there was no significant relationship between the body length of the fish and average distance moved between fixes. Despite considerable variation in distance moved between each time the spotted grunter were positioned, most of the positional fixes were in the lower part of the estuary as 70 % were within the first 3 km, and 89 % were within the first 6 km of the estuary, which has an approximate overall length of 12 km. The average distance moved between positional fixes ranged from 0.06 to 2.7 km (mean 1.0 km).

When capturing the spotted grunter for tagging, the fishing effort was spread in the lower and middle part of the estuary. The higher catch rate in some areas, however, was due to an uneven catch of fish per unit effort within the estuary. This study also indicates that most fish did not have a strong association to the areas close to where they were caught and released. In general, but to varying degree, the fish utilized most of the lower and middle sections of the estuary and some had movements into sea and/ or up into fresh water.

An indication of the fidelity to the catch and release site might be the distance from the catch and release site to the position fixes. This distance varied considerably within each individual, as well as among individuals being 0.1 km to 6.5 km (mean 1.5 km). The average distance for each individual increased gradually up to 2.4 km when comparing all the tagged fish, with exception of two individuals that on average moved considerably longer (6.0 km and 6.5 km). The average distance moved from the catch and release site was not size dependent. While being in the estuary, the area used (maximum distance between positional fixes) by individuals also varied considerably among individuals, and ranged from 0.2 km to 12.0 km (mean 4.9 km). The majority of the fish (75 %), however, utilized between 3.2 and 7.1 km of the estuary, while three used less and two used more. The large variation in the average distance moved from the catch and release site and the total area used also indicate that there was no strong association to the catch site as such, but rather a preference of fish to being in the lower reaches of the estuary.

Physico-chemical environment and fish positions

The coastal environments used by spotted grunters are best described as highly dynamic. They occupy the inshore marine environment with high wave action, varying temperature regimes and tidal levels, and also highly fluctuating estuarine environments with constantly changing salinities, temperatures and strong currents. Estuaries are regions where saline and fresh waters meet and the environment is potentially stressful, and periods of stability are short (Whitfield 1998). Abrupt changes in the abiotic environment may place considerable physiological demands on fishes residing in estuaries. However, those fish species that are broadly tolerant to this changing environment are at an advantage, since they are able to utilise a nutrient-rich environment from which many potential competitors are excluded (Whitfield 1990). In the Great Fish Estuary, the water samples from the fixed stations indicate that the most variable part of the estuary occurred at stations 5 and 6, approximately 4 to 5 km from the estuary mouth.

There is a significant freshwater inflow to the Great Fish Estuary (Vorwerk *et al.* 2003). During this study, the salinity of the bottom water in the estuary was always equal to or higher than in the surface water, illustrating the importance of the river flow into the estuary.

As expected spotted grunter were found to be euryhaline (Blaber and Cyrus 1981). The tagged spotted grunter were observed at salinities ranging between 0 ‰ (freshwater) and 36 ‰ (sea water), with an average of 22.1 ‰. Areas with higher salinities (> 18 ‰) were the more frequently used, as most fish (68 %) stayed in the euryhaline (36 %) and polyhaline (32 %) areas of the estuary.

The difference in water temperature between the bottom and surface varied considerably within each station (up to 8.3 °C), and among the stations. Within the study period the minimum temperature was 15.2 °C and maximum temperature 29.5 °C. However, the water temperature was always 20 °C or higher above station 4, 2.5 km from the mouth. The spotted grunters were observed in water temperatures varying from 17 to 31 °C, but the majority (63 %) of the fish positions were in water temperatures between 22 and 25 °C. Temperature preference studies should be performed under laboratory conditions or with acoustic transmitters with temperature sencor. The results of this study, however, are in accordance with thermal preference studies conducted on 0+ spotted grunter (24 - 25 °C) under laboratory conditions (Deacon and Hecht 1995), and an earlier study on spotted grunter in Great Fish Estuary (Ter Morshuizen *et al.* 1996) where the majority of fish were caught in temperatures between 21 °C and 23 °C.

The recorded minimum water temperature during our study (15.2 °C) was above the critical level (< 13 °C) at low salinities (Blaber and Whitfield 1976). We cannot, however, disregard that stressful combinations of low water temperatures and low salinities might have occurred in areas of the estuary creating an environment potentially physiologically stressful for the tagged spotted grunter. Such conditions are most likely to have occurred in the upper areas of the estuary.

Great Fish Estuary is a very turbid estuary with extreme turbidities (> 700 FTU) in certain areas, especially in the upper reaches. The spotted grunters were observed in turbidities varying from very low (6 FTU) to very high (567 FTU), and 44 % of the fish observations were in turbid water (> 100 FTU) and only 1 % were in clear water (< 20 FTU). Our results, indicating that the spotted grunter utilize waters with varying and also very high turbidities, are supported by *in situ* and laboratory studies showing that the spotted grunter is indifferent to water turbidity (Cyrus and Blaber 1987; Hecht and van der Lingen 1992). The spotted grunter is a non-visual macrobenthic feeder, and has the ability to change foraging strategies in order to optimize food intake under different turbidity conditions (Hecht and van der Lingen 1992). The high turbidity levels in Great Fish Estuary are therefore not expected to have large negative impacts on the feeding of the spotted grunter.

Most grunters were located at depths between 1 and 2 m which also were the most prevalent depths. As the estuary is shallow and between 1 and 2 m in most areas, with certain deep areas in the lower and upper reaches (< 3 m), the depth at fish positions might be strongly influenced by the availability of areas with different depths.

Temperature, salinity and turbidity are all factors that might be stressful for poorly adapted fish, and thresholds might be reduced due to synergic effects of two or more factors. The spotted grunters are euryhaline and have been recorded in salinities varying from 0 – 90 ‰ (Wallace 1975a, Day *et al.* 1981), and can survive in salinities less than 1 ‰ for prolonged periods (Blaber and Cyrus 1981). However, mass mortalities have been recorded when low water temperatures (< 13 °C) occurred together with low salinities (< 4 ‰) (Blaber and Whitfield 1976). Therefore, the synergetic effects of environmental parameters might be harmful for potted grunters at levels where one factor alone may not cause any harm.

Salinity might be the driving factor associated with distribution of fish within an estuary, and Whitfield (1994) suggested that the longitudinal salinity gradient in Eastern Cape estuaries is the single most important factor. However, we were not able to separate the effects of salinity alone as there were strong negative correlations between the environmental parameters salinity and temperature, and salinity and turbidity, and strong positive correlations between temperature and turbidity. This was mainly due to the strong influence of cold, saline and clear marine water and warmer, fresh and turbid riverine water.

From a management point of view it might be important to test whether the spotted grunters were randomly distributed in the estuary, or whether their distribution could be linked to environmental conditions. In the Great Fish Estuary we have studied the combined effects of the environmental variables salinity, turbidity and temperature, as represented by one of them, salinity. The distribution of marine (saline) water seemed to influence the movement of fish as more fish were positioned higher up in the estuary at days with higher salinities in these areas. In addition, there was a significant positive correlation between the mean position of the fish and the salinity at station 6 (5 km from the mouth). Based on this we can conclude that one or more of the environmental parameters salinity, turbidity and temperature have a significant effect on the spotted grunters utilisation and movements in the Great Fish Estuary. However, which one that is most important, and possible synergetic effects, cannot be determined through our *in situ* study.

Fishing effort

All fishing activities on the Great Fish Estuary was conducted either from the shore or from boats by people fishing with rod and line or handline. Subsistence fishers, only fishing from land, accounted for 73 % of the fishing effort (no of lines in the water), while recreational fishers for the rest, where 17 % were fishing from the shore and 10 % from a boat. The majority (80 %) of the fishing effort took place within the first 3 km of the estuary, of which 28 % occured within 500 m from 1.0 to 1.5 km above the estuary mouth. Although, also concentrated in the lower part of the estuary, the subsistence fishers utilised the largest area of the estuary as some persons were also fishing in the upper part. A vast majority (94 %) of the recreational shore anglers fished in the lower 1.5 km of the estuary. Being more mobile than the two other groups, the recreational boat anglers were more evenly distributed in the lower and middle part.

The distribution of subsistence fishers was significantly correlated with the distribution of positional fixes of the spotted grunter. There was no such correlation, however, between the two groups of recreational fishers and fish positions. The difference in the distribution of subsistence and recreational shore anglers can be ascribed to the use of different access points along the river. Most recreational fishers use private cars to commute to the river and access the river from a camping site or a road approximately 1 km from the sea, while subsistence fishers, on foot, access the estuary at various places, except via the camping site situated 0.5 km to 1 km from the mouth. In addition, the local knowledge of the subsistence fishers of the area use of spotted grunter, and hence the best places to fish, might also contribute to the correlation between the distribution of fish and subsistence fishers.

Management implications

During the study period (February - March 2003), the implementation of the currently legislated management measures in the middle and upper reaches of the estuary would have had little effect on the fish population as both the fish and fishers were mainly located in the lower one third of the estuary.

A reduction in the bag limit, which is currently set at five fish per person per day, would need to be substantial to have any effect on the fish population. The findings of a fishery survey conducted between October 2003 and September 2004 in the Great Fish Estyary (Potts *et al.* 2005) revealed that most fishers (65 %) did not catch a single spotted grunter on a daily outing. Furthermore, only 18 % of fishers caught more than one spotted grunter per day, while only 3 % of fishers exceeded the legislated daily bag limit (Potts *et al.* 2005). In addition, a large proportion (29 %) of caught and retained spotted grunter were below the legal size limit of 40 cm TL (Potts *et al.* 2005). Consequently, effective management of spotted grunter on the Great Fish Estuary by way of bag limits and size restrictions would require improved law enforcement and/or better compliance by fishers. However, such changes would be difficult considering that firstly, the Great Fish Estuary is situated in a rural area and secondly, due to the high dependence on fish catch by the large subsistence sector. Other fishery regulation measures should therefore be considered. Alternative measures include closed seasons and protected areas. However, a closed season will have negative impacts on the subsistence fishers who might be deprived of food and income. Therefore, over-exploitation of the juvenile spotted grunter population might be best controlled by establishing a protected area. If a no-fishing zone is to be implemented on the Great Fish Estuary it should be established in the lower reaches (the area between one and two kilometers from the estuary mouth) as this area represented a high use area by juvenile spotted grunter.

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Appendix

Appendix 1. *The fish community in the Great Fish River estuary as described by Whitfield et al. (1994), Whitfield (1998), and Vorwerk et al. (2003).*

Family	Species	Common name
Ambassidae	*Ambassis gymnocephalus*	*Bald glassy*
	Ambassis natalensis	*Slender glassy*
Anguillidae	*Anguilla mossambica*	*Longfin eel*
Ariidae	*Galeichthys feliceps*	*White seacatfish*
Atherinidae	*Atherina breviceps*	*Cape silverside*
Carangidae	*Lichia amia*	*Leervis/garrick*
	Caranx sexfasciatus	*Bigeye kingfish*
Cichlidae	*Oreochromis mossambicus*	*Mozambique tilapia*
Clariidae	*Clarius gariepinus*	*Sharptooth catfish*
Clupeidae	*Gilchristella aestuaria*	*Estuarine roundherring*
Cyprinidae	*Cyprinis carpio*	*Carp*
	Barbus aeneus	*Smallmouth yellowfish*
	Labeo umbratus	*Moggel*
Eleotridae	*Eleotris fusca*	*Dusky sleeper*
Elopidae	*Elops machnata*	*Ladyfish*
Engraulidae	*Engraulis capensis*	
Gerreidae	*Gerres acinaces*	*Smallscale pursemouth*
Gobiidae	*Caffrogobius gilchristi*	*Prison goby*
	Caffrogobius nudiceps	*Barehead goby*
	Glossogobius callidus	*River goby*
	Oligolepis acutipennis	*Sharptail goby*
	Oligolepis keiensis	*Speartail goby*
	Psammogobius knysnaensis	*Speckled sandgoby*
	Redigobius bikolanus	*Bigmouth goby*
Haemulidae	*Pomadasys commersonnii*	*Spotted grunter*
	Pomadasys olivaceum	*Piggy*
Leiognathidae	*Leiognathus equula*	*Slimy*
Monodactylidae	*Monodactylus falciformis*	*Oval moony*
Mugilidae	*Crenimugil crenilabis*	*Fringelip mullet*
	Liza dumerilii	*Groovy mullet*
	Liza macrolepis	*Largescale mullet*
	Liza richardsonni	*Southern mullet*
	Liza tricuspidens	*Striped mullet*
	Mugil cephalus	*Flathead mullet*
	Myxus capensis	*Freshwater mullet*
	Valamugil buchanani	*Bluetail mullet*
	Valamugil cunnesius	*Lomgarm mullet*
	Valamugil seheli	
Platycephalidae	*Platycephalus indicus*	*Bartail flathead*
Poecilidae	*Gambusia affinis*	*Mosquitofish*
Polynememidae	*Polydactylus plebeius*	*Striped threadfin*
Pomatomidae	*Pomatomus saltatrix*	*Elf*
Sciaenidae	*Argyrosomus japonicus*	*Dusky kob*
	Johnius dussumieri	*Mini-kob*
Soleidae	*Heteromycteris capensis*	*Cape sole*
	Solea bleekeri	*Blackhand sole*
Sparidae	*Acanthopagrus berda*	*Estuarine bream*
	Lithognathus lithognathus	*White steenbras*
	Rhabdosargus globiceps	*White stumpnose*
	Rhabdosargus holubi	*Cape stumpnose*
	Diplodus sargus capensis	*Blacktail*
	Diplodus cervinus hottentotus	*Zebra*
Syngnathidae	*Syngnathus acus*	*Longsnout pipefish*
Teraponidae	*Terapon jarbua*	*Thornfish*
Tetraodontidae	*Amblyrhynchotes honckenii*	*Evileye blaasop*

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NINA Norwegian Institute for Nature Research
NINA Mainoffice • Tungasletta 2 • NO-7485 Trondheim • Norway
Phone: +47 73 80 14 00 • Fax: +47 73 80 14 01
http://www.nina.no

SAIAB South African Institute of Aquatic Biodiversity
Private Bag 1015 • Grahamstown 6140 • South Africa
Phone: +27 (046) 603 5800 • Fax: +27 (046) 622 2403
http://www.saiab.ru.ac.za

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