Piscivory and the functioning of shallow tropical estuarine nursery grounds

Thesis submitted by

Ronald BAKER BSc (Hons) JCU

in May 2006

for the degree of Doctor of Philosophy
in the Department of Marine Biology and Aquaculture
School of Biological Sciences
James Cook University

STATEMENT OF ACCESS

I, the undersigned, author of this work, understand that James Cook University will make this thesis available for use within the university library and, via the Australian Digital Thesis network, for use elsewhere.

I understand that, as an unpublished work, a thesis has significant protection under the Copyright Act and;

I do not wish to place any further restrictions on access to this work.

Signature Date

STATEMENT OF SOURCES

DECLARATION

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Signature Date

Abstract

Shallow estuarine habitats around the world are considered important nurseries for a diverse range of fish and crustaceans of ecological and economic importance. One of the key features believed to contribute to the nursery value of these habitats is that they contain few predatory fishes, and thus provide juveniles with a refuge from predation. Despite its global application, there is very little direct evidence to support the shallow-water refuge paradigm.

Within tropical estuarine systems our current knowledge of the role predation may play in structuring juvenile fish faunas and the functioning of shallow water nurseries is limited to broad summaries of the general dietary habits of a limited range of large piscivorous fishes. Small and occasional or 'minor' piscivores, those predators which on average have a low occurrence of fish in their diet, have largely been ignored. Additionally, there is a lack of quantitative detail on dietary composition and on spatial and temporal patterns in the consumption of fish prey. Such details are needed to clarify the importance of predation on particularly vulnerable or critical life stages such as new recruits. Understanding the processes that drive systems such as estuarine nurseries is critical for the effective management and protection of these important systems into the future. The goal of this thesis is to gain a clearer insight into the role of piscivory within shallow tropical estuarine nursery grounds, and by doing so, to significantly enhance our understanding of the functioning of these important systems.

To define the assemblage of piscivorous fishes relevant to the functioning of shallow water nurseries, the diets of almost 5000 predatory fishes collected over 6 years from shallow (<1.5m) sandy habitats in the lower reaches of 17 tropical estuaries were examined. The piscivore assemblage was diverse in terms of taxonomic composition, size structure and predation strategies. Fifty-one taxa were found to have fed on fish, and the piscivore assemblage included many taxa and size classes that have been previously overlooked. The majority of taxa were piscivorous to some degree from sizes well below 100 mm. All of the smaller piscivores (<100 mm) preyed mainly on small new recruits. The larger more widely recognised piscivores preyed on a broader range of fish prey, however few of these consumed significant numbers of small new recruits. The suggestion that shallow-waters in tropical estuaries contain few piscivorous fishes fails to recognise the potential importance of the abundant and diverse assemblage of small and minor piscivores that utilise these habitats.

The potential importance of previously overlooked occasional or minor piscivores as predators of new recruits was explored by relating recruit abundance to predator diets, and by examining spatial and temporal patterns in the consumption of fish prey. The high spatial patchiness of new recruits made it difficult to correlate their abundance with their consumption by minor piscivores. However, the low average occurrence of fish in the diet of minor piscivores was a poor reflection of the spatial and temporal patterns in predation pressure by these on new recruits to shallow nursery habitats. Most of the time, minor piscivores did not consume fish prey but occasionally a large proportion of them did so. When minor piscivores consumed fish prey, they preyed mainly on small new

recruits. Small new recruits were only occasionally abundant, with temporally patchy recruitment to shallow estuarine nurseries. Thus, the low average occurrence of fish in the diet of minor piscivores suggests that while these predators may derive little of their nutritional requirements from fish prey, they may switch to heavily target new recruits. Given that many of the minor piscivores are highly abundant and are themselves small juvenile fishes occupying the shallow nursery habitats, they are potentially major sources of mortality for fish recruiting to shallow estuarine nurseries.

The abundance of large (≥100 mm TL) piscivorous fishes in shallow water habitats where they appeared to have previously been underestimated was determined by visual census. Although flathead (*Platycephalus* spp., Platycephalidae) were the only large piscivores sighted within the transects, the density observed (0.04 ind. m^{-2}) equated to one piscivore for every 10.5 m of shoreline surveyed. This exceeds density estimates for large piscivores in shallow estuarine habitats elsewhere in the world by orders of magnitude. Furthermore, the estimated biomass of flathead (11.56 g m^{-2}) was equivalent to comparable biomass estimates of entire fish assemblages from shallow estuarine habitats in other parts of the world. The densities and depth distribution of these large piscivores, combined with the diverse and abundant assemblage of small and occasional piscivores, suggests that shallow water nurseries may not provide small fishes with the level of refuge from predation previously assumed.

The hypothesis that predation pressure on small fishes is lower in shallow waters than in adjacent deeper water was directly tested by a series of tethering experiments. Over 6

months 17 replicate experimental trials were conducted, deploying a total of 183 tethered fish prey across a depth gradient (0.2 – 3 m) in the lower reaches of a tropical estuary. Despite the clear and consistent patterns found in previous studies elsewhere in the world, there was no evidence of lower predation pressure in the shallow relative to the adjacent deeper waters in the tropical estuaries examined. Given the complexity and diversity of the piscivore assemblage in these estuaries it is hardly surprising that no clear patterns emerged. The findings suggest that the shallow-water refuge paradigm may be too simplistic for diverse and complex tropical estuarine nursery grounds.

Finally, a model was constructed to estimate the relative importance of different members of the diverse shallow water piscivore assemblage within tropical estuaries. Data on variability in the occurrence, number and type of fish in the diet of different piscivores was combined with estimates of the abundance of each group gained from block-net sampling an intertidal marsh over 2 years. The model predicts that previously overlooked small and occasional piscivores have the potential to have orders of magnitude greater impacts than more conspicuous larger piscivores on new recruits utilising shallow tropical estuarine habitats as nurseries. Because of their sheer abundance, a switch by the minor piscivores to target new recruits results in a massive increase in the consumption of fish prey by the piscivore assemblage. As a broad functional group, minor piscivores occur in many systems around the globe, and are likely to play important roles in these systems as predators that shape communities by targeting the critical early life stages of other fishes.

This study revealed a diverse assemblage of piscivores with the potential to cause significant mortality on new recruits to shallow water habitats. Many of the piscivores with the greatest potential to shape community structure through predation on new recruits are themselves small juvenile fishes utilising shallow water habitats as nurseries. In contrast to the idea that shallow waters provide refuge from predation, heavy predation on new recruits entering the nursery may represent a significant input of energy and nutrients from coastal waters to estuarine systems and may act to enhance the productivity and hence the nursery ground value of these systems.

Acknowledgements

I would like to thank my supervisor Dr. Marcus Sheaves for his guidance, support, patience and friendship throughout my research career (Honours and PhD). The many hours of discussions relating to both this research, and to ecology in general, have been invaluable in shaping and focussing this work. Similarly, I would like to thank Dr. John Collins and Dr. Alan Dartnall for their advice and guidance on various aspects of this research. Discussions among the Estuarine and Coastal Ecology Group at JCU (the lab) relating to conference presentations and seminars arising from this work have greatly improved the quality of this thesis. In particular I thank Ross Johnston, Janine Sheaves, Jane Wilson, Pakamas Thinphanga, Ann Penny, Katya Abrantes, Ryan Fisher, James Aumend and Keith van den Broek. John Collins provided extensive assistance and advice in the production of the otolith catalogue. Eleven anonymous reviewers have reviewed papers based on chapters (Ch. 3, 4 & 5) and their comments have greatly improved the quality of this thesis. My dad, Dr. Gordon Baker, also reviewed several manuscripts and chapters, and his advice and comments have been invaluable. Regina Souter (Coastal CRC) reviewed the entire thesis and provided valuable feedback.

Jane Wilson provided a significant contribution of dietary data, particularly for *Ambassis telkara*, *Gerres filamentosus*, the sillaginids and sparids. Ross Johnston provided data and discussions on the depth distributions of common fishes in the region (Fig. 6.2). I would like to thank the many people who assisted in the field work for this study. The 12 months of fortnightly sampling in the Ross River (Ch. 4), and the sorting of these samples, was conducted by myself, Jane Wilson and Keith van den Broek, and the block

net sampling (Ch. 7) was conducted by myself and Jane (and a large team of field volunteers), I thank them for their considerable efforts in this sampling. In addition to the people from the lab, Tom Hatley, Tim Prior, Tanya Cornish, Iony Woolaghan, Tav Bates, Chris Jones and James Baker helped in the field on many occasions. I must also thank Kerry Neil and Rebecca Sheppard for being great bosses. Kerry gave me a job with the flexibility to allow me to begin this PhD without a scholarship, and similarly, the flexibility and understanding Rebecca has given me during my time working at DPI Fisheries has enabled me to complete the PhD.

This research was primarily funded by the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC), and I thank the team at the Coastal CRC for the tremendous support they provide their students. A student stipend was provided by the Coastal CRC between January 2002 and June 2004. Additional research funding was provided by the Department of Marine Biology and Aquaculture, James Cook University.

Finally I thank my friends and family for their tremendous love, support and encouragement throughout my PhD.

Contents

List of figures

List of tables