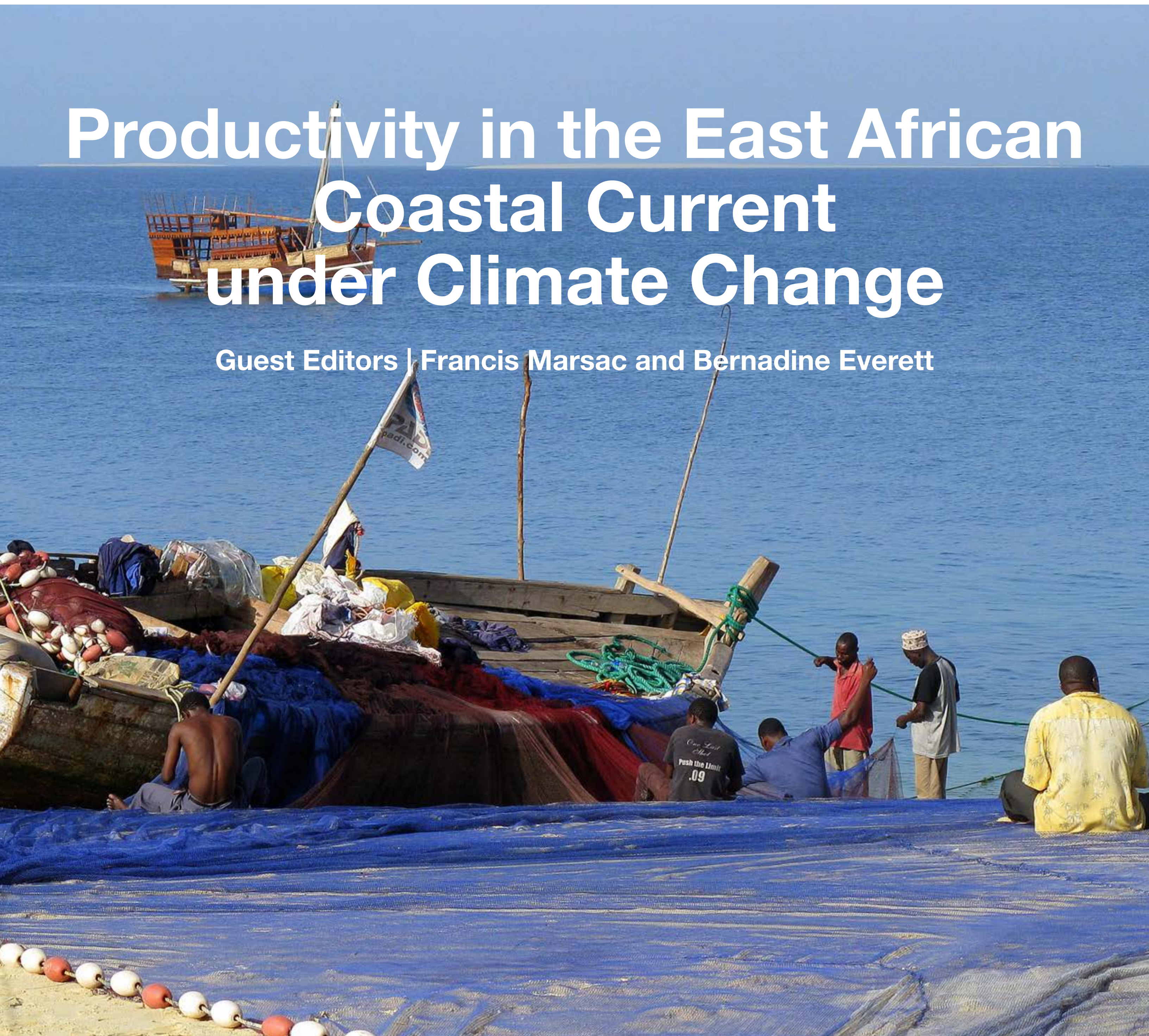
Western Indian Ocean
JOURNAL OF
Marine Science

Special Issue 1/2020 | Dec 2020 | ISSN: 0856-860X



Productivity in the East African Coastal Current under Climate Change

Guest Editors | Francis Marsac and Bernadine Everett

Western Indian Ocean JOURNAL OF Marine Science

Chief Editor **José Paula** | Faculty of Sciences of University of Lisbon, Portugal

Copy Editor **Timothy Andrew**

Published biannually

Aims and scope: The *Western Indian Ocean Journal of Marine Science* provides an avenue for the wide dissemination of high quality research generated in the Western Indian Ocean (WIO) region, in particular on the sustainable use of coastal and marine resources. This is central to the goal of supporting and promoting sustainable coastal development in the region, as well as contributing to the global base of marine science. The journal publishes original research articles dealing with all aspects of marine science and coastal management. Topics include, but are not limited to: theoretical studies, oceanography, marine biology and ecology, fisheries, recovery and restoration processes, legal and institutional frameworks, and interactions/relationships between humans and the coastal and marine environment. In addition, *Western Indian Ocean Journal of Marine Science* features state-of-the-art review articles and short communications. The journal will, from time to time, consist of special issues on major events or important thematic issues. Submitted articles are subjected to standard peer-review prior to publication.

Manuscript submissions should be preferably made via the African Journals Online (AJOL) submission platform (http://www.ajol.info/index.php/wiojms/about/submissions). Any queries and further editorial correspondence should be sent by e-mail to the Chief Editor, wiojms@fc.ul.pt. Details concerning the preparation and submission of articles can be found in each issue and at http://www.wiomsa.org/wio-journal-of-marine-science/ and AJOL site.

Disclaimer: Statements in the Journal reflect the views of the authors, and not necessarily those of WIOMSA, the editors or publisher.

ISSN 0856-860X

Cover image: Stonetown, Zanzibar (© Bernadine Everett, 2012)

Preliminary findings on the food and feeding dynamics of the anchovy *Stolephorus commersonnii* (Lacepède, 1803) and the Indian mackerel *Rastrelliger kanagurta* (Cuvier, 1817) from Tanga Region, Tanzania

Baraka C. Sekadende[1]*, Joseph S. Sululu[1], Albogast T. Kamukuru[2], Mathias M. Igulu[3], Shigalla B. Mahongo[4,5]

[1] Tanzania Fisheries Research Institute, P.O.Box 475, Mwanza, Tanzania

[2] Department of Aquatic Sciences and Fisheries Technology, University of Dar es Salaam, PO Box 60091, Dar es Salaam, Tanzania

[3] WWF Country office, 350 Regent Estate, Mikocheni, PO Box 63117, Dar es Salaam, Tanzania

[4] Tanzania Fisheries Research Institute, Institute Head Quarters, PO Box 9750, Dar es Salaam, Tanzania

[5] Lake Victoria Fisheries Organization, P.O. Box 1625, Jinja, Uganda

* Corresponding author: barakasekadende@tafiri.go.tz

Abstract

Small pelagic fishes play an important role in the ecosystem by linking planktonic production and higher trophic level predators, and provide a livelihood to both the small-scale and commercial fisher communities. This study analyzed the food and feeding habits of *Stolephorus commersonnii* (Lacepède, 1803) and *Rastrelliger kanagurta* (Cuvier, 1817) from the ring-net fishery in Tanga, Tanzania. A total of 1 434 and 320 stomachs of *S. commersonnii* and *R. kanagurta* respectively were examined for gut contents using the relative volumetric method. *S. commersonnii* was found to be a planktivorous carnivore, feeding principally on planktonic penaeid shrimps (48.6%), fish larvae (33.2%) and zooplankton (12.3%). *R. kanagurta* was found to be carnivorous, feeding predominantly on fish (60.6 %), mainly *S. commersonnii*, while penaeid shrimps, juvenile fish, and juvenile stages of squids formed 26.5% of the total number of food items in *R. kanagurta* guts. Both *S. commersonnii* and *R. kanagurta* exhibited ontogenic diet shifts, where they fed exclusively on small prey as juveniles and consumed larger food items as they grew. The index of vacuity was higher in *S. commersonnii* (46.1%) than in *R. kanagurta* (16.6%). This study revealed the importance of penaeid shrimps as food for *S. commersonnii*, that in turn formed the main food for *R. kanagurta*. This implied that the two species were able to coexist in the same niche by avoiding interspecific competition for food.

Keywords: Food and feeding, *Stolephorus commersonnii, Rastrelliger kanagurta,* Small pelagics, Tanga, Tanzania

Introduction

Small pelagic fishes are of global importance both socio-economically and ecologically. Small pelagic fisheries contribute over 50% of the world's wild-caught catches (Cury *et al*., 2000). Ecologically, small pelagic fishes play a crucial role because they can constitute such large biomass in pelagic systems that they have the capacity to exert strong bottom up or top down control (Raab *et al*., 2011). The fishery for small pelagics makes a substantial contribution to catches by commercial and artisanal fishers in the United Republic of Tanzania (Bodiguel *et al.*, 2015), and many other tropical and subtropical countries (van der Lingen *et al.*, 2006). Furthermore, the Tanzanian fishery plays a significant role in job creation and food security, with participation being affordable at all socio-economic levels. Bodiguel *et al.* (2015) estimated that around 10,000 people in both mainland

http://dx.doi.org/10.4314/wiojms.si2020.1.7

WIO Journal of Marine Science Special Issue 1/**2020** 71-80 | B. Sekadende *et al.*

Tanzania and Zanzibar are directly engaged in the small pelagic fishery and related activities (fishers, porters, boiling and drying workers, processing entrepreneurs, traders, wood and salt suppliers, transporters and food vendors).

The findings of this study are part of the *"Responses of biological Productivity and fisheries to changes in atmospheric and oceanographic conditions in the upwelling region associated with the East African Coastal Current"* (PEACC) project which sought to establish relationships between upwelling, marine productivity and the associated fisheries along the East African coast, given the changing global climate. Coastal upwelling is often associated with increased ocean productivity, with small pelagics frequently dominating species composition in coastal upwelling systems around the world (Plounevez and Champalbert, 2000). Small pelagic fishes are ecologically important because of their critical mid-trophic-level position, and their role in mediating the transfer of energy from lower to higher trophic levels, including to top predators (Cury *et al*., 2000).

The enhanced food environment which is associated with upwelling could have a positive impact on reproductive output through an increase in the quantity and/or quality of eggs produced during a spawning season, leading to increased population size (Brander *et al.*, 2016). Knowledge on feeding ecology is therefore necessary for an understanding of the fish stock and population dynamics. Such studies have been used to ascertain factors controlling the abundance and distribution of organisms, as well as providing information on positioning the fish in the food web of their environment (Post *et al.*, 2000). Moreover, the quality and quantity of food are among the most important exogenous factors directly affecting growth, and indirectly, maturation and mortality, of fish, thus being ultimately related to fitness (Wootton, 1990). The spatial and seasonal fluctuations in abundance of the organisms that constitute the food of a species have been evaluated and found to affect and influence biological activities of fishes (Kumar, 2015).

Trophically-mediated impacts of climate change are among the factors which are likely to affect the productivity of marine ecosystems and the composition of their lower trophic levels, particularly the phytoplankton (Brander *et al.*, 2016; Fuchs and Franks, 2010). Changes in phytoplankton composition will ultimately result in changes in the zooplankton community which is the primary food for anchovies and other small pelagic fishes (Ainsworth *et al.*, 2011; Blanchard *et al.*, 2012). Since food type or quantity influences spawning, fecundity, juvenile survival and consequent recruitment to the fishery, understanding the food and feeding habits of small pelagic is an important step in elucidating ecosystem dynamics and responses of fish stocks to climate change perturbations. Knowledge of the food and feeding behaviour patterns is also crucial for understanding the predicted changes that can result from any natural perturbations or anthropogenic interventions (Hajisamae *et al.*, 2006). Moreover, different sizes of fish belonging to the same species may have similar diets; however, they tend to choose or prefer particular dietary items depending on size and availability, among other factors (Sululu *et al.*, 2017). Dietary preferences among individuals of the same species may occur due to factors such as progressive increase in jaw morphology as the fish grows, and differences in locomotory abilities (Sudheesan *et al.*, 2009).

Studies on the food and feeding habits of small pelagic fishes have been reported globally (e.g. Hirota *et al.*, 2003, 2004). Only a few such studies have been carried out in Tanzania (e.g. Kamukuru and Mgaya, 2004; Kimirei *et al.*, 2013; Sululu *et al.*, 2017) and relatively few of these studies address the relationship between feeding habits, marine productivity and upwelling under a changing climate. It is essential to obtain knowledge of the food requirements, feeding behaviour patterns, and predator-prey relationships in order to understand the changes that can result from any natural or anthropogenic intervention (Hajisamae *et al.*, 2006). Therefore, this study was conducted to contribute to achieving the main objective of PEACC project, which was to investigate the responses of biological productivity and fisheries to changes in atmospheric and oceanographic conditions in the upwelling region associated with the East African Coastal Current. The study examined the food and feeding habits of the two most dominant small pelagic fishes, the Indian mackerel (*Rastrelliger kanagurta*) and the anchovy (*Stolephorus commersonnii*) in the coastal waters of Tanga region in Tanzania.

Materials and methods

Study area

The focus of this study was on two administrative districts in Tanga region (Tanzania), namely Mkinga and Tanga City. The selection of the study area was due to its proximity to the East African coastal current region. Fish sampling was conducted at Vyeru landing site for Mkinga district and Sahare landing site for Tanga City (Fig. 1). Selection of the two landing sites was based on the information that was acquired from catch assessment survey reports which indicated that there was a large number of active ring-net fishers who target small pelagic fish species and land their catches at these sites.

were those with relatively high productivity and were vulnerable to fisheries because they are fished heavily by artisanal fishers using ring-nets. For the purpose of this study, two types of samples were taken from two boats each month. The samples from the first boat was dominated with *S. commersonnii* (Engraulidae) individuals, while those from the second boat consisted of several small pelagic fish

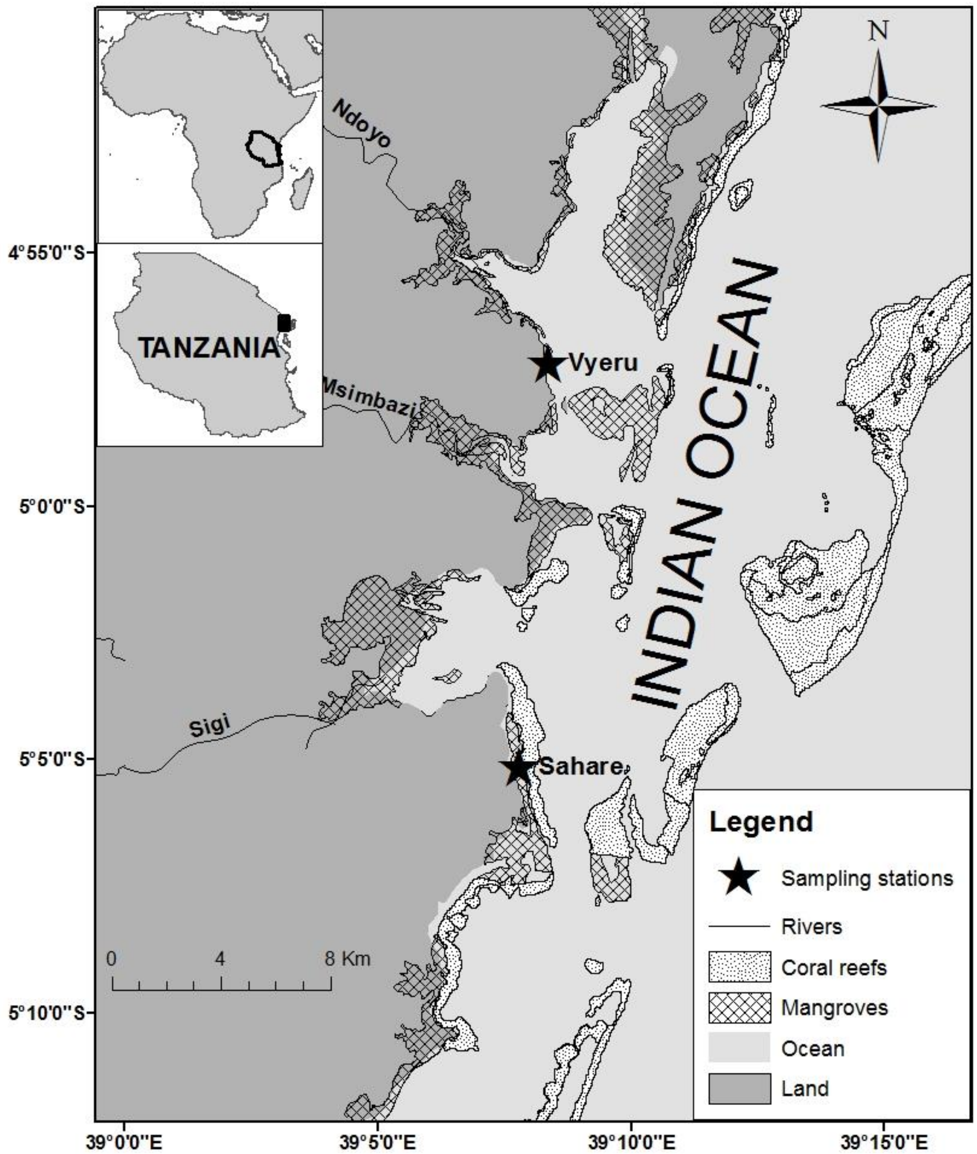


Figure 1. Sampling stations in two administrative districts, Sahare in Tanga City and Vyeru in Mkinga district, Tanzania.

Fish Sampling

Fish specimens were collected on a monthly basis from July 2016 to June 2017. Sampling was conducted for two days each month; one day for each landing site. Samples of small pelagic fishes were randomly selected from the artisanal fishers. Priority species

species dominated by *R. kanagurta* (Scombridae). Both samples were immediately fixed in 10% formalin for analysis in the laboratory. All species encountered in the sample were dissected, but at the end of the field work, two species were chosen due to their dominance in the sample, but also due to their

WIO Journal of Marine Science Special Issue 1/2020 71-80 | B. Sekadende *et al.*

Table 1. Class intervals and their frequency of *S. commersonnii* and *R. kanagurta* from Sahare in Tanga City and Vyeru in Mkinga district, Tanzania.

Rastrelliger kanagurta		*Stolephorus commersonnii*	
Class interval	**Frequency**	**Class interval**	**Frequency**
60-70	4	55-60	5
70-80	8	60-65	6
80-90	27	65-70	26
90-100	52	70-75	88
100-110	41	75-80	216
110-120	33	80-85	205
120-130	36	85-90	137
130-140	30	90-95	38
140-150	27	95-100	10
150-160	13		
160-170	5		
170-180	7		
180-190	3		
190-200	3		
200-210	4		

availability nearly throughout the year. Species which were less common in the sample and which were not available throughout most of the year were used for the species composition study.

Gut content processing

Individuals of each species were measured for total length (TL) to the nearest mm, and weighed for total weight (TW) to the nearest 0.01 g. The stomachs were removed, cut open with surgical scissors, and the gut contents taken out using forceps and poured into a clean petri dish. Care was taken to separate the gut contents from the epithelial layer of the stomach lining to which they were closely adhering. The examination of gut contents was performed macroscopically or under a low power binocular microscope at 20 X magnification. Prey items were identified using Newell and Newell (1963). Identifiable prey were also grouped into two categories, namely large (penaeid shrimps, fish and fish larvae, squids, mantis shrimps and polychaetas), and small (mainly planktonic stages of penaeidae shrimps, Euphausiids, copepods, planktonic stage of gastropods, and phytoplankton) items. The fullness of the stomachs was classified as full, ¾ full, ½ full, ¼ full, or empty. Specimens with empty and ¼ full stomachs were considered to have fed poorly, followed by moderate (½ full) and actively fed (¾ and full). Proportions of food items in each stomach were estimated by eye as relative volumetric quantity, where the maximum volume of stomach contents was set at 100% and the food items found in each stomach were estimated as a volumetric percentage of the total stomach volume (Hyslop, 1980). The gravimetric method was not used due to possible errors associated with weighing small prey items from small fish whose stomachs also contained water. Numerical estimates were not used because they overemphasize the importance of small prey items taken in large numbers (Hyslop, 1980). To assess changes in the diet with fish size, *S. commersonnii* were assigned into eight length classes from 60-65 mm to 95-100 mm TL, and *R. kanagurta* into thirteen classes from 80-90 mm to 200-210 mm TL (Table 1). The volumetric proportions of the main prey categories were then computed per fish size class.

Results

A total of 1434 stomachs of *S. commersonnii* and 320 stomachs of *R. kanagurta* were examined (Table 1). 51.4% of *S. commersonnii* examined had food in their stomachs while 48.6 % had empty stomachs. 73.1% of *R. kanagurta* individuals had food in their stomachs and 26.9% had empty stomachs.

Table 2. Number of *S. commersonnii* and *R. kanagurta* dissected during the study period from Sahare in Tanga City and Vyeru in Mkinga district, Tanzania.

Months-year	*S. commersonnii*	*R. kanagurta*
Jul-17	164	46
Aug-17	150	48
Sep-17	100	19
Oct-17	100	18
Nov-17	100	34
Dec-17	150	29
Jan-18	100	23
Feb-18	150	58
Mar-18	120	0
Apr-18	100	20
May-18	100	0
Jun-18	100	25
Total	**1434**	**320**

Diet composition

Planktonic stages of penaeid shrimps made up the bulk of the diet of *S. commersonnii*, followed by fish larvae and zooplankton. (Fig. 2a). Other minor food items which were recorded included phytoplankton (predominantly the diatoms *Nitzschia* spp and *Flagillaria* spp), fish scales, insect larvae and debris. In contrast, *R. kanagurta* fed predominantly on fish, particularly *S. commersonnii*, together with juvenile stages of other fish species. Sub-adult penaeid shrimps were the second most important food item followed by zooplankton (Fig. 2b). Other minor food items in the stomachs of *R. kanagurta* included mantis shrimps (Stomatopoda), juvenile squids (Cephalopoda), and polychaetes (Polychaeta).

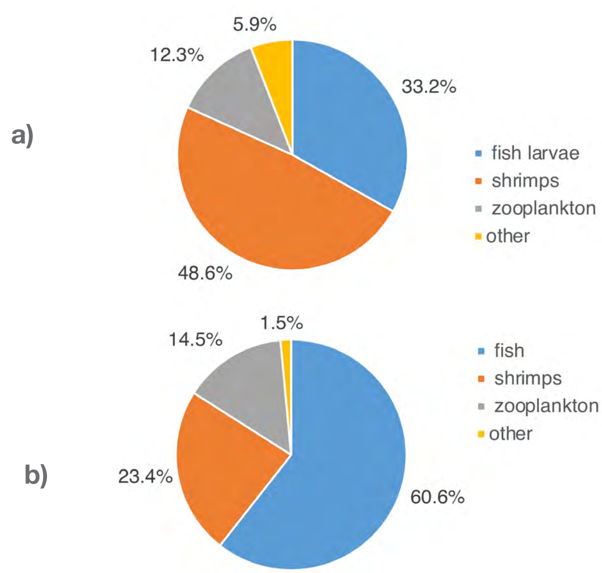


Figure 2. Percentage diet composition of (a) *S. commersonnii* and (b) *Rastrelliger kanagurta* from Sahare in Tanga City and Vyeru in Mkinga district, Tanzania.

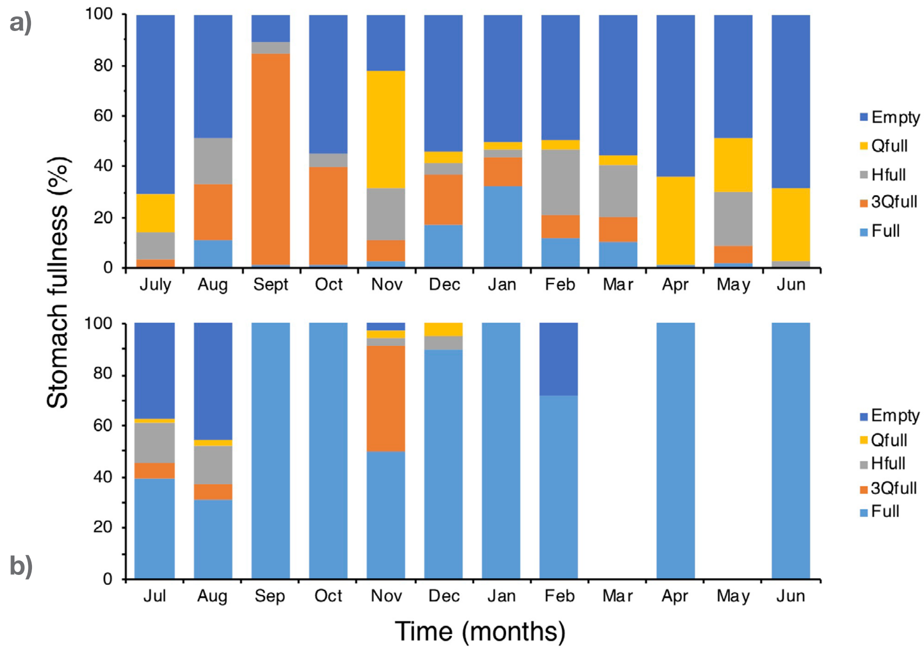


Figure 3. Seasonal variation in feeding intensity of (a) *S. commersonnii* and (b) *R. kanagurta* from Sahare in Tanga City and Vyeru in Mkinga district, Tanzania.

Seasonal variation in feeding intensity

Seasonal variation in feeding intensity of *S. commersonnii* and *R. kanagurta* is shown in Fig. 3a and 3b, respectively. *R. kanagurta* was a more active feeder compared to *S. commersonnii*, having individuals with 100 % full stomachs in the months of September, October, January, April and June, and empty stomachs in August, July, and February, and a small number in November (Fig. 3b). Conversely, *S. commersonnii* fed far less actively, with full stomachs seldom being recorded.

Seasonal variation in diet composition

Fish, particularly *S. commersonnii*, formed the main prey item of *R. kanagurta*, particularly in March, November and February, with penaeid shrimps contributing substantially in January and October (Fig. 4b).

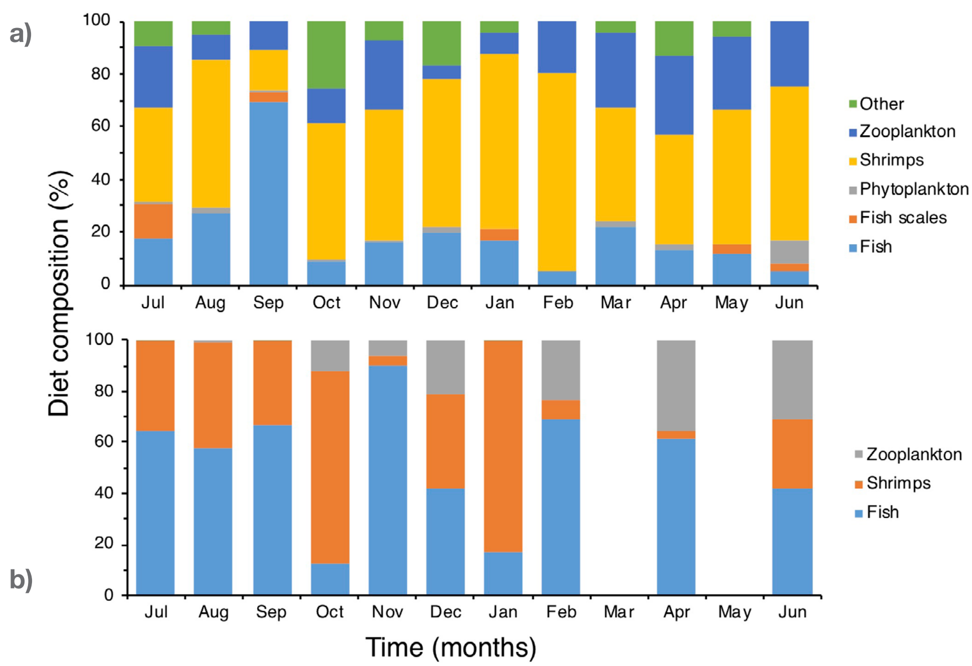


Figure 4. Seasonal variation in diet composition of (%) of (a) *S. commersonnii* and (b) *R. kanagurta* from Sahare in Tanga City and Vyeru in Mkinga district, Tanzania.

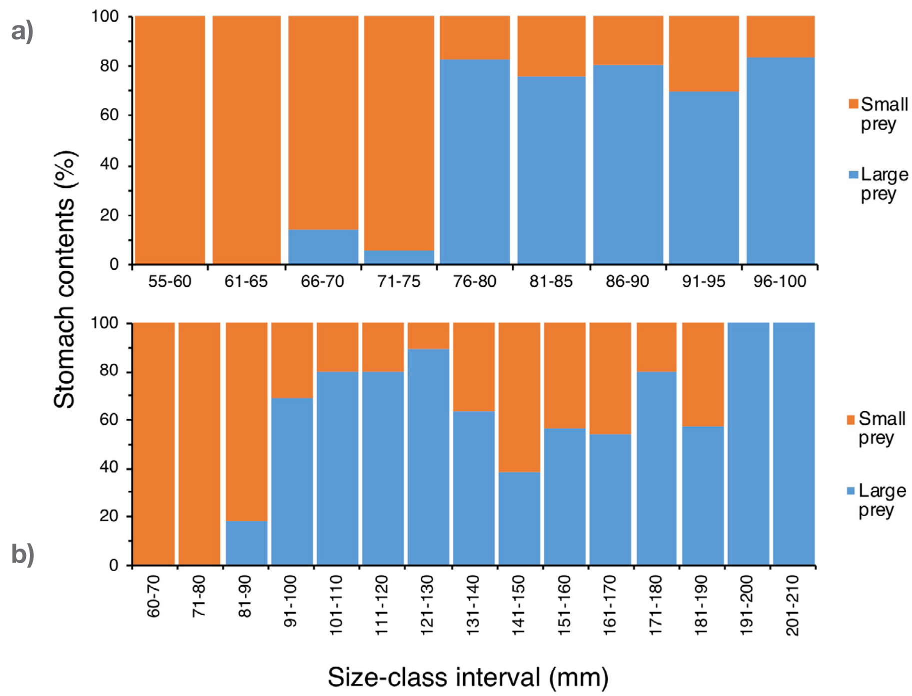


Figure 5. Ontogenic diet shift in (a) *S. commersonnii* and (b) *R. kanagurta* from Sahare in Tanga City and Vyeru in Mkinga district, Tanzania.

Penaeid shrimps were the main prey of *S. commersonnii* throughout the study period (particularly in March, May and December), except in September and November when fish larvae dominated (Fig. 4a). Zooplankton were generally present in the diet of *S. commersonnii* in small fractions, except in March and May (Fig. 4a).

Ontogenic Diet shift

The importance of large prey items increased with increasing fish length in both species (Fig. 5). *S. commersonnii* up to 65 mm TL fed exclusively on small prey items, mainly zooplankton (copepods), phytoplankton (diatoms), and early planktonic stages of penaeid shrimps (mysis and protozoea). At sizes >65 mm, they started to feed on large prey (Fig. 5a), mainly postlarvae and juvenile stages of penaeid shrimps. However, the proportion of large prey items was higher in fish sizes ≥75 mm (Fig. 5a). These were mostly juvenile penaeid shrimps, some polychaetes and fish larvae. Juvenile stages of *S. commersonnii* and fish scales were occasionally found in the stomachs of *S. commersonnii*. Likewise, *R. kanagurta* of sizes ≤ 75 mm only fed on small prey items (Fig. 5b), mainly post-larval stages of penaeid shrimps and zooplankton. At sizes ≥80 mm, this species was already feeding on large prey items, which consisted of juvenile fish and post-larval stages of penaeid shrimps. However, small prey items still appeared in its diet (Fig. 5b). At sizes ≥ 210 mm, the species fed entirely on large prey items (Fig. 5b), which consisted of juvenile penaeid shrimps, juvenile stages of fish other than *S. commersonnii*, and subadult and adult stages of *S. commersonnii.*

Discussion

The present study shows that planktonic stages of penaeid shrimps constituted the main diet of *S. commersonnii*, followed by fish larvae. Zooplankton, especially copepods and crustacean larvae, as well as phytoplankton and fish scales represented minor prey items. This suggests that *S. commersonnii* has two modes of feeding; that is, filter feeding on small food items such as plankton, and particulate feeding on large items such as the planktonic stages of penaeid shrimps (James and Findlay, 1989), which could be the main feeding mode in this species. The results of this study show close similarities with earlier observations from Indian waters by Kumar (2015) who found that planktonic copepods and planktonic crustaceans constituted the core diet of *S. commersonnii*. Studies carried out in Indian waters have indicated that other Engraulid species, in the same family as *S. commersonnii,* have been found to derive the bulk of their carbon from larger zooplankton (van der Lingen *et al.*, 2006).

The diet composition data showed that *R. kanagurta* fed primarily on *S. commersonnii* and penaeid shrimps suggesting that the species is carnivorous. The fishes found in the guts of this species were too large to be caught in the filter feeding apparatus. Additionally, *R. kanagurta* have sharp teeth to facilitate the active capture of prey, which supports the observed dominance of fish in its diet. This finding is contrary to earlier reports that the species is a plankton feeder (Bagheri *et al.,* 2013; Noble, 1965). Pradhan (1956) found neither fish larvae nor vertebrate material in the stomach of *R. kanagurta* and concluded that the species was an exclusive plankton feeder, alternating between zooplankton and phytoplankton in different seasons. The presence of fish in the diet of *R. kanagurta* has also been reported by Sivadas and Bhaskaran (2009) who recorded two to five fish (*Bregmaceros* sp) in each stomach. This supports the contention from this study that the predominance of fishes in the stomachs of sampled *R. kanagurta* was not a result of accidental consumption.

The differences which were observed in the feeding habits of *R. kanagurta* compared to findings from other studies is likely related to availability of food in the area where they were caught, since diet of a fish may change due to extrinsic factors such as biotope or region (Sivadas and Bhaskaran, 2009; Osman *et al*., 2013). Moreover, the methodology used in the other studies to assess prey was different from the present study which might also account for the observed differences. In addition, Hashem *et al*. (1982) stated that the feeding habits of different species, and also within the same species, may appear to vary in catches caught with different fishing methods. In their study they found that fish (*Sardinella aurita* and *Sardinella maderensis*) caught by purse-seine fed particularly on zooplankton, while those that were caught by gill net and beach seine were filter feeders. This could be due to the fact that beach seines are operated in shallow water, where the available food may differ from that of deep/pelagic water where gears like purse seines are operated. The method and gear which was used to catch *R. kanagurta* (using artificial light) in the present study was designed to attract *S. commersonnii*, so it is likely that the predator was feeding on this prey item prior to capture resulting in the observed dominance of *S. commersonnii in R. kanagurta* stomachs.

S. commersonnii fed actively in December, January, September and October. This can be attributed to the high abundance of the preferred food items in those months, or because more energy is needed during the spawning season (Farrag, 2010; Osman *et al*., 2013). The reproductive biology of *S. commersonnii* indicates that spawning occurs throughout the year, but with peaks in October and January (Sululu *et al*., this issue), which agrees well with this assumption. However, the present study reports higher numbers of empty stomachs in *S commersonnii* during the study period, perhaps attributable to a low density of preferred food items in the habitat. These findings agree with other studies such as Manojkumar *et al.* (2015, 2016) who found a predominance of empty stomachs throughout the season and associated this condition with the non-availability of preferred food items during certain months.

Some empty stomachs sampled during the present study appeared shrunken and contained mucous, while others were expanded, but contained no food items. The latter condition is believed to occur in fish which have recently regurgitated food (Madkour, 2012); which could be the case in the present study. Conversely, *R. kanagurta* fed actively throughout the study period, except in July, August, November and December. Generally, the main food item for *R. kanarguta* was available in the environment throughout the study period, which might explain this observation.

Both *S. commersonnii* and *R. kanagurta* exhibited significant ontogenetic variations/shifts in prey items. At early stages, both *S. commersonnii* and *R. kanagurta* fed exclusively on small prey items and shifted to feeding on large prey items with increasing fish size, which may be an adaptation to reduce intra-specific competition among different size groups (Osman *et al*., 2013). On the other hand, ontogenic diet shift has been attributed to factors such as age-specific changes in the use of habitat (Kamukuru and Mgaya, 2004; Kimirei *et al*., 2013). In the present study, both small and large fish of both species were caught in the same habitat indicating that ontogenic diet shift may be related to a difference in energy requirements according to different developmental stages (Madkour, 2012). Larger fish have different diet requirements to smaller individuals and attempt to satisfy their needs by consuming a more extensive variety of prey (Kumar *et al.*, 2015). Changes in the mouth gape and improvement in swimming ability as the fish grows also result in ontogenic diet shifts. A small mouth limits the size of prey items that can be ingested (Kumar *et al*., 2015), and improved locomotory ability and visual detection can allow larger fish to shift to large prey items (Kahilainen, 2004; Wooton, 1998).

Conclusion

The food and feeding habits of *S. commersonnii* and *R. kanagurta* were studied and the results indicated that *S. commersonnii* has two modes of feeding; filter feeding on small food items, and particulate feeding on large particles such as the planktonic stages of penaeid shrimps, suggesting that the species is a planktivorous carnivore. The study also revealed that *R. kanagurta* is a carnivore in the geographic area studied, contrary to previous studies which characterised it as a plankton feeder. Productivity studies have found that increasing temperature has a negative influence on Chl-a concentration (primary productivity). Changes in productivity that results in a changes of zooplankton abundance will likely have an impact on the population of *S. commersonnii* and other species which feed on zooplankton. This study presents results of stomach analysis, which may not show a complete picture of the feeding dynamics of the species. Results from a zooplankton study which was conducted as part of the PEACC project after realising that this would contribute to the understanding of the feeding dynamics of the studied fish species will enhance knowledge of food availability, especially for *S. commersonnii* and other zooplankton feeders.

Acknowledgements

The authors would like to thank WIOMSA and IOC-UNESCO, Africa and the Adjacent Island States for funding this study. Thanks are extended to the Tanzania Fisheries Research Institute for logistics, and the University of Dar es Salaam for the provision of space for laboratory work.

References

Ainsworth CH, Samhouri JF, Busch DS, Cheung WWL, Dunne J, Okey TA (2011) Potential impacts of climate change on North-east Pacific marine food webs and fisheries. *ICES Journal of Marine Science* 68 (6, 1): 1217-1229

Bagheri A, Sadeghi MS, Daghooghi B (2013) Feeding biology of Indian Mackerel (*Rastrelliger kanagurta*) in Hormozgan Province waters (Persian Gulf). Journal of Marine Biology 5: 35-46

Blanchard JL, Jennings S, Holmes R, Harle J, Merino G, Allen JI, Barange M (2012) Potential consequences of climate change for primary production and fish production in large marine ecosystems. Philosophical Transactions of the Royal Society B: Biological Sciences 367 (1605): 2979-2989

Bodiguel C, Breuil C (2015) Report of the meeting on the small marine pelagic fishery in the United Republic of Tanzania. Report/Rapport: SFFAO/ 2015/34. August/ Août 2015. IOC-SmartFish Programme of the Indian Ocean Commission. FAO. Ebene, Mauritius. 90 pp

Brander K, Ottersen, G, Bakker JP, Beaugrand G, Herr H, Garthe, S, Tulp I (2016) Environmental Impacts—Marine Ecosystems. In: Quante M, Colijn F (eds) North Sea region climate change assessment, Chapter 8, pp. 241-274). Springer (Regional climate studies) [doi: 10.1007/978-3-319-39745-0_8]

Cury P, Bakun A, Crawford RJM, Jarre-Teichmann A, Quiñones RA, Shannon LJ, Verheye HM (2000) Small pelagics in upwelling systems: patterns of interaction and structural changes in "waspwaist" ecosystems. ICES Journal of Marine Science 57: 603-61

Farrag MMS (2010) Fishery biology of Red Sea immigrant *Etrumeus teres* (Family: Clupeidae) in the Egyptian Mediterranean water, off Alexandria. MSc Thesis, Zoology Department, Faculty of Science, Al-Azhar University (Assuit), Egypt

Fuchs HL, Franks PJS (2010) Plankton community properties determined by nutrients and size-selective feeding. Marine Ecology Progress Series 413: 1-15

Hajisamae S, Yeesin P, Ibrahim S (2006) Feeding ecology of two sillaginid fishes and trophic interrelations with other co-existing species in the southern part of South China Sea. Environmental Biology of Fishes 76: 167-176

Hashim M, Wassef M, Faltas M (1982). Food and feeding habits of Sardines and their effects on the condition of fish captured by different fishing methods. Bulletin of National Institute of Oceanography and Fisheries 8: 229-238

Hirota Y, Honda H, Ichikawa, T Mitani T (2003) Stomach contents of round herring *Etrumeus teres* in Tosa Bay. Fisheries Biology and Oceanography, Kuroshio 4: 35-44

Hyslop EJ (1980) Stomach contents analysis – a review of methods and their application. Fish Biology 17: 411-429

James AG., Findlay KP (1989) Effect of particle size and concentration on feeding behaviour, selectivity and rates of food ingestion by the Cape anchovy *Engraulis capensis*. Marine Ecology Progress Series 50: 275-294

Kahilainen K (2004) Ecology of sympatric whitefish (*Coregonus lavaretus* (L.)) forms in a subarctic lake. PhD dissertation, University of Helsinki, Helsinki, Finland. 44 pp

Kamukuru AT, Mgaya YD (2004) The food and feeding habits of blackspot snapper *Lutjanus fluviflamma* (Pisces: Lutijanidae) in shallow waters of Mafia Island, Tanzania. African Journal of Ecology 42: 49-58

Kimirei IA, Nagelkerken I, Trommelen M, Blankers P, van Hoytema N, Hoeijmakers D, Huijbers CM, Mgaya YD, Rypel AL (2013) What drives ontogenetic niche shifts of fishes in coral reef ecosystems? Ecosystems 16: 783-796

Kumar MA, Padmavati G, Venu S (2015) Food and feeding dynamics of *Stolephorus commersonnii* (Lacepede, 1803) (Family: Engraulidae) from South Andaman. Marine Biology, Article ID 870919. 8 pp

Manojkumar PP, Pavithran PP, Ramachandran NP (2015) Food and feeding habits of *Nemipterus japonicus* (Bloch) from Malabar coast, Kerala P. Indian Journal of Fisheries 62: 64-69

Manojkumar P P, Pavithran PP (2016). Diet and feeding habits of *Saurida tumbil* (Bloch, 1795) from northern Kerala, south-west coast of India. Indian Journal of Fisheries 63: 41-47

Madkour FF (2012) Feeding ecology of the round sardinella, *Sardinella aurita* (family: clupeidae) in the Egyptian Mediterranean waters. International Journal of Environmental Science and Engineering 2: 83-92

Newell GE and Newell RC (1963) Marine plankton, a practical guide. Hutchinson Educational Ltd., London. 207 pp

Noble A (1965) The food and feeding habit of the Indian mackerel *Rastrelliger kanagurta* (Cuvier) at Karwar. Indian Journal of Fisheries 9A: 701-713

Osman AGM, Farrag MMS, Akel EHK, Moustafa MA (2013) Feeding behavior of lessepsian fish *Etrumeus teres* (Dekay, 1842) from the Mediterranean Waters, Egypt. Egyptian Journal of Aquatic Research 39: 275-282

Plounevez S, Champalbert G (2000) Diet, feeding behaviour and trophic activity of the anchovy (*Engraulis encrasicolus* L.) in the Gulf of Lions (Mediterranean Sea). Oceanologica Acta 23: 175-192

Post D, Conners M, Goldberg D (2000) Prey preference by a top predator and stability of linked food chains. Journal of Ecology 81: 8-14

Pradhan LB (1956) Mackerel fishery of Karwar. Indian Journal of Fisheries 3: 141-185

Raab K, Nagelkerke LAJ, Boerée C, Rijnsdorp AD, Temming A, Dickey-Collas M (2011) Anchovy *Engraulis encrasicolus* diet in the North and Baltic Seas. Journal of Sea Research 65: 131-140

Sivadas M, Bhaskaran M (2009) Stomach content analysis of the Indian mackerel *Rastrelliger kanagurta* (Cuvier) from Calicut, Kerala. Indian Journal of Fisheries 56: 143-146

Sudheesan D, Jaiswar AK, Chakraborty SK, Pazhayamadom DG (2009) Predatory diversity of finfish species inhabiting the same ecological niche. Indian Journal of Fisheries 56: 169-175

Sululu JS, Ndaro SN, Kangwe S J (2017) Food and feeding habits of the Delagoa threadfin bream, *Nimepterus bipunctatus* (Valenciennes 1830) from the coastal waters around Dar es Salaam, Tanzania. Western Indian Ocean Journal of Marine Science 16: 13-23

Van der Lingen CD, Hutchings L, Field G (2006) Comparative trophodynamics of

Anchovy *Engraulis encrasicolus* and sardine *Sardinops sagax* in the southern Benguela: are species alternations between small pelagic fish trophodynamically mediated? African Journal of Marine Science 28: 465-477

Wootton R J (1990) Ecology of teleost fishes. Chapman and Hall, London. 404 pp