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Composition and abundance of deep-water crustaceans in the Southwest Indian Ocean: Enough to support trawl fisheries?

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ABSTRACT

Expanding coastal fisheries into deeper waters is frequently tabled as an option to increase harvests from the sea in the Southwest Indian Ocean. In this region, only Mozambique and South Africa have established deep-water trawl fisheries for mixed crustaceans. To investigate the fishery potential of deep shelf waters over a broader geographical extent, four bottom trawl surveys were undertaken, in Madagascar, Mozambique, Tanzania and Kenya, respectively, in 2011–2012. Teleosts dominated catches in all surveys (59–74% of total catches) and depths. Crustaceans made up 15% of the catch in Mozambique and Madagascar, but only 6% in Kenya and Tanzania, where elasmobranchs (18%) and other invertebrates (11–15%) were more abundant. A generalized linear model was constructed to quantify the effects of country, depth and day/night on the abundance of four common crustacean species. Abundance of *Haliporoides triarthrus* and *Metanephrops mozambicus* declined from south (Madagascar, Mozambique) to north (Kenya, Tanzania), but *Heterocarpus woodmasoni* was more abundant in Madagascar, Tanzania and Kenya. *Chaceon macphersoni* and *H. triarthrus* abundance increased up to 600 m depth, whereas *M. mozambicus* and *H. woodmasoni* peaked shallower, at 350–500 m. Crustacean catch composition in Mozambique was strikingly similar to commercial landings in eastern South Africa, supporting a distinct sub-region for fisheries management, but differed markedly across the Mozambique Channel. Deep-water crustaceans were less abundant in Kenya and Tanzania, with limited commercial appeal. New deep-water trawl fisheries will have to contend with significant teleost bycatch.

1. Introduction

The Southwest (SW) Indian Ocean region comprises developing nations that are among the poorest in the world, based on per capita gross domestic product (GDP) (World Bank, 2014). Most of these countries fall below the top 100 level on the UN development index (UNDP, 2013), and all face severe socio-economic challenges, with a growing need for employment opportunities and food security (van der Elst et al., 2005, 2009). Governments of these countries recognize that nearshore fisheries resources are under immense pressure from ever-increasing exploitation by coastal communities (van der Elst et al., 2009). Consequently, expansion of coastal fisheries into deeper waters is frequently mentioned as an option to increase harvests from the sea.

The assumption of abundant resources in deeper water is not necessarily valid, and historical surveys undertaken on the narrow shelf of Kenya and Tanzania have shown low densities of benthic organisms, with limited fishery potential (Sanders et al., 1988; Sætersdal et al., 1999; Groeneveld and Everett, 2015). The

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continental slope of western Madagascar is steep and irregular, and trawlable areas in deep water are sparse (Crosnier and Jouannic, 1973). Further south, in Mozambique and eastern South Africa, trawl grounds are more productive, and a mixture of crustaceans and fish are caught by established deep-water trawl fisheries (Fennessy and Groeneveld, 1997). These fisheries report landings of approximately 2200 tonnes of crustaceans per year, of which 85% originate from Mozambique (WIOFish, 2013).

Target species in Mozambique and eastern South Africa are deep-water prawns (*Haliporoides triarthrus*, *Aristeus virilis*, *Aristeus antennatus* and *Aristaeomorpha foliacea*), langoustines (*Metanephrops mozambicus*), spiny lobsters (*Palinurus delagoae*) and deep-sea crabs (*Chaceon macphersoni*) (Groeneveld and Everett, 2015). The species mix in catches varies by depth, season, latitude and bottom type trawled (Groeneveld and Melville-Smith, 1995; Dias et al., 2009; Sobrino et al., 2009). Significant quantities of teleosts, elasmobranchs, cephalopods and molluscs are also caught in trawl nets, and are retained if they can be sold, or discarded overboard if their commercial value is considered to be low (Fennessy and Groeneveld, 1997; Fennessy et al., 2004). Far less is known about crustaceans on deeper grounds in Madagascar, Tanzania and Kenya, with most information coming from historical surveys undertaken after the early 1970s. Crosnier and Jouannic (1973) found *H. triarthrus*, *A. foliacea*, two Aristeid species, and *M. mozambicus* in Madagascar trawl surveys. Survey reports from Kenya and Tanzania list deep-water prawns *Heterocarpus* sp., langoustine *Metanephrops andamanicus* and lobsters *Linuparus somniosus* and *Puerulus angulatus* (Birkett, 1978; Sanders et al., 1988). Some of the species names may have changed in the interim.

A recent review of historical trawl information suggested that aggregations of deep-water crustaceans, some with a high unit value, could potentially be exploited at several locations in the SW Indian Ocean (Groeneveld and Everett, 2015). Based on this, the South West Indian Ocean Fisheries Project (SWIOFP; van der Elst et al., 2009) funded a series of bottom trawl surveys to assess the fishery potential of deep-water grounds in Kenya, Tanzania, Mozambique, western Madagascar and eastern South Africa. We determined the relative importance of major taxa (crustaceans, teleosts, elasmobranchs, cephalopods, other invertebrates) represented in trawl catches, and investigated the abundance of crustacean species by country, day/night and depth stratum.

2. Materials and methods

2.1. Study area

The SW Indian Ocean extends along the African coast, from northern Kenya (2°S) to eastern South Africa (31°S), and around the island states of Madagascar, Mauritius, Comoros and Seychelles (Fig. 1). It is a low-latitude mainly tropical region influenced by large-scale oceanographic systems (Lutjeharms, 2006; Ternon et al., 2014a). Monsoon winds affect coastal flow in the north. The East Africa Coastal Current (EACC) off Kenya strengthens during the wet southeast monsoon (April to October), and weakens during the northeast monsoon (November to March), giving rise to a seasonally reversing Somali Current (Schott and McCreary, 2001). Upwelling and deep-water mixing makes the Somali Current region nutrient-rich and productive, compared to oligotrophic waters further south. Mozambique Channel circulation is influenced by seabed topography, including cyclonic and anti-cyclonic cells (Lutjeharms, 2006; Ternon et al., 2014b). The Agulhas Current originates near the southern end of the Mozambique Channel, and flows southwest along the shelf edge of eastern South Africa.

The shelf topography is narrow and steep along much of eastern Africa, widening in bights or near river deltas, such as the Natal Bight (South Africa), Maputo Bay and the Delagoa Bight (Mozambique), the Rufiji Delta (Tanzania) and Malindi-Ungwana Bay (Kenya). The shelf edge is mostly rocky and unsuitable for trawling. Deep trawl grounds in eastern South Africa comprise sand, mud, hardened sediment accretions, foraminifera and spicules (Berry, 1969). Sea surface temperatures are warmer near the equator (25–29 °C; World Sea Temperatures, 2014) than further south (22–27 °C; Smit et al., 2013), however bottom temperatures at >200 m in eastern South Africa have been reported as 9–12 °C (Berry, 1969) and 8–10 °C at 500–700 m depth in western Madagascar (Pripp et al., 2014).

2.2. Survey gear and strategy

Four trawl surveys were conducted in Kenya, Tanzania, Mozambique and western Madagascar, respectively, between October 2011 and March 2012 (Fig. 1). Two commercial fishing trawlers with their crew complement and fishing gear were leased. The FV Caroline (40 m length; 313 t GRT; 745 hp) towed a single otter trawl net deployed from the stern (net length 75 m; footrope length 60 m; mesh in codend 50 mm stretched), and was used in Mozambique and Madagascar. The FV Roberto (23 m length; 117 t GRT; 295 hp) also towed an otter trawl net from the stern (net length 26 m; footrope length 26 m; mesh in codend 38 mm stretched), and was used in Tanzania and Kenya. Both vessels were equipped with echo sounders, global positioning systems and track plotters, radar, and VHF/SSB radios. A team of scientists (minimum 4) accompanied each survey.

Detailed knowledge of existing fishing grounds (Mozambique), information from historical research surveys (Sætersdal et al., 1999), or anecdotal information obtained from fishing companies (Madagascar, Tanzania, Kenya) were used to define survey grounds, based on substrate type (trawlable muddy/sandy grounds) and depth range (100–700 m). Prospective grounds were stratified by depth and latitude (Table 1), and the surface area of individual blocks calculated, based on distance estimates obtained from British Admiralty Nautical Charts (760, 3855, 2930, 2931, 2939 and 2949) with scales of 1: 300 000 to 1: 1000 000. The calculated surface area of sampling blocks totalled 21 319 km^2 in Mozambique, 473 km^2 in Tanzania and 6034 km^2 in Kenya. Sampling effort (number of trawls) was allocated to blocks based on surface area except in Madagascar where the area was unknown and trawls were allocated equally. Given the imprecise geographical information available, it was foreseen that some blocks would be untrawlable. Remaining trawls at the end of each survey were redistributed at the discretion of the survey leader.

Trawls were undertaken roughly parallel to the coast, within the boundaries of each block. Start and end-time of trawls were recorded when the net reached the seafloor (winches stopped), and when hauling commenced. Nominal trawl speed (3 knots) and duration (60 min) could be adjusted based on sampling requirements (i.e., seafloor conditions; expected catch). Most trawls were conducted during daylight. Night trawls (set and hauled between sunset and sunrise) were undertaken so that day/night effects on CPUE could be assessed (Table 1).

No survey was conducted in eastern South Africa (28-31°S), but summarized information on the catch composition of crustaceans was obtained from commercial trawl logbooks (DAFF, 2014), as described in detail by Robey et al. (2013a; 2013b). Similar trawl vessels and nets were used to collect the survey and fisheries information, but in the commercial fishery, the proportions of target species may have been affected by targeting practices.