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Size at onset of maturity of spiny lobsters *Panulirus homarus homarus* at Mambrui, Kenya

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The size at onset of sexual maturity of the scalloped spiny lobster *Panulirus homarus homarus* captured off Mambrui, Kenya, was estimated from ovary condition, presence of external eggs and/or spermatophore remains (berry method), and presence of well developed ovigerous setae (setal method). The predictive utility of morphometric relationships between carapace length (CL), pleopodal exopodite length (exopod length) and second leg length were assessed by fitting linear regressions to lobsters categorised as immature and mature, and comparing the intersect values with other estimates of functional maturity. The smallest female with mature ovaries was 52mm CL, compared with the smallest specimens of 50mm with ovigerous setae and 54mm with external eggs. Logistic curves indicated that 50% maturity was reached at 52.6mm (setal method) or 63.4mm (berry method) during the main breeding season. Female exopod lengths suggested that functional maturity was reached at 50.5mm and male leg lengths increased significantly upon reaching 57.5mm. The analyses indicate that measurements of female exopods and male second leg length can be used as cost-effective methods to estimate size at functional maturity of *P. homarus homarus* in Kenyan waters, and that these indices can augment estimates based on the presence of external eggs and ovigerous setae.

Keywords:

Introduction

Kenya has a coastline of about 450km along East Africa, stretching from 1°30'S at the Somali border to nearly 5°S at the Tanzanian border. The continental shelf is narrow with fringing coral reefs that extend between 0.5km and 2km offshore (UNEP 1984). The coral reefs, along with sea-grasses and mangroves, provide an ideal habitat for spiny lobsters, and several species of the shallow-water tropical genus *Panulirus* occur nearshore, i.e. *P. ornatus*, *P. homarus*, *P. versicolor*, *P. longipes* and *P. penicillatus* (Mutagyera 1978).

An artisanal fishery has exploited spiny lobsters in Kenya since at least 1954, and the ornate spiny lobster *Panulirus ornatus* accounts for >90% of the total landings (Mutagyera 1978, Okechi and Polovina 1994, 1995), followed by the scalloped spiny lobster *Panulirus homarus*. Harvest methods have changed little over the past five decades, and dug-out canoes, outriggers, Arab dhows and other small non-mechanised craft are used by fishers, who skin-dive to depths of about 10m during both daytime and night-time (Okechi and Polovina 1994). The divers use spear guns and hand-nets to capture lobsters, and although artificial shelters have been shown to effectively attract spiny lobsters at Gazi Bay in southern Kenya (Okechi and Polovina 1995), they are not commonly used. Fishing takes place mainly during the north-east monsoon (November to mid-February) and inter-monsoon (mid-February to April) periods, when weather conditions are favourable. The total catch in the Kenyan spiny lobster fishery is estimated at 160 tons year^{-1}, most of which is sold to local hotels. The estimated annual value of the fishery to the Kenyan economy is US$3.2 million per year (Department of Fisheries 2004). There are currently no management regulations governing the exploitation of spiny lobsters in Kenya, except for the establishment of four small marine parks where all fishing is prohibited (Okechi and Polovina 1994, Kulmiye 2004).

The scalloped spiny lobster *P. homarus* is distributed throughout the Indo-West Pacific region, where it is found among rocks, often in the surf zone, in shallow waters ranging from 1m to 90m deep (mostly 1–5m) (Holthuis 1991). *P. homarus homarus*, the species under study here, is the most widely distributed of the three subspecies of *P. homarus*. It extends along the Indian Ocean seaboard, from East Africa to India, and in South-East Asia to Indonesia and Australia (Holthuis 1991). In the West Pacific, it is distributed as far eastwards as Japan and New Caledonia. *P. homarus megasculpta* is only found from the northern Arabian Sea and Somalia (Fielding and Mann 1999), and *P. homarus rubellus* occurs along the east coast of South Africa, Moçambique and Madagascar (Holthuis 1991).

Recent studies on the biology of Kenyan *P. homarus homarus* focussed on its growth and moulting (Kulmiye and Mavuti 2005) and on reproduction and population structure (Kulmiye 2004). Determining the size at onset of sexual maturity is important in the management of the resource, especially for considering minimum legal size of capture. Spiny lobsters become physiologically mature when gonads are capable of producing viable gametes, and are functionally mature when all secondary characteristics have developed to allow successful mating and spawning (Evans *et al*. 1995). Physiological maturity can only be determined from the histology of gonads. However, functional maturity can be estimated from several methods, including the presence of spawned eggs and ovigerous setae (Beyers and Goosen 1987, Groeneveld and Melville-Smith 1994), spermatophore remains on the female abdomen from changes in the relative size of abdominal and thoracic segments (Jayakody 1989), or the lengths of walking legs or pleopodal exopodites (Grey 1979, Juinio 1987, Plaut 1993, Gomez *et al*. 1994, Minagawa and Higuchi 1997, Demartini *et al*. 2005).

The aims of this study were to determine the size at functional maturity of *P. homarus homarus*, using a range of standard estimation methods (presence of external ova, spermatophore remains and ovigerous setae, and ovary condition) and to assess the utility of two body-metrics (allometry of walking legs and pleopodal exopodites) as a practical and accurate estimation of maturity for future use in the Kenyan spiny lobster fishery.

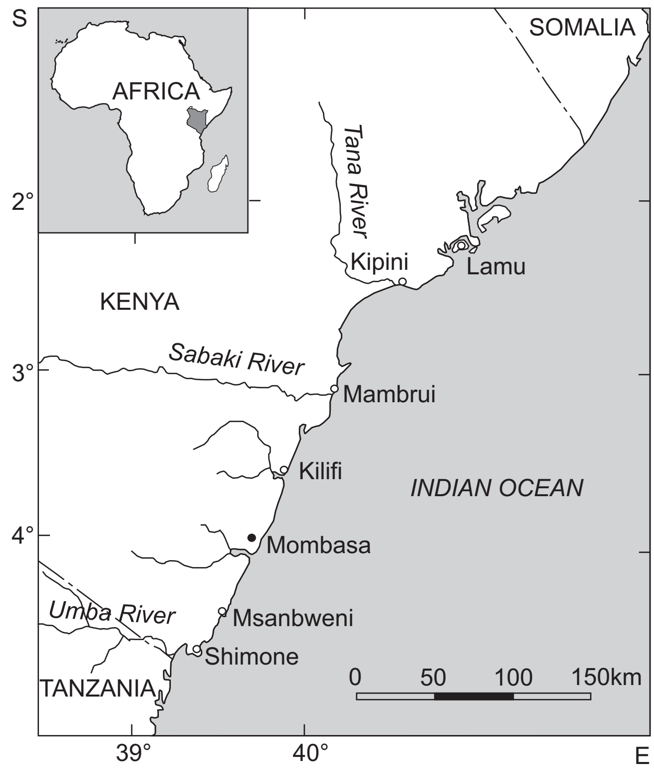

Figure 1: Map of the Kenyan coast showing the study site and locations mentioned in the text

Material and Methods

The study was conducted off Mambrui, Kenya (Figure 1), between January 2000 and December 2001. Lobster specimens were hand-collected from shallow water at low tide by fishers during the night or captured from deeper water by divers during daytime. Lobsters were packed in iceboxes and transported by road to a laboratory in Mombasa. There, the following measurements of individuals were taken: carapace length (CL) — mid-dorsally from the transverse ridge between the frontal spines and the posterior edge of the carapace; leg length of the second pair of walking legs — from the tip of the dactyl to the proximal margin of ischium; and pleopodal exopodite length (exopods) on the first abdominal segment. All measurements were made with a dial-type vernier caliper to an accuracy of 0.1mm.

Female lobsters were examined for the presence of external eggs, a spermatophore (new or eroded) and ovigerous setae. The ovigerous setae of non-berried females were categorised as undeveloped, developing and well developed (after Gregory and Labisky 1981). Ovaries were excised and classified into six macroscopically distinguishable stages (Juinio 1987): Stage 1 (immature), Stage 2 (developing), Stage 2a (redeveloping), Stage 3 (ripe), Stage 4 (newly spawned) and Stage 5 (spent/inactive). The validity of the ovarian stages was confirmed by comparing histological sections and ova diameters of the samples with those of Juinio (1987).

The proportions per 2-mm CL category of females bearing eggs and/or spermatophores during the main breeding season (November–March; Kulmiye 2004) were fitted to a logistic equation of the form

$$P = 1/[1 + \exp(a - bCL)]$$

where P is the proportion of mature females and a and b are constants. The length (CL) at 50% maturity was determined by back calculation.

For morphometric analyses, male and female lobsters were respectively categorised into groups based on the size of the smallest egg-bearing females: immature males and females of CL <53mm; and mature males and females of CL >54mm. For each of the four groups, linear regressions were calculated using the least squares method, and regressions were tested for equality of slopes using Student's t-test (Zar 1984). Where slopes differed significantly, the points of intersection were assumed to represent the size at onset of functional maturity (see George and Morgan 1979).

Results

In total, 1 234 female and 1 220 male lobsters were sampled during the study, ranging in size from 26mm to 115mm CL. The average length of female lobsters was 64.0 ± 10.9 (SD) mm and that of males was 67.9 ± 12.03mm. Of the females, 256 were egg-bearing (with or without spermatophores) and 97 had spermatophores but did not have external eggs.

The smallest female with a developing ovary was 52mm and the smallest egg-bearing female was 54mm. Only 11% of females of 50–54mm bore eggs or had a spermatophore attached, increasing to 56% of females of 60–64mm and to 70–100% of females >70mm. A logistic curve of the proportions of females bearing external eggs and/or spermatophores during the main breeding season indicated 50% maturity at 63.4mm (Figure 2).

A comparison of ovigerous setal development to gonad maturity (Table 1) showed that the majority of immature females (Stage 1) had either undeveloped or developing setae, whereas 90–100% of mature females (Stages 2–5) had well developed setae. Individuals with developed setae were therefore categorised as mature lobsters in further analysis, with the resulting logistic curve showing 50% setal maturity at 52.6mm CL (Figure 2).

Regression slopes of relationships between CL and exopod size differed significantly among mature and immature females ($t = 7.807$, $df = 182$, $p < 0.05$); the intersection of the two regressions was at 50.5mm (Figure 3b). The regression slopes for mature and immature males did not differ significantly ($t = 0.929$, $df = 170$, $p > 0.05$), so no intersection could be calculated (Figure 3a).

The slopes of the regressions between CL and second leg length differed significantly between mature and immature males ($t = 7.447$, $df = 215$, $p < 0.05$), but there was no difference for females ($t = 1.215$, $df = 236$, $p > 0.05$; Figure 4a, b). The intersection of the two regression lines for males (immature vs mature) occurred at 57.5mm.

Discussion

Size at maturity, growth rates, fecundity and population size structure of spiny lobsters vary substantially over time and space in relation to their harvesting, fluctuating natural productivity and changing population densities (Beyers and Goosen 1987, DeMartini *et al.* 2002). A suite of methods or multivariate assessment of maturity is preferable to a single measure, which could be inaccurate (DeMartini *et al*. 2005). Also, the cost of such research is an important consideration, so the most economic methods need to be selected.

The results here show that the length of the second walking leg length in males increased in relative size at onset of

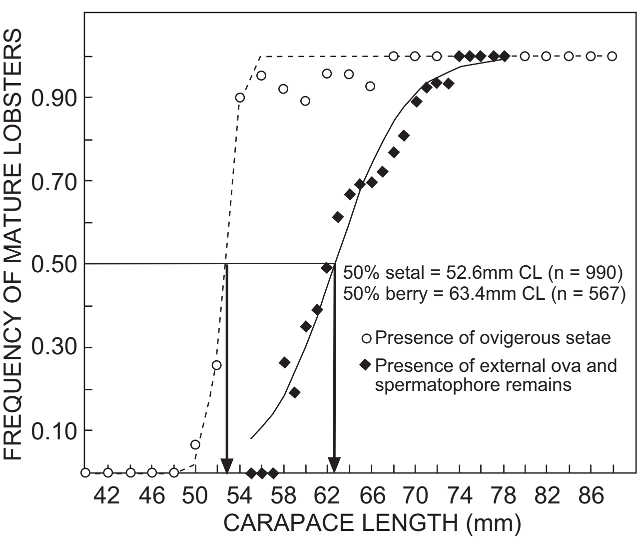

Figure 2: Logistic relationships between the size (CL, mm) and onset of maturity of *P. homarus homarus*, based on the presence of ovigerous setae and the presence of external ova and spermatophore remains

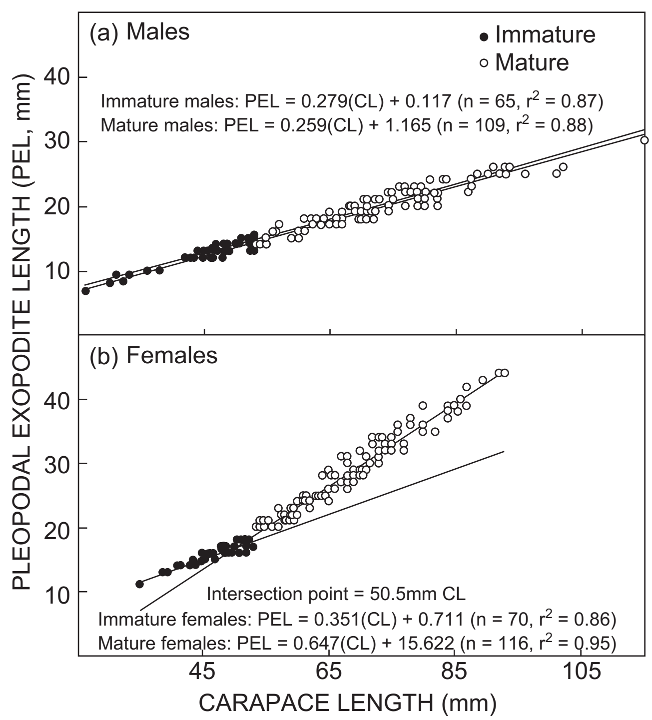

Figure 3: Linear relationships between the size (CL, mm) and pleopod/endopod length (mm) of immature and mature *P. homarus homarus* from Kenya for (a) males and (b) females

Table 1: Ovarian maturity stages for female *Panulirus homarus homarus* exhibiting different stages of ovigerous setal development

		Percentage		
Maturity stage	Number of females	Undeveloped (0–3mm)	Developing (4–8mm)	Well developed (9–16mm)
1	148	47	45	8
2	292	0	2	98
2a	15	0	0	100
3	137	0	0	100
4	142	0	4	96
5	231	0	10	90

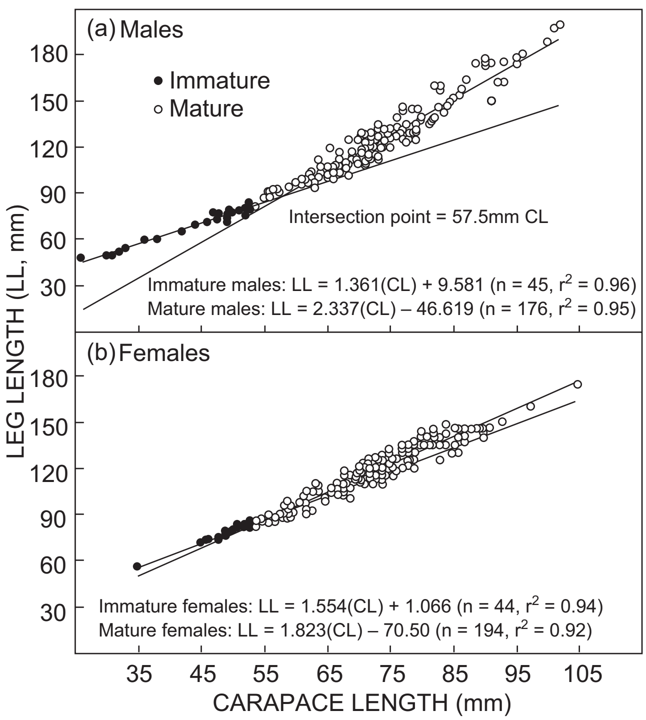

Figure 4: Linear relationships between the size (CL, mm) and second leg length (LL, mm) of immature and mature *P. homarus homarus* from Kenya for (a) males and (b) females

maturity, so this measurement can be used to estimate functional size at maturity. Although no male gonadal index was available to verify that the relative change in leg length is directly linked to attainment of physiological maturity, Minagawa and Higuchi (1997) showed a close correlation between sperm density in the vas deferens of *P. japonicus* and increased leg length. Observations on captive *P. homarus rubellus* also suggest that elongation of legs in adult males play an important role in aggressive behaviour, courtship and mating (Berry 1970). Male spiny lobsters use their front walking legs during mating and in dominance displays, and substantial development of adult male walking legs relative to carapace length have been shown for *Panulirus argus*, *P. guttatus* (Evans *et al*. 1995), *P. penicillatus* (Plaut 1993) and *P. cygnus* (Grey 1979). The present study suggests that male *P. homarus homarus* must be larger than females for successful copulation, a characteristic also found in *P. homarus rubellus* (Berry 1970), *P. cygnus* (Grey 1979), *P. longipes* (Gomez *et al*. 1994) and *P. japonicus* (Minagawa and Higuchi (1997).

Exopod length of females increased proportionally relative to CL at onset of maturity, and this characteristic correlated well with physiological maturity determined from female gonads (50.5mm vs 52mm CL). Spawned eggs attach to pleopodal endopods, and the relatively larger exopods after maturity may play an important role in brooding, protecting and fanning the egg mass (Minagawa and Higuchi, 1997). Proportional changes in exopod and leg length have also been found for several *Panulirus* species (Berry 1970, Grey 1979, George and Morgan 1979, Juinio 1987, Plaut 1993, Gomez *et al.* 1994, Evans *et al.* 1995, Hogarth and Barratt 1996, DeMartini *et al*. 2005).

Functional maturity of *P. homarus homarus* females at Mambrui was estimated at 50mm (smallest ovigerous setae), 50.5mm (exopod method), 52mm (smallest developing ovary), 52.6mm (50% setose), 54mm (smallest egg-bearing female) and 63.4mm (50% egg-bearing). Most secondary characteristics of maturity in females therefore develop at sizes between 50mm and 53mm, compared with egg-bearing females, which start at sizes >54mm. Considering the average moult increment of 1.1mm of captive females in the 46–55mm size-class (Kulmiye and Mavuti 2005), and that first egg-bearing occurs at 54mm, it appears that females may moult after developing most secondary characteristics of maturity, but before bearing eggs. Similar characteristics have been reported for *Jasus verreauxi* (10mm size difference between setal development and egg-bearing; Booth 1984) and for *Palinurus gilchristi* (3–8mm difference, depending on growth rates; Groeneveld and Melville-Smith 1994).

The size at 50% egg-bearing of 63.4mm during the main breeding season of *P. homarus homarus* at Mambrui is similar to that estimated by Jayakody (1989) for the same subspecies off southern Sri Lanka (59.5mm), but larger than that estimated by De Bruin (1962) at the same locality (55–59mm). Onset of maturity in lobsters is age- rather than size-dependent (Plaut 1993), and therefore growth of lobsters at Mambrui may be faster than off Sri Lanka. Size at onset of egg-bearing of *P. homarus homarus* differed only slightly from those of the other two *P. homarus* subspecies in the western Indian Ocean. Berry (1971) reported that the majority of *P. homarus rubellus* attain sexual maturity at 54mm off eastern South Africa, and Fielding and Mann (1999) found that 50% of female *P. homarus megasculpta* in Somalia bore eggs at 58mm. George (1963) estimated the size at maturity of *P. homarus megasculpta* females to be between 60mm and 70mm at Aden (Yemen), and a higher estimate of 80–85mm was reported by Johnson and Al-Abdulsalaam (1991) off the coast of Oman. Mohan (1997) reported a wide variation in the size at maturity of *P. homarus megasculpta* populations at three landing sites along the coast of Oman, ranging from 69mm to 76mm. Whereas variation in size at maturity within a subspecies may be attributable to extrinsic factors (e.g. water temperature, food availability, population densities), variation between subspecies may be a combination of extrinsic factors and intrinsic genetic capacity.

In conclusion, this study shows that changes in the relative lengths of endopodites (females) and walking legs (males) with CL of *P. homarus homarus* in Kenyan waters can be used to estimate size at maturity. Although the estimates using the current morphometric methods are slightly smaller than those from the more widely used setal and berry methods, a range of estimates is more likely to detect temporal changes in size at maturity than single measures, which may be affected by sample size or sampling strategy. The consistency of the present measurements as predictors of maturity needs to be tested in *P. homarus homarus* from other localities along the East African coast. All the measurements used in this study (except for staging of female gonads) could be obtained cost-effectively by field operators, without damage to artisanal catches.

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