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# Age and growth of the little Indian squid, *Loliolus hardwickei* (Gray, 1849) in the Arabian Sea

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## Original Article

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**Abstract**

Age and growth of the little Indian squid *Loliolus hardwickei* (Gray, 1849) were studied using samples collected in the coastal waters of Arabian Sea. Statolith increment counts demonstrated that *L. hardwickei* has a fast growth rate (dorsal mantle length: 0.31–0.73 mm day$^{-1}$ in females and 0.27–0.56 mm day$^{-1}$ in males) and a short lifespan of less than 6 months. Females are the larger sex and their daily growth rates were higher than in males. The oldest male and female were 110 and 130 days old; the youngest mature female and male were 62 and 52 days old respectively. The oviducal fecundity ranged from 104–480 eggs, mean = 360 eggs (14–23 eggs g$^{-1}$ body weight).

## Introduction

The Arabian Sea is one of the most productive maritime regions of the world (Ryther & Menzel, 1965). It is a tropical basin subjected to important seasonal climatic variations due to the reversing monsoon and seasonal upwelling (Nair *et al.*, 1999; Pillai *et al.*, 2000); e.g. inshore mean monthly sea bottom temperature (SBT) varying from 21.5°C to 32.0°C (Krishnakumar & Bhat, 2008).

Loliginid squids are important inshore commercial resources of the Arabian Sea (Meiyappan & Mohamed, 2003). Representatives of the family have short lifespans, high growth rates and early maturity (Jackson, 1990*a*; Jackson *et al.*, 1997, 2007; Hatfield, 2000; Jackson & Moltschaniwskyj, 2001, 2002; Moreno *et al.*, 2007; Ceriola & Jackson, 2010).

The little Indian squid *Loliolus hardwickei* (Gray, 1849) is one of the least studied loliginid squids of Indian waters. It is distributed throughout the northern Persian Gulf, India, Myanmarese coasts and throughout Indonesia (Lu *et al.*, 1985). It is a dwarf species attaining a maximum dorsal mantle length (DML) of 88 mm, body weight of 20 g and inhabits estuarine and shallow coastal waters with depths <30 m (Jereb & Roper, 2006, 2010). Very little information is available on the biology of *L. hardwickei* (Jereb & Roper, 2010). Our study presents the first published data on the length-weight relationships, age, growth rates and maturity of this species in the coastal waters of the Arabian Sea.

## Materials and methods

### *Sampling*

A total of 122 squids, 49 males and 73 females were collected in the south-eastern Arabian Sea during the study. This included 33 squids caught by the research vessel 'F.V. Silver Pampano' on 16 May 2014, off Kochi (09°58′N 76°06′E; 42 m trawl net, codend mesh size 25 mm) at 20 m depth. Additional specimens were purchased from commercial trawlers (30 m trawl net, codend mesh size 25 mm) operating from Cochin Fisheries Harbour (CFH), Kerala, India. A total of 42 individuals were acquired on 21 October 2014, and 47 individuals on 17 January 2015. Immediately after collection, squids were congealed with ice and transported to the laboratory.

Monthly sea surface temperature (SST) and sea bottom temperature (SBT) at 10, 20 and 30 m depth were recorded from January 2014 to January 2015 as part of regular oceanographic monitoring of fishing grounds off Kochi using a reversing mercury thermometer attached to the water sampler (Nansen reversing bottle).

In the laboratory, DML was measured to the nearest millimetre and wet body weight (BW) to the nearest 0.1 g. Maturity stages were assigned according to Lipinski & Underhill (1995), which included Stage I and II (immature), III (maturing), IV (mature) and V (spent).

Statoliths (N = 119) were extracted and processed according to Arkhipkin & Shcherbich (2012) methodology. The total statolith length (TSL) was measured using a microscope (Nikon Eclipse 80i), within 1 µm.

The statolith index (SI) was calculated as, $SI = TSL/DML \times 100$

Statoliths were mounted on a microscope slide using thermoplastic cement adhesive (Crystalbond 509™), keeping the anterior portion on top. Growth rings were visible without

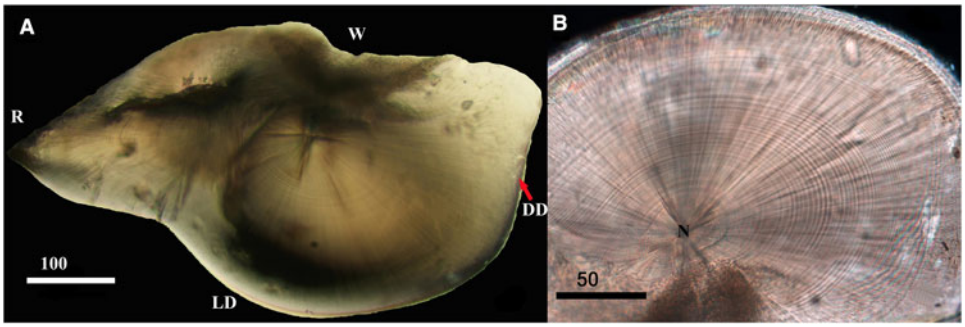


**Fig. 1.** (A) Anterio-lateral sections of the statoliths of *L. hardwickei*, R, Rostrum; W, wing; LD, Lateral dome; DD, Dorsal dome. (B) Ground statolith showing growth increments, N, Nucleus. Scale bar: A, 100 µm; B, 50 µm.

grinding, however, for better visualization, one-stroke polishing was done using a 1500 grit fine lapping film. Growth increments were examined under a microscope (Nikon Eclipse 80i) with 600× magnification and counted from the first check (hatching ring) to the edge of the dorsal dome, where increments were most clearly visible (Dawe *et al.*, 1985; Villanueva, 1992). In some cases, it was necessary to extrapolate counts from adjacent areas to estimate increment numbers in unclear areas. Counts by three independent readers were then averaged.

Growth increments were assumed to be daily, based on the validation of growth increments of *L. noctiluca* described by Jackson (1990*b*) as well as recent and past research supporting the one day-one increment hypothesis in loliginid squids (e.g. Jackson, 2004). Hatching date was back-calculated from the dates of capture. The mean daily growth rates (DGR) were calculated as:

$$\mathrm{DGR} = \frac{(\mathrm{DML} - 1.3)}{A}$$

where $A$ is age in days, and 1.3 is hatchling size, mm DML (Jackson, 1990*b*; Dimmlich & Hoedt, 1998).

The numbers of ripe eggs in the oviduct (oviducal fecundity, OF) were counted and egg measurements were taken in 39 adult females (38–53 mm DML) with a Nikon stereozoom microscope (Nikon-SMZ-25). The relative batch fecundity, RF was estimated as:

$$\mathrm{RF} = \mathrm{OF}/\mathrm{BW}$$

An analysis of covariance (ANCOVA) was performed to test for significant differences in '*b*' values for males, females and for the population following the method of Snedecor & Cochran (1967).

## Results

### Water temperature

During the period of observation, the SST peaked twice: first in April/May (pre-monsoon; 31–31.6°C) and then in October/November (post-monsoon; 29.5–31.0°C). The lowest SST was 27.2–27.8°C in June/July (monsoon). The SBT also first peaked in April/May (29.3–30.0°C) with a second peak in November/December (28.5–28.9°C). The lowest SBT was 23.9–25.4°C in June–August.

### Length-weight relationship

The squid size ranged from 19–57 mm DML in females (0.7–17.2 g BW) and from 20–41 mm DML in males (0.7–7.9 g BW). The relationship between DML and BW was described by the equation:

$$\mathrm{BW} = 0.1846\,\mathrm{DML}^{2.765}\ (r^2 = 0.853)\ \text{in males.}$$

$$\mathrm{BW} = 0.1454\,\mathrm{DML}^{2.965}\ (r^2 = 0.929)\ \text{in females.}$$

The ANCOVA showed no significant differences in these relations ($P = 0.564$) between sexes. Therefore, the length-weight relationship for pooled sexes was:

$$\mathrm{BW} = 0.1674\,\mathrm{DML}^{2.774}\ (r^2 = 0.909).$$

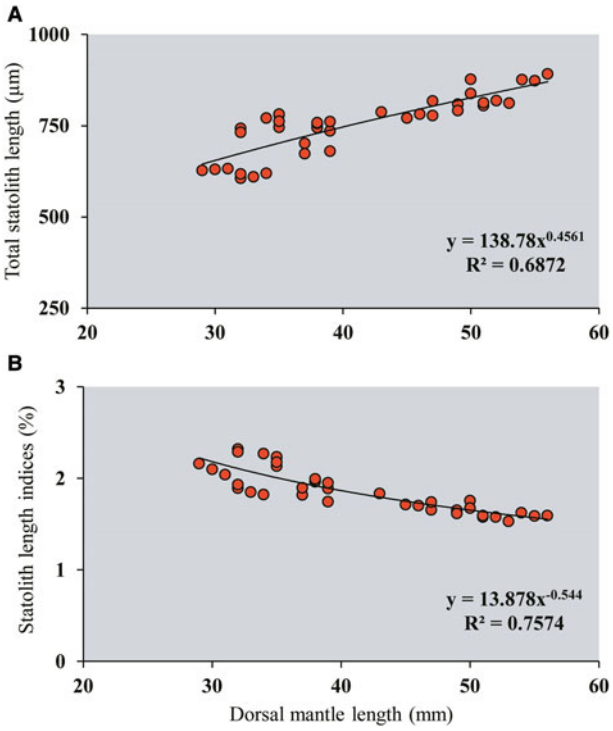


**Fig. 2.** (A) Relationship between dorsal mantle length and statolith length. (B) relationship between dorsal mantle length and statolith index.

### Statolith shape and growth

The *L. hardwickei* statoliths were flat antero-posteriorly and had a broad wing. The lateral dome was well developed, and the rostrum was short (Figure 1A, B). The TSL increased with an increase in DML ($r^2 = 0.68$)/span (Figure 2A). The SI ranged from 1.5–2.32%

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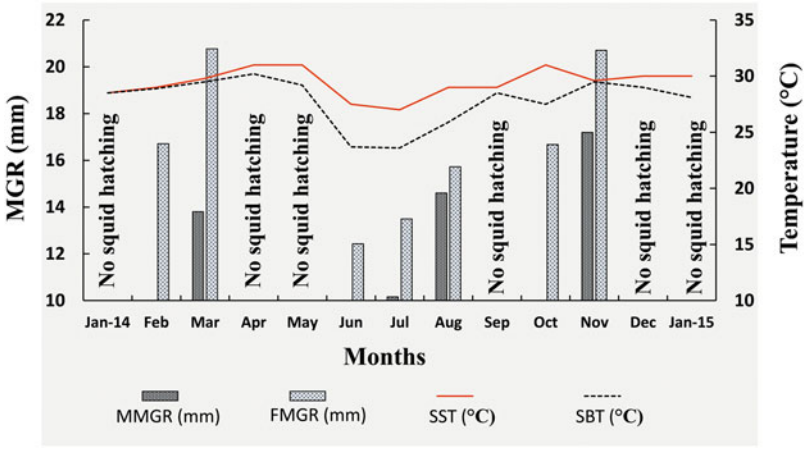


**Fig. 3.** Estimated monthly growth rate (MGR) of mantle length based on the hatching months of *L. hardwickei* from the coastal south-eastern Arabian Sea. MMGR, Male monthly growth rate and FMGR, Female monthly growth rate.

of DML and showed negative allometric growth ($r^2 = 0.75$, $a = 13.87$, $b = -0.544$) (Figure 2B).

### Age and growth

The age of sampled squid ranged from 50–130 days in females and from 56–110 days in males. The daily growth rate was 0.31–0.73 mm, mean = 0.52 mm DML day$^{-1}$ in females and 0.27–0.56 mm, mean = 0.43 mm DML day$^{-1}$ in males. The studied squids hatched in March, June, July, August, October and November. Higher growth rates were observed for male and female squid hatched in October and November, while lower rates were estimated for squid hatched in June to July (Figure 3).

### Maturation and fecundity

The youngest mature female was 62 days old, and the youngest mature male was 52 days old. Both sexes older than 90 days were mature. The OF ranged from 104–480 eggs (mean = 360). The RF was 14–23 egg g$^{-1}$ BW. The size of mature eggs in all months was 1.3–1.6 mm (mean 1.5 mm).

## Discussion

The analysis revealed that there was no significant difference in the length-weight relationship between males and females. This is surprising, as usually, male and female loliginid squids have different length-weight relations due to sexual dimorphism and different maturation rates and females developing larger reproductive systems (e.g. Jereb *et al.*, 2015). In general, length-weight relationships can vary, depending on the season, size range of the population, or annual changes in environmental conditions (Froese, 2006). In our case, absence of such differences could be caused by mixing of the different monthly cohorts maturing at different sizes.

The statolith shape and increment pattern were like those of *L. noctiluca* (Jackson, 1990*b*) and *Lolliguncula brevis* (Jackson *et al.*, 1997), both of which are small-sized species with a short lifespan. Negative allometric growth in statoliths (TSL vs DML) seems to be a characteristic of all squids (Arkhipkin, 1989; Bettencourt *et al.*, 1996).

The maximum age estimated in this study was 130 days for a 57 mm DML mature female and 110 days for a spent male (DML = 45 mm) indicating a probable lifespan of less than 6 months for *L. hardwickei*, similar to that observed in another loliolus squid, *L. noctiluca* from tropical Australian waters (Jackson, 1991). Earlier studies on age and growth of various populations of *L. noctiluca* from Australian waters showed that age ranged between 92 days and 121 days for females and between 84 days and 122 days for males (Ceriola & Jackson, 2010), which is similar to our observations.

Dwarf loliginids exhibit different growth rates at different latitudes and seasons (Dimmilich & Hoedt, 1998; Jackson & Moltschaniwskyj, 2001; Ceriola & Jackson, 2010) which is supported by the results obtained in the present study. The slower growth rate of the individuals born during the monsoon may be due to the poor growth in colder upwelling water as temperature plays a key role in the growth rate of cephalopods (Forsythe & Heukelem, 1987).

All previous studies on age and growth in tropical loliginid squids were carried out in Australian waters (Jackson, 1990*a*; 1990*b*; Jackson & Choat, 1992; Jackson & Moltschaniwskyj, 2001), North Africa (Arkhipkin & Nekludova, 1993), the Gulf of Thailand (Chotiyaputta, 1997) or the Andaman Sea of Thailand (Sukramongkol *et al.*, 2007). In all these studies, the estimated lifespan did not exceed 200 days (Jackson, 2004). The back-calculated hatch dates and presence of maturing and mature specimens in all sampling months in the present study supports the hypothesis that *L. hardwickei* breeds continuously. Such dwarf loliginid squids have a turnover of 2–4 generations within one year. It is evident that squids do not interrupt the spawning season to stop reproducing for 3–4 months as it is the entire life cycle of a single generation.

Females of *L. hardwickei* grow faster (Figure 3) and attain larger size than males, whereas the latter attain maturity earlier than females. Sexual dimorphism, where females are larger than males, is common among the genus *Loliolus* (Lu *et al.*, 1985). Advancing maturation of males is thought to be a characteristic for all cephalopods (Gonzalez *et al.*, 1994) and was also observed in other loliginid species (Arkhipkin, 1995; Jackson *et al.*, 1997) and ommastrephids (Arkhipkin & Silvanovich, 1997; Markaida *et al.*, 2004; Liu *et al.*, 2017). Male maturation is not as energy-demanding as female maturation, and this could be a reason for the difference in age-at-maturity between males (52 days) and females (62 days). In cultured octopuses, *Octopus digueti*, *O. vulgaris* and *Eledone cirrhosa* females attain sexual maturity much later in their life cycle and grow to a larger size than males (DeRusha *et al.*, 1987; Boyle *et al.*, 1988; Domain *et al.*, 2000). Conversely, in many neritic loliginids, males have higher growth rates and grow to larger sizes (Jackson, 2004). *Loliolus hardwickei* seems to be an exception, and the reason could be the female maturation process and the associated multiple broods (Jackson & Moltschaniwskyj, 2001) in a very short span of time.

Very little information is available on the biology of *L. hardwickei*, probably because the species is of little importance to

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commercial fisheries. This study provides pioneer information on the age and growth of this inshore squid in the tropical Arabian Sea, where loliginid growth is not studied at all.

*Loliolus hardwickei* is a very fast growing and short-lived species. Unlike larger loliginids but as in other dwarf species of the family, males were smaller than females at all ages. It demonstrates that populations 'invest' more into female growth, possibly to enhance reproductive output in a dwarf short-living species in which fecundity is restricted by both small body size and short lifespan.

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