Renewed research focus on cephalopod resources in the Southern Ocean

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Abstract

Researchers from ICAR-CMFRI participated in 2 cruises to the Southern Ocean during 2017 and 2020 to gather information on cephalopod resources of the Antarctic region. Four species of squids including three species of ommastrephid squids such as Purpleback flying squid, *Sthenoteuthis oualaniensis*, Neon flying squid, *Ommastrephes cylindraceus (Ommastrephes bartramii),* Antarctic squid *Todarodes filippovae* and one cranchid squid, the Glass squid *Galiteuthis glacialis* were recorded. The presence of paralarvae and juveniles of ommastrephid squid in surface waters between 45°S to 46°S and 57° 29' E to 72°E indicates this area may be their spawning ground. The paralarvae of mesopelagic glass squids *Galiteuthis glacialis* collected from 66° to 57° S and 80° E to 57° E were aged by analysing their statoliths.

Keywords*: Southern Ocean, cephalopods, paralarvae, statoliths*

Introduction

Investigations of Southern Ocean cephalopods began with the pioneering expedition of HMS Challenger (Hoyle,1886) and Valdivia expedition conducted by Germany (Odhner, 1923). After the 1970s, there has been considerable research effort in cephalopod taxonomy and abundance all over the world. However, very little is known about the abundance and biodiversity of cephalopods in the Southern Ocean sector. Southern Ocean cephalopod fauna is distinctive, with high levels of endemism in the squid and play an important role, linking the abundant mesopelagic fish and crustaceans with higher predators such as albatross, seals and whales. Although not yet commercially exploited species of the family Ommastrephidae have high potential (Collins and Rodhouse, 2006). As a national policy objective (NPMF, 2017) India looks at commercial exploitation of marine resources in Areas Beyond National Jurisdiction (ABNJ), and therefore, it will be appropriate if the stock abundance and distribution of commercial cephalopod stocks are well understood. Besides, India is one among 25 member countries of the CCAMLR (Commission for the Conservation of Antarctic Marine Living Resources) aiming for the conservation of marine life in Antarctic Ocean. It is in the light of the above that the Molluscan Fisheries Division of ICAR-CMFRI proposed a study on the assessment of cephalopod biodiversity in the Southern Ocean with particular reference to commercial exploitable cephalopod stocks, including understanding the age and growth of Southern Ocean squids using statoliths and investigating their role as a predator from stomach content analysis. The proposal was approved by the National Centre for Polar and Ocean Research (NCPOR), Goa under the Ministry of Earth Sciences, Government of India and results of the study during the 10th and 11th Southern Ocean expeditions (SOE) are given below.

Cruise transects and sampling

A 111 m LOA, ice-strengthened training ship "*MV Agulhas*" from South Africa, was used for the expeditions (Table 1).

Table 1. Details of the SOE undertaken for research on molluscan resources in Southern Ocean

Expedition	Vessel	Period	Number of participants	Types of equipment carried by ICAR-CMFRI
10th SOE	MV Agulhas	08.12.2017 to 02.03. 2018 (59 days)	35	Issacs-Kidd Midwater Trawl (IKMT), squid jigs, zooplankton net
11th SOE	MV Agulhas	06.01.2020 to 08.03.2020 (62 days)	39	Automatic squid jigging machine, IKMT, Rectangular midwater trawl, squid jigs

10th Indian SOE

Sampling was carried out in the area between 39°56'S to 66°39'S latitude and 57°25'E to 76°24'E longitude as per the cruise track (Fig.1A). 28 observations including those from 7 squid jigging stations, 13 IKMT stations (21 operations) and 8 zooplankton sampling operations were made (Table 2 & Fig. 2).

Ommastrephid squids including Neon flying squid *Ommastrephes bartramii* (Fig.3a), Antarctic flying squid *Todarodes filippovae* (Fig.3b) and Purpleback flying

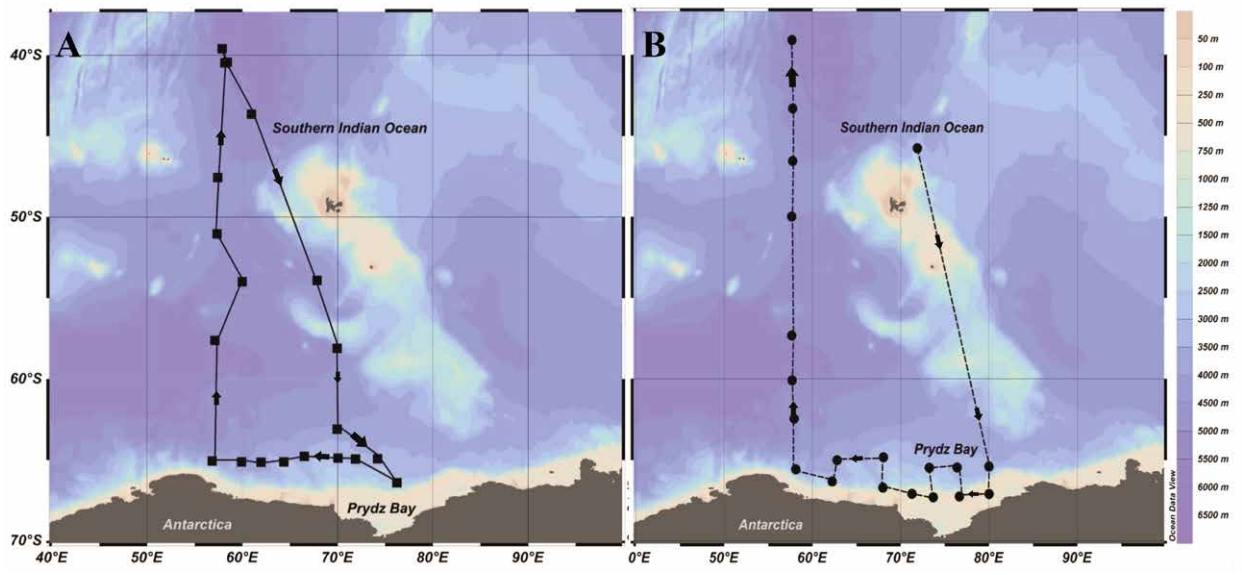

Fig.1. The cruise track and stations for cephalopod observations during (A) 10th and (B) 11th Indian SOE

Table 2. Sampling stations and operations conducted during 10th Indian SOE

Date	Location	Operation	Depth of operation
14/12/2017	40°11'S; 58°30'E	Squid jigging	30 m
18/12/2017	43°02'S; 60°36'E	IKMT	Surface, 200 m
22/12/2017	54°00'S; 68°05'E	Squid jigging	30 m
23/12/2017	54°01'S; 60°07'E	IKMT	Surface, 200 m
25/12/2017	58°55'S; 70°09'E	Squid jigging	30
27/12/2017	63°01'S; 70°05'E	Zooplankton net	Surface
30/12/2017	65°31'S; 74°45'E	Zooplankton net	Surface
31/12/2017	65°32'S; 72°50'E	Zooplankton net	Surface
3/1/2018	66°33'S; 76°24'E	Zooplankton net	Surface
4/1/2018	66°32'S; 76°24'E	Zooplankton net	Surface
5/1/2018	66°37'S; 76°07'E	Zooplankton net	Surface
6/1/2018	66°39'S; 76°06'E	Zooplankton net	Surface

Date	Location	Operation	Depth of operation
8/1/2018	65°28′S; 70°56′E	IKMT	Surface
9/1/2018	65°31′S; 69°08′E	IKMT	100 m
10/1/2018	65°29′S; 66°58′E	IKMT	Surface, 500 m
11/1/2018	65°30′S; 64°56′E	IKMT	Surface, 500 m
12/1/2018	65°46′S; 62°48′E	Zooplankton net	Surface
13/1/2018	65°27′S; 60°57′E	IKMT	Surface, 500 m
15/1/2018	65°27′S; 57°50′E	IKMT	500 m
21/1/2018	57°00′S; 57°36′E	IKMT	Surface, 500 m
24/1/2018	51°04′S; 57°25′E	IKMT,squid jigging	Surface, 500 m
25/1/2018	47°30′S; 57°29′E	IKMT, squid jigging	Surface, 500 m
28/1/2018	40°11′S; 58°24′E	IKMT, squid jigging	Surface
29/1/2018	39°56′S; 57°30′E	IKMT, squid jigging	200 m

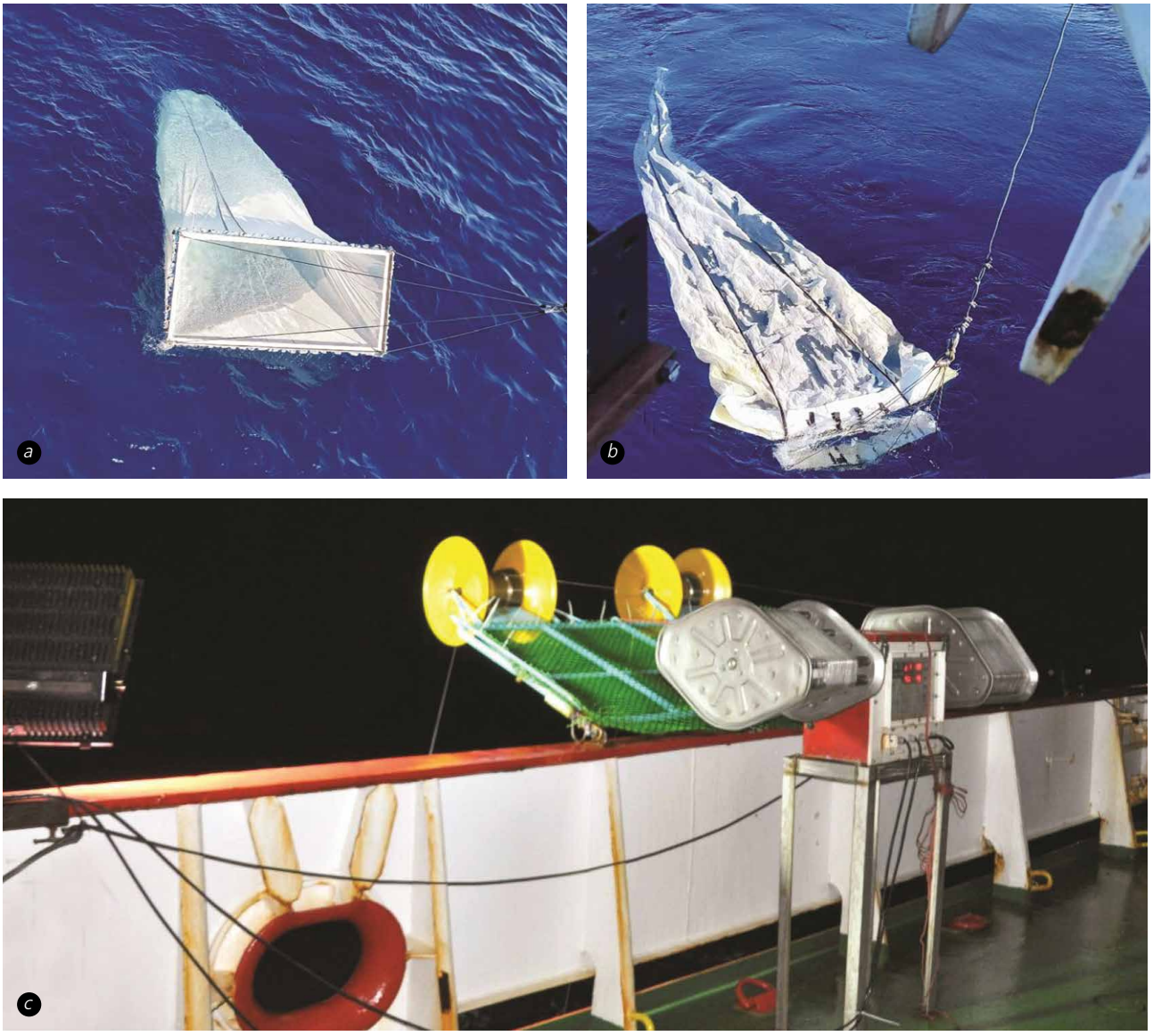

Fig. 2. Sampling operations during the 10th and 11th Indian expedition to Southern Ocean/ Antarctic waters (a) RMT (b) IKMT, for cephalopod paralarvae and juveniles; (c) Automatic squid jigging machine used for the capture of adult squids.

squid *Sthenoteuthis oualaniensis* and their abundance was observed in three stations, 47° S-57° E, 40° S-58° E and 39° S-57° E. Paralarvae of mesopelagic squids collected from 65° S 66° E to 57° S 57° E were identified as *Galiteuthis glacialis* (Fig. 3). Before the 10th SOE, the Neon flying squid, *Ommastrephes bartramii* was considered a monotypic cosmopolitan species with a discontinuous distribution. From the results of the 10th expedition, a combination of morphological and metabolic information were used to resurrect formerly synonymized name *Ommastrephes cylindraceus* (ie., *Ommastrephes bartramii = Ommastrephes cylindraceus*) and propose a revision in the distribution range in collaboration with other international cephalopod researchers (Fernandez-Alvarez *et al*., 2020). Additionally, the distribution, abundance and growth of the paralarvae and juveniles of the glass squid *Galiteuthis glacialis* which were collected from IKMT tows conducted at 500 m depth in Prydz Bay, Antarctica has been documented. Early life stages of *G. glacialis* were distributed over the shelf edge waters of Prydz Bay. Their abundance ranged from 1 to 9 individuals/1000 m^3 with highest abundance observed in both 65° S; 70° E and 66° S; 76° E, which is 120 nautical miles (nmi) north of land area of Prydz Bay (Fig.4). The smallest paralarvae were observed in 65° S; 57° E and largest individuals recorded at 57° S; 57°37' E.

A total of 53 early life stage individuals of *Galiteuthis glacialis* ranging in size from 6.3 to 28.4 mm DML were caught during the survey which included 42 paralarvae and 11 juveniles. The pair of statocysts

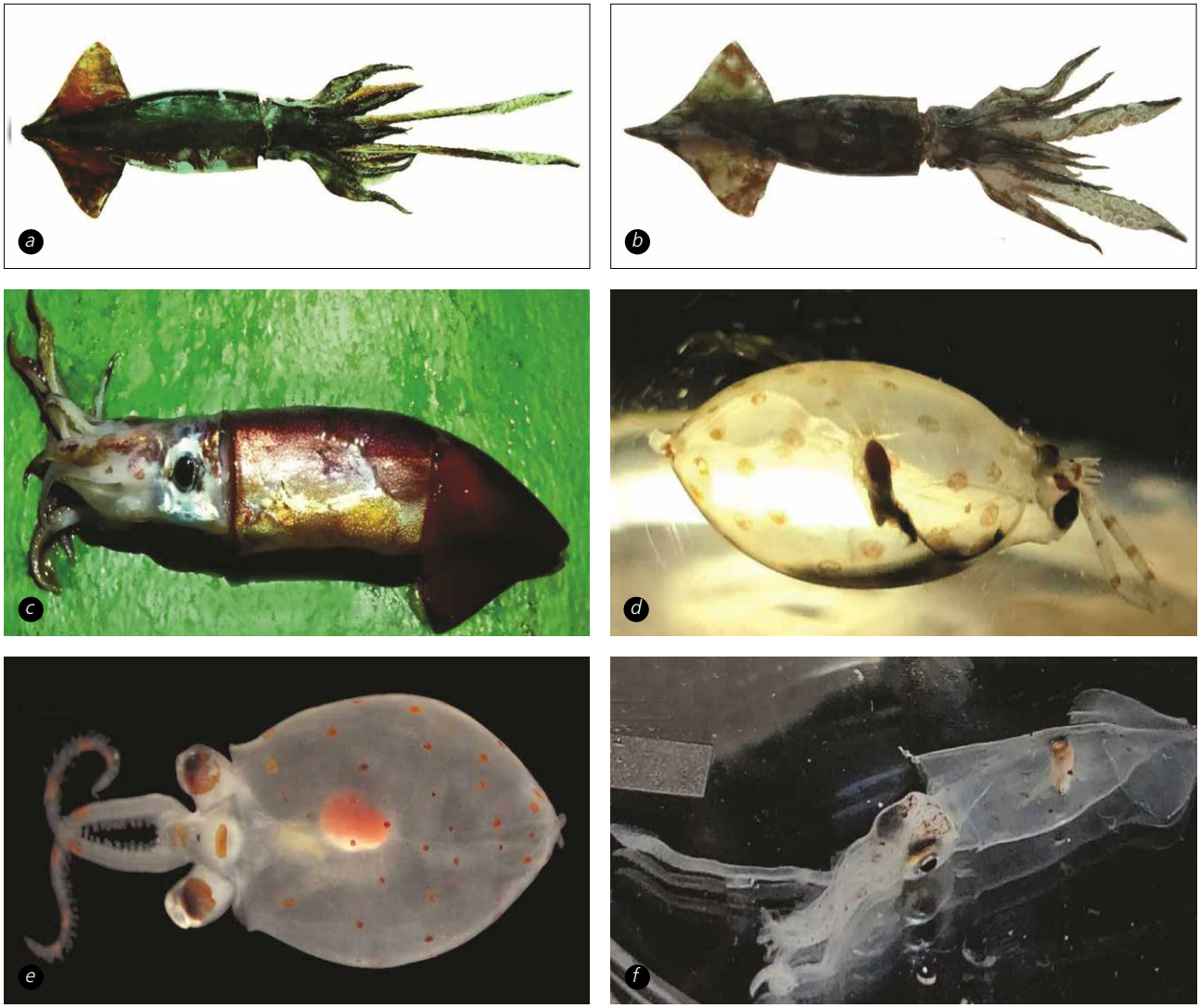

Fig. 3. Squids collected during 10th and 11th expeditions. (a) *Ommastrephes cylindraceus,* (b)*Todarodes filippovae,* (c) *Sthenoteuthis oualaniensis,* (d) Live *Galiteuthis glacialis,* (e) *Galiteuthis glacialis,* (f) Unidentified ommastrephid juvenile

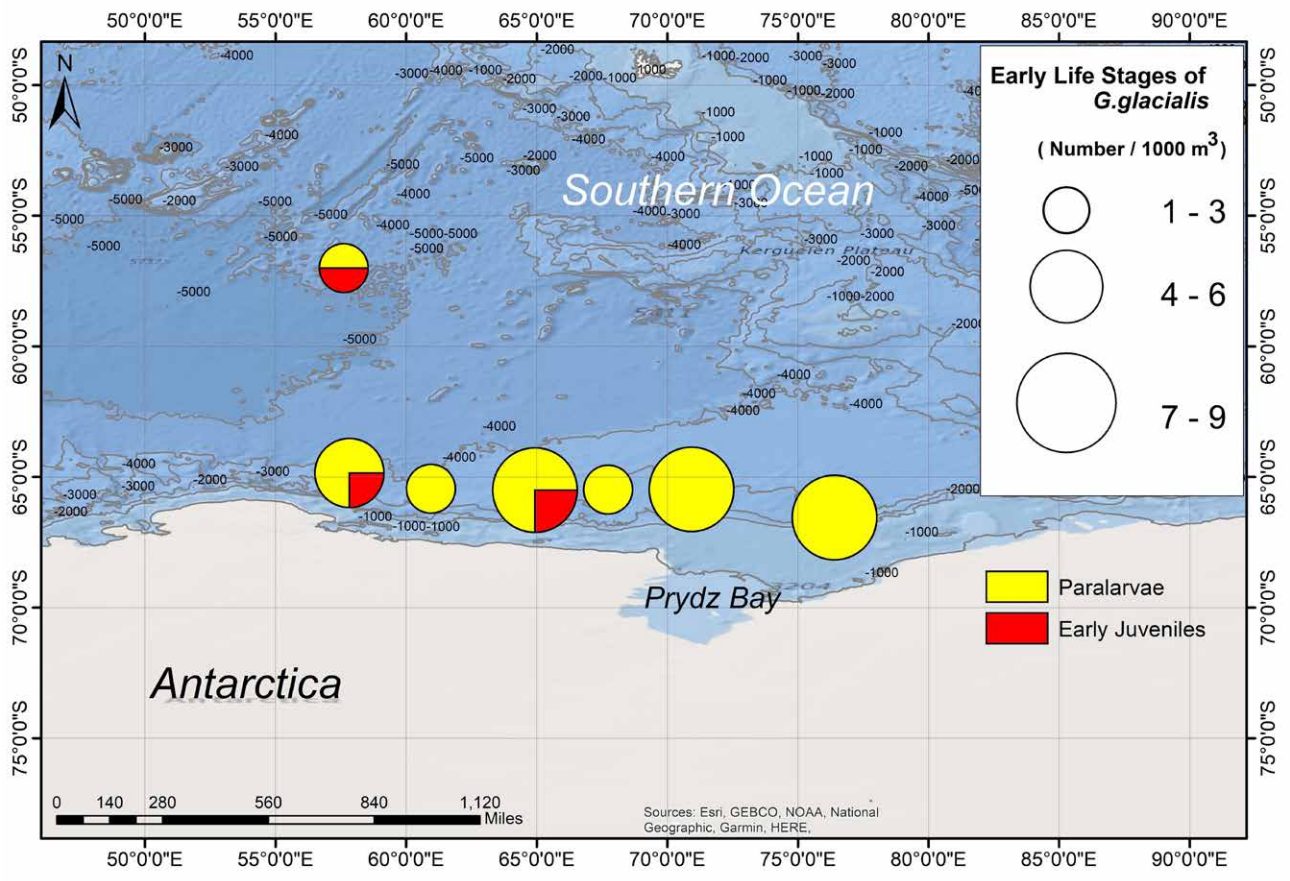

Fig. 4. Distribution and abundance of paralarvae and early juveniles of *Galiteuthis glacialis* in the Indian sector of Southern Ocean (near Prydz Bay). Circles = relative abundance

located in the ventral posterior region of the head had growth rings that ranged from 47 to 106 (6.3 to 28.4 mm DML) (Fig. 5). Age of individuals estimated based on statolith increment counts ranged from 47 to 85 days with a daily growth rate ranging from 0.13 to 0.25 mm dorsal mantle length (DML)/day (mean 0.18 mm) for paralarvae. The early juveniles had an age of 85 to 103 days with a slightly faster growth rate ranging from 0.21 to 0.27 mm DML/day (mean 0.24 mm). The presence of paralarve of *G. glacialis* at the outer continental shelf edge of Prydz Bay during austral summer indicates a probable spawning site in this area (Sajikumar *et al*., 2020). Other observations during the cruise in the Southern Indian Ocean included an opportunistic sighting (39° 59' 49"; 57° 30' 50") of a single sunfish *Mola mola* on 15th December 2017 (Fig. 6).The hydrographic characteristics such as atmospheric temperature (AT), Sea Surface Temperature (SST), humidity and wind speed at the site where the sunfish was sighted are given in Table 3.

Table 3. Hydrographic characteristics of *Mola mola* sighting site.

Characteristics	Variables
Atmospheric temperature (AT)	12.5°C
Sea surface temperature (SST)	16.0°C
Humidity	90%
Wind speed	14 mph
Water depth	3475 m

11th Indian SOE

The sampling was carried out in the area between 39°16' to 67°00' S latitude and 57°28' to 80°04' E longitude (Fig. 1B and Table.4). At each station, sampling for early stages of cephalopods was done using Rectangular midwater trawl (Fig. 2A) and Issacs-Kidd Midwater Trawl (IKMT) (Fig. 2B) operated below the surface and 500 m. Both vertical and horizontal hauls were made. The squids were caught in the night hours after attracting them using LED lamps (4 x 500 watts) by using hand

Fig. 5. (a) Dorsal view of *G. glacialis* (11 mm DML), (b) light micrograph of statocyst (arrow indicates the position of statolith), (c) light micrograph of statolith of *G. glacialis* (16 mm DML)

Fig.6. Ocean sunfish *Mola mola* sighted

Table 4. Sampling stations and operations carried out during the 11th Indian SOE

Date	Location	Operation	Depth of operation
29/01/2020	45° 00 S;72°00 E	IKMT, squid jigging	Surface, 500 m
04/02/2020	65° 00 S;80°04 E	IKMT	Surface, 500 m
07/02/2020	67° 00 S;80°00 E	RMT	300 m
08/02/2020	67° 32 S;76°50 E	RMT	250 m
09/02/2020	65° 00 S;76°59 E	IKMT	Surface, 500 m
10/02/2020	65° 00 S;73°59 E	IKMT	Surface, 500 m
11/02/2020	67° 00S; 74°00 E	IKMT	500 m
12/02/2020	66° 50S; 71°00 E	RMT	300 m
15/02/2020	66° 56S; 67°58 E	IKMT	500 m
16/02/2020	67° 00S; 64°50 E	IKMT	500 m
18/02/2020	65° 00S; 62°02 E	IKMT	500 m
19/02/2020	66° 52S; 61°57 E	IKMT	200 m
20/02/2020	65° 31S; 57°29 E	RMT	1000 m
22/02/2020	61° 59S; 57°28 E	IKMT	500 m
24/02/2020	60° 00S; 57°30 E	IKMT	Surface, 500 m
25/02/2020	57° 00S; 57°29 E	IKMT, squid jigging	Surface, 500 m
28/02/2020	50° 24S; 57°29 E	IKMT, squid jigging	Surface
29/02/2020	46° 59S; 57°29 E	IKMT, squid jigging	Surface, 500 m
02/03/2020	43° 00S; 57°30 E	IKMT, squid jigging	Surface
03/03/2020	39° 16S; 57°28 E	Squid jigging	Surface

jigs and automatic squid jigging machine (Hamade MY- 3DP) with centralized control panel (Fig. 2C). However, jigging operations could be carried out only rarely on most of the nights due to very rough seas, strong currents and winds during the expedition. Abundance estimation of ommastrephid squids were undertaken in all stations by visual observation method (Chesalin and Zuyev, 2002).

Three species of cephalopods *Ommastrephes bartramii* (*O.cylindraceus*), *Todarodes filippovae* and *Sthenoteuthis oualaniensis* were collected using automatic squid jigging machine and hand jig while *Galiteuthis glacialis* was collected using IKMT. The pelagic neon flying squid *Ommastrephes bartramii* (*Ommastrephes cylindraceus*) was observed at 39°16' S; 57°28' E. Paralarvae and juveniles of ommastrephid squids were observed in surface waters of 45°00' S; 72°00' E and juveniles were observed at 46° 59' S; 57°29' E and 43°00' S; 57°30' E. Paralarvae of mesopelagic squids collected from 66° to 57° S and 80° E to 57° E were identified as *Galiteuthis glacialis*. The IKMT collected paralarvae of *G.glacialis* of 13 mm DML could be successfully maintained onboard in a glass tank up to 4 hours Fig.3d.

During the expedition 25 stations were covered among which 6 were squid jigging stations, 15 IKMT stations (23 operations) and 4 stations for RMT operations. Antarctic Krill *Euphausia superba* was also collected using IKMT from 500 m depth from 45°S to 60°S latitude along the cruise track and these are being analysed.

Seabirds, fish, penguin and seals of the Southern Indian Ocean were recorded during the expeditions. Nine species of seabirds were identified during the expedition (Table 5 and Fig.7). The southern giant petrel *Macronectes giganteus* was the most common species in the Southern Ocean. Several groups of Adelie penguin *Pygoscelis adeliae* Antarctic seals such as crabeater seal *Lobodon carcinophagus* and leopard seal *Hydrurga leptonyx* were observed near Prydz Bay (Fig.8).

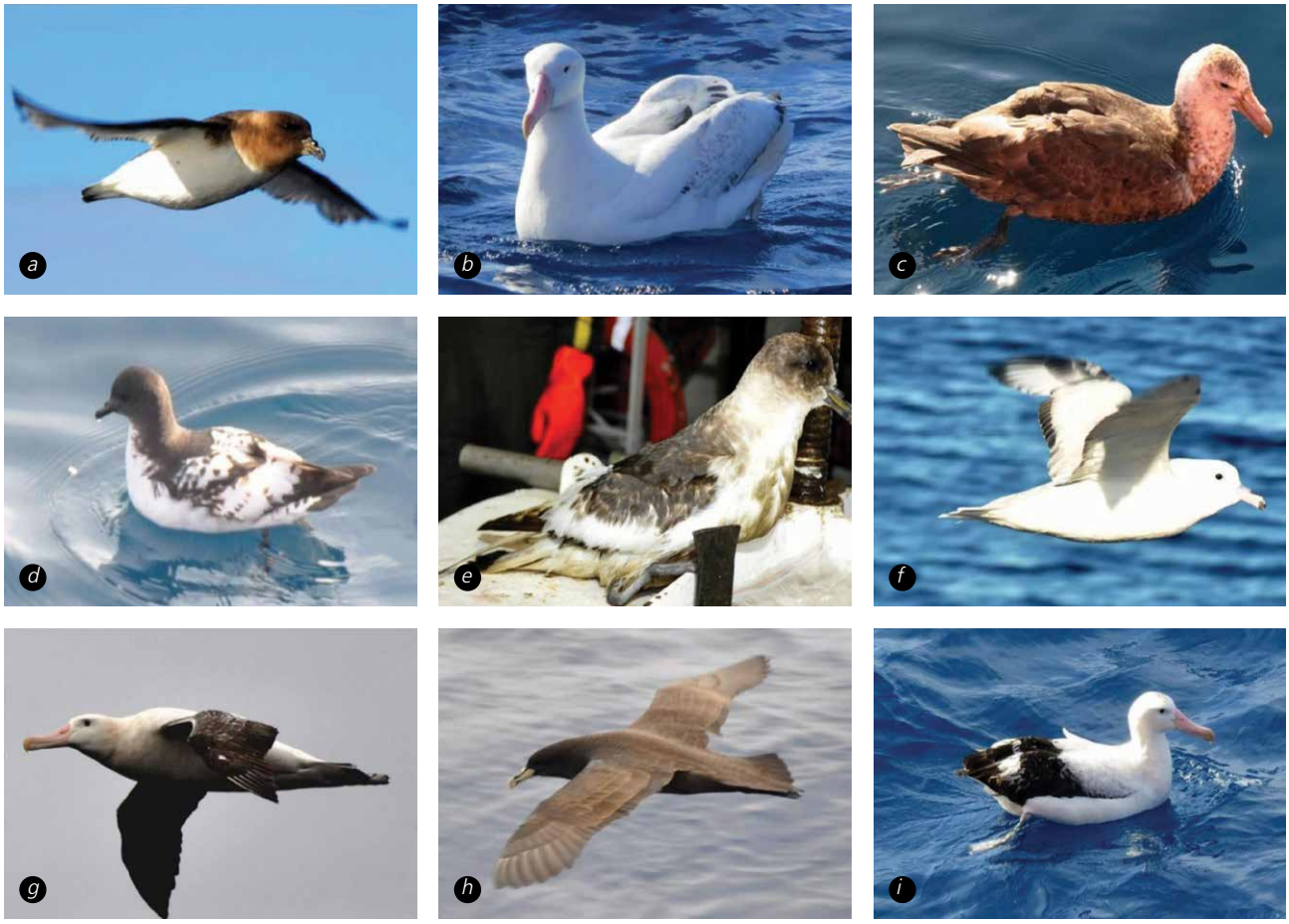

Fig.7. Seabirds observed during the 10th and 11 th Indian Expedition to Southern Ocean/Antarctic waters. (a) *Thalassoica antarctica,*(b) *Diomedea exulans* (c)*Macronectes giganteus,* (d) *Daption capense,* (e) *unidentified,* (f) *Fulmarus glacialoides,* (g) *Diomedea sanfordi,* (h) *Procellaria aequinoctialis,* (i) *Diomedea epomophora*

Table 5. List of birds observed during the 10th and 11th Indian SOE

Species	Common name	Position	IUCN status
Diomedea epomophora	Southern royal albatross	61° 48′ S;57°14′ E	Vulnerable
Procellaria aequinoctialis	White-chinned petrel	40°12′S to 62°35′S	Vulnerable
Diomedea sanfordi	Northern royal albatross	60° 23′S;57°30′E	Endangered
Fulmarus glacialoides	Southern fulmar	65° 20′S;63°12′E	Least concern
Unidentified	-	66° 56′S;67°58′ E	-
Daption capense	Cape petrel	66° 50′S;71°00′ E	Least concern
Macronectes giganteus	Southern giant petrel	57° 00′S to 67°00′S	Least concern
Diomedea exulans	Wandering albatross	61° 00′S;57°28′ E	Vulnerable
Thalassoica antarctica	Antarctic petrel	56°28′S;57°29 E	Least concern

Fig.8. Crabeater seal of Southern Ocean

Endnote

These expeditions suggest the fishery potential of squids belonging to family ommastriphidae, such as *Ommastrephes cylindraceus* and *Todarodes filippovae* distributed up to 45°S during austral summer. The distribution of *Sthenoteuthis oualaniensis* is restricted up to 40°S. The occurrence of the paralarvae and juveniles indicate that Austral summer may be the spawning season for these species in the Southern Indian Ocean. Further on-board/*in situ* statolith increment validation studies for confirming the periodicity of statolith increment formation of Antarctic squids is needed. It is also necessary to carry out more night observations (squid jigging and abundance estimation) especially in the frontal region of the Southern Ocean (40°S) for a comprehensive understanding the abundance and distribution of these valuable resources of the Antarctic. There is also need to understand the relationship between squid stock size, recruitment variability and oceanographic systems.

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