Cephalopod Biodiversity, Ecology and Evolution
Payne, A. I. L., Lipiński, M. R., Clarke, M. R. and M. A. C. Roeleveld (Eds). *S. Afr. J. mar. Sci. 20: 305–310*
1998

A MASS STRANDING OF THE SQUID *MARTIALIA HYADESI* ROCHEBRUNE AND MABILLE, 1889 (TEUTHOIDEA: OMMASTREPHIDAE) AT NEW ISLAND, FALKLAND ISLANDS

C. P. NOLAN, I. J. STRANGE†, E. ALESWORTH* and D. J. AGNEW‡*

On 11 February 1997, during a period of calm weather and spring tides, a mass stranding of approximately 3 000 *Martialia hyadesi* was observed *in vivo* on Protector Beach, New Island, Falkland Islands. Squid made continued and deliberate movements to beach and drove ashore with considerable force, releasing ink into the water as they did. Beached squid were mostly female (61%) and ranged in size from 22 to 27 cm dorsal mantle length. All animals were immature, with females in lower stages of maturity than males. No predatory marine mammals were seen in the area during or after the stranding event. An interpretation of the stranding is presented with reference to historical reports of squid strandings worldwide. Evidence suggests some periodicity in the cycle of squid strandings, which may reflect temporal shifts in frontal zones that alter the behaviour, range and environment of foraging squid populations.

Mass strandings of various ommastrephid squid species have been attributed to a wide variety of circumstances. Strandings have been variously associated with the actions of predators, changes in water temperature or salinity inducing toxic shock, pursuit of food close to shore, lunar influences or excitement immediately prior to copulation (Wilhelm 1930, 1954, Gunther 1936, Gillespie 1953, Hamabe and Shimizu 1959, Smithsonian Institute 1974, Prescott 1977, Lux *et al.* 1978, Brix 1983, O'Sullivan *et al.* 1983, Vyshkvartzev *et al.* 1996).

The fossil record contains similar evidence of cephalopod strandings, catastrophic mass mortality being the most likely explanation for Palaeozoic concentrations of nautiloid cephalopods. In those cases, salinity changes, blooms of phytoplankton, temperature changes and oxygen levels are postulated as being possible causes of mass mortality, although it is difficult to attribute such events to either behavioural or pathological circumstances because of a lack of relevant evidence from the period (Holland *et al.* 1994).

Accounts of strandings have been few. The majority of reports describe dead and decomposing squid and are usually retrospective of the stranding event. Of the small number of strandings witnessed, the behaviour of the stranding squid has received particular attention. Generally confined, in shallow water and apparently confused and panicked by their predicament, the innate escape reaction, to jet backwards at speed, is commonly observed.

Appearing to work their jets at top pressure with the funnel pointed seawards, the squid become firmly stranded and once aground seem forced by instinct to drive farther and farther ashore (Bigelow 1926), commonly resulting in a strandline of individuals on the shore (Lane 1957). Evidence from the Bay of Fundy, between Nova Scotia and New Brunswick in Canada, suggests that, in some areas, such windrows of stranded squid occur regularly with individuals piled to a height of between 10 and 30 cm. Exceptional reports of windrows between 1 and 2 m high have also been reported from the Bay of St Main in Newfoundland on the occasion of a single mass stranding (La Pylaie, as cited in Lane 1957).

On nearly all occasions where observers have been present, it has also been noted that stranded squid physically returned or thrown out into deeper water return to the beach with near immediate effect and strand once again in a determined and forceful manner (Lane 1957).

New Island (51°43.30′S, 61°17.80′W, Fig. 1) is situated north-east of the continental shelf break, in an area influenced by the confluence of Antarctic circumpolar water and water of Patagonian Shelf origin. To the south of the Island, flood tides are charted as flowing north-easterly through Grey Channel, with branches of the main current being directed into South Harbour. The site of the stranding, Protector Beach, lies at the head of this harbour. The beach itself is relatively small, only some 100 m wide, and at very low tides, some 30 m of sand is exposed from the high tide mark to the water's edge. The beach is generally sheltered except from southerly or south-easterly winds.

Martialia hyadesi is a cold water squid considered

* Falkland Islands Fisheries Department, Stanley, Falkland Islands. Email: conor@squidrow.demon.co.uk
† New Island; and The Dolphins, Snake Hill, Stanley, Falkland Islands
‡ Renewable Resources Assessment Group, Imperial College, London. Email: d.agnew@ic.ac.uk

Manuscript received: September 1997

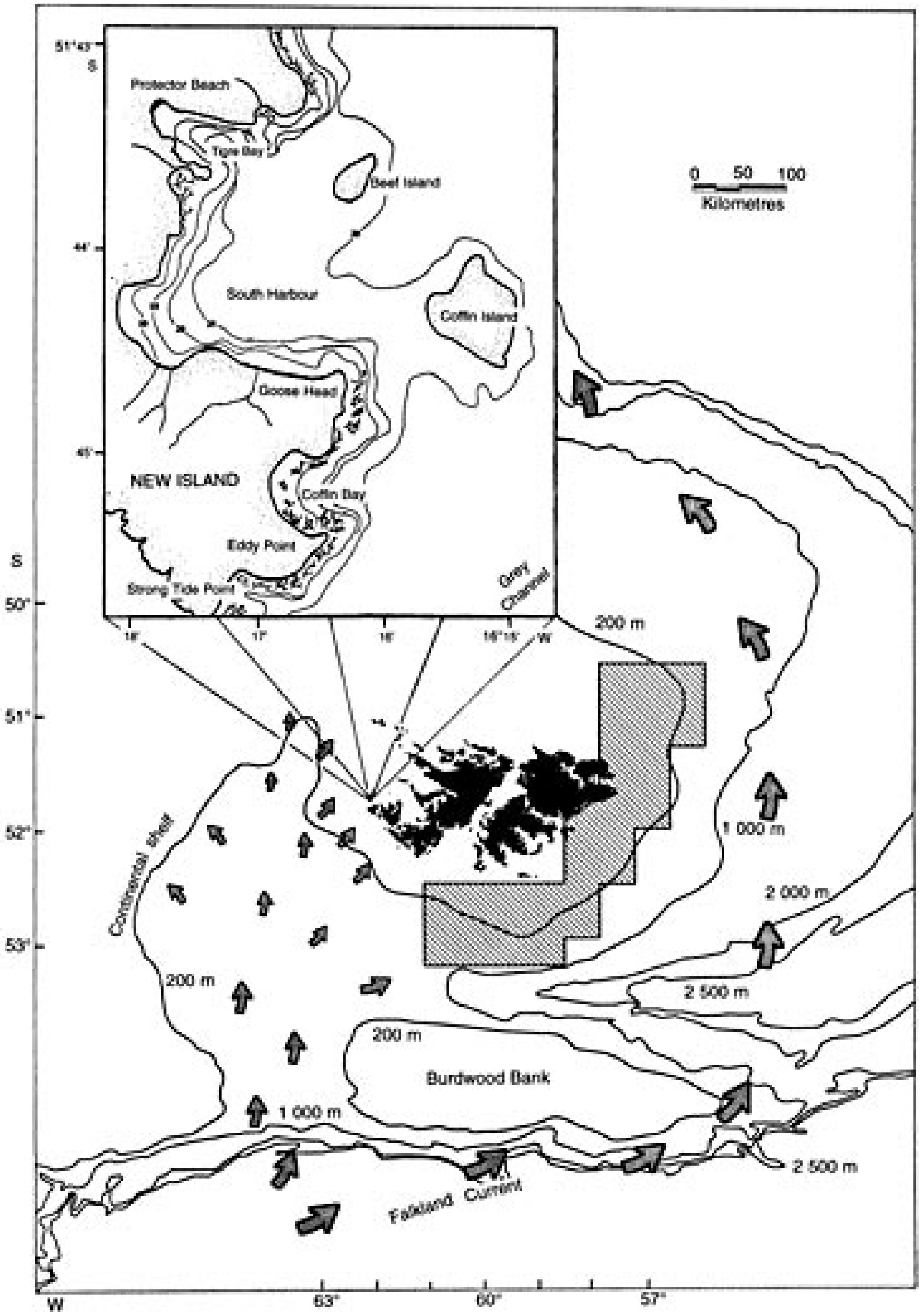

Fig. 1: The location of the stranding site of *Martialia hyadesi* on New Island (inset) relative to the position of the Falkland Islands, the Falkland Current (shaded arrows) and the commercial fishing area for *Loligo gahi* (hatched box)

to have a circumpolar distribution in the South Atlantic (O'Sullivan *et al.* 1983, Piatkowski *et al.* 1991). It is generally associated with the Antarctic Polar Frontal Zone and occasionally with the convergence zone of the Falkland Current and Patagonian Shelf waters within the South-West Atlantic (Rodhouse 1991). The Falkland Islands' commercial fishery for the ommastrephid squid *Illex argentinus* occasionally records a bycatch of *M. hyadesi* (Falkland Islands Government 1997), and such bycatches are generally bigger in years when cold water extends over most of the continental shelf or wind-driven upwelling north-east of the Falkland Islands is recorded. *M. hyadesi* is retained by commercial vessels and is speculated to have the potential to support a commercial fishery (Rodhouse 1990).

The dominant oceanographic feature in the area is a north-flowing branch of the Antarctic Circumpolar Current, which upon exiting the Drake Passage becomes the Falkland Current. The main flow of this current is along the shelf edge to the south and east of the Falkland Islands, where the current is deflected eastwards by the Burdwood Bank. A branch of the current also flows north through the channel between Staten Island and the Burdwood Bank onto the Patagonian Shelf west of the Falkland Islands.

The circulation patterns west of the Falkland Islands remain uncertain and what data there are have been derived from numeric, barotropic models (Glorioso and Simpson 1994, Glorioso and Flather 1995). Fisheries catch data indicate that the distributional ranges of a number of cold water species are limited in their northerly extent to the area of the shelf break and the confluence of Antarctic Circumpolar and Patagonian Shelf water masses in this region. It is likely, therefore, that the area is directly influenced by the flow of the main Falkland Current, the strength and influence of which is controlled by annual variation in current speed and strength of the Antarctic Circumpolar Current (Glorioso and Flather 1995).

OBSERVATIONS

On 11 February 1997, three days after the new moon, the attention of the second author was drawn to the surf zone of Protector Beach at the head of Settlement Harbour (or Tigre Harbour), New Island, by an unusual, high-pitched, squeaking sound. At the time the observations were made, a north-westerly wind of 18–20 knots was blowing off the beach, but it had little effect on the surface water, which was calm. There was little or no tideline movement evident and the day was sunny and calm (2/8 *Cirrus stratus*, air temperature [dry] 15°C, barometric pressure 1 022 mb at 08:00 local time).

Attention was first drawn to the beach when the tide was at its highest at 14:30 local time. Further observation revealed some movement on the tide line, where some 20–30 squid were seen propelling themselves ashore, releasing their ink in the process. Closer inspection revealed squid in the shallows approximately one metre offshore and a raft of detached kelp floating 10 m offshore, which appeared to be being used for shelter by other groups of squid. As this first small group of animals was being watched in the water, at close quarters, there was considerable movement behind the observer as two separate shoals of squid came ashore, each containing an estimated 200–300 animals. In both cases there was a very deliberate movement ashore *en masse*. Animals which appeared unsuccessful in beaching at that point swam around for a few seconds before making a further deliberate movement ashore. Not all animals appeared to be expelling ink, although a cloud of ink could be seen drifting out into open water.

As they drove ashore, water was expelled with such force that spouts of water would shoot an estimated 2 m or more, with the forced expulsion of air and water emitting the squeaking sound first noted. So frenetic and intense was the activity that the observer was forced to move away from his seaward vantage point as a result of becoming soaked by the water being jetted by beaching squid.

Strandings continued at intervals over the course of the following hour when it was estimated that some 3 000 animals had beached themselves along the shoreline. At low tide, another shoal of some 50 animals came ashore on the same beach. In general, the strandings were over the full length of the beach. It was noted, however, that concentrations of animals were associated with two large, drifting, rafts of the giant kelp *Macrocystis pyrifera* a few metres offshore, under which many squid seemed to be lying at times.

During the course of the stranding there was no evidence that a marine mammal predator within the area of Settlement Harbour or to seawards had forced the squid ashore. The sea conditions were such that any seals or cetaceans would have been visible at some distance. Observations made from high ground over the immediate sea area did not detect the presence of any such predator, although an unusually large number of blackbrowed albatrosses *Diomedia melanophris* were noted feeding on the surface, in a line, between Bold Point, on Weddell Island, and the southern tip of New Island. This aggregation was observed on the same day of the stranding at 10:00 local time, some 2½ h prior to the stranding event.

On 21 February 1997 it was discovered that more squid had stranded on the same beach. On that occasion about 100 animals stranded during the night of 20 February or very early on the morning of 21 February. The stranding was located about mid-tide level on the beach and was estimated to have taken place in dark-

Table I: Summary statistics of dorsal mantle length *DML* and mass by sex and maturity stage for a random sample of stranded *Martialia hyadesi* on Protector Beach, New Island, Falkland Islands

Parameter	Value						
	Female			Male			Total sample
	Stage I	Stage II	All females	Stage II	Stage III	All males	
Number sampled	14	35	49	29	3	32	81
Minimum *DML* (cm)	22.5	22.5	22.5	22.0	24.0	22.0	22.0
Maximum *DML* (cm)	24.5	27.0	27.0	27.0	25.0	27.0	27.0
Modal *DML* (cm)	23.0	24.5	24.5	22.0	24.0	24.5	24.5
Mean *DML* (cm)	23.43	24.73	24.36	23.72	24.33	23.78	24.13
SD DML	0.81	1.25	1.28	1.40	0.58	1.35	1.33
Minimum mass (g)	230	210	210	200	280	200	200
Maximum mass (g)	290	400	400	390	320	390	400
Modal mass (g)	240	300	240	320	290	240	240
Mean mass (g)	255.71	293.71	282.86	275.86	296.67	277.81	280.86
SD mass	19.50	49.60	46.32	52.41	20.82	50.47	47.76

ness, because the squid were dead but intact, with such birds as giant petrels *Macronectes giganteus* having to dive to pick them up as the subsequent tide washed over them. That stranding probably occurred one day before full moon and conditions at the time were similar to those on 11 February (NW wind of 10 knots, barometric pressure 1 008 mb).

New Island has experienced one other recorded squid stranding on the same beach, in the summer of 1980. That stranding was also witnessed, but the species of squid was not recorded.

SAMPLE COLLECTION AND ANALYSIS

In all, 81 squid were examined *in situ*, and a smaller sample of 10 animals was preserved in 10% buffered formol saline for later examination.

The squid collected from the stranding on Protector Beach were identified as *Martialia hyadesi* from morphometric and meristic data. Of those sampled *in situ*, 49 were female and 32 were male. All individuals were immature, 79% of the total number sampled assigned to Stage II of Lipiński's maturity scale (Lipiński 1979). Females ranged between 22.5 and 27.0 cm dorsal mantle length (*DML*) and 210 and 400 g and males between 22.0 and 27.0 cm *DML* and 200 and 390 g. Modal classes of 24.5 cm *DML* and 240 g were common to both sexes (Table I).

DISCUSSION

General observations made on the distribution of the commercial fleet targeting *Illex argentinus* from December 1996 to February 1997 suggest that the Falkland Current was particularly strong over this period, the main branch of the current extending farther west and the strength of the flow to the west of the islands substantially greater than normal. This effectively reduced the area of the continental shelf available to southerly migrating squid and restricted their movement offshore.

It is speculated that the strength of the Falkland Current began to build during the austral winter and spring of 1996. Independent of the effects of fishing effort, the recruitment of squid to the *Loligo gahi* fishery off the south coast of the Falkland Islands was poor during February 1996, corroborating the suggestion of a cold water incursion into the area and suggesting an environmental anomaly of some significance that adversely affected the hatching and survival of juvenile *Loligo* and their prey, subsequently affecting recruitment to the fishery. The previous reported stranding of *Martialia hyadesi* off the sub-Antarctic, Australian, Macquarie Island (54°30′S, 158°57′E) in 1971 (O'Sullivan *et al.* 1983) was suggested to have been attributable to a sudden change in wind direction coupled with a rising tide, inducing a change in the hydrology. Similarities between this event and that of the current event are evident.

Observations made on the day of the stranding at New Island describe a feeding aggregation of black-browed albatrosses stretched in a line between Bold Point on Weddell Island and the southern tip of New Island. This would appear to indicate the presence of a zone of productivity and possibly the location of feeding *Martialia* shoals (Clarke and Prince 1981). The strong tidal race in the area is thought to have influenced the movement of the squid and forced them into the confines of South Harbour and shorewards into Tigre Bay to Protector Beach at its head. The rocky sides of Tigre Bay and the sandbar at its entrance all contribute to a funnelling effect on the squid.

In both northern and southern hemispheres, a significant number of ommastrephid strandings have been documented at the extremity of the geographical distribution of a species. In many cases they appear to be associated with localized or regional changes in oceanographic circulation which alter the geographical extent and location of frontal zones between water bodies. Such oceanographic disturbances, at the time of recorded strandings, have been noted or suggested to be of importance in precipitating stranding events (e.g. *Dosidicus gigas* – Gunther 1936; *Todarodes sagittatus* – Stephen 1937, Elmhirst 1938, Gillespie 1953; *Thysanoteuthis rhombus* – Nishimura 1966; *Illex illecebrosus* – Lux *et al.* 1978; *Martialia hyadesi* – O'Sullivan *et al*. 1983). In some instances, these have occurred in conjunction with anomalous aggregations of prey species (*Illex illecebrosus* – Lux *et al.* 1978; *Dosidicus gigas* – Clark and Phillips 1936, Nesis 1983) or while forming spawning aggregations (*Todarodes pacificus* – Hamabe and Shimizu 1959).

In the southern hemisphere, interannual and decadal changes in the strength, temporal extent and position of dominant water masses in areas where squid have stranded, have been associated with the oceanographic influences of *El Niño* and the atmospheric effects of Southern Oscillation (ENSO) events (Wilhelm 1930, Gunther 1936, Miller 1996). During ENSO events in this region, coastal upwelling processes are altered to such an extent that fish behaviour within and among species becomes modified in major ways (Glantz 1996). Cold water communities are displaced by those of warm water affiliation, and species at all trophic levels within the invasive water body experience a temporal extension to their normal geographical range (e.g. Mullin 1997). Changes in global meteorological conditions have also been associated with the displacement of major water masses during ENSO events (Glantz 1996). These include anomalous wet and dry periods on many continents along with regular patterns in the annual extent of Antarctic sea-ice (Murphy *et al.* 1995) and interannual variation at various trophic levels within the Southern Ocean (Priddle *et al.* 1988). Although it may be simply coincidental that many of the mass strandings of oceanic ommastrephids have been during or subsequent to ENSO events, the ecological displacement effects induced by these periods of oceanographic change may underlie a large number of reported squid strandings at a regional level worldwide.

During 1997, the Falkland Islands' fishing season for the warm water ommastrephid *Illex argentinus* saw a substantial quantity of *Martialia hyadesi* taken as bycatch (Falkland Islands Government 1997). Most of the reported catches were taken over and close to the continental shelf edge north-east of the Islands. It would appear that, in association with a warmer than usual south-flowing shelf current, there was a stronger than normal flow of the cold water Falkland Current to the east and west of the Islands over this period. These oceanographic anomalies occurred during a year of moderate *El Niño* effect and suggest a possible association and explanation for the New Island stranding of *Martialia hyadesi*.

ACKNOWLEDGEMENTS

The authors acknowledge the assistance of Fisheries Protection staff, the Master and crew of the P.V. *Cordella*, Dr P. G. Rodhouse (British Antarctic Survey), Mr P. Brickle and Dr K. Pütz (both Falkland Islands Fisheries Department) for their logistic support of this work. Valuable comments on an earlier draft were provided by Dr U. Piatkowski (Institut für Meereskunde, Kiel) and an anonymous reviewer.

LITERATURE CITED

BIGELOW, H. B. 1926 — Plankton of the offshore waters of the Gulf of Maine. *Bull. Bur. Fish., Wash.* **40**(2): 509 pp.

BRIX, O. 1983 — Giant squids may die when exposed to warm water currents. *Nature, Lond.* **303**(5916): 422-423.

CLARK, F. N. and J. B. PHILLIPS 1936 — Commercial use of the jumbo squid, *Dosidicus gigas*. *Calif. Fish Game* **22**(2): 143–144.

CLARKE, M. R. and P. A. PRINCE 1981 — Cephalopod remains in the regurgitations of black-browed and grey-headed albatrosses at South Georgia. *Bull. Br. Antarct. Surv*. **54**: 1–7.

ELMHIRST, R. 1938 — *Todarodes sagittatus* (Lam.) in the Firth of Clyde. *Scot. Naturalist* **1938**: p. 164.

FALKLAND ISLANDS GOVERNMENT 1997 — Fisheries Department, Fisheries Statistics **1** (1989–1996). Stanley, Falkland Islands; Falkland Islands Government Printing Office: 75 pp.

GILLESPIE, A. S. 1953 — An incursion of the flying squid, *Ommastrephes sagittatus* (Lamarck), on the east coast of Scotland. *NWest. Naturalist* **24**: 384–387.

GLANTZ, M. H. 1996 — *Currents of Change : El Niños Impact on Climate and Society.* Cambridge; University Press: 194 pp.

GLORIOSO, P. D. and R. A. FLATHER 1995 — A barotropic model of the currents off SE South America. *J. geophys. Res.* **100**(C7): 13427–13440.

GLORIOSO, P. D. and J. H. SIMPSON 1994 — Numerical modelling of the M_2 tide on the northern Patagonian Shelf. *Continent. Shelf Res.* **14**(2/3): 267–278.

GUNTHER, M. A. 1936 — A report on oceanographical investigations in the Peru coastal current. *"Discovery" Rep.* **13**: 107–276.

HAMABE, M. and T. SHIMIZU 1959 — Littoral aggregation of the squid at the Oki Islands – 2. *A. Rep. Jap. Sea Reg. Fish. Res. Lab*. **5**: 19–27.

HOLLAND, C. H., GNOLI, M. and K. HISTON 1994 — Concentrations of Palaeozoic nautiloid cephalopods. *Boll. Soc. Paleontol. Ital.* **33**(1): 83–99.

LANE, F. W. 1957 — *Kingdom of the Octopus*. London; Jarrolds: xx + 287 pp.

LIPIŃSKI, M. R. 1979 — Universal maturity scale for the commercially-important squids (Cephalopoda: Teuthoidea). The results of maturity classifications of the *Illex illecebrosus* (LeSueur, 1821) populations for the years 1973–1977. *Res. Docum. int. Commn NW. Atl. Fish.* **79/II/38**: 40 pp.

LUX, F. E., UZMANN, J. R. and H. F. LIND 1978 — Strandings of the short fin squid, *Illex illecebrocus*, in New England in Fall 1976. *Mar. Fish. Rev.* **40**(1): 21–26.

MILLER, A. J. 1996 — Recent advances in California Current modeling : decadal and interannual thermocline variations. *Rep. Calif. coop. oceanic Fish. Invest.* **37**: 69–79.

MULLIN, M. M. 1997 — The demography of *Calanus pacificus* during winter-spring Californian *El Niño* conditions, 1992–1993: implications for anchovy? *Fish. Oceanogr.* **6**(1): 10–18.

MURPHY, E. J., CLARKE, A., SYMON, C. and J. PRIDDLE 1995 — Temporal variation in Antarctic sea-ice: analysis of a long term fast-ice record from the South Orkney Islands. *Deep-Sea Res 1* **42**(7): 1045–1062.

NESIS, K. N. 1983 — *Dosidicus gigas*. In *Cephalopod Life Cycles*. **1**. *Species Accounts*. Boyle, P. R. (Ed.). London; Academic Press: 215–231.

NISHIMURA, S. 1966 — Notes on the occurrence and biology of the oceanic squid, *Thysanoteuthis rhombus* Troschel, in Japan. *Publ. Seto mar. biol. Lab.* **14**(4): 327–349.

O'SULLIVAN, D. B., JOHNSTONE, G. W., KERRY, K. R. and M. J. IMBER 1983 — A mass stranding of the squid *Martialia hyadesi* Rochebrune & Mabille (Teuthoidea: Ommastrephidae) at Macquarie Island. *Pap. Proc. R. Soc. Tasmania* **117**: 161–163.

PIATKOWSKI, U., RODHOUSE, P. G. and G. DUHAMEL 1991 — Occurrence of the cephalopod *Martialia hyadesi* (Teuthoidea: Ommastrephidae) at the Kerguelen Islands in the Indian Ocean sector of the Southern Ocean. *Polar Biol.* **11**(4): 273–275.

PRESCOTT, R. 1977 — The stranding of *Illex illecebrosus*. *Cape Naturalist* **6**: 17–19.

PRIDDLE, J., CROXALL, J. P., EVERSON, I., HEYWOOD, R. B., MURPHY, E. J., PRINCE, P. A. and C. B. SEAR 1988 — Large-scale fluctuations in distribution and abundance of krill - a discussion of possible causes. In *Antarctic Ocean and Resources Variability*. Sahrhage, D. (Ed.). Berlin; Springer: 169–182.

RODHOUSE, P. G. 1990 — Cephalopod fauna of the Scotia Sea at South Georgia: potential for commercial exploitation and possible consequences. In *Antarctic Ecosystems. Ecological Change and Conservation*. Kerry, K. R. and G. Hempel (Eds). Berlin; Springer: 289–298.

RODHOUSE, P. G. 1991 —Population structure of *Martialia hyadesi* (Cephalopoda: Ommastrephidae) at the Antarctic Polar front and the Patagonian Shelf, South Atlantic. *Bull. mar. Sci.* **49**(1–2): 404–418.

SMITHSONIAN INSTITUTE 1974 — California coast squid invasion. Smithsonian Institute, Center shortlived Phenomena events.

STEPHEN, A. C. 1937 — Recent invasion of the squid, *Todarodes sagittatus* (Lam.), on the east coast of Scotland. *Scot. Naturalist* **1937**: 77–80.

VYSHKVARTSEV, D. I., MOKRIN, N. M. and E. B. LEBEDEV 1996 — Stranding (the "yori" phenomenon) of the Japanese flying squid *Todarodes pacificus* Steenstrup, 1880, in a shallow-water inlet of Possiet Bay, Japan Sea. *Ruthenica* **6**(2): 161–166 (in Russian with English abstract).

WILHELM, O. 1930 — Las mortandades de jibias (*Omastrephes* [sic.] *gigas*) en la Bahía de Talcahuano. *Boln. Soc. Biol. Concepción* **1929-30**: 23–38.

WILHELM, O. 1954 — Algunas observaciones acerca de las mortandades de jibias (*Dosidicus gigas* D'Orb) en el littoral de Concepcion. *Revta Biol. mar.* **4**(1–3): 196–201.