Extraordinary numbers of giant squid, *Architeuthis dux*, encountered in Japanese coastal waters of the Sea of Japan from January 2014 to March 2015

Tsunemi Kubodera¹ · Toshifumi Wada² · Masahito Higuchi³ · Akiko Yatabe

Received: 21 July 2016 / Revised: 22 October 2016 / Accepted: 29 November 2016 / Published online: 24 December 2016

© The Author(s) 2016. This article is published with open access at SpringerLink.com

Abstract In total, 57 giant squid, *Architeuthis dux*, were found between January 2014 and March 2015 in Japanese coastal waters in the Sea of Japan. Occurrences were especially high around Sado Island and in Toyama Bay. All of the squid occurred individually, and 28 were found alive. The occurrences were categorized into three groups based on distance from the shore and the depth at which they were found: (1) washed ashore on a beach or found floating at the surface close to a beach (19 individuals); (2) caught in a fixed net set in coastal waters between 50 and 150 m depths (28 individuals); and (3) caught by bottom trawl or bottom gillnet fisheries several kilometers offshore between 200 and 300 m depths (ten individuals). Two size groups were recognized, one ranging between 80 and 160 cm dorsal mantle length (DML) with a mode at 110 cm and another larger than 160 cm DML. The sex ratio in the smaller group was nearly equal and the larger group was comprised of all females. The Sea of Japan was considered to be a large natural trap for giant squid migrating through southwestern Tsushima Strait.

Keywords Giant squid · Sea of Japan · Japanese coastal waters · Winter

Introduction

The giant squid is well known as one of the largest marine invertebrates. Not only marine biologists but also the general public have been fascinated by this elusive creature due to their depiction in popular sci-fi novels and movies (Ellis 1998). Since the first species of giant squid, *Architeuthis dux*, was described by Steenstrup in 1857, more than a dozen ill-described and poorly understood *Architeuthis* species have been reported from all over the world (Clarke 1966, 1980; Roper and Boss 1982). In Japanese waters, two nominal species, *A. martensii* (Hilgendorf, 1880) and *A. japonica* Pfeffer, 1912, the latter of which was named based on *Notes on a gigantic cephalopod* by Mitsukuri and Ikeda (1895), were initially described. However, systematic description of *A. martensii* was inadequate for a distinct species; thus, *A. japonica* had been applied to the giant squid in Japanese waters (Sasaki 1916, 1929; Taki 1965). In the early 1980s, Roper and Boss (1982) suggested that the 19 nominal species, *A. martensii* (Hilgendorf, 1880) and *A. japonica* Pfeffer, 1912, the latter of which was named based on “Notes on a gigantic cephalopod” by Mitsukuri and Ikeda (1895), were initially described. However, systematic description of *A. martensii* was inadequate for a distinct species; thus, *A. japonica* had been applied to the giant squid in Japanese waters (Sasaki 1916, 1929; Taki 1965). In the early 1980s, Roper and Boss (1982) suggested that the 19 nominal species identified at that time actually comprised only three species, *A. dux* in the northern Atlantic, *A. japonica* in the northern Pacific, and *A. sanctipauli* in the Southern Hemisphere.

Roeleveld and Lipinski (1991) gave detailed descriptions of the external and internal morphology of the giant squid based on three specimens from southern African waters. They recognized that the three specimens were actually a single species but they hesitated to give it a species name. Förch (1998) examined 16 specimens of *Architeuthis* obtained from New Zealand waters and revealed that there was very high inter-individual variability in external and internal morphology. Förch (1998) recommended that the family
Architeuthidae be reduced to a single genus and species, *A. dux*, consistent with the earliest adequate systematic description. Recent genetic study on whole mitochondrial DNA of the giant squid (Winkelmann et al. 2013) demonstrated that there was no detectable phylogenetic structure at the mitochondrial level among 43 samples obtained from oceans all over the world, and the level of nucleotide diversity was exceptionally low. These results strongly support the hypothesis that only one global species, *A. dux*, is valid.

Historically in Japan, giant squid have occasionally washed ashore or been seen floating at the surface of coastal waters of the Sea of Japan, and such sightings have become local news media stories (Nishimura 1968; Honma et al. 1983). Okiyama (1993) accumulated occurrence data between 1941 and 1971, creating a distribution map and monthly occurrences based on 20 records. Findings were scattered along the coasts of Shimane, Tottori, Hyogo, Kyoto, Ishikawa, Toyama, and Niigata Prefectures, as well as Sado Island. Seasonally, the giant squid has appeared in limited numbers in the winter from December to March and has been most abundant in February. Okiyama (1993) observed mass occurrences in the winters of 1974–75 (six records) and 1975–76 (seven records), and suggested that significant recruitment of giant squid occurred twice in these two successive years through the Tsushima Strait. Since 1998, the senior author of the current study has compiled giant squid occurrences in Japanese waters and recorded 19 sightings in the Sea of Japan as of March 2012. On average, one or two individuals appear every 2 years, but an exceptional six individuals were found in the winter of 2006–07 (Kubodera 2013).

During two winter seasons of 2014–2015, 57 individuals were found in Japanese coastal waters of the Sea of Japan. No such mass occurrence of giant squid has ever been reported from any corner of the world. Therefore, we present detailed information of each encounter and the known biological data for each individual. We discuss hypothetical scenarios to explain the mass findings of giant squid in 2014 and 2015 based on the oceanographic characteristics of the Sea of Japan and other factors.

**Materials and methods**

Whenever an extraordinarily large squid was discovered and brought to the attention of the prefectural fisheries research center, museum, or aquarium, staff were sent to identify and examine the specimen, including measurement and photographs, and to interview the public member(s) who found the squid. The news media was often present and reported the sightings in the local newspapers and on television.

From January 2014 to March 2015, 57 individuals of extra-large squid were discovered along the coastal area of the Sea of Japan, all of which were identified as *A. dux* based on photos and short notes sent by local experts and/or media reports. In addition to those communications, the second author actually visited most of the sites in the western part of the sighting area in 2014 to collect accurate data and specimens, and the third author similarly covered the sites in Niigata Prefecture and Sado Island.

To understand the oceanographic condition of the Sea of Japan, we referred to tri-monthly 10-day mean horizontal water temperature profiles and temperature anomalies at the surface and at depths of 50, 100, and 200 m from December 2013 to March 2015 obtained from the Japan Meteorological Agency (JMA) (http://www.data.jma.go.jp/gmd/kaiyou/data/db/kaikyo/jun/t100_NK.html). In addition, vertical temperature profiles along the PM line (off Echizen Peninsula) and JAY line (from Nihonkai Basin to Yamato Basin) as observed by JMA research vessels in November 2013 were collected (http://www.data.jma.go.jp/gmd/kaiyou/db/vessel_obs/maizuru/index.php?id=2013aut).

**Results**

The date and location of encounter, situation at finding, depth, type of person who found the squid, person confirming the sighting, and other remarks are summarized in Table 1. The geographic location of each find is plotted in Fig. 1. Biological data of each squid, such as dorsal mantle length (DML; measured dorsally from the tip of the fin to the anteriormost point of the mantle), body length (BL; from the tip of the fin to the longest arm tip), total length (TL; from the tip of the fin to the distal end of the stretched tentacle), body weight (BW), sex, and condition when found are summarized in Table 2. The Appendix presents cases where photos were available.

In total, 57 individuals (24 from January to May 2014 and 33 from September 2014 to March 2015) were found, all of which were confirmed to be giant squid.

**Records of findings**

Giant squid appeared broadly along the Japanese coast from Yamaguchi to Niigata, and high occurrences were seen around Sado Island in January–May 2014 and in Toyama Bay in September 2014–March 2015, with one exception of the northermost record from Aomori Prefecture (Fig. 2). In total, 29 individuals out of 57 were actually found in Niigata and Toyama Prefectures.

Giant squid appeared in the winter months and disappeared during the summer months. High occurrences were seen in March–April 2014 and in January–February 2015 (Fig. 3).
| ID no. | Date | Pref. | City | Lat. (N) | Long. (E) | Situation | Finding depth (m) | C.G. | Discovered by | Reported by | Remarks |
|-------|------|-------|------|---------|----------|-----------|-----------------|------|---------------|------------|---------|
| A-1   | 2014/1/4 | Toyama | Off Himi-shi | 36.54 | 137.04 | Fixed net for Japanese amberjack | <100 | 2 | Fisherman | Fuji News Network (1/4) | Landing on the Himi fishing port |
| A-2   | 2014/1/8 | Niigata | 1 km off Shirose, Sado Is. | 38.07 | 138.27 | Fixed net | 70 | 2 | Fisherman | M. Higuchi | Video footage |
| A-3   | 2014/1/19 | Niigata | Anahama Beach, Kashiwazaki-shi | 37.24 | 138.34 | Stranded | On beach | 1 | Fisherman | K. Minowa | |
| A-4   | 2014/1/20 | Tottori | 30 km off Tottori-shi | 35.52 | 134.11 | Bottom gillnets for flounder | 236 | 3 | Fisherman | T. Wada | |
| A-5   | 2014/2/10 | Niigata | 2 km off Shirose, Sado Is. | 38.08 | 138.30 | Bottom gillnets for anglerfish | <274 | 3 | Fisherman | M. Higuchi | Examined by Higuchi and his co-worker |
| A-6   | 2014/2/13 | Niigata | Off Washizaki, Sado Is. | 38.19 | 138.33 | Fixed net | <159 | 2 | Fisherman | S. Abe | Landing on the Moroyori fishing port |
| A-7   | 2014/2/25 | Hyogo | Off Moroyori, Shinonsen-cho | 35.38 | 134.25 | Floating | Surface | 1 | Fisherman | T. Yamauchi | |
| A-8   | 2014/3/2 | Niigata | On the shore of Shidomari, Sado Is. | 38.08 | 138.29 | Stranded | On beach | 1 | Fisherman | S. Abe | |
| A-9   | 2014/3/4 | Tottori | On the rocky shore of Akasaki, Kotoura-cho | 35.31 | 133.37 | Stranded | On beach | 1 | Fisherman | T. Wada | |
| A-10  | 2014/3/5 | Hyogo | Off Amurabe, Kasumi-ku, Kami-cho | 30.53 | 134.34 | Bottom trawl for firefly squid | <223 | 3 | Fisherman | T. Wada | Displayed at the Kinosaki Marine World |
| A-11  | 2014/3/16 | Niigata | Benten-hama, Isoigawa-shi | 37.04 | 137.56 | Stranded | On beach | 1 | Fisherman | M. Baba | |
| A-12  | 2014/3/24 | Shimane | 30 km off Mishima, Hagi-shi | 35.08 | 131.10 | Bottom trawl | <121 | 3 | Fisherman | T. Fujita | Displayed at the Shimane Aquarium Specimen of NSMT |
| A-13  | 2014/3/26 | Niigata | Off Hayoshi, Sado Is. | 38.07 | 138.26 | Fixed net | <206 | 2 | Fisherman | M. Higuchi | |
| A-14  | 2014/3/26 | Niigata | In the port of Ryotsu, Sado Is. | 38.04 | 138.26 | Floating | Surface | 1 | Fisherman | M. Higuchi | |
| A-15  | 2014/4/7 | Toyama | 1 km off Yokataninomachi, Toyama-shi | 36.46 | 137.15 | Fixed net for firefly squid | <100 | 2 | Fisherman | The Sankei Shimbun (4/7) | |
| A-16  | 2014/4/8 | Toyama | 1.5 km off Izumi-shi | 36.48 | 137.07 | Bottom trawl for Japanese glass shrimp | <300 | 3 | Fisherman | The Sankei Shimbun (4/8) | Landing on the Shin-minato fishing port |
| A-17  | 2014/4/9 | Hyogo | West of Peninsula Nekozaki, Toyooka-shi | 35.40 | 134.45 | Floating | Surface | 1 | Angler | T. Wada | |
| A-18  | 2014/4/12 | Shimane | Off Aika-cho, Matsue-shi | 35.30 | 132.54 | Stranded | On beach | 1 | Angler | The Shikoku Shimbun (4/12) | |
| A-19  | 2014/4/12 | Niigata | Off Waki, Sado Is. | 38.09 | 138.29 | Fixed net | <200 | 2 | Fisherman | M. Higuchi | |
| A-20  | 2014/4/13 | Tottori | At the mouth of Yoshida river, Makidani, Iwami-cho | 35.35 | 134.2 | Stranded | On beach | 1 | Fisherman | T. Wada | |
| A-21  | 2014/4/18 | Ishikawa | 2 km off Ohtomari-machi, Nanao-shi | 36.58 | 137.05 | Fixed net for Japanese amberjack | <94 | 2 | The Hokkoku Shimbun (4/19) | Displayed at the supermarket |
| A-22  | 2014/4/27 | Ishikawa | Off Furrin port, Saikai, Sika-machi | 37.07 | 136.39 | Fixed net | <57 | 2 | Fisherman | S. Ikeguchi | Dissected at the Notojima Seaside Park |
| A-23  | 2014/5/6 | Kyoto | North off Kyoatungo-cho, Kyoatungo-shi | 35.52 | 135.05 | Bottom trawl | <218 | 3 | Fisherman | Y. Ueno | |
| A-24  | 2014/5/7 | Niigata | Off Awashima Is, Awashima-mura | 38.26 | 139.17 | Bottom trawl | <79 | 3 | Fisherman | T. Fujita | |
| B-1   | 2014/9/4 | Shimane | Off Hamada-shi | 35.02 | 131.39 | Fixed net | 120 | 2 | Fisherman | T. Fujita | Exhibited at Shimane Aquarium |
| ID no. | Date       | Pref.     | City                                      | Lat. (N) | Long. (E) | Situation                      | Finding depth (m) | C.G. | Discovered by | Reported by                  | Remarks                                                                 |
|--------|------------|-----------|-------------------------------------------|----------|-----------|--------------------------------|-------------------|------|---------------|-------------------------------|------------------------------------------------------------------------|
| B-2    | 2014/10/22 | Fukui     | 900 m off Komeno, Echizen-cho             | 35.53    | 135.58    | Fixed net                     | 65                | 2    | Fisherman     | S. Sasai                     | Exhibited at Echizen Matsushima Aquarium for four days                |
| B-3    | 2014/11/8  | Niigata   | 1 km off Wakl, Sado Is.                   | 38.09    | 138.29    | Fixed net                     | <200              | 2    | Fisherman     | The Asahi Shimbun (11/11)     | Displayed at the Fish Festival Landing on the Sakai port               |
| B-4    | 2014/11/20 | Tottori   | East off Okinoshima                       | 36.16    | 133.4     | Purse seine                   | –                 | 3    | Fisherman     | K. Ichisawa                   | Exhibited and exhibited at Echizen Matsushima Aquarium                |
| B-5    | 2014/11/24 | Fukui     | Around Onami-jima, Wakasa-cho             | 35.38    | 135.47    | Fixed net?                    | <60               | 2    | Fisherman     | The Chunichi Shimbun (11/24) |                                                                       |
| B-6    | 2014/11/24 | Kyoto     | 1 km off Tango-cho, Kyotango-shi          | 35.45    | 135.04    | Floating at surface           | Surface           | 1    | Angler        | Y. Ueno                       | Left undisturbed                                                        |
| B-7    | 2014/11/27 | Toyama    | 3.3 km off Yahatacho, Yozu-cho            | 36.49    | 137.07    | Bottom trawl for glass shrimp | 330               | 3    | Fisherman     | The Chunichi Shimbun (11/27) | Served in an event after hard-cured                                   |
| B-8    | 2014/12/9  | Hyogo     | Kihama beach, Takeno-cho, Toyooka-shi     | 35.39    | 134.44    | Stranded                      | On beach          | 1    | Local people  | T. Wada                      | Specimen of the Museum of Nature and Human Activities, Hyogo          |
| B-9    | 2014/12/23 | Kyoto     | Off Ineura, Ine-cho, Yozu-cho             | 35.38    | 135.17    | Fixed net                     | <60               | 2    | Fisherman     | Y. Ueno                       | Exhibited at the Kyoto Aquarium for two days                           |
| B-10   | 2014/12/24 | Kyoto     | Hengpo beach, Ine-cho, Yozu-cho           | 35.43    | 135.16    | Stranded                      | On beach          | 1    | Local people  | Y. Ueno                       | Recovered by Kyoto Prefectural Agriculture, Forestry and Fisheries Technology Center |
| B-11   | 2014/12/28 | Fukui     | 600 m off Tomari, Obama-shi               | 35.32    | 135.42    | Fixed net                     | <20               | 2    | Fisherman     | Fukui Shimbun (12/28)         | Disposal in the ocean                                                  |
| B-12   | 2014/12/31 | Toyama    | 2 km off Toyama-shi                       | 36.47    | 137.13    | Fixed net                     | <100              | 2    | Fisherman     | Fuji News Network (12/31)     | Video footage                                                          |
| B-13   | 2015/1/6   | Tottori   | Oobanoe beach, Iwami-cho                  | 35.36    | 134.2     | Stranded                      | On beach          | 1    | Local people  | Y. Kyousue                   |                                                                         |
| B-14   | 2015/1/13  | Aomori    | South of Tsubaki-yama, Henashi, Fukuaura-machi | 40.35    | 139.51    | Stranded                      | On beach          | 1    | Fisherman     | E. Koganezaki                 | Empty stomach                                                          |
| B-15   | 2015/1/15  | Toyama    | 500 m off Iino, Nyo-cho                   | 36.56    | 137.25    | Fixed net for amberjack       | 50-60             | 2    | Fisherman     | M. Kanbayashi                 | Exhibited at Michinoeiki Shimmintaro                                  |
| B-16   | 2015/1/19  | Toyama    | 2 km off Shimminato, Hachiman-machi, Imizu-shi | 36.47    | 137.06    | Fixed net                     | 60                | 2    | Fisherman     | The Toyama Shimbun (1/20)     | Video footage                                                          |
| B-17   | 2015/1/19  | Toyama    | 2 km off Yokata-fishing port, Toyama-shi  | 36.46    | 137.11    | Fixed net                     | 90                | 2    | Fisherman     | Fuji News Network (1/19)      | Caught with a school of Japanese common squid                         |
| B-18   | 2015/1/22  | Toyama    | 2 km off Iwase, Toyama-shi                | 36.47    | 137.14    | Fixed net for amberjack       | –                 | 2    | Fisherman     | The Kitanippop Shimmintaro (1/23) |                                                                         |
| B-19   | 2015/1/29  | Toyama    | Off Shinminato, Hachiman-machi, Imizu-shi | 36.47    | 137.07    | Fixed net                     | –                 | 2    | Fisherman     | The Kitanippop Shimmintaro (1/30) |                                                                         |
| B-20   | 2015/1/29  | Toyama    | Off Shinminato, Hachiman-machi, Imizu-shi | 36.47    | 137.07    | Fixed net                     | –                 | 2    | Fisherman     | The Kitanippop Shimmintaro (1/30) |                                                                         |
| B-21   | 2015/2/3   | Toyama    | 2 km off Yokata-fishing port, Toyama-shi  | 36.46    | 137.11    | Fixed net                     | 78.4              | 2    | Fisherman     | Fuji News Network (2/4)       |                                                                         |
| B-22   | 2015/2/4   | Toyama    | 1 km off Aoshima, Uozu-shi                | 36.5     | 137.23    | Fixed net                     | –                 | 2    | Fisherman     | Toyama Television Broadcasting (2/4) |                                                                         |
Table 1 (continued)

| ID no. | Date   | Pref.    | City                  | Lat. (N) | Long. (E) | Situation | Finding depth (m) | C.G. | Discovered by     | Reported by                       | Remarks                              |
|--------|--------|----------|-----------------------|----------|-----------|-----------|-------------------|------|-------------------|------------------------------------|--------------------------------------|
| B-23   | 2015/2/6 | Ishikawa | 500 m off Kodomari, Misakimachi, Suzu-shi | 37.26    | 137.22    | Fixed net | 40                | 2    | Fisherman         | The Hokkoku Shim bun (2/6)           | Was released                          |
| B-24   | 2015/2/7 | Ishikawa | 2 km off forimachi, Nanao-shi | 37.02    | 137.04    | Fixed net | –                 | 2    | Fisherman         | The Yomiuri Shim bun (2/8)           | Exhibited in Notojima Seaside Park    |
| B-25   | 2015/2/7 | Ishikawa | 2 km off Shichimi, Noto-cho | 37.15    | 137.07    | Fixed net | –                 | 2    | Fisherman         | The Yomiuri Shim bun (2/8)           | Exhibited in Notojima Seaside Park    |
| B-26   | 2015/2/16 | Niigata | 1.5 km off Shirouse, Sado Is. | 38.07    | 138.28    | Fixed net | –                 | 2    | Fisherman         | The Niigata Nippo (2/16)             | Exhibited at a local supermarket     |
| B-27   | 2015/2/17 | Fukui   | Gunkan rock, Gunma-cho, Fukui-shi | 36.02    | 136       | Stranded  | At rock reef      | 1    | Local people      | S. Sasaí                          | Dissected and discarded              |
| B-28   | 2015/2/18 | Yamaguchi | Tsunoshima, Toyokita-cho, Shimonoseki-shi | 34.21    | 130.51    | Stranded  | At rock reef      | 1    | Tourist           | The Yamaguchi Shim bun (2/19)        | Exhibited at the Shimonoseki Kaikyokan during a period of the summer holiday |
| B-29   | 2015/2/23 | Toyama  | Ferry pier Koshinokata-machi, Inazushi | 36.46    | 137.06    | Floating  | 1                 | 1    | A harbor official | Tulip-tv (2/23)                     | Swum away                             |
| B-30   | 2015/3/1 | Toyama  | 1–3 km off Namerikawa-shi, Namurama-cho, Fukui-shi | 36.47    | 137.19    | Fixed net for firefly squid | –     | 2    | Fisherman         | Toyama Television Broadcasting (3/1) | Disposal in the oceans                |
| B-31   | 2015/3/1 | Fukui   | Off Takasu, Hamamu-cho, Fukui-shi | 36.07    | –         | Bottom trawl | 200   | 3    | Fisherman         | S. Sasaí                          |                                      |
| B-32   | 2015/3/10 | Niigata | Oshiki beach, Nishiyama-cho, Kashiwazaki-shi | 37.29    | 138.38    | Stranded  | On beach          | 1    | Local people      | K. Minowa                        |                                      |
| B-33   | 2015/3/26 | Niigata | Yoneyama beach, Kashiwazaki-shi | 37.18    | 138.25    | Stranded  | On beach          | 1    | Local people      | M. Baba                          | Swept out to sea                     |

C.G. Categorized group: 1 = washed ashore or floating; 2 = fixed net, shallow; 3 = bottom trawl, deep

a Niigata Prefectural Fisheries and Marine Institute
b Kashiwazaki City Museum
c NHK (Japan Broadcasting Corporation)
d Joetsu Aquarium Museum
e Shimane Aquarium
f Notojima Seaside Park
g Fisheries Technology Department; Kyoto Prefectural Agriculture, Forestry and Fisheries Technology Center
h Echizen Matsushima Aquarium
i Tottori Prefectural Museum
j Museum of Nature and Human Activities, Hyogo
k Ajigasawa Fisheries Office
l Kitanihon Broadcasting
Situation at finding

Among the 57 cases, 28 individuals were found alive, 22 were found dead, and this information was unavailable for seven (Fig. 4). All specimens were grouped according to distance from the shore and depth at which they were found: (1) individual washed ashore onto a beach or found floating at the surface close to a beach (19 cases); (2) individual was caught by a fixed net set in coastal waters at depths between 50 and 150 m (28 cases); (3) individual was caught by bottom trawl or bottom gillnet fisheries operating several kilometers off shore at depths between 200 and 300 m (ten cases) (Fig. 5). Half of these were trapped in fixed nets set in coastal waters shallower than 150 m depth (Table 1)).

Biological information

The DML of 36 of the 57 individuals was measured, the BL was measured for 31, and the TL, including tentacles, was measured for 20. BW was roughly measured in 20 individuals and sex was determined in 19 individuals (Table 2). DML, BL, TL, and BW ranged between 84–196 cm, 270–446 cm, 260–637 cm, and 25.2–ca. 200 kg, respectively. The sex ratio was eight females to five males. The measurements recorded for each specimen varied, so the summary that follows also varies in what can be summarized. The smallest female was 84 cm DML, 448 cm TL, and 33.2 kg BW, and the smallest male was 91 cm DML, 394 cm TL, and 25.2 kg BW. The largest female was 196 cm DML, 446 cm BL, and ca. 200 kg BW, and the largest male was 150 cm DML, 350 cm BL, and BW unknown. Two size groups were recognized, one with a DML of 80–160 cm with a mode at 110 cm and another with a DML of >160 cm with a mode at 170 cm (Fig. 6). The former group had a nearly equal sex ratio. The latter group was all females except for unexamined individuals.

Discussion

The Sea of Japan is a 978,000-km² marginal sea, located in the western periphery of the North Pacific. It is bordered by the Eurasian continent to the west and the Japanese archipelago to the east, and is connected to the Okhotsk Sea through the narrow Soya Strait to the north, to the North Pacific through Tsugaru Strait in the east, and to the East China Sea through the narrow Tsushima Strait to the south. The average depth is about 1667 m and its deepest point is 3742 m. The warm Tsushima Current flows into the Sea of Japan through Tsushima Strait from the south and runs along the Japanese coast to the north and flows out through Tsugaru Strait into the North Pacific and through Soya Strait into the Okhotsk Sea. Due to the narrow (ca. 200-km width) and shallow (90–130-m depth) geography of Tsushima Strait, limited water circulation occurs in the upper layers shallower than ca. 300 m depth. Deeper than that, so-called “Japan Sea Proper Water”, which is characterized by extremely cold (0–1 °C) and high salinity (34.1 PSU) water, is distributed throughout the Sea of Japan (http://www.jma-net.go.jp/jsmarine/japansea.html).

Giant squid are estimated to live in mesopelagic waters of temperate open oceans (Clarke 1966; Roper and Boss 1982).
Kubodera and Mori (2005) revealed that a giant squid off the Ogasawara Islands in the North Pacific appeared at 900 m depth and swam up to 600 m to escape from a jig on which its tentacle was hooked. They reported that the water temperatures at 900 and 600 m depth were about 4 and 6 °C, respectively. This evidence suggests that giant squid in the Sea of Japan might not be permanent residents but, rather, migrants from the south, passing through bottom layer waters of the Tsushima Strait when the water temperature there decreases to below ca. 6 °C in mid-winter to early spring. Once they have traveled into the Sea of Japan, water temperatures in the deep layer are too cold and they probably move through the water column to the more suitable temperature zone between the warm surface layer and the cold Japan Sea Proper Water during summer to fall.

Okiyama (1993) suggested a possible reason for why giant squid have been occasionally found dead on beaches or caught in fixed nets set in Japanese coastal waters of the Sea of Japan during winter to early spring. At the beginning of winter, the surface water is cooling down

### Table 2  Biological data of the giant squids summarized in Table 1

| ID no. | DML (cm) | BL (cm) | TL (cm) | BW (kg) | Sex | Condition | Tentacle | Remarks |
|--------|----------|---------|---------|---------|-----|-----------|----------|--------|
| A-1    |          | 350     | –       | –       | –   | Dead      | Absent   | –      |
| A-2    | 187      | 406     | –       | 163     | F   | Alive     | Absent   | –      |
| A-3    |          | –       | –       | –       | –   | Dead      | Absent   | –      |
| A-4    | 170      | 340     | –       | –       | F   | Alive     | Absent   | –      |
| A-5    | 136      | 305     | –       | ca. 100 | M   | Alive     | Absent   | –      |
| A-6    | 91       |         | –       | 394     | 25.2| M         | Alive    | –      |
| A-7    | 410      | –       | ca. 200 | F       | Alive | Absent   | –       | –      |
| A-8    | 135      | 285     | –       | –       | F   | Dead      | Absent   | –      |
| A-9    | 120.8    | –       | 462.5   | –       | –   | Dead      | –       | –      |
| A-10   | 123      | –       | 430     | 50      | –   | Dead      | Present  | –      |
| A-11   | 196      | 446     | –       | ca. 200 | F   | Alive     | Absent   | –      |
| A-12   | 116      | 270     | 570     | –       | M   | –         | Present  | –      |
| A-13   | 84       | –       | 448     | 33.2    | F   | Alive     | Present  | –      |
| A-14   | 110      | –       | 435     | 37.7    | M   | Alive     | Present  | –      |
| A-15   | 150      | –       | 350     | –       | M   | Alive     | Absent   | –      |
| A-16   | 110      | 275     | 510     | –       | M   | Alive     | Present  | –      |
| A-17   | 112      | –       | 594     | –       | –   | Dead      | Present  | –      |
| A-18   |          | –       | ca. 500 | –       | –   | Alive     | –        | –      |
| A-19   | ca. 100  | –       | –       | –       | –   | –         | –        | –      |
| A-20   | 121.5    | –       | 637     | –       | F   | Dead      | Present  | –      |
| A-21   |          | –       | 480     | 30      | –   | Dead      | Present  | –      |
| A-22   | 111      | 289     | –       | 565     | 60  | F         | Alive    | –      |
| A-23   | ca. 100  | –       | –       | –       | –   | Dead      | –        | –      |
| A-24   | 92       | –       | 420     | –       | –   | –         | –        | –      |
| B1     | 140      | 314     | –       | –       | M   | –         | Absent   | –      |
| B-2    | 117      | 264     | 288     | ca. 40  | M   | –         | Absent   | –      |
| B-3    |          | –       | 260     | –       | –   | –         | –        | –      |
| B-4    | 183.5    | –       | –       | 130     | F   | Dead      | Absent   | –      |
| B-5    | 137      | –       | 740     | 60      | –   | Alive     | Absent   | –      |
| B-6    |          | –       | –       | –       | –   | Dead      | Absent   | –      |
| B-7    | 155      | –       | 630     | –       | –   | Alive     | Present  | –      |
| B-8    |          | 350     | –       | ca. 100 | –   | –         | Absent   | –      |
| B-9    |          | 320     | –       | ca. 70  | –   | Alive     | Absent   | –      |
| B-10   | 178      | –       | 507     | ca. 100 | –   | Dead      | One side only | – |
| B-11   |          | ca. 300 | –       | –       | –   | –         | –        | –      |
| B-12   |          | –       | –       | –       | –   | –         | –        | –      |
| B-13   | 180.5    | 355     | –       | –       | –   | –         | –        | –      |
| B-14   | 127      | –       | –       | –       | –   | –         | –        | –      |
| B-15   | 420      | –       | –       | –       | –   | –         | Absent   | –      |
| B-16   |          | –       | ca. 600 | ca. 200 | –   | –         | –        | –      |
| B-17   |          | ca. 300 | –       | –       | –   | Alive     | –        | –      |
| B-18   | ca. 200  | –       | ca. 600 | –       | –   | –         | –        | –      |
| B-19   |          | ca. 400 | –       | –       | –   | –         | –        | –      |
| B-20   |          | –       | –       | –       | –   | –         | –        | –      |
| B-21   |          | ca. 400 | –       | –       | –   | –         | –        | –      |
| B-22   |          | –       | –       | –       | –   | –         | –        | –      |
| B-23   |          | 335     | –       | –       | –   | –         | –        | –      |
| B-24   |          | 420     | –       | ca. 200 | –   | –         | –        | –      |
| B-25   |          | 360     | –       | ca. 150 | –   | –         | –        | –      |
| B-26   |          | 415     | –       | –       | –   | –         | –        | –      |
| B-27   |          | 175     | 377     | F       | Dead | Absent   | –        | –      |
| B-28   |          | 286     | –       | 65.5    | –   | Dead      | Absent   | –      |
| B-29   |          | 250-300 | –       | –       | –   | –         | –        | –      |
| B-30   |          | ca. 200 | –       | –       | –   | –         | –        | –      |
| B-31   | 177      | 376     | –       | –       | F   | Dead      | Absent   | Empty stomach |
| B-32   | 161      | 327     | –       | –       | –   | Dead      | Absent   | –      |
| B-33   | 190      | 360     | –       | –       | –   | Dead      | Absent   | –      |
from the northern peripheries along the continental coasts and the cold surface water at 0–1 °C subsides into deeper stratum, which is the origin of the Japan Sea Proper Water. Cold water subsidence commences from the north and gradually extends to the south as winter progresses. This cold water movement might reduce the suitable temperature habitat of the giant squid both horizontally and vertically. They are forced to move southward and to shallower depths. Some individuals would be weakened by exposure to extremely cold waters and then transported by eddies of the Tsushima Current and strong northwesterly seasonal winds, which would result in them coming closer to Japanese coastal waters and explain them being stranded on beaches along the Japanese coast.

Although this is one possible explanation for the occurrence of giant squid in Japanese coastal waters of the Sea of Japan, the unusual mass findings of giant squid in 2014 and 2015 are likely due to a different mechanism. Judging from 10-day and monthly mean water temperature anomalies at the surface and 100 m depths during the winter seasons of 2014 and 2015, the water temperatures at these depths were apparently lower in both years than usual, especially in January 2014 and February 2015. Prominent large-scale cold water masses that developed in the middle layer of the central portion of the Sea of Japan in 2014 and 2015 might have worked strongly to carry the giant squid to the surface layer and towards the Japanese coast. In addition, although there were few records of giant squid during 2008–2013 (Kubodera, personal observation), it is possible that a number of giant squid entered the Sea of Japan during these years and survived there until 2014.

One of the important biological findings of giant squid deduced from the recent mass findings is the bimodal size frequency distribution (80–160 cm DML with a mode at 110 cm and 160–190 cm DML with a mode at 170 cm DML) in winter season. The smaller group had a nearly even sex ratio and the larger group was comprised entirely of females. Wada et al. (2015) recently reported that two young giant squid measuring 33 cm DML were caught by purse seine net in the southwestern Sea of Japan on June 14, 2013. Assuming that a young giant squid measuring 33 cm DML in June grows to 110 cm DML by January, the monthly growth rate would be ca. 11 cm DML. This value represents very rapid growth and an inclination towards an S-growth curve, with lower growth rates in earlier and later life stages. The overall size composition of giant squid in the Sea of Japan suggests a longevity of 2 years for males and 3 years for females.

Roper and Shea (2013) reviewed current knowledge on the taxonomy and systematics, distribution, population size, habitat use, age and growth, predation and feeding, reproduction and life cycles, and functional morphology of giant squid and found wide gaps. The present mass findings of 57 individuals within a relatively short period of time, two winter seasons between 2014 and 2015, and

![Fig. 2](image2.png) Regional occurrences of giant squid along the Japanese coast of the Sea of Japan from Yamaguchi Prefecture to Aomori Prefecture (i.e., south to north)

![Fig. 3](image3.png) Monthly occurrences of giant squid along the Japanese coast of the Sea of Japan from January to March 2015 by sex (blue: male, pink: female, gray: undetermined)
Roper et al. (2015) investigated records of giant squid that were discovered in the western North Atlantic Ocean between Newfoundland and the Gulf of Mexico and provided detailed information on 28 individuals found during 1952–2011. They recognized a general upwards trend in the number of sightings in the 1990s and 2000s, reflecting the increased scientific awareness and growing popular interest in giant squid. In Japan, we had two large events concerning giant squid in 2013. One was a TV program airing on Japan’s national public broadcasting organization, NHK, in January, which broadcast the first encounter with a live giant squid using a manned submersible in the deep sea off the Ogasawara Islands. The other was a special exhibition entitled “The Deep” held at the National Museum of Nature and Science in Tokyo from July to September, in which a preserved giant squid specimen as well as videos of live giant squid filmed for the first time were introduced. These two events made Japanese people, especially the younger generations, become more interested in the giant squid. Such a boom in attention directed towards giant squid and other deep-sea creatures likely increases the awareness of giant squid among people in coastal regions and encourages them to alert the media and local experts to any findings.

We also suggest that the Sea of Japan may work as a large natural trap for giant squid migrating from the south during early spring. Their distribution spreads widely into the mid-layers, which are within their suitable water temperature zone, and they continue to grow during summer and fall. In winter, the oceanographic characteristics of the Sea of Japan may compel giant squid to move southward and to shallower surface waters, where the coastal eddy of the Tsushima Current and strong westward seasonal winds may carry them to Japanese coastal waters, where they become entangled in fixed nets or stranded on beaches. For future “giant squid” research, the Japanese coasts of the Sea of Japan during the winter months would be the most suitable area to encounter live giant squid.

Acknowledgements We would like to offer our special thanks to the following people who provided us with valuable information: K. Minowa (Kashiwazaki City Museum), T. Yamaguchi (NHK Japan Broadcasting Corporation), M. Baba (Joetsu Aquarium Museum), T. Fujita (Shimane Aquarium), S. Ikeguchi (Notojima Seaside Park), Y. Ueno (Fisheries Technology Department, Kyoto Prefectural Agriculture, Forestry and Fisheries Technology Center), S. Sasai (Echizen Matsushima Aquarium), K. Ichisawa (Tottori Prefectural Museum), E. Kongozaki (Ajigasawa Fisheries Office) , and M. Kanbayashi (Kitanihon Broadcasting).

Open Access This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

References
Clarke MR (1966) A review of the systematics and ecology of oceanic squids. Adv Mar Biol 4:91–300
Clarke MR (1980) Cephalopoda in the diet of sperm whales of the southern hemisphere and their bearing on sperm whale biology. Discov Rep 37:1–324
Ellis R (1998) The search for the giant squid. Lyons Press, Guilford, CT

Fürch EC (1998) The marine fauna of New Zealand: Cephalopoda: Oegopsida:Architeuthidae (giant squid). National Institute of Water Atmospheric Research (NIWA) Biodiversity Memoir 110, 113 pp

Hilgendorf F (1880) Über einen riesigen Tintenfisch aus Japan. Megateuthis martensi g.n., sp.n. Sitzungsbericht Gesellschaft naturforscher Freude, Berlin, 4, pp 65–67 (in German)

Honma Y, Kitami T, Mizusawa R (1983) Records of cephalopoda in the waters adjacent to Niigata and Sado Island in the Japan Sea, based partially on the pelagic squids stranded ashore. Bull Biogeogr Soc Jpn 38(12):23–29 (in Japanese with English abstract)

Kubodera T (2013) Miracle encounter of the giant squid. Shinchosha, Tokyo, 180 pp (in Japanese)

Kubodera T, Mori K (2005) First-ever observations of a live giant squid in the wild. Proc R Soc Lond B Biol Sci 272:2583–2586. doi:10.1098/rspb.2005.3158, 4 pp

Mitsukuri K, Ikeda S (1895) Notes on a gigantic cephalopod. Zool Mag Tokyo 7:39–50

Nishimura S (1968) A preliminary list of the pelagic cephalopoda from the Japan Sea. Publication of the Seto Marine Biological Laboratory XVI(1):71–83

Okiyama M (1993) Kinds, abundance and distribution of the oceanic squids in the Sea of Japan. In: Okutani T, O’Dor RK, Kubodera T (eds) Recent advances in cephalopod fisheries biology. Tokai University Press, Tokyo, pp 404–451

Pfeffer G (1912) Die cephalopodan der plankton expedition. Zugleich eine monographische heuebersicht der oegopsiden cephalopodan. Ergebnisse der Plankton Expedition der Humboldt Stiftung 2:1–815 (in German)

Roeleveld MAC, Lipinski MR (1991) The giant squid Architeuthis in southern African waters. J Zool 224:431–477

Roper CFE, Boss KJ (1982) The giant squid. Sci Am 246:82–89

Roper CFE, Shea EK (2013) Unanswered questions about the giant squid Architeuthis (Architeuthidae) illustrate our incomplete knowledge of coleoid cephalopods. Am Malacol Bull 31(1):109–122

Roper CFE, Judkins H, Voss NA, Shea E, Dawe E, Ingroo D, Rothman PL, Roper IH (2015) A compilation of recent records of the giant squid, Architeuthis dux (Steenstrup, 1857) (Cephalopoda) from the western North Atlantic Ocean, Newfoundland to the Gulf of Mexico. Am Malacol Bull 33(1):78–88

Sasaki M (1916) Notes on oegopsid cephalopods found in Japan. Annotationes Zoologicae Japonenses 9:89–120

Sasaki M (1929) A monograph of the dibranchiate cephalopods of the Japanese and adjacent waters. J Fac Agric Hokkaido Imp Univ 20(suppl):1–357

Steenstrup J (1857) Oplysninger om Atlanterhavets colossale Blaeksprutter. Forhandlinger ved de Skandinaviske Naturforskeres Syvende Mode 7:182–185 (in Danish)

Taki I (1965) Class cephalopoda. In: Uchida T (eds) New illustrated encyclopedia of the fauna of Japan, pt. II. Hokuryu-kan Publishing, Tokyo, pp 307–326 (in Japanese)

Wada T, Kubodera T, Yamada M, Terakado H (2015) First records of small-sized young giant squid Architeuthis dux from the coasts of Kyushu Island and the south-western Sea of Japan. Mar Biodivers Rec 8:1–8

Winkelmann I, Campos PF, Strugnell J, Cherel Y, Smith PJ, Kubodera T, Alcock L, Kampmann ML, Schroder H, Guerra A, Norman M, Finn J, Ingroo D, Clarke M, Gilbert MTP (2013) Mitochondrial genome diversity and population structure of the giant squid Architeuthis: genetics sheds new light on one of the most enigmatic marine species. Proc R Soc Lond B Biol Sci 280:20130273