Bulletin of the Seismological Society of America, Vol. XX, No. XX, pp. –, – 2019, doi: 10.1785/0120190014

Ⓔ

Short Note

Is Japanese Folklore Concerning Deep-Sea Fish Appearance a Real Precursor of Earthquakes?

by Yoshiaki Orihara, Masashi Kamogawa, Yoichi Noda, and Toshiyasu Nagao

Abstract In Japan, folklore says that uncommon appearances of deep-sea fish are an earthquake precursor. If this folklore is proved to be true, the appearance of deep-sea fish could be useful information for disaster mitigation. However, a statistical survey has not been conducted on this subject because a database of such information had yet to be compiled. In Japanese domestic local newspapers, such appearances have often been reported because rare appearances might attract readers. The authors constructed a database of reports from newspapers, academic articles, and the marine museum. In this study, fish species generally implicated in earthquakes, such as oarfish and slender ribbonfish, were the focus. Although the catalog used might not include all of the events of deep-sea fish appearances around Japan because of a lack of whole coverage observation, the earthquake occurrence rate after deep-sea fish appearances can be evaluated. Thus, the usefulness of the deep-sea fish appearance information for disaster mitigation was evaluated. From this investigation, the spatiotemporal relationship between deep-sea fish appearances and earthquakes was hardly found. Hence, this Japanese folklore is deemed to be a superstition attributed to the illusory correlation between the two events.

Supplemental Content: Information on deep-sea fish appearances around Japan from 26 November 1928 to 11 March 2011.

Introduction

In Northern Europe, the ancient Norwegians believed that if someone injured an oarfish, a deep-sea fish known as the King of Herrings, then herring fishing would result in a poor catch. In addition, the Native Americans of the Pacific Northwest believed a similar taboo for ribbonfishes (Herald, 1961). In Japan, folklore surrounds the appearance of deep-sea fish. For example, deep-sea fish washing ashore, being caught in fishing nets as bycatch, and being sighted near the sea surface all denote a possible earthquake precursor. Kikuoka (1743) reported that a large earthquake occurred 30 days after the appearance of deep-sea fish. Suehiro (1968) associated three earthquake occurrences with three appearances of deep-sea fish: (1) a magnitude (M) 4.7 earthquake that occurred near Niijima Island in 1963, with oarfish caught nearby two days before the earthquake; (2) an M 7.8 earthquake off the coast of Tokachi in 1963 that coincided with a giant squid caught near the Miura Coast, an Atlantic snipe eel caught off the coast of Kushiro, and a long-snouted lancetfish near the Kozu Coast, two days, three days, and eight days before the earthquake, respectively; and (3) an M 6.6 earthquake in Uwajima Bay in 1968 that was preceded by oarfish being caught near the epicenter three months and one month before the earthquake. Folklore regarding deep-sea fish appearances denoting earthquake precursors may have been believed because of such correlations. However, Honma (1990) claimed that oarfish and slender ribbonfish appearances before the 1964 M 7.5 Niigata and the 1983 M 7.7 Sea of Japan earthquakes were of no association because they were not spatiotemporally correlated. The three appearances mentioned by Suehiro (1968) are doubtful for the following reasons. First, the M 4.7 earthquake was too small of a magnitude to discuss the association because M 4.7 and higher earthquakes frequently occur in Japan without similar reports of deep-sea fish appearances. Second, both the Miura and Kozu Coasts were located ~500 km south from the epicenter of the M 7.8 earthquake, which is too large of a distance to consider an association. Third, a three-month lead time to an earthquake is too great for an association.

However, there are still a number of websites operated by amateur researchers claiming that deep-sea fish appearances are an earthquake precursor. Like Suehiro (1968), the

Downloaded from https://pubs.geoscienceworld.org/ssa/bssa/article-pdf/doi/10.1785/0120190014/4753567/bssa-2019014.1.pdf
by Tokai University user

authors of these websites tend to discuss associations between deep-sea fish appearances and earthquakes without statistically considering the earthquake magnitude, distance from the epicenter, and lead time. In addition, some of them claim that deep-sea fish are aware of certain earthquake precursor signals near the seabed. Although this is merely a hypothesis, it is a plausible explanation. Hence, they may have a firm belief that the appearance of deep-sea fish denotes an earthquake precursor. Deep-sea fish appearances preceding an imminent earthquake are an unusual animal behavior, making them a macroscopic anomaly. Woith *et al.* (2018) reviewed 180 articles concerning unusual animal behaviors before earthquakes and claimed that many of them had weak or even defective arguments, such as the time series was too short, normal behavior that was not defined, and the definition of the anomalous behavior was not quantitative or strict enough. The review suggested that the study of macroscopic anomalies was problematic not only in amateur research but also in academic articles.

Other researchers suggested that unusual animal behaviors preceding earthquakes are not an earthquake precursor at all. Grant and Conlan (2013) claimed that swarms of frogs before earthquakes, which were also reported in the 2008 Sichuan earthquake (moment magnitude: M_w 7.9), were not unusual behavior and that such information could cause false alerts in seismic hazard locations. In other words, it could be argued that if an unusual animal behavior is a true alert, the information could be useful for disaster mitigation. Orihara and Noda (2015) suggested that a mass stranding of Melon-headed whales (*Peponocephala electra*) seven days before the 2011 Tohoku earthquake (M_w 9.0) was not an earthquake precursor.

So far, it has been difficult to discuss deep-sea fish having the ability to detect earthquake precursor signals partly because there have not been enough events reported for statistical purposes. However, there have been reports of deep-sea fish appearances cataloged regardless of the earthquake association. Nishimura (1962) reported the number of slender ribbonfish that appeared around Japan between 1958 and 1961. Honma *et al.* (2011) reported the number of order lampriformes, including slender ribbonfish, around Niigata Prefecture in the 1970s. There have also been other academic reports (Kashiyama *et al.*, 2004; Kadowaki *et al.*, 2010; Sakiyama and Senou, 2012) dealing with a limited time period, area, or species. Because deep-sea fish appearances are a rare event, articles about their appearances have often been reported in newspapers, especially local ones. Orihara *et al.* (2018) constructed a catalog of deep-sea fish appearances using not only academic articles as references (Nishimura, 1962; Kashiyama *et al.*, 2004; Kadowaki *et al.*, 2010; Honma *et al.*, 2011; Sakiyama and Senou, 2012) but also newspaper articles archived in libraries and marine museum reports. Although this catalog might not cover the total number of deep-sea fish appearances around Japan, the earthquake occurrence rate (EOR) after deep-sea fish appearances can now be evaluated. In other words, the EOR may show the utility value of deep-sea fish appearance information as an earthquake alert. In this article, we investigate the relationship between deep-sea fish appearances and large earthquakes using this catalog and evaluate the usefulness of deep-sea fish appearance information for disaster mitigation.

Methods

The period of time covered by the catalog was from 26 November 1928 to 11 March 2011 (Orihara *et al.*, 2018). The total number of deep-sea fish appearances was 392, and the total number of species was 45. The newspapers that referred to earthquake precursor as local folklore were 8 of 45 species reported overall, which included oarfish (*Regalecus glesne*), slender ribbonfish (*Trachipterus ishikawae*), Mediterranean dealfish (*Trachipterus trachypterus*), ateleopus tanabensis (*Ateleopus tanabensis*), jellynose fish (*Ateleopus japonicus*), polka-dot ribbonfish (*Desmodema polystictum*), scalloped ribbonfish (*Zu cristatus*), and unicorn crestfish (*Eumecichthys fiski*). In this study, we used data associated with these eight species from 336 events (Ⓔ Table S1, available in the supplemental content to this article). The newspapers referred to earthquake precursors based on the folklore, which means the article might be unbiased because it was issued regardless of earthquake occurrence.

Wadatsumi (1995) claimed that a magnitude of all 25 past earthquakes with precursor phenomena in Japan was more than 6.0. Therefore, earthquakes with magnitudes greater than 6.0 and depths less than 100 km were selected from the Japan Meteorological Agency seismic catalog from longitudes 122° to 150° east and from latitude 20° to 47° north during the same period as the deep-sea fish appearances. Thus, any earthquakes that occurred within a 100 km radius and within 30 days were excluded as aftershocks. After this declustering process, 678 earthquakes were selected.

Figure 1 shows the annual number of deep-sea fish appearance reports from 1928 to 2011. The number before 1958 was small. This might not be due to the small number of deep-sea fish appearances but rather the small number of reports. Hence, the following two periods were analyzed: 26 November 1928 through 11 March 2011 and 1 January 1999 through 11 March 2011. Whereas the former was the whole period of the data set, the latter was the period defined when the number of days of deep-sea fish appearances in 1 yr was continuously reported with exceeding more than twice. The number of appearances in the former and the latter were, therefore, 336 and 184.

Wadatsumi (1995) reported that the unusual animal behaviors appeared approximately one month before the earthquakes, the most frequent occurrence of unusual fish behavior was 3 days before the earthquakes, and approximately 50% of the behavior occurred within 60 km from the epicenter of the ocean earthquakes. Wadatsumi (1995) also reported the most of macroscopic anomalies in the 1923

Downloaded from https://pubs.geoscienceworld.org/ssa/bssa/article-pdf/doi/10.1785/0120190014/4753567/bssa-2019014.1.pdf
by Tokai University user

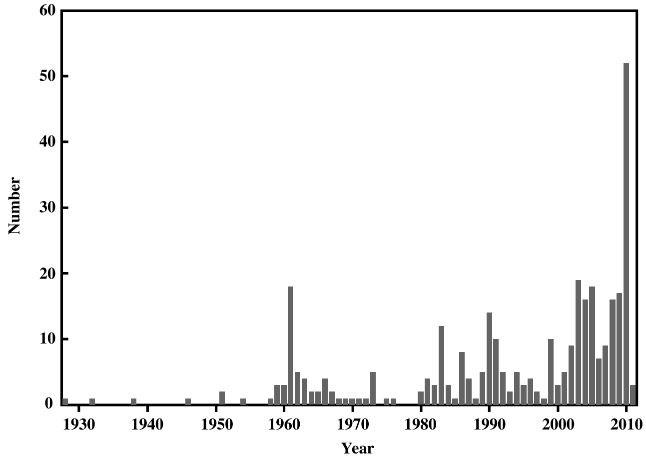

Figure 1. The annual number of deep-sea fish appearance reports from 1928 to 2011.

M 7.9 Kanto earthquake occurred within 100 km from the epicenter. Two lead-time (ΔT) days, the interval days between the days of the deep-sea fish appearance and the earthquake, were defined by 10 and 30 days, termed the alert period. If the deep-sea appearance and earthquake occurred on the same day, $\Delta T = 0$. The target earthquakes for the analysis were selected when earthquakes occurred within a radius (Δr) of 50 and 100 km from the location where the deep-sea fish appeared (termed the alert area), as estimated by Orihara *et al.* (2018). The alert volume was defined as the alert area during the alert period, the unit of which is km^2 a day (each area was estimated from pixel unit using "ImageJ"). If there was an overlap in both alert areas and alert periods, the alert volume was calculated as the union of these alert areas during these alert periods. Two of the magnitude thresholds for the analyses were defined as greater than M 6 and M 7. Blue symbols inside the pink regions shown in Figures 2 and 3 denote the target earthquakes. Based on these criteria, the number of earthquakes were 108 ($M \geq 6$) and 13 ($M \geq 7$) for $\Delta r = 50$ km from 1928 to 2011, 221 ($M \geq 6$) and 22 ($M \geq 7$) for $\Delta r = 100$ km from 1928 to 2011, 9 ($M \geq 6$) and 2 ($M \geq 7$) for $\Delta r = 50$ km from 1999 to 2011, and 18 ($M \geq 6$) and 4 ($M \geq 7$) for $\Delta r = 100$ km from 1999 to 2011. These results are shown in Table 1 and Figures 2a,b and 3a,b, respectively. In addition, Figure 4 shows the monthly number of deep-sea appearance reports and earthquake occurrences from Figure 2b. The frequency of earthquake occurrences was similar for each month, but the deep-sea fish appearance reports were small between July and October.

EOR is defined by the following equation:

$$\mathrm{EOR} = \frac{AN_s}{AN_s + \widetilde{AN}_s} \equiv P(E|A), \qquad (1)$$

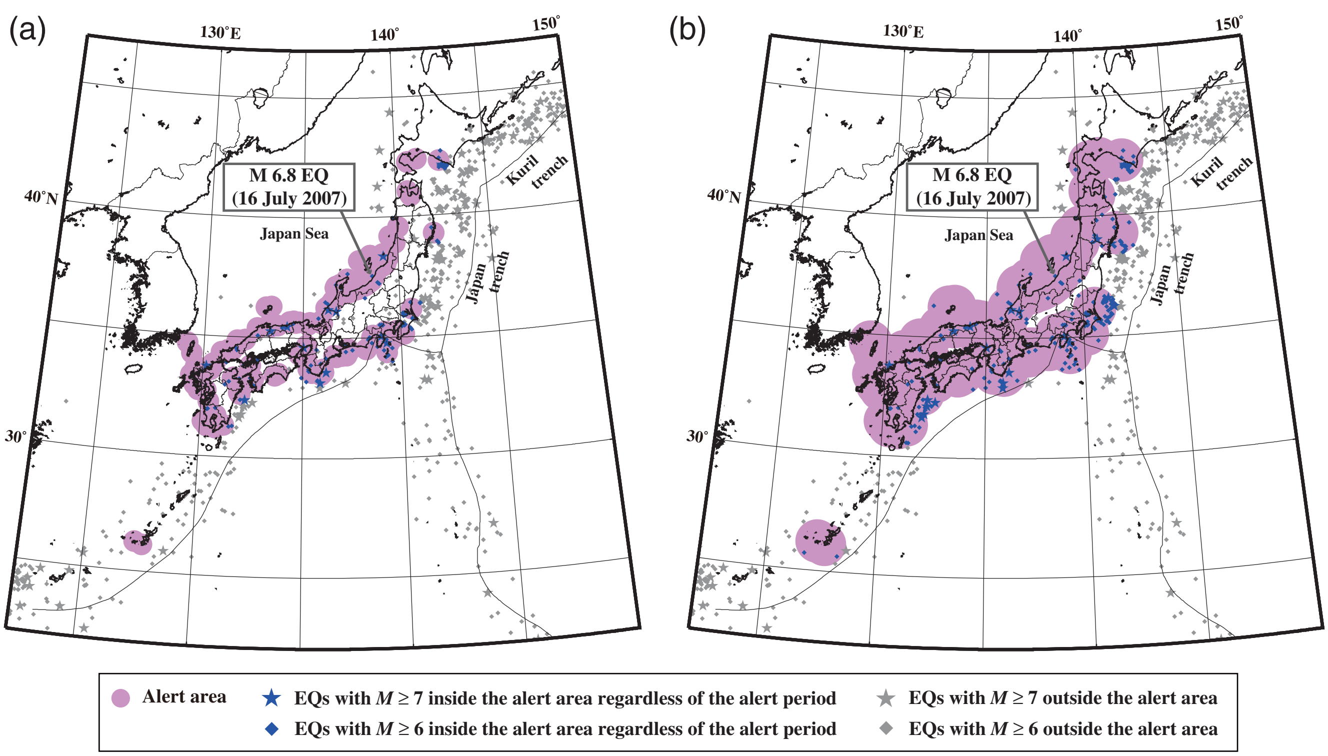

Figure 2. (a) Alert areas for the periods of 1928–2011 and $\Delta r = 50$ km. Pink regions denote all alert areas. Blue diamonds and stars indicate the earthquakes (EQs) with $M \geq 6$ and $M \geq 7$, respectively, inside the alert area regardless of the alert period, and gray diamonds and stars show the earthquakes with $M \geq 6$ and $M \geq 7$, respectively, outside the alert area. (b) The alert areas for the periods of 1928–2011 and $\Delta r = 100$ km.

Downloaded from https://pubs.geoscienceworld.org/ssa/bssa/article-pdf/doi/10.1785/0120190014/4753567/bssa-2019014.1.pdf
by Tokai University user

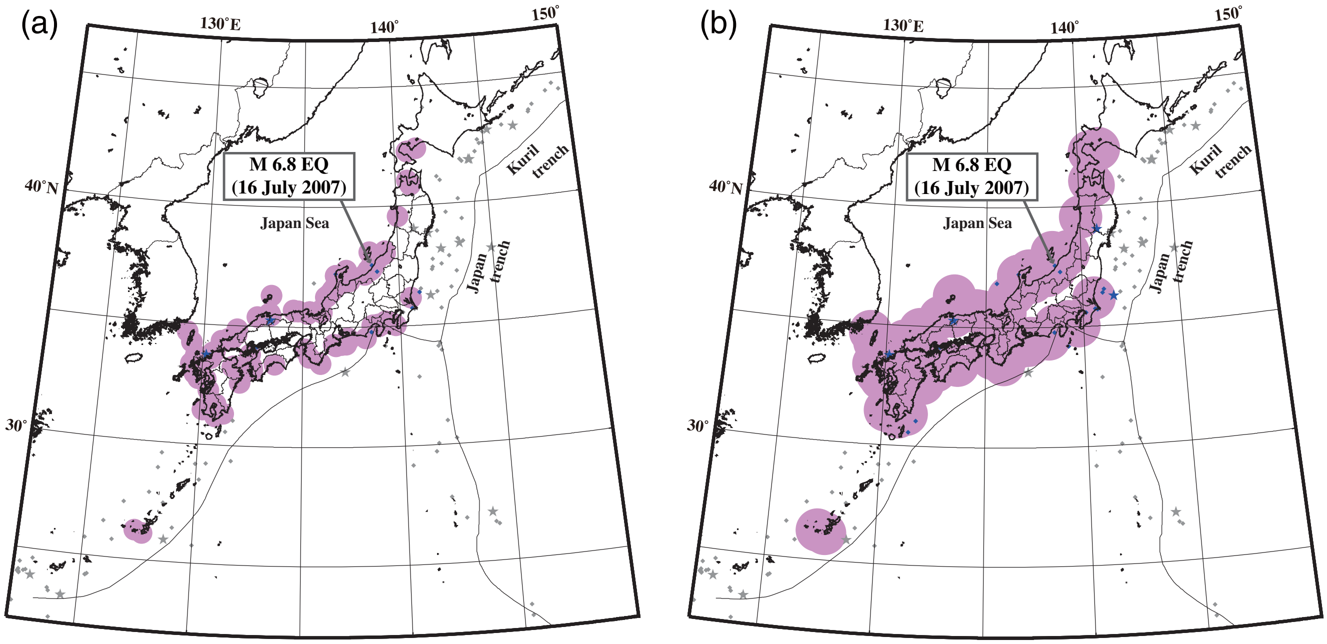

Figure 3. (a) Alert areas for the periods of 1999–2011 and $\Delta r = 50$ km. (b) Alert areas for the periods of 1999–2011 and $\Delta r = 100$ km. Symbols are the same as in Figure 2.

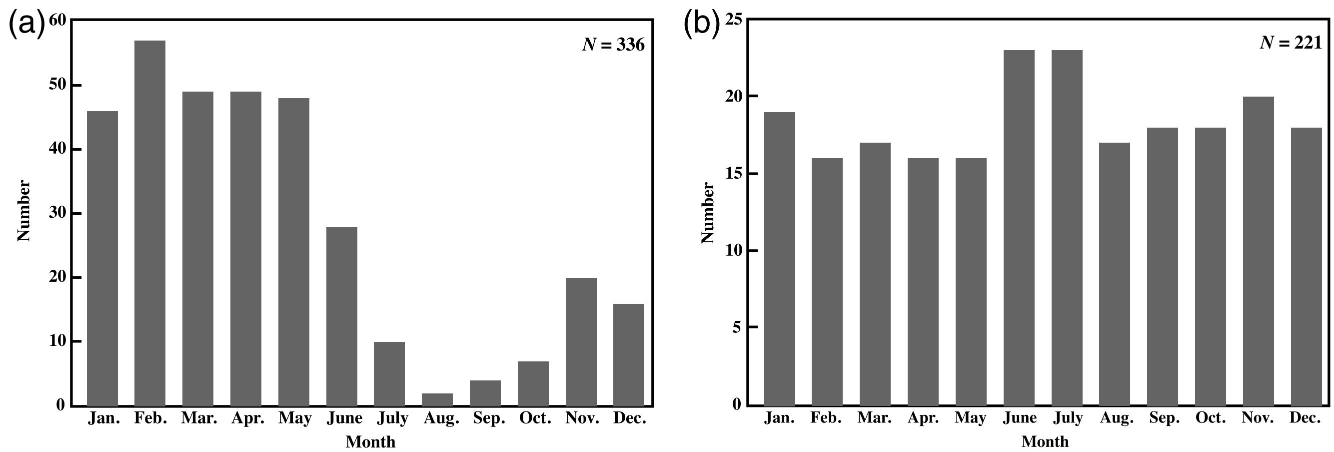

Figure 4. (a) The monthly number of deep-sea fish appearance reports from 1928 to 2011. (b) The monthly number of earthquake occurrences from Figure 2b from 1928 to 2011.

in which AN_s is the total volume of alerts with earthquake occurrences, termed success alerts. $\widetilde{AN}_s$ is the total volume of alerts without earthquake occurrences, termed false alerts. EOR is equivalent to conditional probability (Aki, 1981) and $P(E|A)$. The probability $P(E)$ is defined by the following equation:

$$P(E) = \frac{\mathrm{EQ}_{\mathrm{all}} \Delta T}{T}, \quad (2)$$

in which $\mathrm{EQ}_{\mathrm{all}}$ is the total number of earthquake occurrences within the total alert volume and T is the total time period. $P(E)$ corresponds to the spatiotemporal occurrence probability

Table 1
Number of Earthquakes under Each Condition

Period	26 November 1928–11 March 2011				1 January 1999–11 March 2011			
Δr	50 km		100 km		50 km		100 km	
Magnitude (M)	≥6.0	≥7.0	≥6.0	≥7.0	≥6.0	≥7.0	≥6.0	≥7.0
Number of earthquakes	108	13	221	22	9	2	18	4

Downloaded from https://pubs.geoscienceworld.org/ssa/bssa/article-pdf/doi/10.1785/0120190014/4753567/bssa-2019014.1.pdf
by Tokai University user

Table 2
Values of $P(E|A)$, $P(E)$, and PG: 26 November 1928–11 March 2011

Period	26 November 1928–11 March 2011							
ΔT	10 days				30 days			
Δr	50 km		100 km		50 km		100 km	
Magnitude (M)	≥6.0	≥7.0	≥6.0	≥7.0	≥6.0	≥7.0	≥6.0	≥7.0
$P(E\|A)$	0.000	0.000	0.000	0.000	0.004	0.000	0.004	0.000
$P(E)$	0.040	0.005	0.081	0.008	0.111	0.013	0.228	0.023
PG	0.000	0.000	0.000	0.000	0.036	0.000	0.018	0.000

Table 3
Values of $P(E|A)$, $P(E)$, and PG: 1 January 1999–11 March 2011

Period	1 January 1999–11 March 2011							
ΔT	10 days				30 days			
Δr	50 km		100 km		50 km		100 km	
Magnitude (M)	≥6.0	≥7.0	≥6.0	≥7.0	≥6.0	≥7.0	≥6.0	≥7.0
$P(E\|A)$	0.000	0.000	0.000	0.000	0.007	0.000	0.008	0.000
$P(E)$	0.022	0.005	0.044	0.010	0.063	0.014	0.125	0.028
PG	0.000	0.000	0.000	0.000	0.111	0.000	0.064	0.000

of earthquakes with a magnitude greater than M 6 or M 7. Consequently, the probability gain (PG) is described by the following equation (Aki, 1981; McGuire *et al.*, 2005; Zechar and Jordan, 2008):

$$\mathrm{PG} = \frac{P(E|A)}{P(E)}. \quad (3)$$

Results and Discussion

$P(E|A)$, $P(E)$, and PG are shown in Tables 2 and 3. $P(E|A)$ ranged from 0.0% to 0.8%, which suggests that EOR was much less lower than $P(E)$. In addition, 0.0% of $P(E|A)$ means that no deep-sea fish appearance preceded an earthquake with a magnitude greater than 7.0, and no earthquake event with a magnitude greater than 6.0 occurred within 10 days after a deep-sea fish appearance. These results indicate that there were no deep-sea fish appearance reports before large earthquakes, even just before earthquakes. The largest value of the PG was only 0.111, which was obtained in the case of 1999–2011, $\Delta T = 30$, $\Delta r = 50$ km, and $M \geq 6$. In this case, 184 deep-sea fish appearances were reported, and 9 earthquakes occurred. Whereas the annual mean of the earthquake occurrences was 0.7, that of the deep-sea fish appearance reports was 15.1, that is, the monthly mean of the earthquake occurrences was more than 1.2. Figure 4a indicates that deep-sea appearances have seasonal variability. Although the monthly mean of the deep-sea fish appearance reports was more than 1.2, the actual reports were temporally biased. Therefore, it seems that the PG was only 0.111. A deep-sea fish appearance was only reported before one earthquake, when slender ribbonfish was caught in fishing nets as a bycatch off the coast of Yoneyama-cho, city of Kashiwazaki, Niigata Prefecture, on 19 June 2007. An M 6.8 earthquake occurred on 16 July 2007, 30 km from the appearance site 27 days after the event (see Figs. 2 and 3). In addition to the low PG, this suggested that there was no correlation between the deep-sea fish appearances and the earthquake occurrences.

In Japan, folklore says that the appearance of deep-sea fish denotes an earthquake precursor. Moreover, catfish have also been believed to sense impending earthquakes. Hatai and Abe (1932) and Hatai *et al.* (1932) claimed that catfish behavior was associated with earthquakes. There have also been many articles in which an anomalous change in fish catches was reported before earthquakes (Terada, 1932a,b, 1933; Tomoda and Hironaga, 1989; Shimamoto, 1996; Yoshimura, 2004; Orihara *et al.*, 2014). Such fish behavior is categorized as unusual animal behavior and a macroscopic anomaly. Unusual animal behavior has been reported in many countries around the world (e.g., Tributsch, 1985). Because Japan is surrounded by the sea, not only land animal but also marine animal behaviors have been reported as macroscopic anomalies. In addition, a large number of ocean earthquakes occur in this area. Suehiro (1934) presumed that some activities must occur on the seabed before the rupture, and fish, especially deep-sea fish, could feel those precursor activities. Therefore, in Japan, deep-sea fish appearances have been believed to be an earthquake precursor, although there was only one case of the appearance of deep-sea fish as a candidate for earthquake precursor.

According to Hill (1965), the following nine criteria were used for identifying a causal relationship originating

Downloaded from https://pubs.geoscienceworld.org/ssa/bssa/article-pdf/doi/10.1785/0120190014/4753567/bssa-2019014.1.pdf
by Tokai University user

from epidemiology, known as Hill's criteria: (1) strength, (2) consistency, (3) specificity, (4) temporality, (5) biological gradient, (6) plausibility, (7) coherence, (8) experiment, and (9) analogy. It is not necessary to satisfy all nine of the criteria. In the context of Hill's criteria, the causal relationship in this study is discussed as follows: (1) *Strength:* our results showed low EOR and PG, which indicates that the strength of this relationship is weak. (2) *Consistency:* other similar investigations have barely been investigated. In a rare case, Grant and Conlan (2013) suggested that frog swarms before earthquakes were not unusual behavior. Orihara and Noda (2015) investigated the level of correlation between cetacean stranding at the Kashima-nada beach and earthquakes around Japan and concluded that the strandings were not correlated with earthquake occurrences. (3) *Specificity* and (4) *temporality:* these criteria were not of concern in this study. (5) *Biological gradient:* the biological gradient means that the greater the cause (amount, period, and strength), the greater the degree of the result. In this study, the appearance of about 10 slender ribbonfish was the largest number and was reported on 11 June 2004, and no corresponding $M \geq 6$ earthquakes occurred (Ⓔ Table S1). Similarly, 30 deep-sea fish appearances were reported in January and February of 2010, and no corresponding $M \geq 6$ earthquakes occurred. In addition, there were no corresponding deep-sea fish appearances before any $M \geq 7$ earthquakes. Hence, the criterion is not satisfied. (6) *Plausibility:* Honma *et al.* (2011) suggested that the increase in deep-sea fish appearances around the Japan Sea area between December of 2009 and February of 2011 was caused by the oceanic current and the change in seawater temperature. This is more plausible than a preseismic origin. (7) *Coherence:* for the same reasons as the consistency criterion, this criterion is not satisfied. (8) *Experiment:* Ikeya (2004) claimed that the unusual fish behavior was caused by the anomalous geoelectric telluric current. However, there have been no reports of obvious preseismic phenomena that an unusual fish behavior and an anomalous geoelectric telluric current were observed simultaneously before an earthquake. Therefore, the criterion is also hardly satisfied. (9) *Analogy:* for the same reasons as the consistency and coherence criteria, this criterion is hardly satisfied.

In this study, the number of earthquakes from 1999 to 2011, that is, 9 and 18, referring to more than M 6 and M 7 earthquakes, might not be sufficient to evaluate the correlation. If a threshold of earthquake magnitude, a lead time ΔT, or a detectable area od lower, longer, or wider, respectively, the number of earthquakes after deep-sea fish appearances would increase. In some cases, the PG might be sufficiently high. However, such a correlation between deep-sea fish appearances and earthquakes in this context would be a confirmation bias because the relationship does not satisfy Hill's criterion for biological gradient.

The deep-sea fish appearances catalog used in the present study is certainly not perfect. However, it can at least be claimed that the information on deep-sea fish appearances is not useful for disaster mitigation. In addition, the association between the reported deep-sea fish appearances and the earthquakes is a typical illusory correlation, which is a belief that a relationship exists between two phenomena that are actually not related. As shown in Figures 2 and 3, spatial correlation was hardly found. Moreover, annual temporal correlation was hardly found (Fig. 4). This implies that the dominant reason for deep-sea fish appearances might not be earthquakes. In future studies of the association between deep-sea fish appearances and earthquakes, reports that do not originate from earthquakes should be eliminated.

Conclusions

In Japan, deep-sea fish appearances such as oarfish and slender ribbonfish have been believed to be earthquake precursors. We investigated the relationship between deep-sea fish appearances and earthquakes using the following thresholds: target periods (26 November 1928 to 11 March 2011 and 1 January 1999 to 11 March 2011), lead times ($\Delta T =$ 10 days and $\Delta T = 30$ days), alert areas ($\Delta r = 50$ km and $\Delta r = 100$ km), and magnitudes ($M \geq 6.0$ and $M \geq 7.0$). Even comparing 336 deep-sea fish appearances with 221 earthquakes, only one event showed a plausible correlation. As a result, one can hardly confirm the association between the two phenomena. Although the catalog might not cover all events, it can be concluded that a deep-sea fish appearance is not useful for disaster mitigation. In addition, the Japanese folklore of a deep-sea fish appearance before a large earthquake is a typical illusory correlation. Because the dominant reason for the deep-sea fish appearances might not be the earthquakes, reports that do not originate from earthquakes should be eliminated for future investigations of the association between deep-sea fish appearances and earthquakes.

Data and Resources

Figures 2a,b and 3a,b were constructed by pixel unit using https://imagej.net (last accessed January 2019). The latitude and longitude in Ⓔ Table S1 (available in the supplemental content to this article) were calculated using http://www.wellhat.co.jp/tools/googlemap.html (last accessed January 2019).

Acknowledgments

The authors thank Editor-in-Chief Thomas Pratt and three anonymous reviewers for their useful comments and the Japan Meteorological Agency (JMA) for the earthquake catalog. This study was partially supported by the Earthquake Research Institute, the University of Tokyo Joint Usage/Research Program, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan, under its Observation and Research Program for Prediction of Earthquakes and Volcanic Eruptions, the Nara Machinery Co., Ltd., Scientific research fund for earthquake prediction, and Institute of Oceanic Research and Development, Tokai University Project Research.

Downloaded from https://pubs.geoscienceworld.org/ssa/bssa/article-pdf/doi/10.1785/0120190014/4753567/bssa-2019014.1.pdf
by Tokai University user

References

Aki, K. (1981). A probabilistic synthesis of precursory phenomena, in *Earthquake Prediction: An International Review*, D. W. Simpson and P. G. Richards (Editors), Maurice Ewing Ser., Vol. 4, AGU, Washington, D.C., 566–574.

Grant, R. A., and H. Conlan (2013). Frog swarms: Earthquake precursors or false alarms? *Animals* **3,** 962–977, doi: 10.3390/ani3040962.

Hatai, S., and N. Abe (1932). The responses of the catfish, Parasilurus Asotus, to earthquakes, *Proc. Imp. Acad.* **8,** 375–378.

Hatai, S., S. Kokubo, and N. Abe (1932). The earth currents in relation to the responses of catfish, *Proc. Imp. Acad.* **8,** 478–481.

Herald, E. S. (1961). *Living Fishes of the World*, Hamish Hamilton Ltd., London, United Kingdom, 156 pp.

Hill, A. B. (1965). The environment and disease association or causation, *Proc. Roy. Soc. Med.* **58,** no. 5, 295–300.

Honma, Y. (1990). Revised records of large marine animals stranded on the coast of Niigata and Sado Island in the Sea of Japan, *Spec. Publ. Sado Mar. Biol. Stn.* **5,** 1–39 (in Japanese).

Honma, Y., K. Minowa, Y. Nakamura, A. Aoyagi, and T. Nomura (2011). A revision of the stranding and netting records of Lampridiformes (Taeniosomatous fishes) in and off the Coast of Niigata (the Province of Echigo) and Sado Island, Sea of Japan, *Bull. Hoshizaki Green Found.* **14,** 31–41 (in Japanese).

Ikeya, M. (2004). *Earthquakes and Animals: From Folk Legends to Science*, World Scientific, Singapore, 86–90.

Kadowaki, S., N. Osada, and A. Kawakubo (2010). Swim method of slenderoarfish, *Trans. Nagasaki Biol. Soc.* **67,** 36–38 (in Japanese).

Kashiyama, Y., H. Tanase, and S. Kubota (2004). Records of living Trachipteridae from coastal waters of Wakayama Prefecture, Japan, *J. Japan Driftol. Soc.* **2,** 31–32 (in Japanese).

Kikuoka, S. (1743). *Shokoku rijindan*, Vol. 5, Nihombashi-Tori (toto): Suharaya-Heizaemon Press, Edo (Tokyo), Japan (in Japanese).

McGuire, J. J., M. S. Boettcher, and T. H. Jordan (2005). Foreshock sequences and short-term earthquake predictability on East Pacific Rise transform faults, *Nature* **434,** no. 7032, 457–461.

Nishimura, S. (1962). Recent increase in the occurrence of the deal-fish in adjacent water to Japan, *Bull. Japan Sea Reg. Fish. Res. Lab.* **10,** 51–58.

Orihara, Y., and Y. Noda (2015). Mass stranding before the 2011 Tohoku Earthquake, Japan—Correlation between strandings of cetaceans at the Kashima-Nada beach and earthquakes around Japan, *Bull. Inst. Ocean. Res. Dev.* **36,** 39–46 (in Japanese).

Orihara, Y., M. Kamogawa, and Y. Noda (2014). Investigation of anomalous fish catch before the 2011 off the Pacific Coast of Tohoku Earthquake—Comparison with the case of the 1986 Meiji-Sanriku earthquake and the 1933 Sanriku earthquake, *Zisin 2* **67,** 81–85 (in Japanese).

Orihara, Y., Y. Noda, and M. Kamogawa (2018). Reports on deep-sea fish appearances around Japan during 1928–2011, *Bull. Inst. Ocean. Res. Dev.* **39,** 37–78 (in Japanese).

Sakiyama, T., and H. Senou (2012). Regalecus russelii (Lampriformes: Regalecidae) from Sagami Bay, *Natural History Report of Kanagawa*, Vol. 33**,** 95–101 (in Japanese).

Shimamoto, N. (1996). An uncommon mitigation of red sea bream caused by the earthquake in southern Hyogo Prefecture, *Hyogo Suishi Kenpo* **33,** 5–11 (in Japanese).

Suehiro, Y. (1934). Some observations on the unusual behavior of fishes prior to an earthquake, *Bull. Earthq. Res. Inst.* (suppl. 1), 228–231.

Suehiro, Y. (1968). Unusual behavior of fishes to earthquake, *Scientific Report of the Keikyu Aburatsubo Marine Park Aquarium*, Vol. 1, 4–11 (in Japanese).

Terada, T. (1932a). On some probable influence of earthquakes upon fisheries, *Bull. Earthq. Res. Inst.* **10,** 393–401.

Terada, T. (1932b). Earthquakes and fisheries, *Proc. Imp. Acad. Japan* **8,** 83–86.

Terada, T. (1933). Earthquakes and fisheries 2, *Bull. Earthq. Res. Inst.* **11,** 714–716.

Tomoda, Y., and H. Hironaga (1989). The effect of geophysical phenomena on long-term variation of the catch of pelagic fish, *Proc. Intel. Symp. on the Long Term Variability of Pelagic Fish Population and Their Environment: International Symposium*, Sendai, Japan, 14–17 November 1989, 359–366.

Tributsch, H. (1985). *Animals Would Predict Earthquakes (Translated Version of Wenn die schlangen erwachen in German, 1978, by T. Watanabe)*, Asahisensyo, Tokyo, Japan (in Japanese).

Wadatsumi, K. (Editor) (1995). *1519 Statements on Precursors*, Tokyo Pub., Tokyo, Japan, 265 pp. (in Japanese).

Woith, H., G. M. Petersen, S. Hainzl, and T. Dahm (2018). Review: Can animals predict earthquakes? *Bull. Seismol. Soc. Am.* **108,** no. 3A, 1031–1045, doi: 10.1785/0120170313.

Yoshimura, A. (2004). *Sanriku Offshore Great Tsunami*, Bungeishunju, Tokyo, Japan, 191 pp. (in Japanese).

Zechar, J. D., and T. H. Jordan (2008). Testing alarm-based earthquake predictions, *Geophys. J. Int.* **172,** 715–724.

Yoshiaki Orihara
Yoichi Noda
Toshiyasu Nagao
Division of Earthquake Prediction, Volcano and Tsunami Research
Institute of Oceanic Research and Development
Tokai University
Shizuoka 424-0902, Japan
orihara@tsc.u-tokai.ac.jp
orihara@u-gakugei.ac.jp
noda@sems-tokaiuniv.jp
nagao@scc.u-tokai.ac.jp

Masashi Kamogawa
Division of Earthquake Prediction Research
Global Center for Asian and Regional Research
University of Shizuoka
Shizuoka 420-0839, Japan
kamogawa@u-shizuoka-ken.ac.jp
kamogawa@u-gakugei.ac.jp

Manuscript received 29 January 2019;
Published Online 18 June 2019

Downloaded from https://pubs.geoscienceworld.org/ssa/bssa/article-pdf/doi/10.1785/0120190014/4753567/bssa-2019014.1.pdf
by Tokai University user