Prevalence of Anisakid Nematodes in Fish in China: A Systematic Review and Meta-Analysis

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Anisakidosis, caused by anisakid larvae, is an important fish-borne zoonosis. This study aimed to summarize the prevalence of anisakid infection in fish in China. A systematic review and meta-analysis were performed using five bibliographic databases (PubMed, CNKI, ScienceDirect, WanFang, and VIP Chinese Journal Databases). A total of 40 articles related to anisakid infection in fish in China were finally included. Anisakid nematodes were prevalent in a wide range of fish species, and the overall pooled prevalence of anisakid nematodes in fish in China was 45.5%. Fresh fish had the highest prevalence rate (58.1%). The highest prevalence rate was observed in Eastern China (55.3%), and fish from East China Sea showed the highest prevalence of anisakid nematodes (76.8%). Subgroup analysis by sampling years suggested that the infection rate was higher during the years 2001–2011 (51.0%) than the other periods. Analysis of study quality revealed that the middle-quality studies reported the highest prevalence (59.9%). Compared with other seasons, winter had the highest prevalence (81.8%). The detection rate of anisakid nematodes in muscle was lower (7.8%, 95% CI: 0.0–37.6) than in other fish organs. Our findings suggested that anisakid infection is still common among fish in China. We recommend avoiding eating raw or undercooked fish. Region, site of infection, fish status, and quality level were the main risk factors, and a continuous monitoring of anisakid infection in fish in China is needed.

Keywords: anisakid nematodes, fish, prevalence, China, meta-analysis

INTRODUCTION

Anisakidosis is a parasitic zoonosis caused by any member of the family Anisakidae, including the genera Anisakis, Contracaecum, and Pseudoterranova (1–3). The first case of anisakiasis was reported in the Netherlands around 1960, and the total number of anisakiasis cases up to December 2017 was estimated to be about 76,000 throughout the world (4, 5). The pathogenic effects of infection by anisakid nematodes are due mainly to two mechanisms, direct tissue damage and allergic reactions (6). The clinical syndromes can be categorized into gastric anisakiasis, intestinal anisakiasis, ectopic anisakiasis, and allergic anisakiasis (7, 8). Gastric anisakiasis represents about 95% of cases in Japan, and the typical symptom is acute and severe epigastric pain (6, 9). The symptoms of intestinal anisakiasis include intermittent or constant abdominal pain and/or
intestinal obstruction, and treatment often requires surgery to remove the worm (7, 10). Moreover, infection with anisakids can lead to life-threatening anaphylaxis (6).

Anisakid nematodes have an indirect life cycle, and crustaceans are intermediate hosts while fish (and mollusks) are paratenic hosts (7, 11, 12). The larvae of anisakid nematodes, especially when located in the musculature, can affect the commercial value of fish (13). Furthermore, anisakid nematodes can lead to disease in fish (13). Humans act only as an accidental host in the life cycle of anisakid nematodes, and the infection can be obtained through consumption of raw or incompletely cooked fish infected with the third-stage larvae of the nematode (14, 15). Hence, infection of fish with anisakid nematodes should be given high priority not only because of anisakiasis in humans, but also because of the economic losses to the fishing industry (13, 16).

Fish are one of the most important food sources in China, and a number of individual studies have reported the prevalence of anisakid nematodes in fish in China. Meanwhile, the first human case of anisakiasis in China has been reported (17). Herein, a systematic review and meta-analysis was performed to analyze the prevalence of anisakid nematodes in fish in China, and the potential related factors were also investigated.

MATERIALS AND METHODS

Search Strategy

This study was performed following the PRISMA guideline (Supplementary Table 1) (18). Five bibliographic databases (VIP Chinese Journal Databases, WanFang, ScienceDirect, CNKI, and PubMed) were used to identify published articles regarding anisakid infection in fishes in China in both Chinese and English up to August 2020. The detailed search strategy and restriction information are recorded in Table 1. Meanwhile, the reference lists of retrieved articles and recent reviews were reviewed. Additionally, we did not contact the original investigators for additional data, and unpublished reports were not retrieved. Endnote X9.3.1 software was utilized to collate information for all studies.

Study Selection

After removing duplicates, the relevant articles were selected through an initial screen of identified abstracts and/or titles and a second screen of full-text articles. Qualified studies needed to meet all of the following criteria: (i) targeted objects must be fish (ii) selected fishing sites within China; (iii) cross-sectional study; (iv) the content of the studies must include the prevalence of anisakid nematodes; and (v) natural infection. Studies with the following characteristics were excluded: using the same data; incomplete data or article; fish from abroad; having internal data conflict; other nematodes; review article; river fish article (Figure 1). Eligibility for inclusion for all studies was evaluated by two independent reviewers (QL and QW). Any disagreements were resolved by the primary reviewer’s (QLG) opinion as necessary.

Data Extraction and Quality Assessment

Two reviewers (QW and JYM) independently extracted the following variables from each included study: Year of sampling, first author, publication year, study region, province, detection method, site of infection, collection season, sea, the total number of fishes, the number of positive samples, fish status, and fish category. The statistical geographic factor data (longitude range, latitude range, annual average rainfall, altitude, annual average temperature, and annual average humidity) were acquired from the National Meteorological Information Center of China Meteorological Administration. The primary reviewer (QLG) confirmed all the extracted data. A “quality” assessment of each included study was made by using criteria derived from the GRADE (Grading of Recommendations Assessment, Development, and Evaluation) approach (19–21). The scoring method was used for grading, and each of the below mentioned

| Database     | Limitation | Search formula*                                                                 |
|--------------|------------|---------------------------------------------------------------------------------|
| PubMed       | All files  | (Anisakis [MeSH Terms] OR Anisaki OR Pseudoterranova OR Contracaccum OR Hysterothylacium) AND (“Fishes” [Mesh] OR fish) AND (“China”[Mesh] OR People’s Republic of China OR Mainland China OR Manchuria OR Sinkiang OR Inner Mongolia) |
| ScienceDirect| Title, abstract or author-specified keywords: China, fish | Anisakis OR Hysterothylacium OR Pseudoterranova OR Contracaccum AND fish AND China |
| CNKI         | Advanced search and subject term and fuzzy retrieval and synonym extension | “Anisakis” (Chinese) and “fish” (Chinese) or “Hysterothylacium” (Chinese) and “fish” (Chinese) or “Pseudoterranova” (Chinese) and “fish” (Chinese) or “Contracaccum” and “fish” (Chinese) |
| Chongqing VIP| Advanced search and title or keyword and fuzzy retrieval and synonym extension | “Anisakis” (Chinese) and “fish” (Chinese) or “Hysterothylacium” (Chinese) and “fish” (Chinese) or “Pseudoterranova” (Chinese) and “fish” (Chinese) or “Contracaccum” and “fish” (Chinese) |
| WanFang      | Advanced search and title or keyword and fuzzy retrieval and synonym extension | “Anisakis” (Chinese) and “fish” (Chinese) or “Hysterothylacium” (Chinese) and “fish” (Chinese) or “Pseudoterranova” (Chinese) and “fish” (Chinese) or “Contracaccum” and “fish” (Chinese) |

*“OR” was used to connect the entry terms, and “AND” was used to connect MeSH terms, they are both boolean operators.
criteria was determined as 1 point: (i) randomly sampled; (ii) clear detection method; (iii) provide a detailed description of sampling method; (iv) clear sampling time; and (v) contained four or more risk factors. Studies with total score of four or five points were considered to be of high quality, studies with total scores of 2–3 points were considered to be of moderate quality, whereas studies with lower scores were marked as low quality.

**Statistical Analysis**

We performed meta-analysis using the package “meta” (version 4.11-0) in R software (version 3.5.2) (22). Prior to meta-analysis, we tried different methods to fit the data to a Gaussian distribution: double-arcsine transformation (PFT), logarithmic conversion (PLN), logit transformation (PLOGIT) and arcsine transformation (PAS). As indicated by previous studies, PFT has better variance stabilization performance (Table 2) (23–25). The formulas for PFT were as follows:

\[
t = \arcsin(\sqrt{r/(n+1)}) + \arcsin(\sqrt{(r+1)/(n+1)})
\]

\[
se(t) = \sqrt{1/(n+0.5)}
\]

\[
p = (\sin(t/2))^2
\]

**TABLE 2** | Normal distribution test for the normal rate and the different conversion of the normal rate.

| Conversion form | W   | P   |
|-----------------|-----|-----|
| PRAW            | 0.928 | 0.013 |
| PLN             | NaN | NA |
| PLOGIT          | NaN | NA |
| PAS             | 0.954 | 0.109 |
| PFT             | 0.941 | 0.038 |

PRAW, original rate; PLN, logarithmic conversion; PLOGIT, logit transformation; PAS, arcsine transformation; PFT, double-arcsine transformation; NaN, meaningless number; NA, missing data.

t, transformed prevalence; n, sample size; r, positive number; se, standard error.

Hence, PFT was used for rate conversion in this study. Heterogeneity across all eligible studies was tested by using the Cochran Q-test and I-squared statistic. A \( P < 0.05 \) was considered to indicate statistically significant heterogeneity, and \( I^2 \)-values of \( \geq 25 \), \( \geq 50 \), and \( \geq 75\% \) correspond to low, moderate,
### TABLE 3 | Studies included in the analysis.

| Reference ID | Sampling time | Province | Detection methods* | No. tested | No. positive | Quality score | Quality level |
|--------------|---------------|----------|--------------------|------------|--------------|---------------|---------------|
| **Eastern China** | | | | | | | |
| Zhou (29) | 1997.11–1998.1 | Zhejiang | Morphological identification | 172 | 69 | 4 | High |
| Ye et al. (30) | 2004–2005.11 | Zhejiang | Morphological identification | 281 | 135 | 4 | High |
| Zhang et al. (31) | 2005.03–2006.03 | Shandong | Comprehensive test | 123 | 66 | 3 | Middle |
| Wang et al. (32) | 2007.11–2008.12 | Zhejiang | Morphological identification | 420 | 218 | 4 | High |
| Zhang et al. (33) | 2006–2010 | Shanghai | Morphological identification | 418 | 55 | 5 | High |
| Li et al. (34) | 2010.01, 05, 06, 09, 11, 12, 2011.01 | Shandong | Morphological identification | 113 | 98 | 5 | High |
| Wen (35) | 2011.05 | Fujian | Comprehensive test | 506 | 283 | 4 | High |
| Zhang et al. (36) | 2012.04 | Jiangsu | Morphological identification | 40 | 32 | 3 | Middle |
| Liao et al. (37) | 2013.11 | Shandong | Morphological identification | 49 | 10 | 4 | High |
| Kong et al. (38) | 2011.04–2013.07 | Zhejiang | Comprehensive test | 122 | 116 | 3 | Middle |
| Li et al. (39) | 2008.10–2010.10 | Zhejiang | Morphological identification | 430 | 269 | 4 | High |
| Li et al. (40) | 2011.04 | Shandong | Comprehensive test | 85 | 85 | 3 | Middle |
| Lin et al. (41) | 2012–2016 | Fujian | Morphological identification | 463 | 85 | 5 | High |
| Ye et al. (42) | 2016.06–09 | Shandong | Morphological identification | 169 | 28 | 5 | High |
| Zhang et al. (43) | 2016.01–12 | Shandong | Morphological identification | 256 | 170 | 4 | High |
| Zhou et al. (44) | 2013–2014 | Zhejiang | Morphological identification | 89 | 82 | 4 | High |
| Chen et al. (45) | 2016.09–2017.06 | Zhejiang | Comprehensive test | 204 | 204 | 3 | Middle |
| Gong et al. (46) | 2016.09–2017.06 | Shandong | Morphological identification | 708 | 112 | 5 | High |
| Lu et al. (47) | 2015–2017 | Shanghai | Morphological identification | 633 | 204 | 5 | High |
| Xu et al. (48) | 2017.03–10 | Jiangsu | Comprehensive test | 360 | 128 | 4 | High |
| Zhang et al. (49) | 2016.01–2018.12 | Zhejiang | Comprehensive test | 42 | 42 | 2 | Middle |
| Lin et al. (50) | 2016.01–2018.12 | Fujian | Morphological identification | 763 | 269 | 5 | High |
| Qiao et al. (51) | 2015–2017 | Zhejiang | Comprehensive test | 140 | 108 | 3 | Middle |
| Yang et al. (52) | 2016–2017 | Fujian | Morphological identification | 264 | 86 | 4 | High |
| Yang et al. (52) | 2016–2017 | Jiangsu | Morphological identification | 349 | 154 | 4 | High |
| Yang et al. (52) | 2016–2017 | Shandong | Morphological identification | 336 | 85 | 4 | High |
| Yang et al. (52) | 2016–2017 | Shanghai | Morphological identification | 192 | 67 | 4 | High |
| Yang et al. (52) | 2016–2017 | Zhejiang | Morphological identification | 438 | 155 | 4 | High |
| Zhang et al. (53) | 2018 | Zhejiang | Morphological identification | 119 | 78 | 3 | Middle |
| **Northern China** | | | | | | | |
| Zhang (54) | 2001.10–2002.4.17 | Hebei | Morphological identification | 607 | 83 | 3 | Middle |
| Bi and Zhang (55) | 2017 | Hebei | UN | 246 | 71 | 4 | High |
| Ma et al. (56) | 2018 | Beijing | UN | 20 | 0 | 3 | Middle |
| Yang et al. (52) | 2016–2017 | Hebei | Morphological identification | 338 | 43 | 4 | High |
| **Northeastern China** | | | | | | | |
| Cai and An (57) | 1990–1991 | Liaoning | Morphological identification | 474 | 126 | 4 | High |
| Zhang et al. (58) | 2011.03–09 | Liaoning | Morphological identification | 777 | 221 | 2 | Middle |
| Bao and Shi (59) | 2018.03–10 | Liaoning | Morphological identification | 413 | 182 | 5 | High |
| Du and Zhou (60) | 2016–2017 | Liaoning | Comprehensive test | 193 | 35 | 5 | High |
| Geng et al. (61) | 2016–2017 | Liaoning | Morphological identification | 222 | 70 | 4 | High |
| Yang et al. (52) | 2016–2017 | Liaoning | Morphological identification | 321 | 90 | 4 | High |
| **South China** | | | | | | | |
| Sun et al. (62) | 1985.3–1985.7 | HongKong | Morphological identification | 455 | 249 | 3 | Middle |
| Liao et al. (63) | 1999.05–06 | Guangdong | Morphological identification | 70 | 11 | 3 | Middle |
| Liu et al. (64) | 2004–2005 | Guangdong | Morphological identification | 322 | 17 | 2 | Middle |
| Ruan et al. (65) | 2010.04–11 | Guangdong | Comprehensive test | 410 | 226 | 4 | High |
| Huang (66) | 2013.02–12 | Guangdong | Morphological identification | 382 | 181 | 5 | High |
| Chen et al. (67) | 2013.12.8–11 | Guangdong | Comprehensive test | 211 | 38 | 4 | High |
| Zhao et al. (68) | 2017.03–10 | Jiangsu | Comprehensive test | 360 | 128 | 4 | High |
| Yang et al. (52) | 2016–2017 | Zhejiang | Morphological identification | 184 | 15 | 4 | High |

*UN, unclear.

Detection methods*: Comprehensive test: Morphological identification, PCR.
TABLE 4 | Pooled prevalence of anisakid nematodes in China.

| Region* | No. studies | No. tested | No. positive | % (95% CI)* | Heterogeneity | Univariate meta-regression |
|---------|-------------|------------|--------------|-------------|--------------|---------------------------|
|         |             |            |              |             | χ² P-value I² (%) | P-value Coefficient (95% CI) | R²* |
| Eastern China | 29 | 8,284 | 3,493 | 55.3 (45.2–65.2) | 2,382.70 0.00 98.8 | <0.001 0.330 (0.186–0.474) | 15.63% |
| Northern China | 4 | 1,211 | 197 | 13.9 (6.8–22.9) | 36.84 <0.01 91.9 |                   |    |
| Northeastern China | 6 | 2,400 | 724 | 29.3 (23.3–35.7) | 54.49 <0.01 90.8 |                   |    |
| Southern China | 8 | 2,120 | 749 | 35.1 (25.9–45.8) | 516.20 <0.01 98.6 |                   |    |
| Sampling years | | | | | | | 0.05% |
| Before 2001 | 5 | 1,814 | 635 | 32.9 (21.4–45.5) | 118.69 <0.01 97.8 |                   |    |
| 2001–2011 | 12 | 3,892 | 1,712 | 51.0 (36.1–65.8) | 977.25 <0.01 98.9 | 0.040 0.146 (0.007–0.286) |    |
| After 2011 | 19 | 7,485 | 2,396 | 37.3 (29.6–45.3) | 802.33 <0.01 96.6 |                   |    |
| Site of infection | | | | | | | 0.00% |
| Muscle | 3 | 635 | 58 | 7.8 (0.0–37.6) | 143.79 <0.01 98.6 |                   |    |
| Others | 10 | 2,787 | 1,285 | 41.5 (24.0–60.1) | 952.84 <0.01 99.0 | 0.046 0.411 (0.007–0.814) |    |
| Season* | | | | | | | 9.86% |
| Autumn | 7 | 1,430 | 549 | 60.9 (39.2–80.7) | 282.37 <0.01 97.9 |                   |    |
| Spring | 7 | 1,677 | 829 | 79.9 (58.2–95.2) | 412.66 <0.01 98.5 |                   |    |
| Summer | 3 | 757 | 222 | 78.0 (16.2–100.0) | 102.75 <0.01 98.1 |                   |    |
| Winter | 4 | 303 | 126 | 81.8 (23.7–100.0) | 221.81 <0.01 98.6 | 0.166 −0.198 (−0.479–0.082) |    |
| Sea* | | | | | | | 11.21% |
| Bohai sea | 2 | 1,020 | 265 | 27.5 (4.4–60.6) | 118.12 <0.01 99.2 | 0.084 −0.395 (−0.842–0.053) |    |
| East China sea | 8 | 2,402 | 1,361 | 76.8 (56.5–92.1) | 747.42 <0.01 99.1 |                   |    |
| South China sea | 3 | 707 | 276 | 37.8 (5.8–58.0) | 117.49 <0.01 98.3 |                   |    |
| Yellow sea | 4 | 370 | 259 | 71.4 (32.5–97.6) | 174.82 <0.01 98.3 |                   |    |
| Fish status | | | | | | | 28.90% |
| Fresh fish | 16 | 5,973 | 2,435 | 41.3 (34.8–47.8) | 1,769.92 0.00 99.2 | 0.003 0.383 (0.130–0.636) |    |
| Frozen fish | 2 | 205 | 28 | 5.9 (0.0–30.9) | 13.83 <0.01 92.8 |                   |    |
| Live fish | 5 | 1,530 | 503 | 32.9 (12.5–49.4) | 242.38 <0.01 98.3 |                   |    |
| Quality level | | | | | | | 8.00% |
| High | 26 | 10,889 | 3,851 | 38.0 (31.4–44.9) | 1,913.33 <0.01 99.3 | 0.009 0.219 (0.054–0.385) |    |
| Middle | 14 | 3,126 | 1,312 | 41.6 (37.6–45.7) | 1,302.76 0.00 98.1 |                   |    |
| Total | 40 | 14,015 | 5,163 | 45.5 (37.8–53.3) | 3,282.18 0.00 98.8 |                   |    |

*CI*, Confidence interval.

Region*: Eastern China: Fujian, Jiangsu, Shandong, Shanghai, Zhejiang; Northern China: Beijing, Hebei; Northeastern China: Liaoning; Southern China: Guangdong, Guangxi, Hainan.

R²*: Proportion of between-study variance explained by joint test with provinces as a covariate.

Part*: Other: Body cavity, gonad, various tissues, and organs.

Season*: Spring: March–May; Summer: June–August; Autumn: September–November; Winter: December–January.

and high heterogeneity, respectively (26). Heterogeneity was present, and hence the random effect pooled measure was selected. Forest plots were generated for overall assessment of the results of each included study and the heterogeneity between studies. A funnel plot, trim and fill method and an Egger’s test were used to evaluate the publication bias of studies. In addition, the stability of our study was determined by using a sensitivity analysis (27).

Meanwhile, we performed subgroup analysis stratified by the potential risk factors to explore the potential sources of heterogeneity in our meta-analysis (28). The factors included the region (eastern China vs. other regions), the year of collection (2001–2011 vs. other periods), site of infection (others vs. muscle), season (winter vs. spring, summer, and autumn), seas (Bohai Sea vs. East China Sea, South China Sea, and Yellow Sea), fish status (Fresh fish vs. frozen fish, and live fish), and quality level (middle vs. high). In the meta-analysis of prevalence, regional factor is usually the source of heterogeneity. Hence, meta-regression analysis with other risk factors using the provinces as a covariate was conducted to explain the heterogeneity caused by the provinces. The explained heterogeneity of the covariates is expressed in $R^2$.

Also, potential sources of heterogeneity were explored by subgroup analysis based on geographical factors. We evaluated latitude (30–35° vs. other latitudes), longitude (>120° vs. other longitudes), altitude (>500 m vs. other altitudes), precipitation (1,000–1,500 mm vs. other precipitation categories), humidity...
Figure 2 | Forest plot of prevalence of anisakids in fish amongst studies conducted in China. The length of the horizontal line represents the 95% confidence interval, and the diamond represents the summarized effect.

(<70% vs. other humidity categories), mean temperature (15–20°C vs. mean temperature of other groups), lowest average temperature (10–15°C vs. lowest average temperature in other groups) and highest average temperature (>25°C vs. highest average temperature in other groups). The R software code for meta-analysis is shown in Supplementary Table 2.

RESULTS

Included Studies

In this study, a total of 358 relevant articles were found. Following initial screening and removal of duplicates, 92 articles were identified. Following full text review, 52 articles were further excluded. A further search was carried out based on the reference lists of relevant studies. However, no additional qualified articles were found. Finally, 40 full-text studies published between 2000 and 2020 were included in the quantitative analysis (Figure 1). Of which, eight articles were published in English. According to our quality criteria, 26 publications were of high quality (four or five points), 14 publications showed moderate quality (two or three points), and no publications were of low quality (Table 3, Supplementary Table 3).

Pooling and Heterogeneity Analysis

A total of 40 studies involving 14,015 fish were included in this meta-analysis. However, high heterogeneity ($I^2 = 98.8\%$, $P < 0.001$) in the selected studies was observed (Table 4, Figure 2). Hence, a random effects model was adopted for the analysis. The overall pooled prevalence of anisakid nematodes in fish in China was 45.5% (95% CI: 37.8–53.3) (Table 4). The included studies covered a variety of fish species, and the prevalence of anisakid nematodes ranged from 0 to 100% (Table 5).
### Table 5: Estimated pooled prevalence in different species of fish.

| Fish category               | No. studies | No. tested | No. positive | % Prevalence | % (95% CI) |
|-----------------------------|-------------|------------|--------------|--------------|------------|
| Ablennes hians              | 1           | 43         | 0            | 0.0          | 0.0–4.0    |
| Abudefduf septemfasciatus   | 2           | 16         | 0            | 0.0          | 0.0–11.6   |
| Acanthocepola limbata       | 2           | 34         | 19           | 56.1         | 38.2–73.3  |
| Acanthogobius flavimanus     | 1           | 21         | 18           | 85.7         | 66.9–98.0  |
| Acanthopagrus australis      | 1           | 4          | 0            | 0.0          | 0.0–38.9   |
| Acanthopagrus latus         | 5           | 63         | 10           | 11.2         | 2.2–23.8   |
| Acanthopagrus schlegeli     | 4           | 66         | 21           | 35.2         | 2.0–79.1   |
| Acustrallassius             | 1           | 17         | 11           | 64.7         | 40.2–86.0  |
| Albiflora croaker           | 1           | 31         | 6            | 19.4         | 7.1–35.4   |
| Alectis ciliaris            | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Alepes melanopterus         | 1           | 2          | 1            | 50.0         | 0.0–100.0  |
| Anguilla japonica           | 1           | 1          | 0            | 0.0          | 0.0–100.0  |
| Anguillidae                 | 3           | 32         | 8            | 23.3         | 8.6–41.4   |
| Anoplophora limbraria       | 2           | 19         | 2            | 7.0          | 0.0–36.2   |
| Apogon carinatus            | 1           | 3          | 2            | 66.7         | 5.9–100.0  |
| Apogon ellioti              | 1           | 2          | 1            | 50.0         | 0.0–100.0  |
| Apogon semilineatus         | 1           | 6          | 1            | 16.7         | 0.0–58.6   |
| Apteranotus albiglans       | 1           | 7          | 0            | 0.0          | 0.0–23.2   |
| Argyrosomus argentatus      | 1           | 8          | 1            | 12.5         | 0.0–48.2   |
| Argyrosomus macrocephalus   | 1           | 3          | 3            | 100.0        | 50.0–100.0 |
| Aristichthys nobilis        | 3           | 50         | 3            | 4.9          | 0.0–22.0   |
| Astroconger myriaster       | 2           | 67         | 25           | 37.5         | 26.0–49.4  |
| Atle mate                   | 1           | 3          | 2            | 66.7         | 5.9–100.0  |
| Bembus japonicus            | 1           | 7          | 3            | 42.9         | 8.1–81.4   |
| Blotch fish                 | 1           | 1          | 0            | 0.0          | 0.0–100.0  |
| Branchiostegus albus        | 1           | 4          | 1            | 25.0         | 0.0–79.3   |
| Branchiostegus argentatus   | 4           | 26         | 10           | 40.5         | 5.0–81.5   |
| Branchiostegus japonicus    | 1           | 9          | 0            | 0.0          | 0.0–18.3   |
| Branchiostegus wardi        | 1           | 5          | 3            | 60.0         | 13.8–98.2  |
| Brula barbata               | 1           | 10         | 1            | 10.0         | 0.0–38.1   |
| Callionichthys japonicus    | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Caranx malabaricus          | 1           | 2          | 2            | 100.0        | 30.3–100.0 |
| Carassius auratus           | 1           | 73         | 28           | 38.4         | 27.5–49.8  |
| Centroberyx linnaeus        | 1           | 2          | 2            | 100.0        | 30.3–100.0 |
| Chaetodonidae butterflyfish | 1           | 7          | 2            | 28.6         | 1.0–68.2   |
| Channa argus                | 1           | 1          | 0            | 0.0          | 0.0–100.0  |
| Chelodonichthys kumu        | 3           | 14         | 7            | 54.4         | 18.4–86.5  |
| Choroderon azulio           | 1           | 4          | 2            | 50.0         | 3.0–97.1   |
| Choromnus moaletta          | 1           | 5          | 1            | 20.0         | 0.0–67.5   |
| Cimrinus molitorella        | 2           | 22         | 2            | 16.3         | 0.0–96.7   |
| Claris lucius Lacepede      | 1           | 3          | 1            | 33.3         | 0.0–94.1   |
| Cleisthenes herzensteini    | 2           | 24         | 12           | 50.0         | 28.3–71.6  |
| Cleisthenes piniformis      | 1           | 1          | 0            | 0.0          | 0.0–100.0  |
| Clupanodon punctatus        | 1           | 8          | 6            | 75.0         | 38.5–99.2  |
| Ctenochaetus punctatus      | 3           | 22         | 9            | 45.4         | 0.0–100.0  |
| Cociella crocodilus         | 2           | 5          | 4            | 86.2         | 21.3–100.0 |
| Cola elenae                | 2           | 26         | 8            | 30.7         | 13.7–50.6  |
| Cola myrtus                | 2           | 88         | 3            | 5.9          | 0.0–34.3   |
| Colichthys lucidus          | 2           | 16         | 3            | 15.4         | 0.0–48.4   |
| Colichthys niveatus         | 5           | 125        | 67           | 53.7         | 44.6–62.6  |
| Colubris saira              | 4           | 75         | 22           | 25.6         | 4.3–54.8   |

(Continued)
TABLE 5 | Continued

| Fish category                  | No. studies | No. tested | No. positive | % Prevalence | % (95% CI) |
|--------------------------------|-------------|------------|--------------|--------------|------------|
| Conger myriaster               | 1           | 204        | 204          | 100.0        | 99.2–100.0 |
| Cynoglossus joyneri            | 1           | 14         | 0            | 0.0          | 0.0–11.9   |
| Cynoglossus robustus           | 8           | 101        | 20           | 2.3          | 0.0–23.0   |
| Cynoglossus semilaevis         | 1           | 9          | 0            | 0.0          | 0.0–18.3   |
| Dasyatis akajei                | 1           | 4          | 0            | 0.0          | 0.0–38.9   |
| Decapterus maruadsi            | 7           | 122        | 55           | 45.1         | 12.2–95.1  |
| Dentex tumifrons               | 5           | 29         | 7            | 33.1         | 0.0–84.6   |
| Ditrema terminckii             | 5           | 257        | 79           | 11.0         | 0.0–39.3   |
| Echeneis naucrates             | 1           | 3          | 3            | 100.0        | 50.0–100.0 |
| Enedrias fangj wang&wang       | 2           | 192        | 29           | 15.5         | 3.6–23.9   |
| Epinephelus moaena             | 4           | 21         | 4            | 37.4         | 0.0–100.0  |
| Epinephelus                    | 3           | 19         | 4            | 10.5         | 0.0–51.2   |
| Epinephelus amblycephalus      | 1           | 3          | 3            | 100.0        | 50.0–100.0 |
| Epinephelus areolatus          | 2           | 5          | 3            | 60.3         | 10.3–99.7  |
| Epinephelus awoara             | 4           | 13         | 3            | 32.7         | 0.0–99.0   |
| Epinephelus chlorostigma      | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Epinephelus epistictus         | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Epinephelus fasciatus          | 1           | 3          | 2            | 66.7         | 5.9–100.0  |
| Epinephelus sp                | 1           | 42         | 5            | 11.9         | 3.6–23.7   |
| Euploegrannus muticus          | 1           | 2          | 2            | 100.0        | 30.3–100.0 |
| Formio niger                   | 3           | 10         | 2            | 15.2         | 0.0–50.2   |
| Fuscoius spinefoot             | 1           | 1          | 0            | 0.0          | 0.0–100.0  |
| Gadus                          | 1           | 12         | 0            | 0.0          | 0.0–13.9   |
| Gadus morhua                   | 3           | 33         | 26           | 75.4         | 5.1–100.0  |
| Gerres acinaceus               | 1           | 5          | 3            | 60.0         | 13.8–98.2  |
| Gerresmorpha javonica          | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Girella punctata               | 2           | 40         | 8            | 19.4         | 7.5–34.6   |
| Gymnocyrombus tenesi           | 1           | 24         | 20           | 83.3         | 65.4–96.0  |
| Harengula zunasi               | 2           | 34         | 5            | 41.8%        | 0.0–100.0  |
| Harpador nehereus              | 8           | 152        | 52           | 40.2         | 14.6–68.6  |
| Hemirhpampus sajori            | 1           | 36         | 29           | 80.6         | 65.8–92.1  |
| Hemisalanx prophanus           | 2           | 17         | 0            | 0.0          | 0.0–1.8    |
| Hexagrammos otaki              | 1           | 125        | 39           | 31.2         | 23.4–39.6  |
| Hoplobrotula armata            | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Hypomesus olidus               | 2           | 83         | 2            | 1.8          | 0.0–6.5    |
| Ilisha elongata                | 10          | 75         | 15           | 16.0         | 6.6–27.5   |
| Inimicus japonicus             | 1           | 2          | 0            | 0.0          | 0.0–69.7   |
| Japanese Spanish mackerel      | 1           | 2          | 0            | 0.0          | 0.0–69.7   |
| Johnius belenghii              | 1           | 12         | 10           | 83.3         | 56.1–99.6  |
| Johnius grypus                 | 2           | 11         | 2            | 35.9         | 0.0–100.0  |
| Kalwarninus equula             | 1           | 3          | 2            | 66.7         | 5.9–100.0  |
| Katsuwonus pelamis             | 1           | 2          | 0            | 0.0          | 0.0–69.7   |
| Konosirus punctatus            | 1           | 75         | 13           | 17.3         | 9.5–26.8   |
| Larimichthys                   | 1           | 34         | 1            | 2.9          | 0.0–12.2   |
| Larimichthys crocea            | 13          | 556        | 49           | 11.3         | 1.6–25.9   |
| Larimichthys polyactis        | 21          | 1,492      | 705          | 58.0         | 42.7–72.5  |
| Lateolabrax japonicus          | 11          | 118        | 26           | 17.4         | 0.3–45.2   |
| Lepidotrigla microptera        | 3           | 28         | 16           | 64.1         | 26.7–93.5  |
| Lepidotrigla micropterus       | 1           | 4          | 4            | 100.0        | 61.2–100.0 |
| Lepturacanthus savala          | 1           | 8          | 3            | 37.5         | 6.7–74.1   |

(Continued)
| Fish category      | No. studies | No. tested | No. positive | % Prevalence | % (95% CI) |
|------------------|-------------|------------|--------------|--------------|------------|
| Lophiiformes     | 1           | 20         | 0            | 0.0          | 0.0–8.4    |
| Lophius litulon  | 7           | 82         | 79           | 99.5         | 91.5–100.0 |
| Lutjanus argentimaculatus | 2          | 13         | 0            | 0.0          | 0.0–10.3   |
| Lutjanus eriythropterus | 3         | 14         | 13           | 17.7         | 0.2–46.8   |
| Lutjanus fulviflamma | 1          | 5          | 0            | 0.0          | 0.0–31.7   |
| Lutjanus fulvus  | 1           | 6          | 5            | 83.3         | 41.4–100.0 |
| Lutjanus lutjanus | 1           | 9          | 9            | 100.0        | 81.7–100.0 |
| Lutjanus ophuyseni | 1          | 7          | 6            | 85.7         | 48.3–100.0 |
| Lutjanus russelli | 1           | 7          | 1            | 14.3         | 0.0–51.7   |
| Megalaspis cordyla | 3          | 19         | 2            | 5.1          | 0.0–20.2   |
| Mene maculata    | 3           | 18         | 14           | 87.8         | 32.8–100.0 |
| Micrthys miluy   | 10          | 105        | 36           | 37.5         | 17.8–59.1  |
| Monopterus albus | 1           | 1          | 0            | 0.0          | 0.0–100.0  |
| Mugl cephalus    | 3           | 19         | 5            | 19.3         | 0.0–92.2   |
| Mullidae subvittatus | 1         | 6          | 6            | 100.0        | 73.2–100.0 |
| Muraenesox cinereus | 10         | 152        | 120          | 76.4         | 51.5–91.3  |
| Mustelusmanazo   | 1           | 5          | 0            | 0.0          | 0.0–31.7   |
| Navodon modestus | 1           | 4          | 2            | 50.0         | 3.0–97.1   |
| Nemipterus bathybus | 1          | 12         | 12           | 100.0        | 86.1–100.0 |
| Nemipterus japonicus | 1          | 14         | 10           | 100.0        | 83.5–100.0 |
| Nemipterus virgatus | 6          | 68         | 30           | 37.5         | 0.0–96.1   |
| Nenipterus toler | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Nibea albiflora  | 8           | 115        | 25           | 27.6         | 4.4–57.7   |
| Oncorhynchus     | 4           | 101        | 0            | 0.0          | 0.0–2.1    |
| Oncorhynchus keta | 1           | 25         | 0            | 0.0          | 0.0–6.8    |
| Oncorhynchus mykiss | 1          | 2          | 0            | 0.0          | 0.0–69.7   |
| Ophiocephalus argus | 1          | 20         | 20           | 100.0        | 91.6–100.0 |
| Oreochromis      | 2           | 2          | 0            | 0.0          | 0.0–78.7   |
| Pagrosomus major | 67          | 73         | 46           | 67.9         | 30.1–70.0  |
| Pago major       | 1           | 1          | 0            | 0.0          | 0.0–100.0  |
| Pampus argenteus | 9           | 124        | 9            | 4.4          | 0.0–15.8   |
| Pangiusi suthi   | 1           | 4          | 0            | 0.0          | 0.0–38.9   |
| Paralichthys lethostigma | 2        | 17         | 5            | 28.7         | 7.9–54.3   |
| Paralichthys olivaceus | 7          | 183        | 29           | 21.7         | 3.7–45.9   |
| Parapercis cylindrica | 1          | 10         | 2            | 20.0         | 0.5–51.3   |
| Parapristopoma trilineatum | 1       | 11         | 0            | 0.0          | 0.0–15.1   |
| Parargyrops edita | 1           | 17         | 14           | 82.4         | 60.0–97.4  |
| Parastromateus niger | 1         | 1          | 0            | 0.0          | 0.0–100.0  |
| Parapeneus chrysopleuron | 1       | 9          | 4            | 44.4         | 13.0–78.1  |
| Paralichthys bicoloratus | 1       | 16         | 7            | 43.8         | 20.1–68.9  |
| Paralichthys indicus | 3          | 54         | 28           | 39.1         | 0.0–97.7   |
| Pelecanoides cinctus | 4          | 32         | 5            | 13.5         | 2.2–29.5   |
| Pectorhinchus cinctus | 6          | 6          | 0            | 0.0          | 0.0–26.8   |
| Pectorhinchus nigrus | 1          | 6          | 5            | 83.3         | 41.4–100.0 |
| Pectorhinchus cinctus | 3          | 78         | 26           | 28.8         | 16.3–42.7  |
| Fish category            | No. studies | No. tested | No. positive | % Prevalence | % (95% CI) |
|--------------------------|-------------|------------|--------------|--------------|------------|
| Pleuronectiformes        | 1           | 59         | 7            | 11.9         | 4.7–21.5   |
| Pleuronichthys comutus   | 1           | 10         | 0            | 0.0          | 0.0–16.5   |
| Pneumatophorus japonicus | 24          | 583        | 482          | 75.8         | 61.0–88.3  |
| Pogonoperca punctata     | 1           | 12         | 3            | 25.0         | 3.9–53.9   |
| Pomfret                  | 1           | 155        | 1            | 0.7          | 0.0–2.8    |
| Priacanthus boops        | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Priacanthus cruentatus   | 2           | 7          | 5            | 77.3         | 27.9–100.0 |
| Priacanthus macracanthus | 2           | 9          | 3            | 27.9         | 0.0–100.0  |
| Priacanthus tayenus      | 5           | 24         | 16           | 70.4         | 9.3–100.0  |
| Pristigenys niphonia     | 1           | 4          | 3            | 75.0         | 20.8–100.0 |
| Pristomoides typus       | 1           | 7          | 5            | 71.4         | 31.8–99.0  |
| Prognichthys agoo        | 1           | 10         | 7            | 70.0         | 37.5–96.0  |
| Psenopsis anomala        | 2           | 19         | 2            | 7.5          | 0.0–44.8   |
| Pseudopriacanthus niphonius | 1    | 5          | 3            | 60.0         | 13.8–98.2  |
| Pseudorrhombus arsius    | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Pseudorrhombus cinnamoneus | 1     | 85         | 85           | 100.0        | 98.0–100.0 |
| Pseudosciaena polyactis | 2           | 20         | 20           | 95.1         | 72.1–100.0 |
| Rachycentron canadum     | 2           | 4          | 2            | 50.0         | 0.0–100.0  |
| Raja hollandi            | 1           | 5          | 0            | 0.0          | 0.0–31.7   |
| Raja parosa              | 3           | 32         | 7            | 15.4         | 0.0–62.7   |
| Rastrelliger kanagurta   | 2           | 15         | 10           | 76.3         | 5.8–100.0  |
| Rock fish                | 1           | 8          | 0            | 0.0          | 0.0–20.4   |
| Sardine                  | 4           | 72         | 2            | 0.9          | 0.0–9.7    |
| Saurida elongata         | 2           | 36         | 28           | 78.2         | 62.6–90.9  |
| Saurida filamentosa      | 1           | 2          | 2            | 100.0        | 30.3–100.0 |
| Scatophagus argus        | 3           | 21         | 1            | 1.0          | 0.0–14.8   |
| Sciaenidae               | 2           | 60         | 9            | 14.9         | 6.6–25.4   |
| Sciaenops ocellatus      | 1           | 18         | 16           | 88.9         | 69.4–99.8  |
| Scolopsis taeniopterus   | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Scolopsis trilineata     | 1           | 4          | 1            | 25.0         | 0.0–79.3   |
| Scolopsis vosmeri        | 1           | 9          | 1            | 11.1         | 0.0–41.8   |
| Scomber australasicus    | 1           | 4          | 4            | 100.0        | 61.2–100.0 |
| Scomber japonicus        | 1           | 20         | 13           | 65.0         | 42.5–84.7  |
| Scomberomorus commerson  | 1           | 10         | 2            | 20.0         | 0.5–51.3   |
| Scomberomorus guttatus   | 1           | 4          | 1            | 25.0         | 0.0–79.3   |
| Scomberomorus niphonius  | 19          | 468        | 214          | 36.9         | 22.9–51.9  |
| Scophthalmus maximus     | 6           | 101        | 2            | 0.0          | 0.0–0.0    |
| Sca latfish              | 1           | 4          | 0            | 0.0          | 0.0–38.9   |
| Sebastiscus marmoratus   | 3           | 88         | 24           | 27.1         | 6.9–52.9   |
| Sebastodes fuscescens    | 2           | 22         | 19           | 96.0         | 74.0–100.0 |
| Secutor insidator        | 1           | 2          | 1            | 50.0         | 0.0–100.0  |
| Secutor ruconius         | 1           | 3          | 1            | 33.3         | 0.0–94.1   |
| Salariaeides leptoepis   | 1           | 2          | 2            | 100.0        | 30.3–100.0 |
| Seriola lalandi          | 1           | 4          | 0            | 0.0          | 0.0–38.9   |
| Setipinna tenutilis      | 3           | 104        | 20           | 22.5         | 0.0–71.1   |
| Siganus argenteus        | 1           | 3          | 0            | 0.0          | 0.0–50.0   |
| Siganus fuscescens       | 3           | 47         | 4            | 3.5          | 0.0–14.1   |
| Sillagjaponica           | 1           | 5          | 2            | 40.0         | 1.9–86.2   |
| Soleidae                 | 1           | 12         | 0            | 0.0          | 0.0–13.9   |
| Sphyraena pingais        | 2           | 5          | 3            | 70.0         | 1.4–100.0  |
| Sphyraena pinguis        | 1           | 5          | 0            | 0.0          | 0.0–31.7   |
TABLE 5 | Continued

| Fish category                  | No. studies | No. tested | No. positive | % Prevalence | % (95% CI) |
|--------------------------------|-------------|------------|--------------|--------------|------------|
| Sphyraenus                     | 3           | 53         | 26           | 47.8         | 0.0–100.0  |
| Stingray                       | 1           | 1          | 0            | 0.0          | 0.0–100.0  |
| Stromateoides argenteus        | 1           | 36         | 0            | 0.0          | 0.0–4.7    |
| Stromates                      | 1           | 3          | 2            | 66.7         | 5.9–100.0  |
| Synancea verrucosa             | 1           | 4          | 0            | 0.0          | 0.0–38.9   |
| Taisus tumifrons               | 1           | 24         | 21           | 87.5         | 70.7–96.3  |
| Talismania longifilis          | 1           | 4          | 0            | 0.0          | 0.0–38.9   |
| Tenuola reevesi                | 4           | 24         | 0            | 0.0          | 0.0–4.5    |
| Terapon jarbua                 | 1           | 11         | 2            | 18.2         | 0.5–47.4   |
| Thamnaconus modestus           | 4           | 31         | 3            | 6.7          | 0.0–21.1   |
| Thamnaconus septentrionalis    | 1           | 6          | 0            | 0.0          | 0.0–26.8   |
| Therapon oxyrhynchus           | 1           | 25         | 3            | 12.0         | 1.7–28.2   |
| Therapon theraps               | 2           | 29         | 2            | 8.1          | 0.0–27.6   |
| Thunnus alalunga               | 4           | 36         | 6            | 7.5          | 0.0–38.1   |
| Trachinocephalus myops         | 1           | 7          | 7            | 100.0        | 76.8–100.0 |
| Trachinotus blochii            | 1           | 2          | 1            | 50.0         | 0.0–100.0  |
| Trachinotus ovatus             | 13          | 148        | 1            | 0.0          | 0.0–1.0    |
| Trachurus japonicus            | 7           | 108        | 85           | 81.0         | 55.8–98.3  |
| Trisopterus singeri            | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Trichurus haemela              | 2           | 109        | 103          | 94.7         | 89.4–98.4  |
| Trichurus lepizinus            | 25          | 1,631      | 840          | 69.8         | 57.1–87.3  |
| Trididental trigonephalus      | 1           | 20         | 2            | 10.0         | 0.2–27.8   |
| Trisopterus demopterus          | 1           | 1          | 1            | 100.0        | 0.0–100.0  |
| Tuna Rubrum                    | 1           | 5          | 0            | 0.0          | 0.0–31.7   |
| Tylosurus anastomella          | 1           | 4          | 1            | 25.0         | 0.0–79.3   |
| Tylosurus melanotus            | 1           | 21         | 8            | 38.1         | 18.3–60.0  |
| Upeneus luzonius               | 1           | 2          | 1            | 50.0         | 0.0–100.0  |
| Upeneus moluccensis            | 1           | 2          | 2            | 100.0        | 30.3–100.0 |
| Upeneus sulphureus             | 2           | 14         | 8            | 60.3         | 24.7–91.8  |
| Uranoscopus japonicus          | 1           | 7          | 6            | 85.7         | 48.3–100.0 |
| Zebras zebra                   | 1           | 1          | 0            | 0.0          | 0.0–100.0  |
| Zoarces slongatus              | 1           | 2          | 0            | 0.0          | 0.0–69.7   |
| Zoarcidae                      | 1           | 22         | 2            | 9.1          | 0.2–25.5   |
| Zuta jilfish                   | 1           | 23         | 3            | 13.0         | 1.8–30.5   |

In the subgroup analysis, a random effect model was selected due to the fact that significant heterogeneity was observed (Table 4). The subgroup analysis based on geographical areas suggested that eastern China had the highest prevalence rate (55.3%, 95% CI: 45.2–65.2), and fish in East China Sea showed the highest point estimate of prevalence of anisakid nematodes (76.8%, 95% CI: 56.5–92.1). At the single province level, Zhejiang Province had the highest rate of 75.3% (1,398/2,338; 95% CI: 57.6–89.5) (Table 6). No anisakid nematodes were found in fish in Beijing City (Table 6, Figure 3).

The subgroup analysis by sampling years demonstrated that the infection rate was higher during 2000–2011 (51.0%, 95% CI: 36.1–65.8) than other periods. Compared with other seasons, autumn had the lowest prevalence rate (60.9%, 95% CI: 39.2–80.7) (Table 4).

Analysis of study quality indicated that the middle-quality studies reported the highest prevalence rate (59.9%, 95% CI: 37.6–80.2). The detection rate of anisakid nematodes in muscle was lower (7.8%, 95% CI: 0.0–37.6) than in other fish organs. The meta-regression analysis showed that the heterogeneity can be explained by the province ranges from 0.00 to 31.93% after joint analysis with province (Table 4).

We also evaluated the impact of geographical and climatic parameters on prevalence and calculated the latitude range (30–35°; 68.6%, 95% CI: 51.9–83.1), the longitude range (>120°; 61.4%, 95% CI: 47.8–74.2), and altitude (<100; 54.1%, 95% CI: 42.5–65.5). Compared with other groups, the prevalence of anisakid nematodes in fish in these geographic ranges was significantly higher ($P < 0.05$), which may account for the heterogeneity (Table 7).
TABLE 6  |  Estimated pooled prevalence of anisakid nematodes by provinces in China.

| Province | No. studies | Region          | No. tested | No. positive | % Prevalence | % (95% CI) |
|----------|-------------|-----------------|------------|--------------|--------------|------------|
| Beijing  | 1           | Northern China  | 20         | 0            | 0.0          | 0.0–8.4    |
| Fujian   | 4           | Eastern China   | 1,996      | 723          | 36.0         | 20.5–51.0  |
| Guangdong| 5           | Southern China  | 1,120      | 347          | 29.6         | 8.4–57.0   |
| Guangxi  | 2           | Southern China  | 270        | 27           | 10.4         | 5.3–16.7   |
| Hainan   | 1           | Southern China  | 275        | 126          | 45.8         | 40.0–51.7  |
| Hebei    | 3           | Northern China  | 1,191      | 197          | 17.8         | 10.0–27.2  |
| Jiangsu  | 4           | Eastern China   | 868        | 392          | 55.3         | 39.6–70.5  |
| Liaoning | 6           | Northeastern China| 2,400      | 724          | 29.3         | 23.3–35.7  |
| Shandong | 8           | Eastern China   | 1,839      | 654          | 50.4         | 26.5–74.2  |
| Shanghai | 3           | Eastern China   | 1,243      | 326          | 26.0         | 13.0–41.5  |
| Zhejiang | 10          | Eastern China   | 2,338      | 1,398        | 75.3         | 57.6–89.5  |
| Total    | 47          |                 | 13,560     | 4,914        | 42.7         | 35.5–50.1  |

FIGURE 3  |  Map of anisakid infection in fish amongst studies conducted in China.

Publication Bias and Sensitivity Analysis
The funnel plot was asymmetric, suggesting that the included studies might have publication bias or small-study effect bias (Figure 4). Meanwhile, the trim and fill analysis showed six studies with negative results (white circles in Figure 5), indicating that there was potential publication bias in the present study. Additionally, Egger’s test suggested that there might be publication bias among the studies selected for our analysis ($P < 0.05$) (Supplementary Table 4, Figure 6). We also used funnel plots (Supplementary Figures 1–9) and forest plots (Supplementary Figures 10–16) for all subgroups to test for the presence of publication bias and heterogeneity. However, the
sensitivity analysis showed that the pooled data were basically the same after omitting one study at a time, indicating that our results were statistically robust (Figure 7).

**DISCUSSION**

Human anisakiasis is caused by consumption of raw or poorly cooked fish parasitized by anisakid nematodes (69, 70). Hence, detailed knowledge of the epidemiological status of anisakid nematodes in fish is central for the prevention and control of human anisakiasis. Our meta-analysis revealed that the pooled estimate of Anisakidae larvae prevalence among fish in China was 45.5%, and the prevalence varied by sea areas. East China Sea and Yellow Sea had high prevalence. Fish species may contribute to such high prevalence, such as hairtail (*Trichiurus haumela*), chub mackerel (*Pneumatophorus japonicus*), yellow croaker (*Pseudosciaena polyactis*) and whitespotted conger (*Conger myriaster*) in East China Sea, and chub mackerel (*P. japonicus*) in Yellow Sea. Several previous studies showed that they were highly infected species (52, 71–73). Additionally, the relationship between the lowest prevalence in Bohai Sea and fish species needs to be further studied, because only two studies were included for analysis, and one did not disclose the 23 fish species which were tested negative for anisakid nematodes (74).

A previous investigation using fish collected from three sea areas of the Republic of Korea also showed that the infection rate was higher in East Sea than that in Yellow Sea (71). However, fish from South Sea, Republic of Korea had higher prevalence rate than that from South China Sea (71). This may be due to the fact that fat greenling (*Hexagrammos otakii*) and Korean rockfish (*Sebastes schlegeli*) from South Sea with high infection...
rate were not included in fish species sampled from South China Sea (71). In addition to fish species, differences in prevalence may be associated with fishing grounds (15). For example, previous studies demonstrated that the distribution of *Anisakis* spp. and the infection levels in the same fish species varied among different fishing grounds (15, 75).
Among five provinces within eastern China, Zhejiang province had the highest prevalence. This may be due to the fish species, such as hairtail (*Trichiurus lepturus*) and yellow croaker (*Larimichthys polyactis*) which were reported to be highly infected species of marine fish (52). Previous studies showed that the high incidence of anisakidosis was significantly associated with living on the coast, where the habit of consuming raw fish is higher compared to inland regions (76, 77). Considering that consumption of raw or undercooked fish is a common practice in the coastal areas of China, there should be some potential cases of anisakiasis in eastern China, especially in Zhejiang province (17, 40). However, no cases of human infection by anisakid nematodes have been reported in eastern China. To date, only one case of anisakiasis has been reported in other areas of China (17). This may be due to misdiagnosis and missed diagnosis (78). Infection by anisakid nematodes should be considered in patients who had a history of ingestion of raw fish with associated symptoms, such as vomiting and frequent mucous diarrhea (17).

The method of examining fish for anisakid infection include routine visual inspection, digesting the fish filet using a pepsin/HCl solution, and incubation of internal organs (79). In all of the included studies, prevalence of anisakid nematodes in fish in China was determined by routine visual inspection. Additional species identification using PCR method was performed only in several studies. Hence, detection method as the risk factor was not included.

China released the National Agricultural and Rural Economic Development in the Tenth Five-Year Plan implemented from June 2001 (2001–2005). Of which, speeding up the development of the aquaculture industry was included. Meanwhile, establishing and perfecting a system for monitoring the safety and quality of aquatic products was mentioned. Hence, 2001 was used to be a first cut-off point for subgroup analysis. The 12th Five-Year Plan on Fishery Development and the 13th Five-Year Plan on Fishery Development were released in June 2011 and December 2016, respectively, each gives a higher priority for epidemic prevention and control of aquatic animals as well as safety and quality of aquatic products than before. Thus, we chose 2011 as the cut-off point to analyze the prevalence of anisakid nematodes. It is worth noting that we found 19 studies published after 2011, but only 5 studies before 2001. Hence, we speculated that the pooled estimates after 2011 was more likely to reflect prevalence of anisakid nematodes in fish in China.

Additionally, the rareness of anisakiasis in China may be associated with anisakid nematode species. Previous studies showed that the majority of human cases of anisakiasis were caused by *Anisakis simplex*, *Anisakis pegreffii*, and *Pseudoterranova decipiens* (10, 80, 81). However, *A. simplex* and *A. pegreffii* were reported only in 12 and 11 articles, respectively. The PCR approach proved to be cost-effective and reliable for the identification of the species of the genus *Anisakis* (82). However, PCR approach was not used in all studies related to species identification, which may lead to species misidentification. Moreover, only one article reported the presence of *P. decipiens* in fish in China.
Parasites were detected in muscle, intestine, mesentery and gonads. Although the point estimate of anisakid nematodes in muscle was low, larval migration to the muscles may occur after the death of the fish, which can increase the risk of anisakiasis (83, 84). Moreover, the differences between the two sibling species (A. simplex and A. pegreffii) in migration to the muscles of fish and to penetrate into the tissue of accidental hosts were found in several studies (38, 85, 86). From the perspective of food safety, further studies are needed to reveal the species composition of Anisakis and their geographical distribution in China.

The included studies covered a variety of fish species, and the prevalence of anisakid nematodes ranged from 0 to 100%. The results can serve as a guideline associated with food safety. Yellow goosefish (Lophius litulon) is a commercially important marine fish, and its stomach, intestine and liver are considered to be a delicacy in China (49). Also, cinnamon flounder (Pseudorhombus cinnamoneus) is a frequently consumed marine fish in China (40). Our analysis showed that L. litulon and P. cinnamoneus had a high prevalence, respectively. The high prevalence may be due to the fact that they eat crustaceans and small fishes, which
are intermediate or paratenic hosts of anisakid nematodes (7, 11, 12). Additionally, several fish species, such as banded sergeant (Abudelfuluf septemfasciatus), sablefish (Anoplopoma fimbria), and skipjack tuna (Katsuwonus pelamis) tested negative for anisakid nematodes. This may be due to the small sample size for each of these fish species, because infection of K. pelamis by Anisakis larvae has been reported (12). Hence, further studies employing a larger number of sampled fish are needed to determine the prevalence in several fish species.

The advantages of the present study include the wide coverage, large total sample size, valid analysis method, large time span, and a comprehensive risk factor analysis. This is the first meta-analysis of the prevalence of anisakid nematodes in China. In the present study, most of the articles of medium quality reached the score of three. In addition, four or more potential risk factors were explored in the majority of articles. We believe that the study can reflect the prevalence of anisakid nematodes in fish in China during the last two decades. However, there are some limitations in this meta-analysis as follows: (i) five databases were used to identify publications, which may exclude some qualified articles from other databases; (ii) parts of the subgroups (such as sites of infection) have included fewer articles, which may lead to unstable results; (iii) this study was not registered in Cochrane, however, our meta-analysis was carried out strictly in accordance with the steps of PRISMA; and (iv) the range of environmental temperatures in the sea area where fish live is quite different from that of the land area, and analysis based on different regions of land areas may only serve as a reference. It is suggested that the researchers should clarify the sampling locations and fishing sites (such as the latitude and longitude of the specific sea area), which can contribute to the assessment of the environmental factor.

CONCLUSION

This study has shown that anisakid infection in fish was widespread in China, and the pooled prevalence varied among different fish species and provinces. Region, site of infection, fish status and quality level were the main factors affecting the prevalence rate. There is a need for continuous monitoring of anisakid infection in fish in China. Meanwhile, it is necessary to educate people, especially those living in coastal regions, about the risk of infection with anisakid nematodes and to avoid consumption of raw or undercooked fish.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding authors.

AUTHOR CONTRIBUTIONS

Q-LG and JJ contributed to conception and design of this analysis. QL, QW, and J-YM collected the data and built the database. QW and Q-LG analyzed the results. QL prepared the manuscript. Q-LG and X-QZ revised the manuscript. All authors contributed to manuscript editing and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fvets.2022.792346/full#supplementary-material

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