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Research Article

Illegal, unreported, and unregulated fishing: A risk scoring method for prioritizing inspection of fish imported to Australia for zoonotic parasites

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ABSTRACT

The global burden of illegal fishing is estimated to be extensive. Intricately constructed trade routes introduce illegally caught fish products into the global commercial market, including Australia. To date, no studies have investigated the potential for illegally caught fish to harbor zoonotic parasites. Any tests applied to fish imported to Australia must be scientifically justified according to international trade agreements. The primary aim of this study was to develop a risk scoring method that provides a scientific basis for the development of protocols to examine fish imported to Australia for zoonotic parasites. The secondary aim was to estimate and prioritize the provenance of fish, which may be high-risk areas for illegal, unreported, and unregulated (IUU)[1] fishing. The third aim was to calculate the amount of unreported catch from each of the ten highest-risk countries. Scoring was conducted using seven predictor variables, which were identified in the published literature as important, within the forensics of IUU fishing, for identifying the "*IUU or unreported catch risk*" of each provenance. The unreported catch (UC)[2] for the highest scoring provenances (1–10) was calculated after risk scoring. The highest and second highest scoring provenances, 30 and 67, had 39.8% and 41.55% UC, respectively; Provenance 79, which had the tenth highest risk score, had 6.9% UC. Linear regression analysis showed a non-significant association between the size of the exclusive economic zone and UC. Number of commercial spp. was the greatest indicator of UC. The analysis showed that for every unit increase in the number of different commercial spp. available, there was an increase of 5.28 units in the percentage of UC. Mean provenance risk scores and percentage of UC were linearly related. There was a 79.4% decrease in the mean risk scores between provenances 1–5 and 6–10; a decrease was also observed in the UC between the two groups (33.7% and 15.5%, respectively). The proposed scoring method appears to be a good predictor of UC, with a clear association between the mean risk scores for each provenance and percentage UC.

1. Introduction

Illegal, unreported, and unregulated fishing (IUU) (Fig. 1) is a concentrated effort to illegally harvest more fishery resources than are sustainable, thereby violating the laws of the sea.[1] The burden of IUU fishing in the marine environment is of escalating global concern. According to Miller et al. (2016)[2] and Pramod et al. (2014),[3] IUU fishing significantly undermines the responsible management of marine ecosystems and fish stocks worldwide. Agnew et al. (2009)[4] considered illegal activity to be a serious impediment to the economic development of many fishing communities. The yearly global burden from IUU fishing is considered to be 26 million tonnes,[5] equating to ~ US $10–23.5 billion and 10–22% of total global fisheries production.[4] In Europe, 500,000 tons of imported seafood per year is estimated to be a product of illegal catch.[6,7] A study estimated that 20–32% of seafood legitimately imported to the USA may be product of illegal catch.[3]

The threat to human health occasioned by fish substitution has been well documented. However, the human health risks from zoonotic seafood-borne parasites in illegal catch have, thus far, not been explored. It is generally acknowledged that unscrupulous operators exploit weaknesses in the global supply chain to introduce their illegal catch into the global consumer market.[9] IUU fish may have been smuggled past the country-of-origin testing procedures for zoonotic parasites and pose a human health risk. Fig. 2 shows a simplified schematic diagram of the fish supply chain, where illegal activity may increase the risk of parasitic contamination of edible fish. Accredited safety observers are a recommended presence on registered vessels[10] and are assumed to be absent

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[1] Illegal, unreported, unregulated (IUU)
[2] Unreported catch (UC).

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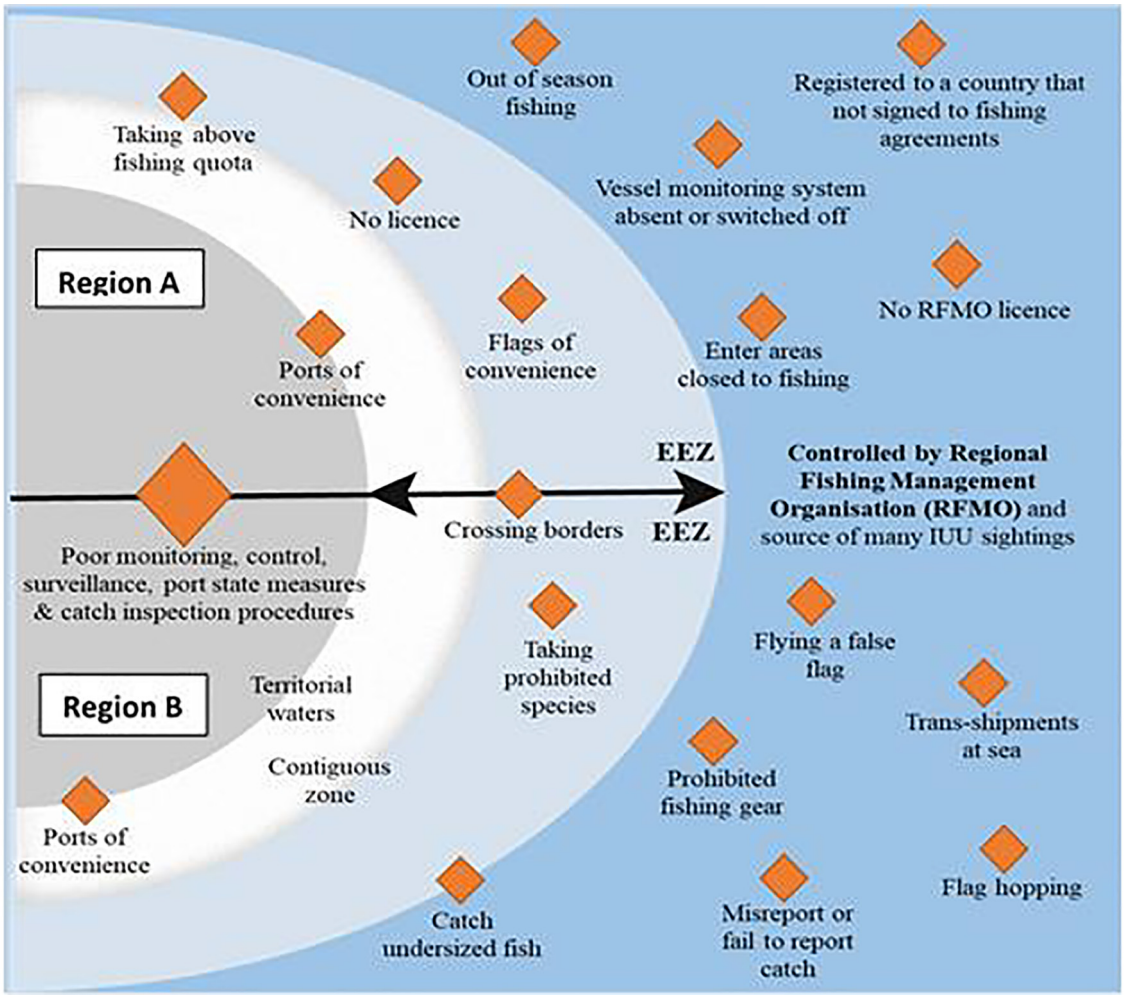

Fig. 1. Representing examples of fishing activities which contravene the law of the sea and factors which contribute to the perpetuation of illegal, unreported, unregulated (IUU) fishing in certain regions. Each orange diamond is an example of an activity or factor related to IUU fishing which have been placed in the marine zones most associated with each illegal activity. IUU fishing prevails in areas with inadequate government controls and where fisheries are poorly managed/monitored. This factor is represented with a large orange diamond to indicate the importance of poor governance in the forensics of IUU fishing. The grey half circle represents a hypothetical land mass up to the shoreline; white semi-circle the regions territorial waters and the combined white and pale blue semi-circles the EEZ of the hypothetical region (Developed from information in Seafish (2016) and Chapsos and Hamilton (2019)).

from IUU fishing vessels. Parasite mitigation strategies, such as immediate evisceration, trimming, and appropriate cold room storage of fish at high risk for zoonotic nematodes, may not be carried out on fish from IUU vessels.[11,12]

Slavery and human rights abuses have been reported on IUU fishing vessels, where workers are often at sea for years. The use of extreme violence, long work hours, and food deprivation to intimidate workers have been widely reported. There are no publications that discuss how fish safety is influenced by slavery on IUU vessels. However, it seems logical that IUU operators engaged in human rights abuses would have a similar disregard for parasite mitigation strategies that affect end-point consumer health.

Biogeographical differences between regions have been identified as determinants of host-parasite associations.[13] Forged documentation that misrepresents the species and/or geographic origin of fish[8,14] to cover fraudulent activity may increase the risk of introducing a fish species at high risk for zoonotic parasites into the global food chain. Tuna and olive flounder from Japanese waters, for example, are at high risk for zoonotic myxozoan parasites[15–18] and are frequently substituted for other species of fish.[19] Fish may be substituted on board an IUU vessel, or at any stage in the supply chain.[20–22]

Australia is vigilant in patrolling its sovereign waters to control IUU fishing, ratified in Australia's Second National Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing.[23] Australia also stands in solidarity with the global community by supporting the International Plan of Action to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing.[24] Australia's biosecurity is an essential national asset,[25] which has kept the country free of many diseases that are prevalent in other countries. However, when dealing with an open access resource, such as fisheries, there is vast potential for illegal activity to occur[5] that may be impossible for Australian biosecurity to detect, and which may affect the safety of the fish products that Australia imports.

Australia is a signatory to the World Trade Organization (WTO) General Agreement on Tariffs and Trade,[26] Agreement on Sanitary and Phytosanitary Measures,[27] and Technical Barriers to Trade Agreement.[28] Australia, along with other WTO member nations, is bound by the above agreements and prevented from examining imported seafood for zoonotic parasites without scientific justification. Any additional tests that Australia, or any other nation, may wish to apply to imported seafood without justification could be viewed as arbitrary and discriminatory within these agree-

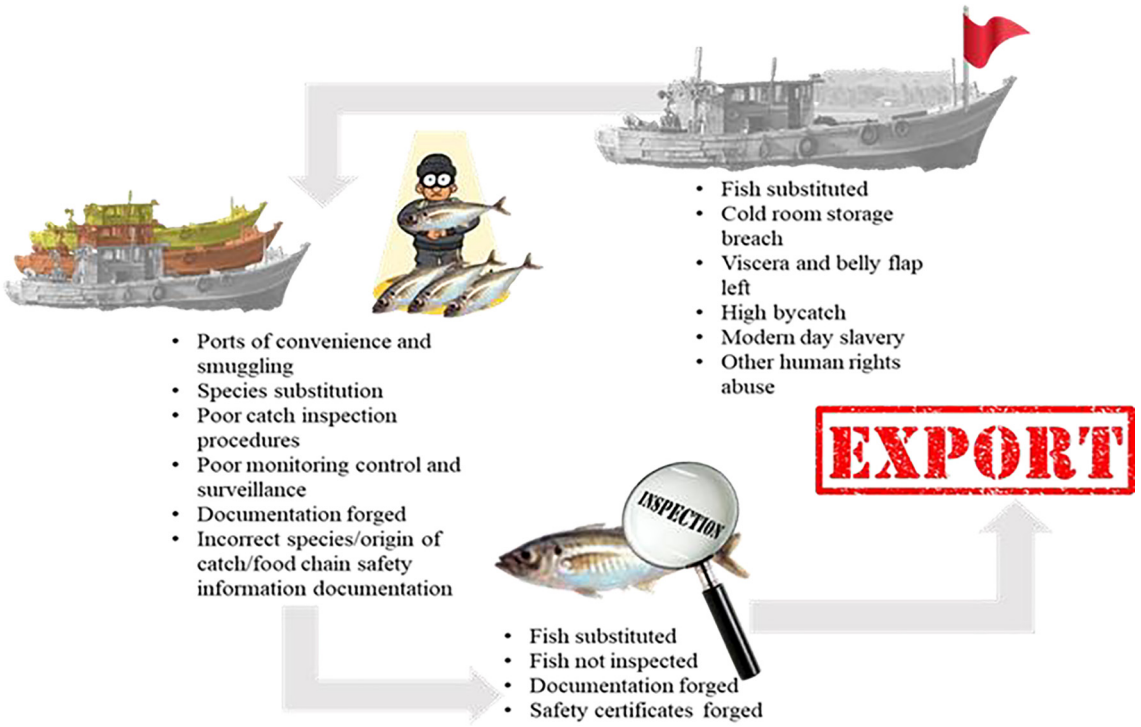

Fig. 2. A simple schematic diagram of how product of IUU fishing is distributed and situations which may contribute to product of illegal catch as high risk for zoonotic parasites in fish imported into Australia. (Original figure with images available via creative commons open access).

ments.[26–28] As a result, despite seafood being the most highly traded food globally,[29] studies investigating the safety of imported products are absent from published literature.

Australians are heavily reliant on imported edible seafood.[30–32] As a result, it is imperative to verify the safety of the products. Australia's current seafood inspection scheme does not include additional tests for zoonotic parasites in imported products after arrival in the country.[33–36] To date, no studies have investigated the potential of illegally caught seafood to harbor zoonotic parasites, which may be a threat to human health. The aims of this study were (1) to develop a risk scoring method that provides scientific justification for identifying the '*IUU or unreported catch risk*' of provenances (countries of origin) and to examine the seafood they export to Australia for zoonotic parasites; (2) to estimate and prioritize, according to potential risk, the provenances and species of seafood that may be a product of illegal fishing and unintentionally imported into Australia; (3) to validate the scoring method used in this study as an accurate identifier of provenances demonstrating significant discrepancies in reported catch.

2. Materials and methods

The study was conducted in two parts. In Part A, a biosecurity risk ranking system was developed to identify the IUU or unreported catch risk for each provenance. In Part B, reported seafood catch was collated from the seafood production profile of each provenance and the unreported element of the catch was calculated. Justifications for inclusion of the seven predictor variables are provided in Table 1. Each of the 84 countries that Australia imported seafood from in 2017 were included in this study, and were randomly allocated a provenance number as an identifier. No country description, seafood species, or EEZ size data that could identify a country have been included in this study. Any data that could lead to a conclusion being made as to the identity of the respective provenances has been omitted from the manuscript.

2.1. Part A

Seven predictor variables were used to calculate the outcome variable of "*IUU or unreported catch risk*". The scoring method and the predictor variables "*Patrol boats per 100,000 sq. km*" and "*Monitoring, control, and surveillance*"' were based on a study by Petrossian (2015).[37] The outcome variable "*Degree of illegal fishing*" in Petrossian (2015)[37] was included as a predictor variable in this study. Other predictor variables included in this study were sourced from the nine types of fraud identified by Fox et al. (2018),[9] and the titles were modified as appropriate. Categories that were modified were (Fox study/this study) "*Modern day slavery*"/"*Unskilled labor*" and "*Catch method fraud*"/"*Catch inspection procedures*". Two additional variables were included in this study: "*Corruption*" and "*Inspector coercion*", which Sumaila et al. (2017)[5] and Metuzals et al. (2010)[38] identified as important within the forensics of illegal fishing. Governance index and corruption were included as predictor variables in a study of illegal fishing conducted by Agnew et al. (2009),[4] however, it is believed that this study is the first to use "*Inspector coercion*" as a predictor variable.

2.2. Description of predictor variables

2.2.1. Variable 1: Degree of illegal fishing

Incidents of IUU fishing were collated from Pramod et al. (2008)[39] for each provenance from which Australia imports seafood. The information in Pramod et al. (2008)[39] was obtained from six selected regional fisheries management organizations (RFMOs) and individual provenance high seas activities from previous reports.[40–42] This information was supplemented with additional contemporaneous information from the IUU Fishing Vessel List, which included data from 12 RFMO's, and IUU vessels identified by INTERPOL after the issue of purple infringement notices.[43] IUU vessel names identified in the data were then entered into the IUU Fishing Vessel Site search engine using the filter "Show vessels

Table 1
Factors and/or consequences associated with IUU fishing, justification for inclusion of each predictor variable and scoring used in this study. (See below-mentioned references for further information.)

Relevant predictor variable (PV) included in this study	Factors and/or consequences associated with the forensics of IUU fishing	Predictor variable justification	Scoring
1. Degree of illegal fishing	Poorly crafted regulations and weak enforcement of EEZ Metuzals, et al. (2010) Poach fishing outside EEZ and serious labour abuses Tickler, et al. (2018)	Illegal activity associated with seafood is recognised as a significant influencer of seafood safety. Important safety procedures to minimise zoonotic parasites in fish occur on the vessel. It is expected that IUU vessels would concentrate on harvesting as much seafood in the least amount of time and basic parasite mitigation strategies may not be conducted. The degree of IUU fishing is expected to negatively impact seafood safety in some regions	A score of 1 awarded for each incident of IUU fishing to the country responsible
2. Patrol boats per 100,000 sq. km	Failure to regulate high seas fishing Metuzals, et al. (2010) Weak patrol capability and surveillance Petrossian (2015)	Multiple studies have demonstrated that IUU fishing is more likely to occur in areas where patrol boat surveillance is limited.	A score of 1–100 was awarded based on calculation of patrol boats standardised by the size of the exclusive economic zone (EEZ). 100 as the worst patrol boat presence
3. Monitoring control and surveillance (MCS)	Chain of custody abuses Fox, et al. (2018) Fish substitution and hidden or undeclared catch Fox, et al. (2018), Williams, et al. (2020), Helyar, et al. (2014) Violence in monitoring control and surveillance Metuzals, et al. (2010) Corrupt governments, poorly crafted regulations with weak MCS capacity and enforcement Metuzals, et al. (2010), Petrossian (2015), Miller, et al. (2016) Failure to substantiate authenticity of relevant documentation, vessel's compliance with fisheries regulations Petrossian (2015) Poor trans-shipment regulations and ineffective formal surveillance over port operations Petrossian, et al. (2015) Failure to produce clear fishery statistics Pramod, et al. (2008) Extremely low observer coverage or ill equipped inspect fishing vessels or fishing gear Petrossian, et al. (2015), Pramod, et al. (2008) Poor catch reporting in conjunction with labour abuses at sea Tickler, et al. (2018)	The monitoring of legally sourced seafood along the supply chain is well regulated to ensure edible seafood is compliant with international food safety standards. Documentation which falsifies safety checks for zoonotic parasites in seafood, the region of capture or substitutes a highly parasitised species of fish for another increases the risk of undetected zoonotic parasites entering the seafood supply chain. Product of illegal catch is more likely to be offloaded from the IUU vessel to a region with poor MCS.	Actual scores from the references cited in Materials and Methods were used to score this variable
4. Catch inspection procedures	Low safety costs onboard vessel Metuzals, et al. (2010) Violence in monitoring control and surveillance Metuzals, et al. (2010) Ill-equipped to inspect species/origin of fish caught, fishing vessels or fishing gear Petrossian, et al. (2015) Low and predictable inspection levels Pramod, et al. (2008) Information gaps, incomplete observer and landing data Pramod, et al. (2008)	Catch inspection is carried out to authenticate seafood species, tonnage, vessel compliance and origin of seafood harvested. Regions where catch inspection procedures are bypassed introduces safety uncertainty into the global seafood supply chain. Host parasite associations are frequently determined by biogeographical differences. Accurate representation of seafood species and region of capture is important to ensure appropriate parasite mitigation strategies have and will be conducted on vessel and during processing. In addition, information and data gaps make traceback impossible should there be a human health safety concern identified along the food chain.	Actual scores from the references cited in Materials and Methods were used to score this variable
5. Corruption	Laundering and mislabeling seafood Metuzals, et al. (2010) Corruption, concealment and ease of obtaining false documentation Metuzals, et al. (2010) Other illicit activities. Fraud and money laundering. Transfer crime across networks and borders Metuzals, et al. (2010) Failure to prosecute transgressors Metuzals, et al. (2010), Pramod, et al. (2008) High corruption and ineffective catch inspection procedure Petrossian, et al. (2015) Weak governance and corruption, lax regulations and enforcement Petrossian (2015), Pramod, et al. (2008) Bribes to bypass regulations Metuzals, et al. (2010), Petrossian, et al. (2015)	Institutional corruption within a region has been demonstrated to influence all stages of the seafood supply chain. Corruption influences the degree of IUU fishing and the entry of illegally sourced seafood into the global supply chain. Bribes to bypass inspection in conjunction with probable poor on vessel parasite mitigation strategies is considered to increase the risk of zoonotic parasites in illegally caught seafood	Scores out of 100 from the Corruption Perceptions Index were used to score this variable.

Table 1 (*continued*)

Relevant predictor variable (PV) included in this study	Factors and/or consequences associated with the forensics of IUU fishing	Predictor variable justification	Scoring
	Culture of illegal activity Pramod, et al. (2008)		
6. Inspector coercion	Armed resistance to surveillance and enforcement Metuzals, et al. (2010) Low observer presence Metuzals, et al. (2010), Pramod, et al. (2008) Observer harassment, physical or verbal attack, sexual assault or intimidation PEER (2007), NOAA (2014) Observer abuse rarely prosecuted PEER (2013) No assistance or support available to observers when attacked or prevented from observing and monitoring PEER (2016) Sleep deprivation, intimidation, bribes, official documentation stolen PEER (2007)	Observers onboard registered and legally operating vessels record and authenticate seafood species, tonnage, vessel fishing gear, safety compliance and origin of seafood harvested. Observers also report any on vessel safety breaches to port inspectors for further action. It is considered IUU vessels would not be harvesting with an observer onboard and basic parasite mitigation strategies would not be conducted. In addition, there are also some regions with high observer harassment recorded on registered vessels. Observers on registered vessels, subject to various forms of intimidation and harassment, may be unlikely to report on vessel safety breaches to port inspectors. This may increase the risks from zoonotic parasites in the seafood supply chain from these regions	A score of 1 was awarded to the provenance responsible for each separate incident in Table 3 where an observer or inspector was harassed
7. Unskilled labour	Modern day slavery Fox, et al. (2018) Low labour costs and almost no safety costs Metuzals, et al. (2010) Human rights violations, including slavery, human trafficking and physical abuse, the smuggling of migrants, and illicit drugs trafficking, torture and murder Miller, et al. (2016), Sutton & Siciliano (2016), Environmental Justice Foundation (2015) Poor education and lack of training Pramod, et al. (2008) Reduced expenditure on crew pay, safety and living conditions Tickler, et al. (2018) Slavery risk seafood importation to developed countries Tickler, et al. (2018) Labour abuses at sea and unreported catch associated Tickler, et al. (2018)	There are many publications which discuss human rights abuse on IUU vessels. However, the impact these may have on zoonotic parasites in seafood has yet to be explored. Poorly trained and overworked on vessel workers may not have been instructed/ encouraged by vessel operators on the importance of parasite mitigation strategies. In Tickler, et al. (2018) the estimated potential slavery risk in imported seafood to USA was 3.1 kg per tonne. USA like Australia has a great dependency on imported seafood product. In 2019, Australia imported 214,867.30 tonnes of seafood. Based on the same potential risk, 69,312.02 tonnes of seafood imported into Australia may be product of slavery/IUU fishing and be of uncertain safety	A score of 1 was awarded to the provenance responsible for each separate incident and/or number of people involved in each incident where unskilled labour was involved. Unskilled labour as defined in 2.1.6 of the manuscript

currently on RFMO IUU vessels list" to obtain more detailed information[44] regarding vessel sightings, owners, and visits to ports of convenience. Results for owners or operators of IUU vessels and any ports where IUU catch was confirmed as offloaded were included in the overall scores for the provenances. In cases where the owner/operator was unidentifiable, the IUU vessel name was entered into the Food and Agriculture Organization (FAO) vessel finder search engine[45] and, if identified, the provenance of the owner was included in the scoring. Scores for Provenance 21, which has a highly visited port of convenience for the region, included all IUU scores for three other adjacent provenances, even though they were not exporters of seafood to Australia.

2.2.2. Variable 2: Patrol boats per 100,000 sq km

The United States Naval Institute Guide[46] was used to compile information on the number of patrol boats owned by each of the provenances. The number of patrol boats was standardized by the size of the exclusive economic zone (EEZ) of each provenance to reflect the number of patrol boats per 100,000 sq km, as described in Petrossian (2015).[37] The size of the EEZ for each provenance used in the calculations was obtained from the Sea Around Us program,[47] which is a collaborative effort between the Pew Charitable Trusts[48] and the Paul G. Allen Family Foundation.[49] The Sea Around Us program evaluates the impact of fisheries on global marine ecosystems. Unless it was stated in the remarks section of Wertheim (2015)[46] that boats were not used for EEZ patrol, the number of patrol boats (PB) or patrol craft (PC) used to defend the EEZ of the respective provenances were used for scoring. The prefix W, in Wertheim (2015),[46] denotes all ship types that are not under the authority of the provenance's navy, which includes the coast guard, customs service, border guard, or government-owned scientific ships. Categories WPB and WPC were included in the count unless it was stated that the vessels were not used for EEZ defense. Patrol combatants were not included unless it was stipulated that they were used for EEZ defense. Drug control vessels were excluded. Other patrol boats and craft were included in the count if they were clearly defined in the remarks as used for EEZ defense.

2.2.3. Variables 3 and 4: Monitoring, control, and surveillance and catch inspection procedures

The references used to score variables 3 and 4 are included in Table 2. Evaluations of monitoring, control, and surveillance performance from Pitcher et al. (2008)[42] for all provenances were included in the scoring for variable 3. Pitcher et al. (2008)[42] included the results of a project initiated by The World Wide Fund for Nature and University of British Columbia Fisheries Centre to assess 54 countries on their implementation and compliance with the provisions of the UN Code of Conduct for Responsible Fisheries.[42,50] The evaluations of the countries' performance scores for "*Observer scheme*", "*Vessel monitoring*", and "*Control of access in stopping illegal fishing*", were combined to score the predictor variable "*Monitoring control and surveillance*" (MCS) in this study. For 23/84 of the provenances included in this study, scores for variable 3 were obtained from Pramod (2018),[51] which provided the most recent scores (~2018) and five provenances were scored from the Marine Resources Assessment Group (MRAG) (2005).[52] If no scores were available in Pitcher et al. (2008),[42] Pramod (2018),[51] or MRAG (2005),[52] an objective score was awarded by the authors based on information in the Fishery and Aquaculture Country Profiles for the respective provenances.[53] The same sources were used to score variable 4 for all provenances.

2.2.4. Variable 5: Corruption

Scores for variable 5 were obtained from the 2018 Corruption Perceptions Index (CPI),[54] which is published yearly by Transparency International. The index is designed to advance "accountability, integrity, and transparency" by ranking public sector corruption on advice from businesspeople and experts. The CPI score is based on thirteen external sources of data, from the public and private sectors, which includes the World Bank, World Economic Forum, and other private risk assessment and consultation groups. The score is awarded yearly so that country scores are kept current and are a true representation for each country during the respective time period. The scores allocated by Transparency International are out of a possible 100, with the lowest scores representing the most corrupt countries.

Table 2
Predictor variables used to score the outcome variable '*IUU or unreported catch high risk*' in this study and the sources of information which were used. The sources of information to score variables 6 and 7 have been omitted to maintain provenance confidentiality.

Variable	Predictor variable	Sources of information
1	*Degree of IUU fishing*	Pramod et al., (2008) Tracking, (2019a) Tracking, (2019b) FAO, (2019b)
2	*Patrol boats per 100,000 sq km EEZ*	Wertheim, (2015) Sea Around Us, (2016)
3	*Monitoring control surveillance*	FAO, (2019a) MRAG, (2005) Pitcher et al., (2008) Pramod, (2018)
4	*Catch inspection procedures*	Pramod, (2018) MRAG, (2005) Pitcher et al., (2008) FAO, (2019a)
5	*Corruption*	Corruption et al., (2018)
6	*Inspector coercion*	Not cited for reasons of confidentiality
7	*Unskilled labour*	Not cited for reasons of confidentiality

2.2.5. Variable 6: Inspector coercion

Scoring for this variable included published literature and media reports that described cases in which an observer on a fishing vessel was prevented from performing catch inspection duties. Although these cases occurred on registered, and not IUU, vessels, the results of catch not being properly inspected were considered to have similar outcomes. The criteria for cases that were included in scoring this variable are displayed in Table 3.

2.2.6. Variable 7: Unskilled labor

Scoring for this variable included published literature and media reports that described cases of child labor and/or

Table 3
Categories used to score Variable 6 "*Inspector coercion*". Each case identified in media or published literature was scored with 1 for any of the scoring criteria. In the case of multiple reports each separate occurrence was scored with 1.

Variable 6 scoring categories	Cases included in scoring
Observer intimidation	Murder, threats of personal harm, general harassment; sleep deprivation, surveillance which restricts the observer's ability to fulfil inspection duties
Attempted bribery	Money or alcohol offered to observer
Tampering with observer documentation	Theft, unauthorised reading, document destruction, statistical fraud and corrupt licence agreements of official documentation
Subterfuge	Hauls during observer meals times, IUU catch hidden under legitimate catch, IUU catch transfer at sea to another vessel
Inspectors denied access	Observer not permitted onboard ship or impeded in catch inspection duties whilst onboard

Table 4
The top 10 provenances '*IUU or unreported catch high risk*' after scoring and calculating the mean. The percentage of unreported catch calculated for each provenance is shown in column 3.

Provenance number	Mean	% unreported catch
30	486.29	39.78
67	448.71	41.55
19	144.61	22.88
59	133.10	39.10
22	78.14	30.01
74	73.13	27.36
16	69.05	6.80
55	66.33	14.24
82	65.86	17.50
79	54.00	6.89

modern-day slavery on IUU fishing vessels, sleep or food deprivation, torture, or murder.

2.3. Risk scoring: Predictor variables 1–7

Combined scores were included for variables 1 and 3–7. Variable 2 had a broad range (patrol boats per EEZ/100,000 sq km) and a standardized scoring system of 1–100 was needed; a score of 100 represented the worst patrol boat presence in the EEZ, and 1 represented a dedicated patrol boat presence. Variable 2 results were included in the combined scores for each provenance. For variables 1 and 3–7 a score of 1 was awarded for each separate incident that could be ascribed to any of the 84 provenances. In publications or media reports that describe multiple infringements/incidents, 1 was awarded for each separate incident or, for Variable 7, the number of people involved in each incident**.** A score was then allocated to the responsible provenance. For example, if 25 children were reported as exploited in the seafood trade, 25 was the score awarded to the provenance responsible**.** Variable 4 corruption scores awarded by CTI (2018)[54] were reverse scored to represent the highest score as most corrupt and lowest score as least corrupt (Table 1). Scores for the seven variables were added, and the mean scores were calculated for each provenance.

2.4. Part B

Reconstructed data from the Sea Around Us program (year excluded to maintain provenance anonymity), which included official reported and reconstructed estimates of unreported catch data, were used to calculate the total and unreported catch for each of the 10 top-scoring provenances. The percentage of unreported catch was calculated as a percentage of the total catch for each provenance. The size of EEZ and number of commercial spp. were cited most frequently in the published literature as the key factors contributing to IUU fishing; analysis was conducted to measure the importance of each. Associations between unreported catch as the outcome variable and EEZ size, number of commercial spp., and total catch as the explanatory variables, were investigated using linear mixed regression analyses. For these analyses, provenance was incorporated into the model as a random effect. In the first instance, univariable analyses were used and variables with P values < 0.2 were retained for the multivariable analysis. The backward (Wald's) selection method was used to build the final model, and explanatory variables with $P < 0.05$ were considered significantly associated with the outcome and were retained in the model. The commercial spp. included in the statistical analysis were those cited in the Sea Around Us program as commercially important for each of the ten highest scoring provenances.

3. Results

The results for the top scoring provenances are presented in Table 4, which shows the mean scores, calculated from the combined scores for the seven predictor variables, and the reconstructed unreported catch for each of the ten highest scoring provenances. The catch data for the top 10 provenances are shown in Fig. 3. The highest unreported catch was for Provenance 67 (41.6%), which had the second highest risk score. Only 1.8% of undeclared catch separated the highest scoring provenance (Provenance 30) from the second highest (Provenance 67). If the scoring system was valid (Aim 3), a positive correlation between calculated mean scores and percentage of undeclared catch would be expected. There was a 79.36% decrease in the calculated mean risk scores between the highest scoring provenances 1–5 and 6–10. A similar decrease in overall undeclared catch was also observed: the mean undeclared catch for provenances 1–5 was 33.72% and that of provenances 6–10 was 15.5%. Linear regression analysis to determine the association between provenance EEZ size and unreported catch showed a non-significant association. However, the percentage unreported catch was associated with the number

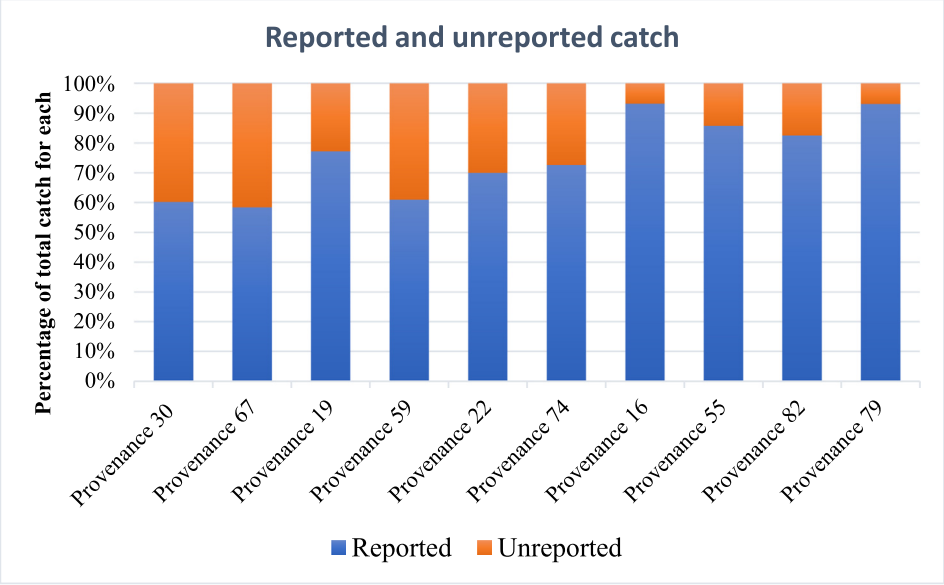

Fig. 3. Showing the top 10 highest scoring provenances for the outcome variable 'IUU or unreported catch high risk' and catch data for each provenance.

of different commercial spp. available in the provenance's EEZ; for every unit increase in the number of commercial spp., there was an increase of 5.28 units in the percentage unreported catch. Provenance did not have a significant random effect.

4. Discussion

The scoring model and seven predictor variables appear to be good predictors of unreported catch, with a clear association between the calculated mean risk scores for each provenance and the percentage unreported catch. It seems feasible that commercial spp. from the top 10 provenances in this study may have been of IUU origin. Provenance EEZ size and unreported catch showed a non-significant association. Similar results were reported by Agnew et al. (2009),[4] who found no significant relationship between illegal fishing and EEZ size. The best predictor of unreported catch in the present study was the number of commercial spp. within an EEZ. For every unit increase in commercial spp., there was an increase of 5.28 units in the percentage unreported catch. Seafood exports from the 10 highest scoring provenances provided 32.7% of all edible seafood consumed in Australia in 2017.

Theories that seek to explain criminal events within a certain environment are included in the rational choice theory. When applied to illegal fishing, it would be expected that offenders would be more likely to focus on areas of maximum reward and minimal risk.[37] However, in this study, many relatively small EEZs had very high unreported catch when there was a significant number of commercial spp. In Petrossian (2015),[37] the number of international commercial spp. in the EEZ was a significant predictor of illegal fishing. The inference is that a considerable quantity of commercially attractive seafood species that are part of the seafood supply chain may have been illegally caught. This conclusion is supported by Xiong et al. (2016),[55] who identified broad-scale fish fraud for Patagonian toothfish (*Dissostichus eleginoides*) and declarations inconsistent with catch areas and species range, despite strong policing of the natural waters by the Coalition of Legal Toothfish Operators.[56] Many studies have examined the motivational and opportunistic factors that contribute to illegal fishing, seafood chain breaches, and fish fraud,[5,57] while others have endeavored to construct predictive models that illustrate these constituent factors.[3,4,37,58,59] All of these studies have provided valuable contributions to our understanding of the motivational forces that drive illegal activities along the seafood supply chain. However, while the global war on illegal fishing continues, the threats to human health from seafood-borne zoonotic parasites and pathogens in illegally caught seafood remain unaddressed.

The global fish trade is an important factor in shifts in the traditional geographical boundaries associated with species of zoonotic seafood-borne parasites.[60] The consumption of imported fish has been linked to cases of human parasitic infection globally,[60–68] which may infer a deficiency in the seafood inspection schemes of the respective countries, or that illegally caught seafood is entering the market uninspected. A significant number of the reported cases of human parasitism from consumption of seafood have occurred in Provenance 67, which had the highest percentage of unreported catch (41.55%). Provenance 19, which had the third highest risk score and 22.88% unreported catch, has recently experienced a marked increase in cases of fish-borne human parasitism in a relatively restricted geographical area. It was concluded that these cases were from insufficient cold storage when transporting fish along the supply chain (publication not cited to maintain provenance confidentiality). These cases may reflect a cultural preference for undercooked seafood dishes, or that uninspected or inappropriately transported IUU parasite-infected seafood is entering the global export market from these regions. The Codex Alimentarius Commission (CAC) provides information, advice, and procedural recommendations to ensure that traded fish are safe and of suitable quality for human consumption. The CAC Code of Practice for Fish and Fishery Products (CAC/RCP 52-2003[12] itemizes parasites in fish as a public health hazard and provides recommendations for cold storage and processing, such as trimming/candling to minimize the parasitic-infection risk. It is assumed that fish caught by a registered vessel, supervised by a safety observer, where the catch is then absorbed into a legitimate supply chain that includes provenance inspection procedures, would deliver safe parasite-free fish for export. No such assumptions can be made for IUU-sourced fish. The species of parasites that may be imported into fish products are largely dependent on national trading exchanges.[69] However, IUU fishing negates international parasite mitigation strategies by introducing uncertainty regarding fish species and the region of capture.

Transshipment at sea is often a point of laundering of IUU fish and may involve mixing documented legal catches with transshipped IUU catches.[8] Additionally, proximity to known ports of convenience is also recognized as a facilitator for IUU fishing.[37] These ports admit IUU-fishing vessels and allow illegal catches to be absorbed into international markets.[70] An exerpt from Trygg Mat Tracking (2019)[44] clearly indicates how IUU fishing contributes to the uncertainty and safety of seafood in the global supply chain: "*PERLON, requested port access Singapore, February 20th 2012. Port access was withheld, and the vessel afterwards moved away from the outer port limits of Singapore. In April 2015, the vessel was spotted and boarded by an Australian maritime patrol in the region west of Cocos (Keeling) Islands, in the eastern Indian Ocean. Inspectors found a significant quantity of frozen fish in storage, believed to be illegally caught toothfish. The vessel was apprehended in Malaysia in May 2015 and was charged and fined for offences under the Malaysian Fisheries Act, including unauthorized transhipment (transferring toothfish to an anchored barge). A total of 330 t of illegally caught toothfish was confiscated and the vessel was fined. The vessel was released from detention 5 August 2015*". At legitimate ports, fraudulent catch documentation data have been endorsed by inspectors[71] and copies of official customs forms can also be obtained from government officials to allow the entry of IUU seafood into legitimate ports. IUU seafood products without accompanying documentation may also be smuggled into countries by bribing government officials.[8] Although not a product of IUU, bribery of government officials and fraudulent documentation is thought to have been how white spot syndrome virus was introduced into Australia.[72] Fig. 4 shows the recognized ports of convenience and those that are highly visited (in red). All of the five highest scoring provenances have access to one highly visited port of convenience. Globalization of fish trade is considered a significant driver of human fish-borne parasitism outside normal areas of endemicity. For example, the fish-borne zoonotic cestode *Diphyllobothrium nihonkaiense* in Europe[73] and New Zealand,[74] where the disease has no traditional endemic foci.[75] It must be considered that IUU-sourced seafood may be a significant driver in this spread and that Australian government officials may wish to consider this in regards to seafood inspection biosecurity.

The risk scoring system in the present study appears to be a good indicator of unreported catch. Data from this study could provide the impetus to examine species of fish that are imported to Australia from high-risk provenances for zoonotic parasites. A limitation of this study was the lack of information for all seven variables for one specific time period, which would have enabled us to align the outcome variable with catch data from the same point in time. In addition, IUU fishing attributed to one country may not actually be where the illegal catch was offloaded or absorbed into the food chain. The transport of seafood products through a series of countries for processing and export provides a legitimization of fraudulent catches.[3] Russia, Japan, Korea, and China have been

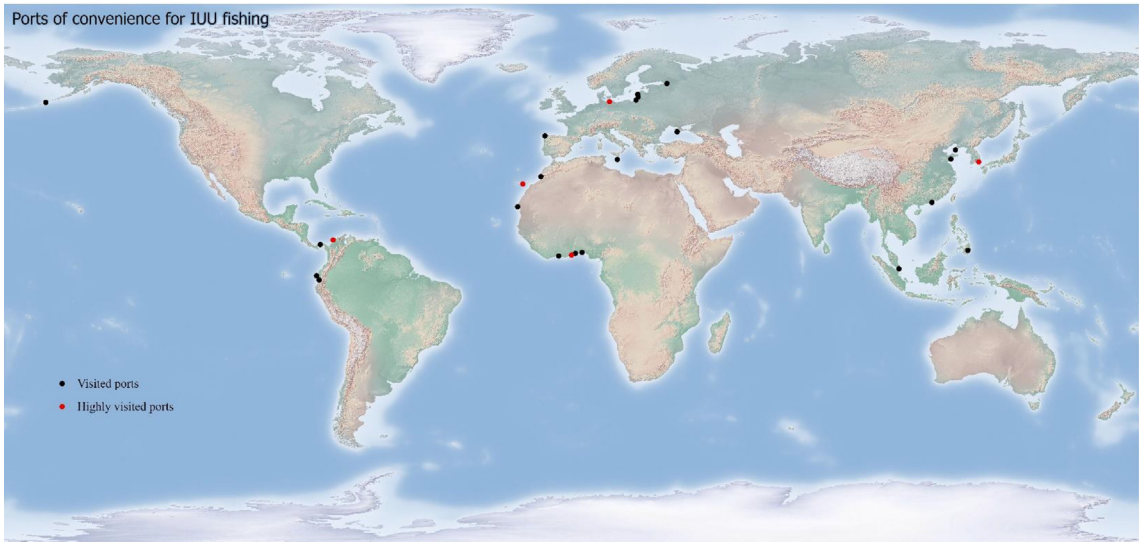

Fig. 4. Showing recognised ports of convenience where IUU fish is permitted to be offloaded. Red points represent highly visited ports.

implicated in fraudulent seafood supply chain activity[9] but may not necessarily be the countries responsible for IUU fishing.

5. Conclusions

According to Sumaila et al. (2017)[5] "with marine resources becoming scarcer and access to them becoming more valuable, incentives for corrupt practices are bound to increase". Australia is vigilant in the control of IUU fishing in its sovereign waters but has little control over countries that have limited ability or interest in controlling illegal fishing or access to ports of convenience. In this case, it is crucial that seafood imported to Australia is examined for seafood-borne zoonotic parasites, so that high-risk exposure pathways can be identified. IUU fishing has been the subject of many statistical evaluations. To our knowledge, this is the first study to use a risk scoring system to justify an investigation into the human health risks of zoonotic parasites in imported seafood.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

1. Baird R. Illegal, unreported and unregulated fishing: an analysis of the legal, economic and historical factors relevant to its development and persistence. *Melb J Int Law.*. 2004;5:1–36.
2. Miller DD, Sumaila UR, Copeland D, et al. Cutting a lifeline to maritime crime: marine insurance and IUU fishing. *Front Ecol Environ.*. 2016;14(7):357–362.
3. Pramod G, Nakamura K, Pitcher TJ, Delagran L. Estimates of illegal and unreported fish in seafood imports to the USA. *Mar Policy.*. 2014;48:102–113.
4. Agnew DJ, Pearce J, Pramod G, et al. Estimating the worldwide extent of illegal fishing. *PLoS ONE*. 2009;4(2):e4570.
5. Sumaila UR, Jacquet J, Witter A. When bad gets worse: corruption and fisheries*Corruption, natural resources and development*. Edward Elgar Publishing; 2017:93–105.
6. Seafish. The Seafish Guide to Illegal, Unreported and Unregulated (IUU) Fishing Website https://www.seafish.org/media/Publications/SeafishGuidetoIUU07-2016.pdf Accessed 1/7/2019.
7. Palin C, Gaudin C, Espejo-Hermes J, Nicolaides L. Compliance of imports of fishery and aquaculture products with EU legislation. *European Union, Directorate general for internal policies Policy department B: Structural and cohesion policies*. 2013.
8. Roheim CA. Seafood supply chain management: Methods to prevent illegally-caught product entry into the marketplace. IUCN World Conservation Union-US for the project PROFISH Law Enforcement, Corruption and Fisheries Work; 2008:1–23.
9. Fox M, Mitchell M, Dean M, Elliott C, Campbell K. The seafood supply chain from a fraudulent perspective. *Food Secur.*. 2018;10(4):939–963.
10. FAO Fisheries Technical Paper 414. Guidelines for developing an at-sea fishery observer programme. *Rome, FAO Food and Agriculture Organisation of the United Nations*. 2002:1–12.
11. Wootten R, Cann D. Round worms in fish Scotland, Marine Laboratory of the Department of Agriculture and Fisheries for Scotland and the Torry Research Station of the Ministry of Agriculture; Marine Laboratory of the Department of Agriculture and Fisheries for Scotland and the Torry Research Station of the Ministry of Agriculture, Aberdeen, Scotland; 2001.
12. Codex Alimentarius. Code of practice for fish and fishery products. In. Vol CAC/RCP 52-2003. Rome, Italy: FAO/WHO Food Standards Programme; 2016.
13. Luque J, Poulin R. Metazoan parasite species richness in Neotropical fishes: hotspots and the geography of biodiversity. *Parasitol.*. 2007;134(6):865–878.
14. Chapsos I, Hamilton S. Illegal fishing and fisheries crime as a transnational organized crime in Indonesia. *Trends Org Crime.*. 2019;22(3):255–273.
15. Suzuki J, Murata R, Yokoyama H, Sadamasu K, Kai A. Detection rate of diarrhoea-causing *Kudoa hexapunctata* in Pacific bluefin tuna *Thunnus orientalis* from Japanese waters. *Int J Food Microbiol.*. 2015;194:1–6.
16. Yokoyama H, Suzuki J, Shirakashi S. Kudoa hexapunctata n. sp.(Myxozoa: Multivalvulida) from the somatic muscle of Pacific bluefin tuna *Thunnus orientalis* and re-description of *K. neothunni* in yellowfin tuna *T. albacares*. *Parasitol Int.* 2014;63(4):571–579.
17. Kasai A, Li Y-C, Mafie E, Sato H. New host records of monacanthid fish for three *Kudoa spp.* (*K. septempunctata, K. thyrsites, and K. shiomitsui*) prevalent in the olive flounder (*Paralichthys olivaceus*), with the description of *K. parathyrsites* n. sp. from a black scraper (*Thamnaconus modestus*). *Parasitol Res.* 2016;115(7):2741–2755.
18. Sugita-Konishi Y, Sato H, Ohnishi T. Novel foodborne disease associated with consumption of raw fish, olive flounder (*Paralichthys olivaceus*). *Food Saf.*. 2014;2014026.
19. Williams M, Hernandez-Jover M, Shamsi S. Fish substitutions which may increase human health risks from zoonotic seafood borne parasites: a review. *Food Control.*. 2020;107429:1–45.
20. Hanner R, Beckker S, Ivanova NV, Steinke D. FISH-BOL and seafood identification: Geographically dispersed case studies reveal systemic market substitution across Canada. *Mitochondr DNA.*. 2011;22(S1):106–122.
21. Christiansen H, Fournier N, Hellemans B, Volckaert FA. Seafood substitution and mislabeling in Brussels' restaurants and canteens. *Food Control*. 2018;85:66–75.

22. Carvalho DC, Palhares RM, Drummond MG, Gadanho M. Food metagenomics: next generation sequencing identifies species mixtures and mislabeling within highly processed cod products. *Food Control.*. 2017;80:183–186.
23. Australian Government. Australia's second national plan of action to prevent, deter and eliminate illegal, unreported and unregulated fishing. In: Australian Government Department of Agriculture, ed. Canberra; 2014:1-25.
24. FAO of the UN. International plan of action to prevent, deter and eliminate illegal, unreported and unregulated fishing. In: Food and Agriculture Organization of the United Nations, ed. Reprinted 2017 ed. Rome: FAO of UN; 2001:1–16.
25. Craik W, Palmer D, Sheldrake R. Priorities for Australia's biosecurity system. An independent review of the capacity of the national biosecurity system and its underpinning intergovernmental agreement. *Canberra, Department of Agriculture and Water Resources*. 2017:1–188.
26. WTO. General Agreement on Tariffs and Trade (GATT) signed October 30, 1947 and in force 1 January 1948. Version The World Trade Organisation GATT signed Marrakesh on 14 April 1994, and in force 1 January 1995. In: The WTO Agreement series, ed. Geneva, Switzerland: World Trade Organisation; 1994:1–2.
27. WTO. Sanitary and Phytosanitary Measures signed Marrakesh on 15 April 1994. In: Organisation WT, ed. The WTO agreement series, Vol Entered into affect by World Trade Organization on 1 January 1995. Switzerland: World Trade Organisation; 1994:1–50.
28. WTO. Agreement on Technical Barriers to Trade (TBT) signed 1979 Tokyo Round of Trade Negotiations. Resigned as the World Trade Organisation TBT at Uruguay round of talks in 1994 entered into force 1 January 1995. In: The WTO Agreement series, ed. Switzerland: World Trade Organisation; 1994:1–22.
29. Asche F, Bellemare MF, Roheim C, Smith MD, Tveteras S. Fair enough? Food security and the international trade of seafood. *World Dev.*. 2015;67:151–160.
30. Savage J. Australian fisheries and aquaculture statistics 2015. *Fisheries Research and Development Corporation Project 2016–246*. Canberra, Australia: ABARES; 2015:1–160.
31. FRDC. Seafood import and export by commodity. Fisheries Research and Development Corporation, Web site. https://app.powerbi.com/view?r=eyJrIjoiZTg2NTlhYmQtM2ZhMy00ZGUyLTkwMTktMDJhODE5MmUxNjQ2IiwidCI6Ijk3M2YzMGJjLTNlMWYtNGQwMC05NmEyLTVjZGM2NTE5YjQxOCIsImMiOjEwfQ%3D%3D Accessed 22/7/2018.
32. Aust. Bureau of Stat. Selected living cost indexes, CAT number 6467.0. ABS. Website http://www.abs.gov.au/AUSSTATS/abs@.nsf/97adb482c0aba769ca2570460017d0e7/0e1fe191c5e59d18ca2570d7001ad238!OpenDocument# Timeseries Accessed 24/10/2018.
33. FSANZ. Australia and New Zealand Food Standards Code. *The FSANZ*. Melbourne, Victoria: Information Australia; 1997.
34. FSANZ. The Australian and New Zealand Food Standards Code. In. Imported foods: Imported foods inspection scheme. Vol 2018. Canberra: Food Standards Australia and New Zealand; 2018.
35. FSANZ. The Australian and New Zealand Food Standards Code. *In. The Compendium of Microbiological Criteria for Food*. Canberra: Food Standards Australia and New Zealand; 2018.
36. Aust. Gov. Imported Food Control Act 1992 In: Federal Register of Legislation, ed. Vol Compilation No. 25. Canberra: Australian Government; 2018:1–86.
37. Petrossian GA. Preventing illegal, unreported and unregulated (IUU) fishing: a situational approach. *Biol Conserv.*. 2015;189:39–48.
38. Metuzals K, Baird R, Pitcher T, Sumaila UR, Ganapathiraju P. One fish, two fish, IUU and no fish: unreported fishing worldwide. *Handbook of marine fisheries conservation and management*. New York, NY: Oxford University Press; 2010:165–181.
39. Pramod G, Pitcher TJ, Pearce J, Agnew D. Sources of information supporting estimates of unreported fishery catches (IUU) for 59 countries and the high seas. *Fish Cent Res Rep.*. 2008;16(4):1–241.
40. Pitcher T, Kalikoski D, Pramod G, Short K. Not honouring the code. *Nature.*. 2009;457(7230):658–659.
41. Pitcher T, Kalikoski D, Pramod G, eds. Evaluations of compliance with the FAO (UN) code of conduct of responsible fisheries. Vancouver, Canada; 2006. Fisheries Centre Research Reports No. 14. pp. 1–77.
42. Pitcher T, Kalikoski D, Ganapathiraju P, Short K. *Safe conduct? Twelve years fishing under the UN Code*. Switzerland: World Wide Fund for Nature; WWF-International and University of British Columbia; 2008.
43. Trygg Mat Tracking. Combined IUU vessel list. Website https://iuu-vessels.org/. Accessed 1/7/2019.
44. Trygg Mat Tracking. Current IUU vessel search. Website https://iuu-vessels.org/Home/Search Accessed 1/7/2019.
45. FAO. Fishing vessels finder. Food and Agriculture Organisation of the United Nations. Website http://www.fao.org/figis/vrmf/finder/search/#stats *Accessed*. 1/7/2019.
46. Wertheim E. *The naval institute guide to combat fleets of the world: Their ships, aircraft, and systems*. 16th ed. London, UK: US Naval Institute Press; 2015:1–1008.
47. Sea Around Us. Sea around us project [interactive database]. http://www.seaaroundus.org/data/#/eez Accessed 24/10/2018.
48. PEW. Missions & Values. *The Pew Charitable Trusts*. Web site. https://www.pewtrusts.org/en/about/mission-and-values *Accessed*. 18/8/2018.
49. Allen J. About our efforts. The Paul G. Allen Family Foundation. Web site. https://pgafamilyfoundation.org/About Accessed 1/7/2019.
50. FAO. Code of Conduct for Responsible Fisheries. In: Food and Agriculture Organisation of the United Nations, ed. Rome;1995:1–108.
51. Pramod G. Policing the Open Seas: Global Assessment of Fisheries Monitoring, Control and Surveillance in 84 Countries. Website https://iuuriskintelligence.com/global-fisheries-mcs-report/ *Accessed*. 1/7/2018.
52. MRAG. Review of impacts of Illegal, Unreported and Unregulated fishing on developing countries. *Marine Resources and Fisheries Consultants*. 2005:1–176.
53. FAO. Fishery and Aquaculture Country Profiles. Fisheries and Aquaculture Department. Website http://www.fao.org/fishery/countryprofiles/search/en *Accessed*. 19/12/2019.
54. CTI. Corruption perceptions index Corruption Transparency Index. Web site. https://www.transparency.org/cpi2018 accessed 9 May 2019. Accessed 9/5/2019.
55. Xiong X, Guardone L, Cornax MJ, et al. DNA barcoding reveals substitution of Sablefish (*Anoplopoma fimbria*) with Patagonian and Antarctic Toothfish (*Dissostichus eleginoides* and *Dissostichus mawsoni*) in online market in China: How mislabeling opens door to IUU fishing. *Food Control*. 2016;70:380–391.
56. COLTO. Coalition of legal toothfish operators inc. Website https://www.colto.org/toothfish-fisheries/. *Accessed*. 1/6/2019.
57. Kleboth J, Luning P, Fogliano V. Risk-based integrity audits in the food chain–a framework for complex systems. *Trends Food Sci Technol.*. 2016;56:167–174.
58. Pramod G, Pitcher TJ, Mantha G. Estimates of illegal and unreported seafood imports to Japan. *Mar Policy.*. 2017;84:42–51.
59. Spink J, Moyer DC, Speier-Pero C. Introducing the food fraud initial screening model (FFIS). *Food Control.*. 2016;69:306–314.
60. Pastor-Valle J, González LM, Martín-Clemente JP, Merino FJ, Gottstein B, Gárate T. Molecular diagnosis of diphyllobothriasis in Spain, most presumably acquired via imported fish, or sojourn abroad. *New Microb. New Infect.*. 2014;2(1):1–6.
61. Esteban J, Muñoz-Antoli C, Borras M, Colomina J, Toledo R. Human infection by a "fish tapeworm", *Diphyllobothrium latum*, in a non-endemic country. *Infection*. 2014;42(1):191–194.
62. Kuchta R, Esteban J-G, Brabec J, Scholz T. Misidentification of *Diphyllobothrium* species related to global fish trade, Europe. *Emerg. Infect Dis.*. 2014;20(11):1955–1957.
63. Paugam A, Yera H, Poirier P, Lebuisson A, Dupouy-Camet J. *Diphyllobothrium nihonkaiense* Bothricephalosis: a new risk linked to the consumption of salmon. *La Presse Médicale.*. 2009;38(4):675–677.
64. Yera H, Estran C, Delaunay P, Gari-Toussaint M, Dupouy-Camet J, Marty P. Putative *Diphyllobothrium nihonkaiense* acquired from a Pacific salmon (*Oncorhynchus keta*) eaten in France; genomic identification and case report. *Parasitol Int.*. 2006;55(1):45–49.
65. Shimizu H, Kawakatsu H, Shimizu T, et al. *Diphyllobothriasis nihonkaiense*: Possibly acquired in Switzerland from imported Pacific Salmon. *Intern Med J.*. 2008;47(14):1359–1362.
66. Wicht B, de Marval F, Peduzzi R. *Diphyllobothrium nihonkaiense* (Yamane et al., 1986) in Switzerland: first molecular evidence and case reports. *Parasitol Int.*. 2007;56(3):195–199.
67. Wicht B, Marval F, Gottstein B, Peduzzi R. Imported diphyllobothriasis in Switzerland: molecular evidence of *Diphyllobothrium dendriticum* (Nitsch, 1824). *Parasitol Res.*. 2008;102(2):201–204.
68. Ko KKK, Cao DYH, Wee LWY, Hsu LY, Yamasaki H. First two confirmed cases of *Dibothriocephalus nihonkaiensis* in Southeast Asia (Singapore). *Pathology.*. 2019;51(4):433–434.
69. Autier B, Belaz S, Degeilh B, Gangneux J-P, Robert-Gangneux F. *Dibothriocephalus nihonkaiensis*: an emerging foodborne parasite in Brittany (France)?. *Parasit Vectors.*. 2019;12(1):1–6.
70. Petrossian GA, Marteache N, Viollaz J. Where do "undocumented" fish land? An empirical assessment of port characteristics for IUU fishing. *Eur J Crim Policy Res.*. 2015;21(3):337–351.
71. HSTF. High Seas Task Force Closing the Net: Stopping Illegal Fishing on the High Seas. Governments of Australia, Canada, Chile, Namibia, New Zealand, and the UK, WWF, IUCN, and the Earth Institute at Columbia University. France, IUU Fishing Coordination Unit Department for Environment, Food and Rural Affairs; 2006:1–116.
72. ABC. Outbreak. Australian Broadcasting Commission. Four Corners. Web site. https://www.abc.net.au/4corners/outbreak/9932836. Accessed 2/7/2018.
73. De Marval F, Gottstein B, Weber M, Wicht B. Imported diphyllobothriasis in Switzerland: molecular methods to define a clinical case of *Diphyllobothrium* infection as *Diphyllobothrium dendriticum*. *Euro Surveil.*. 2013;18(3):20355.
74. Yamasaki H, Kuramochi T. A case of *Diphyllobothrium nihonkaiense* infection possibly linked to salmon consumption in New Zealand. *Parasitol Res.*. 2009;105(2):583–586.
75. Ikuno H, Akao S, Yamasaki H. Epidemiology of *Diphyllobothrium nihonkaiense* Diphyllobothriasis, Japan, 2001–2016. *Emerg Infect Dis.*. 2018;24(8):1428–1434.
76. PEER. High seas harassmnent of fisheries observers more than doubles. *USA, Public Employees for Environmental Responbsibility*. Web site. https://www.peer.org/news/press-releases/high-seas-harassment-of-fisheries-observers-more-than-doubles.html. 2013.
77. PEER. Open season on harassing fisheries observers. *USA, Public Employees for Environmental Responbsibility*. Web site. https://www.peer.org/news/press-releases/open-season-on-harassing-fisheries-observers.html. 2016.
78. PEER. Attacks on fishing observers rise by almost half in 2006. USA. *Public Employees for Environmental Responbsibility*. Web site. https://www.peer.org/news/press-releases/attacks-on-fishing-observers-rise-by-almost-half-in-2006.html. 2007.
79. NOAA. Oregon deck boss charged with assaulting federal fishery observer. *USA, National Oceanic and Atmospheric Administration*. Web site. https://www.westcoast.fisheries.noaa.gov/stories/2014/08152014_observer_asaulted.html. 2014.