

SFP Report on the Wild Shrimp Sector

Bycatch in Global Shrimp Fisheries

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SFP Report on the Wild Shrimp Sector: Bycatch in Global Shrimp Fisheries

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EXECUTIVE SUMMARY

This SFP issue report presents analysis of the problem of bycatch in global wild shrimp fisheries. Shrimp trawling collectively accounts for more bycatch volume and has a higher proportion of bycatch (compared to harvest volumes) than any other fishery type, although individual shrimp trawl fisheries have taken proactive management measures resulting in low bycatch rates and volumes. Various environmental impacts have been associated with bycatch, including depletion of protected, endangered, and threatened (PET) species; depletion of other bycatch species; and ecosystem impacts such as trophic cascades. Again, individual fisheries have taken actions to limit or eliminate these impacts. The environmental impacts of bycatch are important risks for retailers and suppliers of seafood to take into account when sourcing shrimp from global fisheries. Furthermore, consumers may perceive large volumes of discarded bycatch as wasteful and unethical even if the above-described impacts are not a concern for a particular fishery. In light of these concerns, we aim to educate the seafood industry and the public about bycatch and what can be done to manage it on a more precautionary basis.

Our analysis focuses upon a group of 20 global, industrial, bottom trawl shrimp fisheries that accounts annually for approximately 1.1 million metric tons, or almost one-third, of global annual wild shrimp harvest. The fisheries were chosen to represent the diversity of this fishery type, with the sample including cold- and warm-water species, data-rich and data-deficient fisheries, and locations encompassing six continents. Information on each of these fisheries was gathered from our web database FishSource (www.fishsource.com), scientific literature, management reports, and other publications. Subsequently, each fishery was rated for 12 criteria grouped under four categories: 1) impacts of bycatch, 2) precautionary management of bycatch, 3) monitoring of bycatch, and 4) enforcement of and compliance with measures intended to limit bycatch. These criteria were developed specifically for this analysis and for future use rating fisheries on FishSource. For each criterion, the fishery was rated as a “low,” “medium,” or “high” sustainability risk or, in the absence of information, a rating of “data deficient” was assigned to the fishery.

In summary, the report concludes that:

- Warm-water shrimp fisheries generally have higher bycatch rates and volumes than cold-water shrimp fisheries. The harvest of most of the warm-water fisheries included in our study comprises 75% or more bycatch, and the majority of these fisheries have annual bycatch volumes of over 100,000 metric tons.
- Among the cold-water shrimp fisheries in our sample, bycatch generally comprises 10% or less of the harvest and annual bycatch volumes do not exceed 2,500 metric tons.
- Well over half of warm-water shrimp fishery volume was rated as “high risk” or “data deficient” for each of the four categories included in our analysis (impacts, management, monitoring, compliance/enforcement). High-volume, multispecies trawl fisheries in Asia contributed prominently to these volumes. Information necessary to assess fishery impacts on bycatch species was particularly lacking among warm-water shrimp fisheries, including the multispecies trawl fisheries. However, several warm-water shrimp fisheries performed well in our analysis and received low and medium risk ratings on most (at least 11 of 12) criteria: namely, the Gulf of Mexico, Gulf of California, Northern Australia, and Suriname trawl fisheries.
- Low and medium risk ratings were attributed to the majority of the cold-water shrimp fishery harvest for each of the four categories of analysis. Northern prawn fisheries in Atlantic Canada, West Greenland, and the Barents Sea performed particularly well (“low risk” on all but one scored criterion) in our analysis, as did Oregon pink shrimp.
- Many warm-water fisheries received ratings of “high risk” due to inadequate observer coverage, as well as compliance and enforcement of gear regulations and closed areas.
- While many of the fisheries studied have implemented bycatch reduction device (BRD) and turtle excluder device (TED) regulations, some have not.

When fisheries commit to efforts to reduce bycatch, they can and do succeed: fisheries that required use of BRDs and TEDs have achieved meaningful reductions in the proportion of their harvests comprising bycatch.



On the basis of those findings, the report offers the following improvement recommendations to catchers and regulators engaged in those shrimp fisheries that have room for improvement with respect to management of bycatch:

- Fisheries that target shrimp should make bycatch reduction devices mandatory by law among all licensed boats, and warm-water fisheries should additionally make turtle excluder devices mandatory by law among all licensed boats. These devices have been proven effective in achieving meaningful bycatch reductions. Regulators should work closely with scientists and fishery participants to determine which devices are best suited to the fishery and should monitor effectiveness.
- In addition to gear regulations, managers should evaluate distribution and composition of bycatch to determine whether instituting closed areas would further reduce bycatch and associated impacts.
- Bycatch reduction and turtle excluder device regulations, as well as closed area regulations, are not sufficient on their own to ensure successful reduction of bycatch. Fisher compliance must be ensured through adequate enforcement. Warm-water fisheries performed poorly on relevant criteria in our analysis, indicating that compliance and enforcement are particular areas where improvement is needed.
- The measures described in the preceding three bullets should form the basis of a bycatch reduction plan that describes fishery objectives with respect to bycatch and the means by which those objectives will be achieved.
- Fishery impacts to bycatch species, including PET species, are often poorly understood, resulting in many “data deficient” ratings on impacts criteria in our analysis. Risk assessment should be carried out on bycatch species, particularly on PET and main (commonly-occurring) bycatch species, to ensure that the fishery is not depleting or prohibiting recovery of these species. This recommendation is applicable both to fisheries that target shrimp and to multispecies fisheries that target a low-trophic species aggregate including shrimp.

Furthermore, the following recommendations are made to the seafood supply chain:

- Demand low risk performance from your source fisheries using the criteria described in this report as a guide.
- Source preferentially from fisheries certified by the Marine Stewardship Council or engaged in a fishery improvement project (FIP): this applies to 75% of global harvest from cold-water shrimp fisheries and 8% of global harvest from warm-water shrimp fisheries.
- Participate in existing FIPs in shrimp fisheries, and initiate FIPs in source fisheries that are neither engaged in the Marine Stewardship Council process nor in a FIP.



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INTRODUCTION

This SFP *issue report* is intended to inform the seafood industry and the public about a prevalent sustainability concern in global shrimp fisheries: bycatch. While this problem is not limited to shrimp fisheries, bycatch rates and cumulative volumes of bycatch in shrimp fisheries exceed those of all other wild capture fisheries (Alverson et al. 1994, Kelleher 2005). SFP believes that bycatch mitigation relies partially upon an educated supply chain that is informed about the status of its source fisheries with respect to sustainability and committed to partnering with catchers and regulators to achieve systematic improvement. To this end, we are publishing periodic *sector reports* describing the performance of fisheries in a particular sector (e.g. shrimp) against the five measures of sustainability applied in our web database FishSource (www.fishsource.com), as well as *issue reports* like this one, which focus more specifically upon a single sustainability concern. This report describes impacts associated with bycatch in shrimp bottom trawl fisheries, measures that can be taken to manage bycatch appropriately, and the status and progress of individual fisheries with respect to bycatch impacts and precautionary management. Our main findings are subsequently summarized as recommendations to catchers and regulators engaged in the shrimp sector, as well as recommendations on how the supply chain can further engage in addressing bycatch issues.

This analysis comprises 20 bottom trawl fisheries that account annually for approximately 1.1 million metric tons, or almost one-third of global wild shrimp harvest. The choice of these fisheries reflects an underlying goal of representing the diversity of this type of fishery (our sample includes cold- and warm-water species, data-rich and data-deficient fisheries, and a variety of geographies). However, the fisheries are all industrial, as bycatch data are entirely absent for many artisanal fisheries.¹ Another motivating factor in the choice of these fisheries was supply chain partner interest: we have received requests for information about all of these fisheries from our supply chain partners, resulting in their representation in FishSource, from which information for the report was partly drawn.

The strategies for bycatch reduction described in this report reflect work that SFP undertook in 2013–2014 to develop a shrimp-specific sustainability evaluation method for FishSource. The method, which particularly emphasizes analysis of bycatch, is still in draft form. In years to come, we intend to apply our new method to tracking the progress of individual shrimp fisheries in reducing their bycatch.

What is bycatch?

Terminology surrounding the issue of bycatch differs regionally and among management entities and researchers. For the purposes of this report, “bycatch” is defined as the catch of non-target animals, including retained (kept on board and landed) and discarded (dumped at sea, dead or alive) species, as well as discarded harvest of undersized, juvenile, or otherwise undesirable individuals of the target species.

Bycatch and shrimp fisheries

Estimates of the amount of bycatch in global shrimp fisheries vary widely, in part due to differences in how “bycatch” is defined, but also because of data deficiency, season-to-season variability, differences in measurement methods among management entities, and other complicating factors. A 2005 FAO report on discards indicated that 1.87 million metric tons of biomass, or 62% of the total harvest volume, are discarded annually by shrimp trawl fisheries. The study found that shrimp trawl fisheries exceeded all others in both discard volume and rate: demersal finfish trawls ranked second in terms of volume, with 1.7 million metric tons of annual discards, while tuna longline fisheries ranked second in terms of discard rate (28.5%). The study furthermore indicated that, in 1992–2001, discards from shrimp fisheries accounted for 26% of total global discards, which averaged 7.29 million metric tons annually (Kelleher 2005).

¹ There are data available for a subset of artisanal shrimp fisheries, and it indicates that, in some cases, bycatch is lower when artisanal gears are used (Ramirez and Morales 2012). However, artisanal fisheries can still have significant impacts on bycatch species: for example, entanglement net artisanal shrimp fisheries in the Gulf of California, Mexico, are implicated in the decline of the vaquita purpose to its current near-extinct status (CIRVA 2014).



The Kelleher report served as an update to an earlier FAO report (Alverson et al. 1994) quantifying global fishery discards. The 1994 report's estimates of annual global fishery discards and those of shrimp fisheries (averages, 1980–1992) were approximately four-fold greater than those of the 2005 update (see Table 1). Many experts believe that the difference is accounted for by growing retention of bycatch in order to produce feed for use in fish farming, although contrasting interpretations of the statistics exist.

Table 1. Global discard data from FAO reports covering the 1980s and 1990s illustrate that discard volumes and ratios are decreasing, with increasing retention of bycatch a possible cause of the trend.

	Alverson et al. (1994): reviews data from 1980–1992		Kelleher (2005): reviews data from 1992–2001	
	Average annual discard ratio (percent of harvest)	Average annual discard volume (metric tons)	Average annual discard ratio (percent of harvest)	Average annual discard volume (metric tons)
Shrimp trawls	84%	9,511,973	62.3%	1,865,064
Global fisheries	26%	27,012,099	8%	7,290,170

In the absence of a more recent study of similar scale, we assume that in the 2000s: 1) bycatch volumes in some shrimp fisheries continue to be significant;² and 2) increasing amounts of bycatch in warm-water fisheries are being retained (and decreasing amounts are being discarded) due to steady growth in the aquaculture industry and overall high demand for protein amidst human population growth.

Commercial shrimp fishing occurs all over the world, with 105 countries reporting commercial shrimp harvest in the 2012 fishing season to the FAO (FAO 2014). Bycatch quantity and species composition vary widely by geography. In a particular fishery, bycatch can also vary significantly among individual fishing grounds, among seasons, and even by time of day. In general, bycatch volumes and diversity are more limited in cold-water fisheries compared with warm-water fisheries. The reasons for this are two-fold: 1) There is lower species diversity in colder waters compared with the tropics and therefore fishery selectivity is easier to achieve, and 2) the predominantly developed nations where cold-water shrimp fishing takes place have been able to devote more resources to bycatch reduction than the predominantly developing nations that account for global warm-water shrimp catch.

Fishing gears

In addition to geography, fishing gear is another important determinant of bycatch quantity and composition. Most industrial shrimp harvest is done by bottom trawls, of which otter and beam trawls are the most common types. Both of these trawl types are generally towed with very close bottom contact, although the extent varies with how the gear is rigged. In addition to net placement in the water column, net size, net configuration, and net mesh size are also important factors in determining bycatch volume and species composition.

Trawling is generally not considered a very selective fishery method, as, depending upon trawl type, fishery regulations, and the species present in the geography where the fishery occurs, a trawl might catch all animals in its path. Among worldwide wild-capture fisheries including shrimp fisheries, bottom trawls account for over 50 percent of bycatch, but only 22 percent of total harvest, and account for the most discarded bycatch by weight of any gear type (Kelleher 2005). However, gear technology innovations over the last several decades, including bycatch reduction devices (see below), have allowed for improved trawl selectivity in a growing number of fleets.

There are a handful of other gear types that are used in smaller-scale shrimp fisheries: notably, pots and traps, which are used in some west coast North America prawn fisheries; entanglement nets; and stow nets used in coastal fisheries in Southeast Asia (Gillett 2008). These gear types have their own challenges with respect to bycatch: for example, loss of traps and gillnets can result in associated bycatch mortality (known as “ghost fishing”). Meanwhile, mesh size in stow nets is very small, often resulting in high species diversity and occurrence of juveniles in the catch.

² The fact that global shrimp harvest increased 32% between the 1990s and the 2000s suggests that global bycatch volume has also increased since the Kelleher estimates were made upon the basis of 1990s data (2005). However, many fisheries have undertaken bycatch reduction strategies during that time, thereby reducing bycatch ratios. In the absence of new information, we presume that bycatch volumes continue to be significant.



OVERVIEW OF THE IMPACTS OF BYCATCH IN SHRIMP FISHERIES

Why should the supply chain be concerned about bycatch in shrimp fisheries? Does the growing trend of bycatch retention mean that bycatch is less of a concern than it once was?

More bycatch retention means less waste, and the issue of waste, first and foremost an ethical rather than environmental dilemma, has historically posed a reputational challenge to the seafood supply chain. While this challenge is growing less urgent due to increasing bycatch retention rates, the sections below illustrate that other environmental impacts can occur regardless of whether the bycatch is retained or discarded.

Impacts on PET species

An important concern of bycatch in shrimp fisheries is associated mortality of protected, endangered, and threatened (PET) species (species with regulatory-concern status according to national legislation or an international treaty, or with an IUCN designation as vulnerable, endangered, or critically endangered). Shrimp trawler interactions with sea turtles in warm-water fisheries have received particular scrutiny in scientific and popular literature, as well as in management regulations. However, albeit less well-documented, some shrimp fisheries are also known to interact with PET marine mammals, seabirds, elasmobranchs (sharks, skates, and rays), syngnathids (e.g., seahorses), sea snakes, jellyfish, sponges, and fish. Among the 20 fisheries examined in preparation of this report, 16 had data available on the number of PET species known to appear in fishery bycatch. On average, these 16 fisheries interacted with 26 PET species each—among these fisheries, seven cold-water fisheries averaged eight PET species in their respective bycatches, while the nine warm-water fisheries averaged 39 PET species each (see Review of Fishery Performance section below).

The declining status of global sea turtle populations has been recognized for several decades, as has the role of fishery bycatch as the single most important anthropogenic cause of their mortality (Hillested et al. 1981, NRC 1990). Of the seven species of sea turtles in the world, six are rated as vulnerable, endangered, or critically endangered by the IUCN, with the seventh unrated due to data deficiency (IUCN 2014). As sea turtles primarily inhabit tropical waters, bycatch of these species is of particular concern for warm-water fisheries. Bottom trawler fleets have notably been implicated in sea turtle bycatch, although gillnet fisheries also interact with turtles. Fisheries with turtle bycatch are widely distributed throughout the tropics (e.g., Gulf of Mexico, US; Bay of Bengal, India; Gulf of Tonkin, Vietnam; Northeast Australia; and many other locations) due to the expansive habitat range of sea turtles (NRC 1990, Cartwright 2003, Poseidon 2011, Rao 2011).

Although the global scale of shrimp fishery impacts upon non-turtle PET species is not known, localized issues suggest that impacts can be serious. For example, in the Gulf of California, Mexico, bottom trawl shrimp vessel interactions with the totoaba fish played a direct role in the decline of the species to its current, critically endangered status (IUCN 2014). However, fleet size reductions and the introduction of gear regulations (required use of turtle excluder devices, which also allow for the escapement of small fishes) have since reduced totoaba bycatch to 0.01% of fleet harvest (Barrera-Guevara 1990, Rodriguez-Romero et al. 2012).

As part of our analysis, we estimated the sustainability risk of the 20 studied fisheries with respect to impacts upon PET species, particularly assessing direct fishery threat to viability or rebuilding of a PET species population (Table 2).

**Table 2.** Criterion used to estimate fishery sustainability risk with respect to impacts upon PET species.

Criterion	Low Risk	Medium Risk	High Risk
1. Are direct fishery impacts upon PET species acceptable?	There is strong evidence that PET species interactions do not occur or do not jeopardize the viability or rebuilding of a PET species population.	There is some evidence that PET species interactions do not jeopardize the viability or rebuilding of a PET species population.	There is some evidence that PET species interactions likely jeopardize the viability or rebuilding of a PET species population.

Impacts on other species

Bycatch can also negatively impact non-PET species, particularly those that are depleted but not listed as a species of regulatory concern. One example of a fishery where this may have occurred in the recent past is the Argentinian red shrimp bottom trawl fishery where hake, a main bycatch species in the shrimp fishery, has been below its biomass limit reference point in 6 of the last 9 years. However, in the last three years hake biomass has increased, achieving its target reference point in 2013 (INIDEP 2014). A fishery may also negatively impact the target species by overharvesting juvenile or undersized shrimp. This problem is often associated with coastal artisanal fisheries that overlap with shrimp nursery grounds. Trawl fisheries that take place close to shore, in estuaries or bays, and/or with small-meshed nets can also be implicated (Poseidon 2011). Determining whether a fishery is adversely affecting or impeding recovery of a particular species is complicated by the large number of species that appear in the bycatch of many shrimp fisheries. Of the 18 fisheries included in this report that had data on the species composition of their bycatch, the number of harvested species ranged from 15 to 800, with an average of 206 (60 for cold-water fisheries and 298 for warm-water fisheries).

Overwhelmed by the task of assessing impacts on so many species, managers may choose to prioritize those that comprise large proportions of the harvest, or those species for which the fishery accounts for a significant proportion of fishing mortality. For our analysis, we gathered information on impacts to species that comprise 5% or more of fishery harvest by volume, which we termed “main” bycatch species. As with PET species, we differentiated the sustainability risk of the studied fisheries by examining direct fishery threat to the rebuilding of an overfished main bycatch species (Table 3). The 18 fisheries for which data were available had an average of five main bycatch species in their respective harvests. Information on impacts to these species was notably lacking—approximately half of the fisheries included in our report were found to lack substantive information on impacts to main bycatch species.

Table 3. Criterion used to estimate fishery sustainability risk with respect to impacts upon main bycatch species.

Criterion	Low Risk	Medium Risk	High Risk
2. Are direct fishery impacts upon main bycatch species acceptable?	Yes, main bycatch species do not appear to be overfished OR if main bycatch species are overfished, there is strong evidence that bycatch mortality from this fishery is not implicated in the species' failure to rebuild.	Somewhat, main bycatch species are overfished but there is some evidence that bycatch mortality from this fishery is not implicated in the species' failure to rebuild.	No, main bycatch species are overfished and there is some evidence that bycatch mortality from this fishery is likely implicated in the species' failure to rebuild.

Impacts on ecosystems

Impacts of bycatch can extend beyond issues for individual bycatch species and result in ecosystem changes of a more systemic nature. Fisheries that harvest representatives of other low-trophic species groups in addition to shrimp can, through overharvest, change trophic food webs and adversely affect fish that depend upon low-trophic species as a source of food, such as large, long-lived, demersal predators (Essington et al. 2006, Smith et al. 2011). This is a concern for tropical shrimp fisheries, where a greater diversity of low-trophic species occurs, and particularly for multispecies fisheries that target and retain a low-trophic species aggregate. Several fisheries included in our study fall into this category (Chinese bottom beam trawl, Orissa and Kerala (India) bottom trawls, and



Vietnamese bottom otter trawl).³

Furthermore, contact between bottom trawling nets and benthic habitat can affect benthic community health and composition (Watling and Norse 1998, Fossa et al. 2002, Kaiser et al. 2003). Finally, discards provide a localized food source to scavengers, including seabirds, as well as predators. This source of food would not exist without the presence of the shrimp fishery and therefore impacts trophic food webs, although not necessarily in a negative way (Furness 2003, Louzao et al. 2011).

We did not include a criterion devoted to any of the above-described ecosystem impacts in our analysis due to limited capacity for information gathering. We hope to do so in a future publication.

Other impacts

Bycatch has other consequences for society, including: possible conflict between artisanal and industrial fishers (artisanal fishers may perceive industrial trawler discards as wasteful or polluting their shared environment); increasing need for taxpayer funds to support monitoring and enforcement programs; and a difficult-to-quantify cost to society of lost iconic species or high-value habitat (Kelleher 2005). We did not undertake in-depth assessment of fishery performance with respect to these indirect impacts.

In light of the likelihood of all of the above-described impacts when bycatch rates are high, we also included a criterion in our analysis that sets thresholds for bycatch rate (Table 4).⁴

Table 4. Criterion used to estimate fishery sustainability risk with respect to bycatch impacts generally.

Criterion	Low Risk	Medium Risk	High Risk
3. Is bycatch low?	Yes, bycatch is <85% total catch (bycatch ratio of approximately 5:1 or less).	Somewhat, bycatch is <90% total catch (lower than 10:1 bycatch ratio).	No, bycatch is ≥90% total catch (10:1 or higher bycatch ratio).

BYCATCH REDUCTION

Bycatch reduction is basically accomplished through three approaches: avoiding capture, allowing escape, and reducing mortality of bycatch species. Successful implementation of one or more of these three approaches in turn entails precautionary management (for example, gear regulations), monitoring (including for the purpose of tracking bycatch reduction effectiveness), and enforcement to ensure fisher compliance with regulations. This recipe for bycatch reduction is explored further below.

³ It is important to distinguish between directed fisheries that particularly target shrimp and fisheries that target a multispecies, low-trophic aggregate that includes shrimp. A multispecies fishery has a different set of objectives compared with a directed shrimp fishery, and bycatch reduction recommendations appropriate for directed fisheries may not be suitable for multispecies fisheries that are retaining and attempting to maximize the harvest of low-trophic species besides shrimp. Therefore, while we collected information on trawl fisheries in China, India, and Vietnam for this report, it is important to note that these fisheries appear to target a multispecies aggregate rather than only shrimp (note: it is unclear whether the target species are clearly defined for some of these fisheries).

⁴ Criterion 3, conceived on the basis of bycatch levels in warm-water shrimp fisheries, is indicative of bycatch rates in fisheries that have not implemented bycatch reduction versus those that have. In general, warm-water shrimp fisheries with bycatch ratios of 10:1 or greater have not implemented bycatch reduction techniques, while bycatch ratios of 5:1 or less have likely been achieved through bycatch reduction strategies. With this criterion we do not intend to declare all fisheries with bycatch rates of <85% to be “low risk”—a truly “low risk” fishery would earn “low risk” ratings across all of the criteria, partly through the striving of its managers to reduce bycatch regardless of whether or not the baseline bycatch rate is high (see Table 8 below).



Precautionary management

Precautionary fishery management “exercises prudent foresight to avoid unacceptable or undesirable situations” (FAO 1996). A key means of embedding “prudent foresight” into a management system is developing and following plans, including plans focused upon bycatch reduction. Another important component of precautionary management of bycatch entails including regulations that minimize bycatch, including gear restrictions and closed zones, in a fishery’s legal framework.

Bycatch reduction plans

In our analysis we took note of whether fisheries engage in long-term planning to reduce bycatch (Table 5). This planning takes different forms in different fisheries: the Northern Australian prawn fishery, for example, has a Bycatch and Discarding Work Plan and an Ecological Risk Management Strategy, which mandate risk assessments be conducted for bycatch species, indicate management responses to high ecological risks, and describe measures to avoid interactions with PET species (MRAG Americas 2012). Meanwhile, the Gulf of Mexico shrimp fishery does not have a separate bycatch reduction plan, but includes relevant measures in the overall fishery management plan (GMFMC 2014).

Table 5. Criterion used to estimate fishery sustainability risk with respect to bycatch reduction planning.

Criterion	Low Risk	Medium Risk	High Risk
4. Is there a plan in place to reduce bycatch and impacts upon PET species?	Yes, a plan is in place to reduce bycatch and impacts on PET species. Risk is deemed particularly low if the plan mandates risk assessments for all main bycatch and PET species.	No plan is in place to reduce bycatch and impacts on PET species, but information available suggests that impacts on individual PET species are likely low.	No plan is in place to reduce bycatch and impacts on PET species, and fishery impacts on an individual PET species are likely considerable.

Bycatch reduction devices (BRDs) and turtle excluder devices (TEDs)

Gear regulations such as required use of bycatch reduction devices, minimum trawl net mesh sizes, net size specifications, gear rigging modification requirements, and trap volume limitations can achieve meaningful results in the effort to avoid capture, allow escape, or limit mortality of bycatch species. The innovation of bycatch reduction devices has proven to be a particular game-changer in the effort to reduce bycatch in shrimp fisheries, and was therefore included as a particular focus of our analysis (Table 6). Use of bycatch reduction devices began in the mid-1960s in cold-water European shrimp fisheries, and since then diverse devices have been adopted in fisheries around the world. The type of bycatch reduction device used varies by fishery depending on both the target species and the bycatch species with which the fishery interacts: some devices use size differences between the target and bycatch species to improve fishery selectivity, while others use differences in behavior (Gillett 2008).

There is less diversity among bycatch reduction devices used in cold-water fisheries compared with warm-water fisheries, as cold-water fisheries generally endeavor to avoid a more homogenous group of bycatch species. Thus, a single device, the Nordmore grate, has been widely used by Northern prawn fisheries. This device consists of a sorting grid mounted within a trawling net that allows larger fish to exit the net while the smaller shrimp pass through the grid into the back end of the net where they are retained. In some Northern prawn fisheries where interactions with small, juvenile fish are common, the Nordmore grate is used in concert with an additional sorting grid that allows juvenile fish to escape. While the Nordmore grate is the most common bycatch reduction device used in cold-water shrimp fisheries, there are other devices, and they are constantly evolving through technology improvements. Examples include the use of veil nets in the North Sea brown shrimp beam trawl fishery and, recently, LED lights to avoid eulachons in the Oregon pink shrimp trawl fishery (Catchpole et al. 2008, NOAA 2014b).

In addition to the challenge of avoiding fish, faced by both warm-water and cold-water shrimp fisheries, warm-water shrimp fisheries must also avoid sea turtles. For this purpose, turtle excluder devices, which operate similarly to the Nordmore grate but are size-specific to turtles rather than fish, are widely used in sub-tropical and tropical shrimp fisheries. A United States law prohibiting import of shrimp and shrimp products that were harvested in a manner



that may adversely affect sea turtles has helped to motivate the adoption of turtle excluder device regulations in approximately 30 countries (Li 2015).

Table 6. Criteria used to estimate fishery sustainability risk with respect to bycatch reduction device and turtle excluder device regulations.⁵

Criterion	Low Risk	Medium Risk	High Risk
5. Are BRDs used in the fishery, and is their use mandated by law?	Yes, 100% BRD use in the fishery is mandated by law.	Yes, BRDs are required in part of the fishery.	No, BRDs are not required in any portion of the fishery.
6. Are TEDs used in the fishery, and is their use mandated by law?	Yes, 100% TED use is mandated by law.	Yes, TEDs are required in part of the fishery.	No, TEDs are not required in any portion of the fishery.

Fishery closures and protected areas

In addition to gear regulations, measures that limit fisher access to bycatch species' high-value habitats are another means by which fisheries can reduce impacts on bycatch species (Table 7). Ideally, representative habitats of bycatch species are protected in a holistic network of Marine Protected Areas (MPAs). However, this is not the case in most fisheries, as MPAs encompass only 1.3% of marine areas worldwide, far below the Convention on Biodiversity's existing target of 10% (Toropova 2010). Despite poor global performance on MPA creation, much more than 1.3% of the world's marine areas has some protected status conferred by national and state fishery regulations. Such closed areas are defined temporally as well as spatially: examples of temporal protections include seasonal closed areas intended to protect vulnerable portions of species' life cycles on an annual basis, as well as "real-time" closures enacted on a temporary basis in immediate response to elevated bycatch rates. Shrimp fisheries that employ real-time closures include the Spencer Gulf, Australia, king prawn bottom trawl fishery and the Danish and Norwegian Northern prawn fisheries in the Skagerrak and Norwegian Deep (EC Reg. 724/2010, Noell et al. 2014, Pastoors 2014). Otherwise, areas may be open to certain gear types but closed to others. For example, Indonesia enforces a trawling ban in much of its EEZ; and trawling is not allowed in the vicinity of two prominent sea turtle nesting beaches in the Orissa, India, shrimp trawl fishery (Kumar and Deepthi 2006, Poseidon 2011).

Table 7. Criterion used to estimate fishery sustainability risk with respect to habitat protection measures.

Criterion	Low Risk	Medium Risk	High Risk
7. Are high-value habitats of bycatch species protected through the use of spatial and temporal closures or protected areas?	Yes, a network of protected areas and/or fishery closed areas prevent fishery impacts on bycatch species. OR No, but bycatch is adequately managed through other means.	Somewhat, protected areas and/or fishery closed areas prevent some fishery impacts on bycatch species, but more could be done.	No, protected areas and/or fishery closed areas have not been implemented and are needed for the purpose of reducing impacts associated with bycatch.

Metrics of success in bycatch reduction

Ideally, a shrimp fishery is managed with adequate precaution so as not to pose a risk of serious or irreversible harm to any bycatch species, nor to hinder recovery of any depleted bycatch species. In the absence of comprehensive risk assessments for all bycatch species, which many fisheries lack, how can we quickly and easily gauge the effectiveness of bycatch reduction measures? A readily available statistic, bycatch proportion of harvest, can be used to this effect.

⁵ Fisheries that do not have potential for significant interactions with sea turtles (i.e., cold-water shrimp fisheries) were not scored for Criterion 6.



If bycatch reduction measures have been successful, this parameter should exhibit a meaningful decline over time (Table 8).

Table 8. Criterion used to estimate fishery sustainability risk with respect to bycatch reduction.

Criterion	Low Risk	Medium Risk	High Risk
8. Has bycatch been reduced from the baseline?	Yes, bycatch has been reduced from the baseline by $\geq 25\%$.	Somewhat, bycatch has been reduced from the baseline by $\geq 10\%$.	Not really, bycatch is at or near baseline levels ($< 10\%$ bycatch reduction has occurred).

Quantifying and monitoring bycatch and associated impacts

Availability of reliable information about the type, amount, and mortality of bycatch is essential to its effective management. One means of carrying out bycatch monitoring is through onboard observers and regulations requiring that observers are on board to witness a minimum of tows or fishery landings (“minimum observer coverage”) (Table 9). If an observer program has been evaluated and the minimum observer coverage has been deemed statistically robust, then observer bycatch data can be extrapolated to make estimations for the entire fishery. Other means of gathering bycatch data include logbooks that fishers must fill out and submit to authorities (can be paper or electronic), onboard cameras or trawl sensors, fishery independent surveys, and dockside surveys of retained bycatch. Some researchers have indicated that a 20% or greater observer coverage of trawl tows is necessary to ensure the accuracy of fishery observer data. However, others consider that the sufficiency of observer coverage can only be assessed on a case-by-case basis, as seasonal and spatial variations in bycatch composition and abundance need to be taken into account and are highly fishery-specific (Babcock et al. 2003). For example, despite only 2–5% observer coverage, the Canadian Northern prawn seasonal otter trawl fishery’s observer program has been evaluated by scientists and deemed sufficient, a finding that was corroborated by the certification body in the fishery’s most recent Marine Stewardship Council assessment (Benoît and Allard 2009, Intertek Moody Marine 2014).⁶

While estimates of bycatch proportion of harvest and bycatch species composition are available for many fisheries, mortality of bycatch is often poorly studied, particularly for individuals that interact with trawls but are not landed. As a result of the scarcity of research on bycatch-trawl interactions not landed on deck, few fisheries are able to set and manage to achieve fishing mortality limits for PET and juvenile bycatch species.

Table 9. Criteria used to estimate fishery sustainability risk with respect to bycatch monitoring.

Criterion	Low Risk	Medium Risk	High Risk
9. Is bycatch adequately monitored?	Yes, bycatch monitoring provides qualitative and some quantitative information on the type, amount, and mortality of bycatch.	Somewhat, bycatch monitoring provides some qualitative information on the type, amount, and mortality of bycatch.	No, little information is available on the type, amount, and mortality of bycatch.
10. Is there an observer coverage plan in place?	Yes, there is a scientifically designed observer program in place with a demonstrated statistically robust coverage level.	Yes, there is an observer coverage program in place, but it is either inadequate or its statistical and scientific soundness has not been demonstrated.	No, there is no routine observer coverage in place.

⁶ The year-round Canadian Northern prawn trawl fishery, which accounts for most of national Northern prawn harvest, has 100% observer coverage.



Compliance and enforcement

In addition to precautionary management and adequate monitoring, the third pillar of successful bycatch mitigation is sufficient compliance and enforcement (Table 10). For our analysis, we reviewed literature indicating fisher compliance with bycatch reduction and turtle excluder device regulations, as well as compliance with fishery closures. Government records of gear regulation and closed area violations can provide evidence of the scale of non-compliance. For example, a recent National Atmospheric and Oceanic Administration (NOAA) study focused upon the Gulf of Mexico, US, shrimp fishery examined fisher non-compliance with turtle excluder device regulations and found non-compliance rates of 17–42% during the 17-month study period of June 2012 through October 2013 (NOAA 2014a). However, in most other cases, similar, comprehensive government reviews have not been conducted, and we relied upon qualitative and/or independent assessments published in scientific literature and fishery sustainability assessments.

Compliance with closed area regulations is, in some fisheries, enforced through the use of vessel monitoring systems (VMS), which was taken into account when scoring Criterion 12. Important aspects of a VMS program include its scope (are all boats in the fleet required to use VMS, or only boats of a certain size or in a certain geography?) and regulations regarding VMS failure to transmit (does the fishery require and enforce return to port after several hours of VMS failure to transmit?).

Table 10. Criteria used to estimate fishery sustainability risk with respect to fisher compliance and enforcement.

Criterion	Low Risk	Medium Risk	High Risk
11. Do fishers comply with mandatory use of bycatch reduction devices and turtle excluder devices (BRDs and TEDs)?	Yes, (a) compliance with and enforcement of BRD and TED regulations is generally good, but there are occasional violations; or (b) BRD and TED use is not required in the fishery, but they are used voluntarily by a significant proportion of the fleet.	Somewhat, compliance with and/or enforcement of BRD and TED regulations is below acceptable.	No, there is systematic non-compliance with BRD and TED regulations enabled by poor enforcement.
12. Do fishers observe spatial and/or temporal fishery closures?	Yes, compliance with and enforcement of spatial and temporal fishery closures is generally good, but there are occasional violations.	Somewhat, compliance with and enforcement of spatial and temporal fishery closures is below acceptable.	No, there is systematic non-compliance with spatial and temporal fishery closures enabled by poor enforcement.

REVIEW OF FISHERY PERFORMANCE

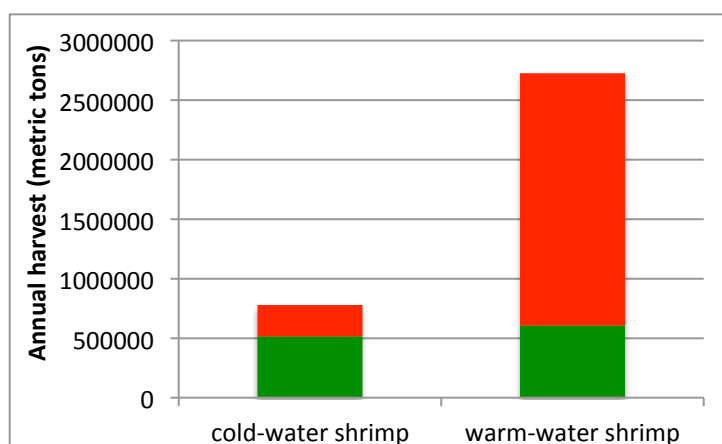


Figure 1. Proportion of average annual global wild shrimp harvest included in this study (green) and not included (red), separated by cold-water and warm-water target species.

Below follows a review of the performance of the 20 fisheries included in this analysis against the 12 criteria described above. First, some notes about the sample of fisheries:

- The fisheries' individual annual harvests range from 1,300 to 178,000 metric tons, and their aggregate annual harvest of 1.1 million metric tons comprises 32% of global shrimp harvest.
- 13 of the fisheries target warm-water shrimp species and account for 22% of global warm-water shrimp harvest, while the remaining seven fisheries target cold-water species and account for 66% of global cold-water shrimp harvest (Figure 1).
- 16 of the fisheries use otter trawls and four use beam



trawls.

- Five of the fisheries target low-trophic, multispecies aggregates (including shrimp), while the other 15 primarily target shrimp.
- Six of the fisheries are located in Asia; four in Europe; four in North America; and two each in Africa, Australia, and South America.
- The 20 fisheries generate 5.3 million metric tons of bycatch annually.

The below section describes analysis results. Risk ratings were attributed to each of the 20 fisheries for each of the 12 criteria. The lowest rating received by a fishery for a criterion nested within each of four analysis categories (1. impacts, 2. management, 3. monitoring, and 4. compliance and enforcement) was applied to the fishery's shrimp harvest volume. Data deficient (DD) ratings were applied to the harvest volume if a fishery received DD ratings on more than half of the criteria nested within a performance area. Harvest volumes were then aggregated across the 20 fisheries to draw conclusions about proportions of harvest falling into each of the risk rating categories.

- Warm-water shrimp fisheries generally have higher bycatch rates and volumes than cold-water shrimp fisheries (Figure 2). The majority of the warm-water shrimp fisheries included in our analysis have bycatch proportions of harvest that exceed 75% and annual bycatch volumes of over 100,000 metric tons. Meanwhile, among the majority of the cold-water shrimp fisheries, bycatch comprises 10% or less of the harvest and annual bycatch volumes do not exceed 2,500 metric tons.

- Warm-water shrimp fisheries have more diverse bycatch that includes more endangered species than that of cold-water shrimp fisheries. Warm-water fisheries in our study had five times as many species and five times as many PET species in their bycatches as cold-water fisheries (Table 11).

- The majority of the warm-water shrimp fishery harvest warranted high risk ratings and data deficient ratings (which were assigned when there was not enough available information to assign a risk rating) for each of the four categories of analysis: impacts (to PET and main bycatch species), precautionary management, monitoring, and compliance and enforcement (Figure 3).

High-volume, multispecies trawl fisheries

in Asia contributed prominently to these volumes. However, several warm-water shrimp fisheries performed well in our analysis and received low and medium risk ratings on most (at least 11 of 12) criteria: namely, the Gulf of Mexico, Gulf of California, Northern Australia, and Suriname trawl fisheries.

- High risk among warm-water fisheries was most prevalent for monitoring, where it was applicable to 53% of the harvest volume. Absence of sufficient observer coverage was identified as a high risk for six fisheries.

- Compliance/enforcement was the second most troubled area for warm-water fisheries, with 50% of the harvest volume rated high risk due to poor compliance with gear regulations and closed areas.

- Warm-water fishery performance against impacts (to PET and main bycatch species) and compliance/enforcement criteria, while better than that of impacts and monitoring, also leaves room for improvement. Among the four categories of analysis, data deficiency was most prevalent for impacts, as, particularly for main bycatch species, there is often inadequate information to determine whether the fishery is responsible for depleted status and failure

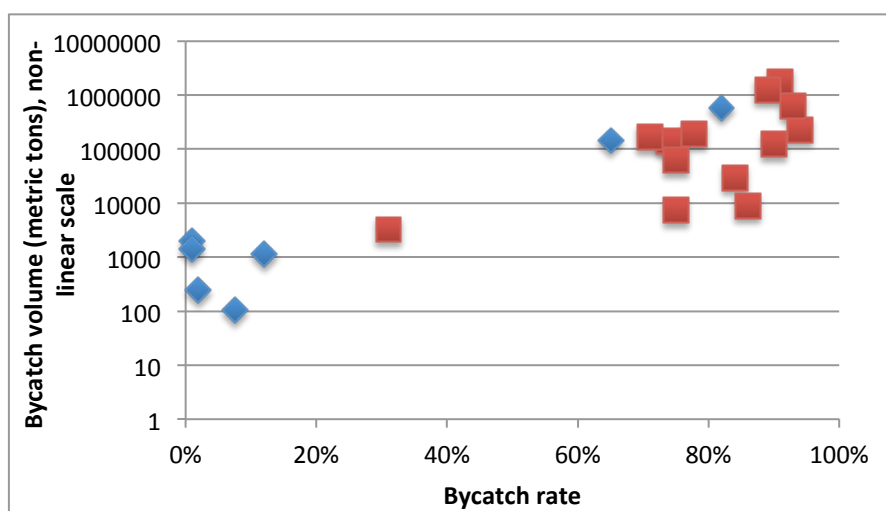


Figure 2. Bycatch rate vs. annual bycatch volume (metric tons) for warm-water shrimp fisheries (red squares) and cold-water shrimp fisheries (blue diamonds) included in our analysis. The warm-water shrimp fisheries exhibit higher bycatch rates and volumes than the cold-water shrimp fisheries.



to rebuild. Meanwhile, 29% of fishery volume received high risk management scores, with one fishery failing to apply BRD regulations, two fisheries failing to apply TED regulations, and two fisheries failing to have bycatch reduction plans. Five fisheries also did not have data available on bycatch reduction (baseline figures were not available).

- Low and medium risk ratings were attributed to the majority of the cold-water shrimp fishery harvest for each of the four categories of analysis. Northern prawn fisheries in Atlantic Canada, West Greenland, and the Barents Sea performed particularly well (low risk ratings on all but one scored criterion) in our analysis, as did Oregon pink shrimp. A couple of issues that occurred among multiple cold-water fisheries on individual criteria were data deficiency on bycatch reduction (baseline bycatch figures were not available for three fisheries) and inadequate observer coverage among five fisheries (medium risk).

- When fisheries commit to efforts to reduce bycatch, they can and do succeed. All fisheries in our analysis that required use of bycatch reduction devices achieved 18% or more reduction in the bycatch proportion of harvest. Turtle excluder device regulations were even more successful at reducing bycatch of turtles: all fisheries with TED regulations achieved turtle bycatch reductions of at least 86% from the baseline (Table 12).

Table 11. Summary of quantitative data gathered on bycatch magnitude and species composition. Notably, warm-water fisheries included in our study harvest six times more bycatch species and PET bycatch species than cold-water fisheries.

Fishery type	Bycatch Proportion of Harvest			Number of Bycatch Species			Number of PET Bycatch Species			Number of Main Bycatch Species (comprise ≥5% of harvest)		
	Average	Range	No. of data pts.	Average	Range	No. of data pts.	Average	Range	No. of data pts.	Average	Range	No. of data pts.
Cold-water	24%	1-82%	7	60	15-150	7	8	0-28	7	2	0-5	7
Warm-water	79%	31-94%	13	298	47-800	11	39	6-128	9	6	2-9	9

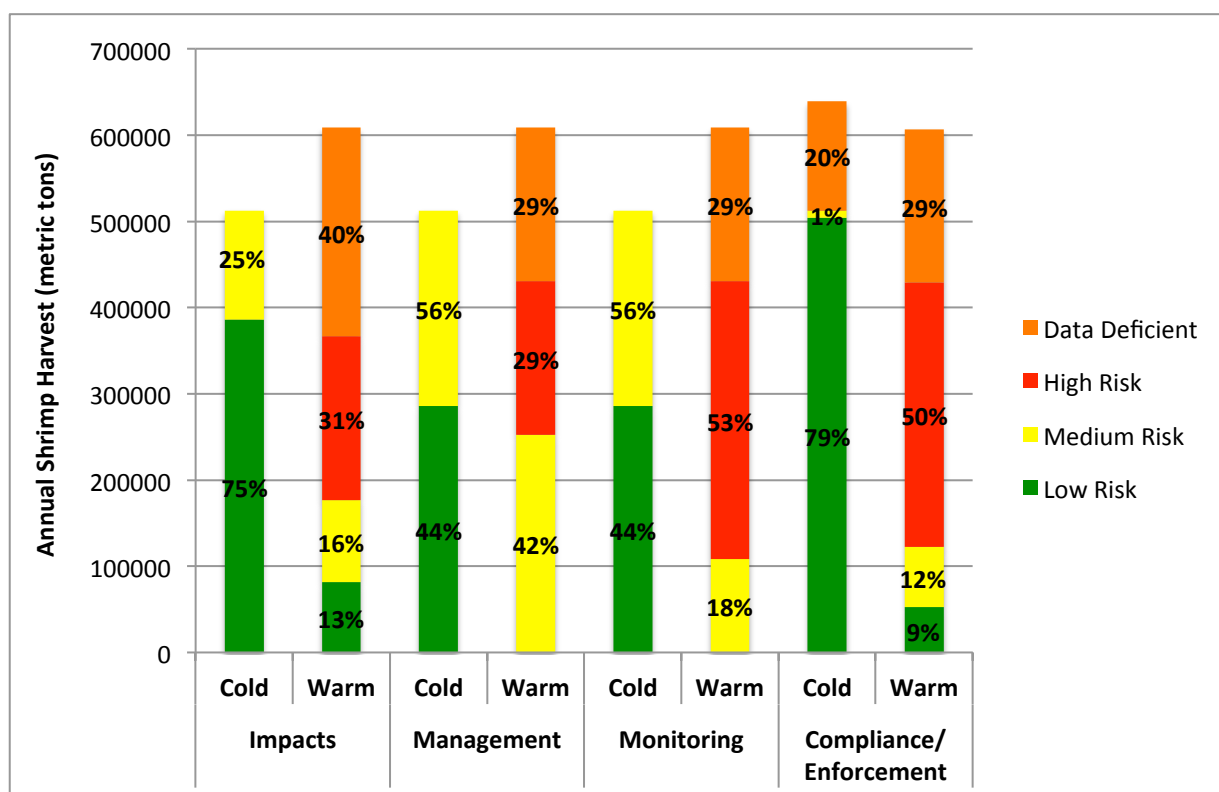


Figure 3. Ratings of shrimp harvest for the four categories of analysis: impacts, management, monitoring, and compliance and enforcement. The lowest rating received by a fishery for an associated criterion was applied to the fishery's shrimp harvest. Data deficient (DD) ratings were applied if a fishery received DD ratings on more than half of nested criteria. Ratings for cold- and warm-water fisheries are displayed in separated bar plots.



Table 12. Summary of general bycatch reduction from the baseline achieved through the implementation of BRD regulations, as well as turtle bycatch reduction from the baseline achieved through the implementation of TED regulations. Reductions in bycatch were substantial ($\geq 18\%$ reduction) in all cases, although baseline data was not available for many fisheries.

	Bycatch Reduction Devices			Turtle Exclusion Devices		
	Average	Range	No. of data pts.	Average	Range	No. of data pts.
Cold-water fisheries	66%	36–87%	4	n/a	n/a	n/a
Warm-water fisheries	45%	18–75%	7	93%	86–99%	4

See Annex A, below, and the Excel data annex for scores for individual fisheries on individual criteria, as well as rationales for scores with accompanying citations.

MAIN CONCLUSIONS

Recommendations to catchers and regulators

On the basis of our analysis, the following recommendations are offered to catchers and regulators engaged in those shrimp fisheries that have room for improvement with respect to management of bycatch:

:

- Fisheries that target shrimp should make bycatch reduction devices mandatory by law among all licensed boats, and warm-water fisheries should additionally make turtle excluder devices mandatory by law among all licensed boats. These devices have been proven effective in achieving meaningful bycatch reductions. Regulators should work closely with scientists and fishery participants to determine which devices are best suited to the fishery and should monitor effectiveness.
- In addition to gear regulations, managers should evaluate distribution and composition of bycatch to determine whether instituting closed areas would further reduce bycatch and associated impacts.
- Bycatch reduction and turtle excluder device regulations, as well as closed area regulations, are not sufficient on their own to ensure successful reduction of bycatch. Fisher compliance must be ensured through adequate enforcement. Warm-water fisheries performed poorly on relevant criteria in our analysis, indicating that compliance and enforcement are particular areas where improvement is needed.
- The measures described in the preceding three bullets should form the basis of a bycatch reduction plan that describes fishery objectives with respect to bycatch and the means by which those objectives will be achieved.
- Fishery impacts to bycatch species, including PET species, are often poorly understood, resulting in many data deficient ratings on impacts criteria in our analysis. Risk assessment should be carried out on bycatch species, particularly on PET and main bycatch species, to ensure that the fishery is not depleting or prohibiting recovery of these species. This recommendation is applicable to both fisheries that target shrimp and multispecies fisheries that target a low-trophic species aggregate including shrimp.



Recommendations to seafood suppliers and buyers

The following recommendations are offered to suppliers and buyers of wild shrimp:

- Demand low-risk performance from your source fisheries using the criteria described in this report as a guide.
- Source preferentially from fisheries certified by the Marine Stewardship Council or engaged in a fishery improvement project (FIP): this applies to 75% of harvest from cold-water shrimp fisheries and 8% of harvest from warm-water shrimp fisheries.
- Participate in existing FIPs in shrimp fisheries, and initiate FIPs in source fisheries that are neither engaged in the Marine Stewardship Council process nor in a FIP.

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APPENDIX A

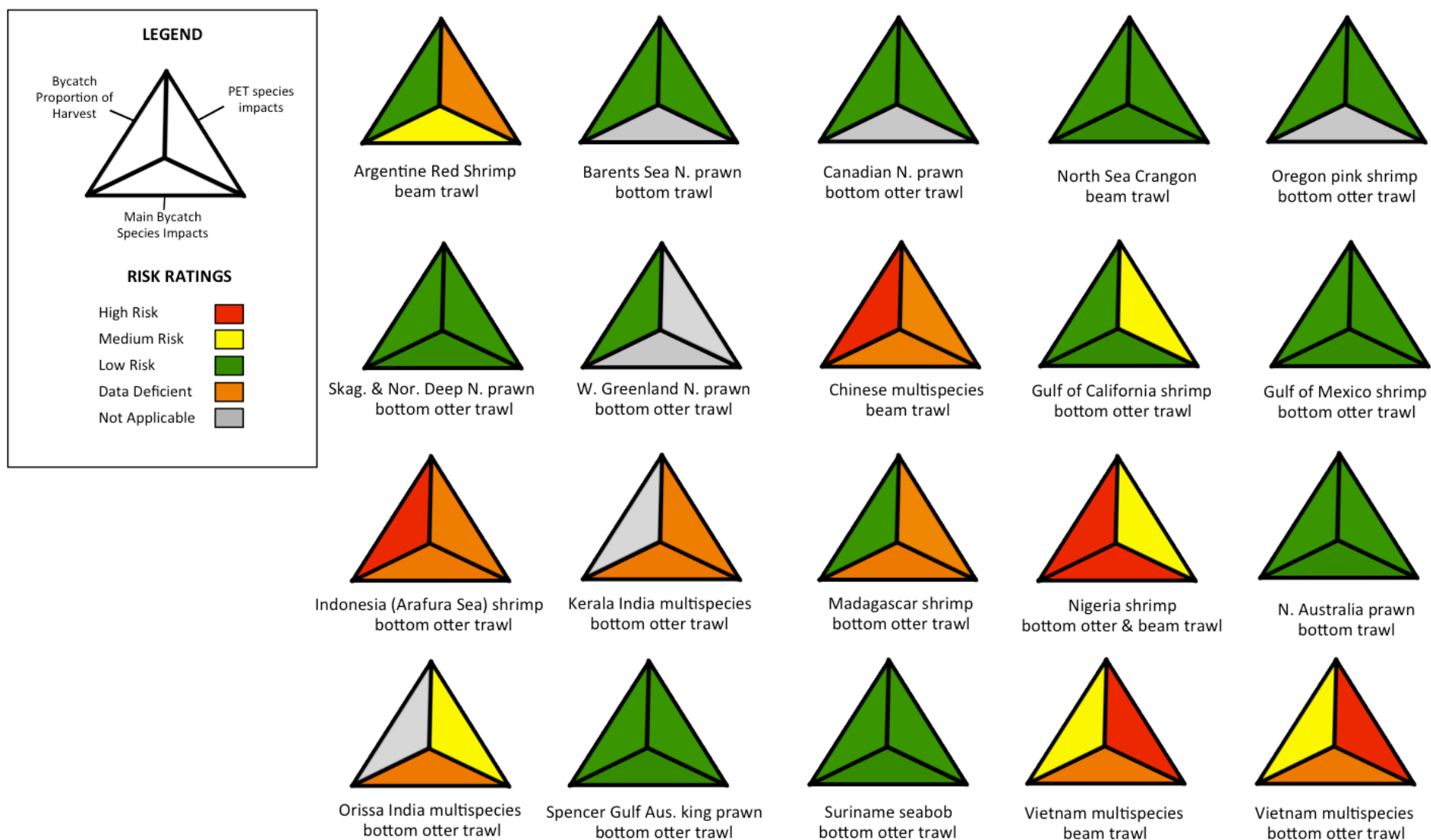


Figure App.A-1 Star plots exhibiting risk ratings for individual fisheries for bycatch impacts.

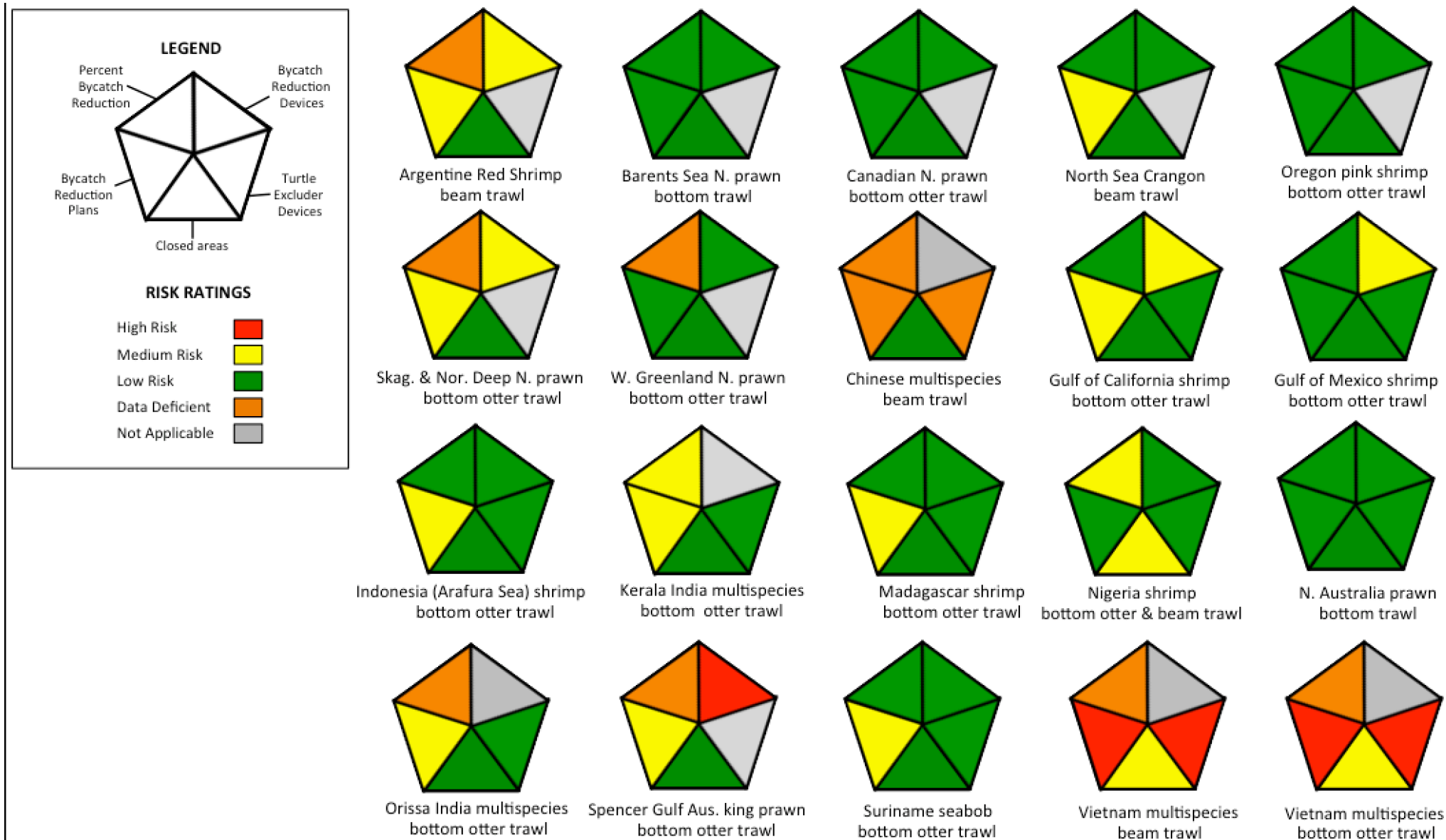


Figure App.A-2 Star plots exhibiting risk ratings for individual fisheries for precautionary management of bycatch.

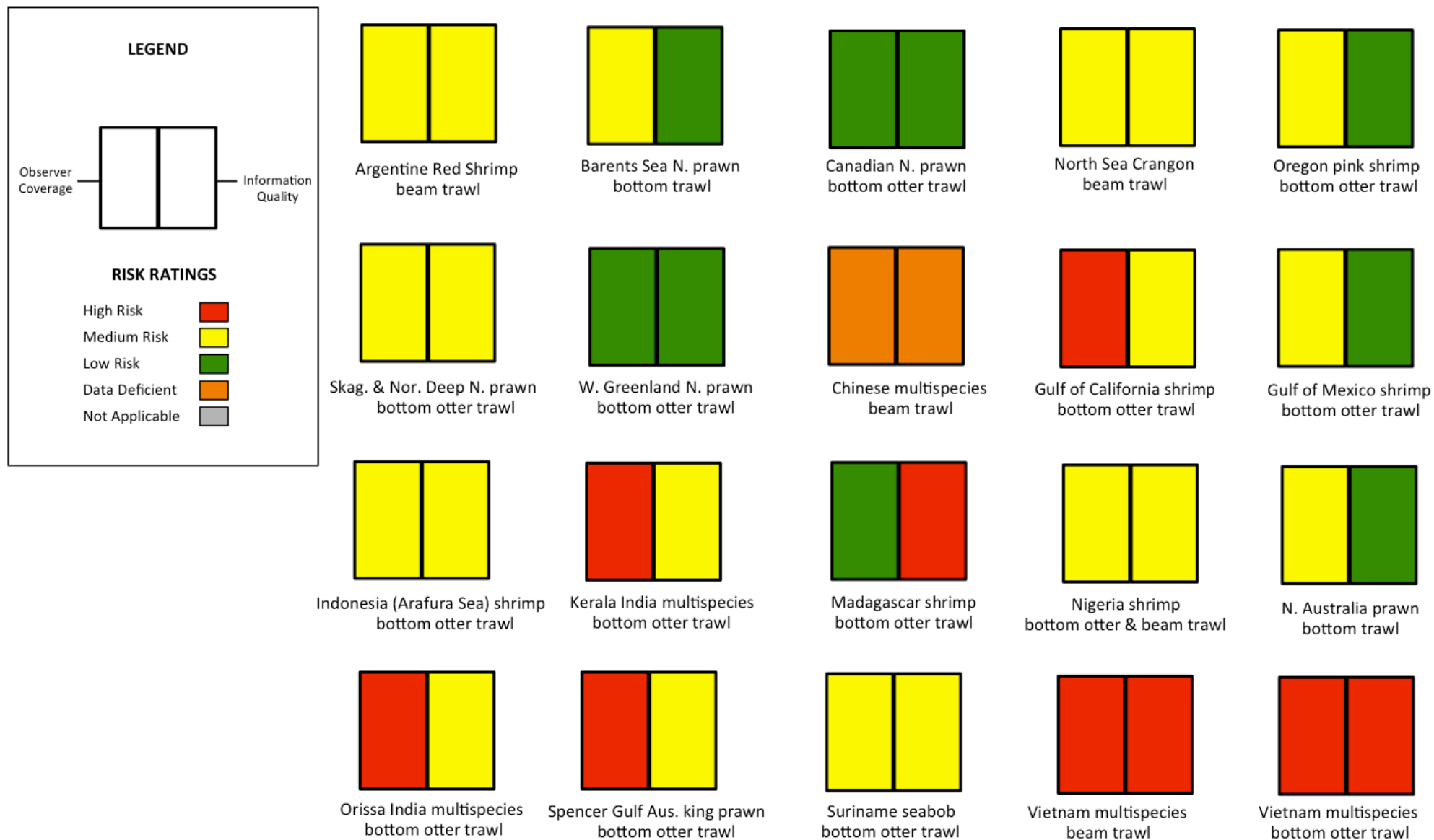


Figure App.A-3 Star plots exhibiting risk ratings for individual fisheries for bycatch monitoring.

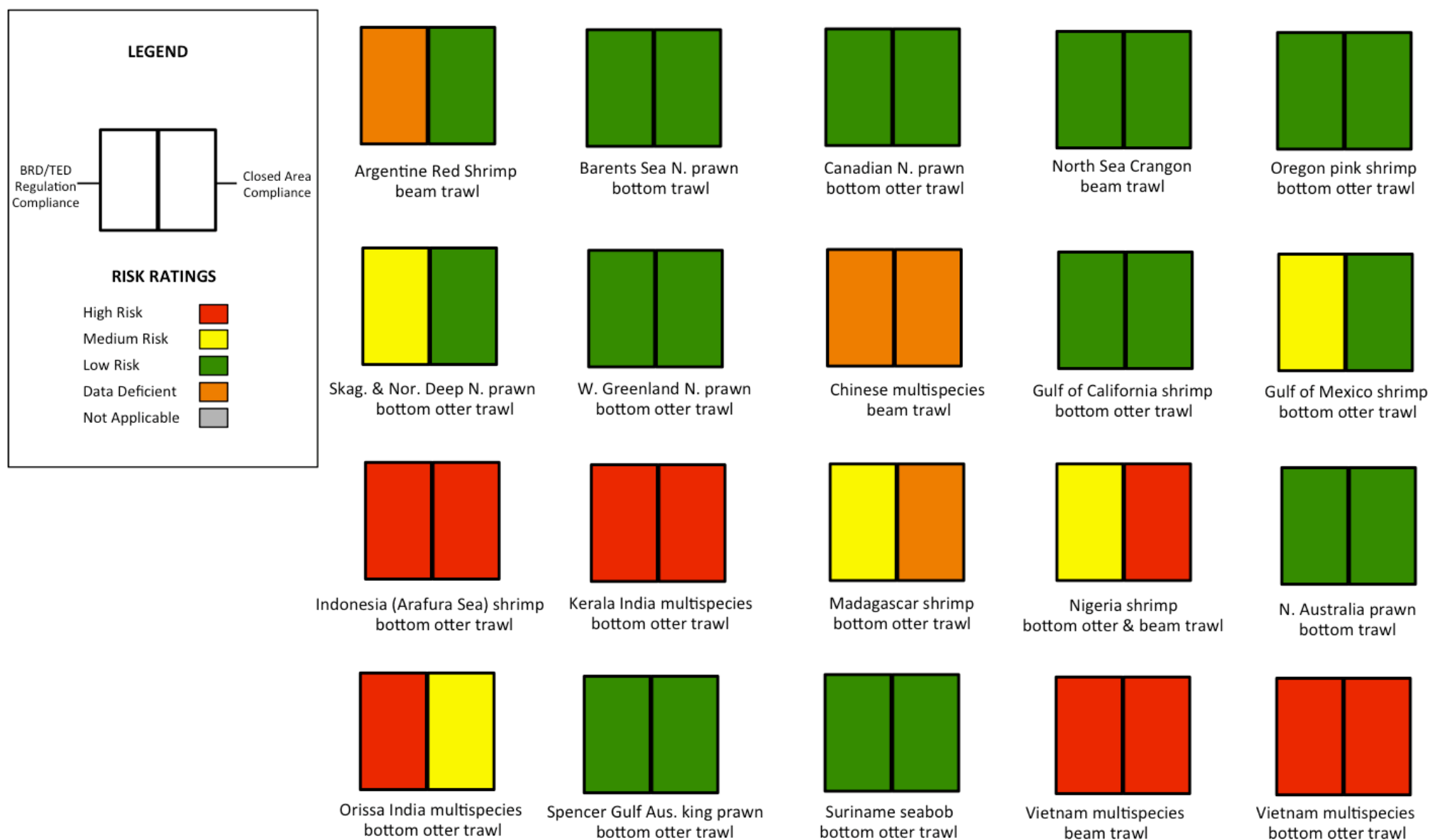


Figure App.A-4 Star plots exhibiting risk ratings for individual fisheries for compliance with and enforcement of bycatch regulations.