Seafood Watch® Criteria for Fisheries

The Monterey Bay Aquarium is committed to inspiring conservation of the oceans. To this end, Seafood Watch®, a program of the Monterey Bay Aquarium, researches and evaluates the sustainability of fisheries products and shares these seafood recommendations with the public and other interested parties in several forms, including regionally specific Seafood Watch pocket guides, smartphone apps and online at www.seafoodwatch.org.

The criteria laid out in this document allow assessment of the relative sustainability of wild-capture fisheries according to the guiding principles and conservation ethic of the Monterey Bay Aquarium. Farmed seafood sources are evaluated with a different set of criteria.

Seafood Watch® defines "sustainable seafood" as seafood from sources, whether fished or farmed, that can maintain or increase production without jeopardizing the structure and function of affected ecosystems. Sustainable wild-capture fisheries should ensure that the abundance of both targeted and incidentally caught species is maintained in the long term at levels that allow the species to fulfill its ecological role* while the structure, productivity, function and diversity of the habitat and ecosystem are all maintained. A management system should be in place that enforces all local, national and international laws to ensure long-term productivity of the resource and integrity of the ecosystem by adhering to the precautionary approach and responding to changing circumstances.

Scope
Seafood Watch® recommendations apply to a single stock or species caught in a single fishery as defined by gear type, region and management body.

*Underlined terms have been defined in the glossary. Ctrl + Click to view.

Table of Contents

Criterion 1 – Impacts of the Fishery on the Stock for which you want a Recommendation

Guiding principles

The stock is healthy and abundant.* Abundance, size, sex, age and genetic structure should be maintained at levels that do not impair the long-term productivity of the stock or fulfillment of its role in the ecosystem and food web.

Fishing mortality does not threaten populations or impede the ecological role of any marine life. Fishing mortality should be appropriate given current abundance and inherent vulnerability to fishing while accounting for scientific uncertainty, management uncertainty, and non-fishery impacts such as habitat degradation.

Assessment instructions

Evaluate Factors 1.1–1.3 under **Criterion 1** to score the stock for which you want a recommendation. Evaluate Factors 2.1–2.4 under **Criterion 2** to score all other main species in the fishery, including both bycatch and retained species as well as any overfished, depleted, endangered, threatened or other species of concern that are regularly caught in the fishery.

Note that if wild stocks are assessed only in combination with hatchery-raised populations, the health of the wild stock cannot be considered better than "moderate concern".

Factor 1.1 Inherent Vulnerability

Goal: *Ensure fishing mortality and other management measures are appropriate for the inherent vulnerability of the stock.*

Instructions: Where available, Seafood Watch uses FishBase "vulnerability" scores to assign a score for inherent vulnerability of the stock. The FishBase vulnerability score is derived from Cheung et al. (2005) and is found at www.fishbase.org on the species' page.

FishBase vulnerability score	Corresponding Seafood Watch inherent vulnerability category
0–35	Low inherent vulnerability
36–55	Moderate inherent vulnerability
56–100	High inherent vulnerability

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Some fish and all invertebrates do not have a FishBase score. For these species, use the steps below (modified from the MSC Productivity Attributes from PSA Analysis used in Risk-Based Framework. Source (MSC 2009)).

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Step 1: Assign a score for each productivity attribute based on the table below. Scores will be 1, 2 or 3 for each attribute you select (if an attribute falls in between categories, intermediate scores (e.g. 2.5) may be used if well justified). Once all scores are selected, average the values to arrive at an overall vulnerability score (from 1–3). If any attribute is unknown or any value falls into an NA category (for moderate to high fecundity), that attribute is omitted from the average.

Resilience attribute	**Fish**			**Invertebrates**		
	Score = 1	**Score = 2**	**Score = 3**	**Score = 1**	**Score = 2**	**Score = 3**
Average age at maturity	> 15 yrs	5–15 yrs	< 5 yrs	>15 yrs	5–15 yrs	< 5 yrs
Average maximum age	> 25 yrs	10–25 yrs	< 10 yrs	> 25 yrs	10–25 yrs	< 10 yrs
Fecundity	< 100 eggs/ yr	N/A	N/A	< 100 eggs/ yr	NA	NA
Average maximum size	> 300 cm	100–300 cm	< 100 cm	N/A	N/A	N/A
Average size at maturity	> 200 cm	40-–200 cm	< 40 cm	N/A	N/A	N/A
Reproductive strategy	Live bearer	Demersal egg layer	Broadcast spawner	Live bearer	Demersal egg layer or brooder	Broadcast spawner
Trophic Level	>3.25	2.75-3.25	<2.75	N/A	N/A	N/A
Density dependence	N/A	N/A	N/A	Depensatory dynamics at low population sizes (Allee effects) demonstrated or likely	No depensatory or compensatory dynamics demonstrated or likely	Compensatory dynamics at low population sizes demonstrated or likely

Step 2**:** Assign a Seafood Watch inherent vulnerability category of high, medium or low based on the overall inherent vulnerability value calculated above (the average of all attribute scores):

Overall inherent vulnerability score from analysis		**Corresponding Seafood Watch inherent vulnerability category**
Finfish	**Invertebrates**	
2.44-3	2.46-3	Low inherent vulnerability
1.80-2.43	1.85-2.45	Moderate inherent vulnerability
1-1.79	1-1.84	High inherent vulnerability

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Factor 1.2	Stock Status

Goal: *Stock abundance and size structure is maintained at a level that does not impair recruitment or productivity.*

The scoring of health of stock depends on the abundance of the stock and quality of data available. Advice for scoring data-poor fisheries or fisheries that do not use formal stock assessment techniques is incorporated into the table below. Further guidance is provided in Appendix 1. Examples and further explanation of underlined terms can be found in the Glossary.

Instructions: This Factor is used to score the current abundance of the fishery stock. Note that a species should be assigned to the most conservative relevant tier such that, for example, a species that is both overfished and endangered is classified as "Endangered".

For further guidance on interpretation of the health of stocks or populations, see Appendix 1.

NOTE: This is based on current abundance or biomass metrics, not on fishing mortality (e.g., F/F_{MSY} or measures of whether overfishing is occurring). In this context, "overfished" means that biomass is below a threshold, not that overfishing is occurring.

Conservation Concern	Description	Score
Very Low	There is a reliable quantitative stock assessment, and biomass is estimated to be above or fluctuating around an appropriate target reference point with no scientific controversy around that estimate, **or** Stock is at or very near its historic high or virgin biomass.	5
Low	Stock is classified as not overfished but quantitative stock assessment is lacking, **or** Biomass is above the limit reference point but may be below a target reference point, **or** Biomass is above the limit reference point and may be estimated to be above a target reference point, but there is significant uncertainty (e.g., widely varied results depending on model or assumptions) or scientific controversy around that estimate or around the suitability of the reference point.	4
Moderate	There is no evidence to suggest that stock is either above or below reference points; Unknown **and** Stock inherent vulnerability is moderate or low (as scored in Factor 1.1).	3
High	Probable that stock is below the limit reference point, **or** Stock is listed by management body as overfished or depleted, or is a stock or species of concern (as listed by state or federal management body), an IUCN Near Threatened or Vulnerable species, or equivalent, **or** There is no evidence to suggest that stock is either above or below reference	2

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	points; Unknown **and** Stock inherent vulnerability is high (as scored in Factor 1.1).	
Very High	Stock or species is listed by a state, national or international scientific body as endangered or threatened.	1

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Factor 1.3	Fishing Mortality

Goal: *Fishing mortality is appropriate for current state of the stock.*

NOTE: Rankings are based on fishing mortality/exploitation rate, e.g., F/F_{MSY}. For the purposes of this table, a stock is deemed "not depleted" if ranked as Very Low to Moderate Conservation Concern under 1.2; and is deemed "depleted" if ranked as High to Very High Conservation Concern under 1.2. When determining whether a fishery is a substantial contributor, and/or whether fishing mortality is at or below a sustainable level, err on the side of caution when there is uncertainty. For further guidance, see Appendix 1 (guidance on evaluating fishing mortality).

For Target Species or When Fishery is a Substantial Contributor to Mortality (include cases where fishery is one of many fisheries that equally contribute to overall mortality)

Very Low Concern	• Highly likely that fishing mortality is at or below a sustainable level that will allow population to maintain current level or rebuild if depleted, **OR** • Large proportion of population is protected. [NOTE: large proportion protected suffices only if not depleted]
Low Concern	• Probable (>50% chance) that fishing mortality is at or below a sustainable level that will allow population to maintain current level or rebuild if depleted, but some uncertainty, **OR** • Population trends are increasing in short and long term due to management
Moderate Concern	• F is fluctuating around FMSY, **OR** • F is unknown, but for any depleted populations, effective management is in place [Note: If F is unknown and population is depleted, effective management must be in place to get 'moderate' score]
High Concern	• Overfishing is occurring/cumulative fishing pressure may be too high to allow species to maintain abundance or recover, but for any depleted populations, management that is reasonably expected to curtail overfishing is in place (make sure does not meet critical rating below), **OR** • F is unknown, population is depleted, and no effective management in place
Critical	Overfishing is occurring/cumulative fishing pressure may be too high to allow species to maintain abundance or recover; population is depleted; and reasonable management to reduce fishing mortality/curtail overfishing is **not** in place.

For non-target species in which fishery contribution to mortality may be low or unknown

Very Low Concern	• Fishery's contribution to mortality is negligible, **OR** • Meets definition of "Very Low Concern" in table above
Low Concern	• Fishery contribution to mortality may not be negligible, but does not adversely affect population, **OR** • Fishery contribution is unknown, but population is not depleted and susceptibility (see Appendix 2) to fishery is low, **OR** • Meets "Low concern" in table above.
Moderate Concern	Fishery contribution is unknown, but population may be depleted (and if so, management is in place) or susceptibility to fishery is moderate to high (see Appendix 2)
High Concern	Fishery contribution is unknown, but population is depleted and no reasonable management to curtail overfishing is in place.

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Criterion 1 Score and Rank

Score = geometric mean (Factors 1.2, 1.3). Factor 1.1 is not included in the calculation; instead it modifies the score of Factor 1.2 in some circumstances (See Factor 1.2 table for more information).

Rank is based on the Score as follows:

- >3.2 = **Green**
- >2.2 and <=3.2 = **Yellow**
- <=2.2 = **Red**

Rank is **Critical** if Factor 1.3 is Critical.

Criterion 2 – Impacts of the Fishery on Bycatch and Other Retained Species

Guiding principles

The fishery minimizes bycatch. Seafood Watch® defines bycatch as all fisheries-related mortality or injury other than the retained catch. Examples include discards, endangered or threatened species catch, pre-catch mortality and ghost fishing. All discards, including those released alive, are considered bycatch unless there is valid scientific evidence of high post-release survival **and** there is no documented evidence of negative impacts at the population level.

Fishing mortality does not threaten populations or impede the ecological role of any marine life. Fishing mortality should be appropriate given each impacted species' abundance and productivity, accounting for scientific uncertainty, management uncertainty and non-fishery impacts such as habitat degradation.

Assessment instructions

The Criterion 2 score for the stock for which you want a recommendation is the lowest score of all the other main species caught with it, multiplied by the discard rate. A species is included in the assessment as a main species if:

- The catch of the species in the fishery under assessment composes >5% of that fishery's catch, *or*
- The species is >1% of that fishery's catch *and* the fishery causes >5% of the species' total mortality across all fisheries, *or*
- The species is <1% of that fishery's catch *and* the fishery causes >20% of species' total mortality across all fisheries, *or*
- The species is overfished, depleted, a stock of concern, endangered, threatened, IUCN Near Threatened, US MMPA strategic species, and/or subject to overfishing *and* the fishery causes >1% of species' total mortality across all fisheries.
- If there are no other "main species" (based on the above guidance) besides the one assessed under criterion 1, but the total catch of other discarded and retained species is >5% (i.e. catch of criterion 1 species is <95% of total), assess the top 3 species by volume of catch (if there are only 1-2 other species caught, assess those species).

In some cases, bycatch or retained species in the fishery are not known. If species are unknown, Appendix 3 should be used to aid scoring. If some bycatch or retained species are known but information is incomplete (e.g., some or all retained species are recorded but bycatch species are not), assess each known species following guidance for "known species" **and** assess the fishery following guidance for "unknown species" under each Factor. Scoring for this criterion is based on the worst case, so the lowest of these scores will be used.

If there is no bycatch and no other species landed, the fishery receives a score of five for this criterion, the remaining questions in Criterion 2 can be skipped, and the assessor can continue with Criterion 3.

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Factor 2.1	Inherent Vulnerability

Goal: *Ensure fishing mortality and other management measures are appropriate for the inherent vulnerability of all bycatch stock(s).*

Known species

Follow the assessment for Factor 1.1 above (the Factors for Inherent Vulnerability, Stock Status and Fishing Mortality are identical for all main species caught in the fishery, whether target, other retained or discarded).

Unknown species

Where the catch composition is not completely known, use Appendix 3 to identify those taxa that are most likely to interact substantially with the fishing gear, defined as taxa **scoring a 3.5** or below. The numbers in the unknown bycatch matrix will be used extensively for scoring Criterion 2.3.

Vulnerability is assigned to the taxa that are identified as interacting with the fishery as follows:

High = marine mammals, turtles, sharks, seabirds, deepwater and shallow biogenic habitat (seagrass beds, coral, sponges, etc.). **Moderate** = invertebrates and fish.

Factor 2.2	Stock Status

Goal: *Stock abundance and size structure of all main bycatch species/stocks is maintained at a level that does not impair recruitment or productivity.*

Known species

Follow the assessment for Factor 1.2 above (the Factors for Inherent Vulnerability, Stock Status and Fishing Mortality are identical for all main species caught in the fishery, whether target, other retained or discarded).

Unknown species

If bycatch species and/or other retained species are *unknown*, use Appendix 3, the unknown bycatch matrix, and additional bycatch guidance (in Appendix 3) to determine the types of taxa that are likely to interact with the fishery based on gear type and location. Factor 2.2 is scored as “moderate concern” for each taxon listed in Appendix 3 for this type of fishery with a score of **3.5** or below unless the taxon is comprised largely of species that are either of high vulnerability as scored in Factor 2.1, or overfished, endangered or threatened within the range of the fishery (e.g., sea turtles, seabirds, marine mammals and sharks); in these cases, it is scored as “high concern.” Species scoring a **4** or above do not need to be addressed.

Factor 2.3	Fishing Mortality

Goal: *Fishing mortality is appropriate for the current state of all main bycatch species/stocks.*

Known species

Follow the assessment for Factor 1.3 above (the Factors for Inherent Vulnerability, Stock Status and Fishing Mortality are identical for all main species caught in the fishery, whether target, other retained or discarded).

Additional guidance for scoring of marine mammals caught in US fisheries is given below (due to the availability of data on potential biological removal (PBR) and fishing mortality rates on all bycaught marine mammals, available in marine mammal stock assessments and List of Fisheries reports, see http://www.nmfs.noaa.gov/pr/interactions/lof/)

% of PBR taken by fishery	Stock is "strategic" due to cumulative fisheries mortality >100% PBR?	Seafood Watch Ranking	Fishery category in "List of Fisheries" (based on that species)
<1%	No	Very Low	Category III
1-10%	No	Very Low	Cat II (if cumulative take >10%) or III (if cumulative take <=10%)
10-50%	No	Low	Cat II
50-100%	No	Moderate	Cat I
<1%	Yes	Very Low	Cat III
1-10% and not one of the main contributors to total mortality	Yes	Low	Cat II
10-50% and not one of the main contributors to total mortality	Yes	Moderate	Cat II
>50% OR a main contributor to total fisheries-related mortality	Yes	High OR Critical depending on management	Cat I

If PBR or fishery mortality relative to PBR is not known, score conservatively given what is known (e.g., fishery and/or species classification) or score as "moderate". Example: if it is unknown but fishery is classified as Category II and species is not strategic, score as "low".

Unknown species

If bycatch and/or other retained species are *unknown*, use Appendix 3, the unknown bycatch matrix, and additional bycatch guidance (in Appendix 3) to determine the types of taxa that are likely to interact with the fishery based on gear type and location. Each score from Appendix 3 has a corresponding fishing mortality conservation concern (below).

* **Appendix 3**, the unknown bycatch matrix and additional guidance for unknown bycatch species should **ONLY** be used as a general guide to help rank bycatch potential (for Factor 2.3, mortality caused by the fishery) when no data on the composition of bycatch are available. In these cases, Appendix 3 provides guidance based on gear-type and its potential to interact with species other than the target fishery, as reported in the scientific literature. When assigning a conservation concern for unknown bycatch, other factors to consider before using the unknown bycatch matrix include: geographic range of the fishery, degree of overlap, if any (with foraging areas, breeding grounds, etc.) there is between fishing and potential bycatch species, fishing depth, whether the fishery is operating in coastal (some coastal areas may have a greater impacts on some species) or open-ocean systems, whether the fishery operates seasonally and coincides with breeding season, and other concerns based on fishing region and the conservation concern for the potential bycatch species. Species with scores **above 3.5** from the unknown bycatch matrix do not need to be addressed.

Bycatch score from Appendix 3 (1–5)	Moderate Concern species status (under 2.2)	High Concern species status (under 2.2)
3-3.5	Low Concern	Low Concern
2-2.5	Moderate Concern	Moderate Concern
1	High Concern	• High concern, if there are some efforts, believed to be effective, to reduce mortality • Critical, if there are no effective efforts to reduce mortality

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Factor 2.4	Modifying Factor: Discards and Bait Use

Goal: *Fishery optimizes the utilization of marine resources by minimizing post-harvest loss and by efficiently using marine resources as bait.*

Instructions: This weighting factor is addressed once for each fishery under assessment. Ascertain whether bycatch species are known or not. Both bait and dead discards are considered relative to total landings. This ratio refers to the total dead discards and/or bait use relative to total landings **of all species** caught in the fishery. The discard mortality rate is generally assumed to be 100% (i.e., all discards count as dead discards). Exceptions include cases where research has demonstrated high post-release survival, including invertebrates caught in pots and traps. Research that demonstrates high post-release survival for the same or similar species caught with the same or comparable gear types may qualify as showing high post-release survival. When discard mortality rates are known, multiply these rates by the amount of discards for the relevant species to determine the amount of dead discards. If the bycatch:landings ratio and/or bait use are unknown, refer to average bycatch rates for similar fisheries (based on gear type, target species and/or location) as given in review papers (e.g., Kelleher 2005 and Alverson et al. 1994). Bait use, if unknown, need only be addressed in cases where it is likely to be substantial relative to landings (e.g., lobster pot fishery). Err on the side of caution when there is no information.

Amount of dead discards plus bait use relative to total *landings* (in biomass or numbers of fish, whichever is higher)

Ratio of bait + discards/landings	Factor 2.4 score
< 20%	1
20–40%	0.95
40–60%	0.9
60–80%	0.85
80–100%	0.8
>100%	0.75

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Criterion 2 Score and Rank

Criterion 2 Score for the stock for which you want a recommendation = Subscore * Discard Rate (Factor 2.4).

- Subscore = lowest score of all other assessed species caught.
  - Score for each species = geometric mean (Factors 2.2, 2.3). Factor 2.1 is not included in the calculation; instead it modifies the score for Factor 2.2 in some circumstances (See Factor 2.2 table for more information).

Rank is based on the lowest *Subscore* as follows:

- >3.2 = **Green**
- >2.2 and <=3.2 = **Yellow**
- <=2.2 = **Red**

Rank is **Critical** if Factor 2.3 is Critical.

Criterion 3 – Effectiveness of Fishery Management

Guiding principles

The fishery is managed to sustain the long-term productivity of all impacted species. Management should be appropriate (see Appendix 4 for more guidance) for the inherent vulnerability of affected marine life and should incorporate data sufficient to assess the affected species and manage fishing mortality to ensure little risk of depletion. Measures should be implemented and enforced to ensure that fishery mortality does not threaten the long-term productivity or ecological role of any species in the future.

Assessment instructions

Assess Factors 3.1 and 3.2 once for each fishery.

Factor 3.1	Harvest Strategy

Goal: *Management strategy has a high chance of preventing declines in stock productivity by taking into account the level of uncertainty, other impacts on the stock, and the potential for increased pressure in the future. See Appendix 4 for more guidance.*

Instructions

Step 1: Assign a ranking for each of the seven management subfactors using the table below:

	Highly effective	**Moderately effective**	**Ineffective**
Management strategy and implementation	Fishery has highly appropriate strategy and goals, **and** there is evidence (scientific or other rigorous source) that the strategy is being implemented successfully	Some effective management (see Appendix 4) is in place, but there is a need for increased precaution (e.g., stronger reductions in TAC when biomass declines, quicker reaction to changes in populations, etc.), **or** management strategy is moderately successful at achieving goals	Management strategy is insufficiently precautionary to protect populations or strategies have not been implemented successfully
Recovery of stocks of concern	If overfished, depleted, endangered or threatened species are targeted and/or retained, management has a rebuilding or recovery strategy in place with a high likelihood of success in an appropriate timeframe, **and** best management practices (Appendix 4) are in use to minimize mortality of these species to the greatest extent possible, **and** harvest control rules are in place that will allow for rebuilding OR There are currently no overfished, depleted, endangered or threatened species targeted or retained in the fishery	If overfished, depleted, endangered or threatened species are targeted and/or retained, management has a rebuilding or recovery strategy in place whose eventual success is probable, **or** best management practices to minimize mortality of "stocks of concern" are in use where needed and are believed to be effective OR Fishery is not a substantial contributor to mortality of these species (i.e., they are rated as "very low concern" under 1.3 and/or 2.3)	If overfished, depleted, endangered or threatened species are targeted and/or retained, and fishery is a substantial contributor to mortality of the species, management lacks an adequate rebuilding or recovery strategy and/or effective practices designed to limit mortality of these species
Scientific research and monitoring	The management process uses an independent and up-to-date	Some collection of data related to stock	No data or very minimal data are

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	scientific stock assessment or analysis, or other appropriate method that seeks knowledge related to stock status, **and** this assessment is conducted regularly and is complete and robust, which may include both fishery-independent and appropriate fishery-dependent data	abundance and health is collected, but data may be insufficient (or too uncertain) to maintain stock	collected
Scientific advice	Management nearly always follows scientific advice (e.g., does not have a track record of exceeding advised TACs or otherwise disregarding scientific advice)	Management only sometimes follows scientific advice (e.g., only sets TACs at or below the recommended level half of the time)	Management has a track record of regularly exceeding recommended TACs, or otherwise not complying with scientific advice
Enforcement	Regulations and agreed voluntary arrangements are regularly enforced and independently verified, including VMS, logbook reports, dockside monitoring and other similar measures appropriate to the fishery	Enforcement and/or monitoring are in place to ensure goals are successfully met, although effectiveness of enforcement/monitoring may be uncertain (e.g., regulations are enforced by fishing industry or by voluntary/honor system, but without regular independent scrutiny)	Enforcement and/or monitoring is lacking or believed to be inadequate, or compliance is known to be poor
Track record	Measures enacted by management have resulted in the long-term maintenance of stock abundance and ecosystem integrity; management has maintained stock productivity and ecosystem integrity over time	Measures enacted by management have not been in place long enough to result in the long-term maintenance of stock abundance, **or** the track record is uncertain	Management measures currently in place have resulted in stock declines and/or failed to allow depleted stocks to recover
Stakeholder inclusion	The management process is transparent and includes stakeholder input.	There is limited transparency, stakeholder input or consultation.	Stakeholders are not included in decision-making and decisions are not made transparently

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Step 2: Assign a ranking and a score for the fishery's management of impacts on retained stocks (Criterion 3.1 score) based on the seven subfactors rated above.

Conservation Concern:	Description	Score
Very Low	Meets or exceeds the standard of "highly effective" management for all seven subfactors	5
Low	Meets or exceeds all the standard for "moderately effective " management for all seven subfactors **and** Meets or exceeds the standard of "highly effective" management for, at a minimum, "management strategy and implementation" and "recovery of stocks of concern" **but** Does not fully meet the standard for "very low concern" as defined above	4
Moderate	Meets or exceeds all the standards for "moderately effective" management for all seven subfactors **but** Does not fully meet the standard for "low concern" as defined above	3
High	There is management in place where a clear need exists, and there is not a high degree of IUU fishing **and** Meets or exceeds the standard for "moderately effective" management for, at a minimum, "management strategy and implementation" and "recovery of stocks of concern" **but** Does not fully meet the standards for "moderate concern" as defined above	2
Very High	There is management in place where a clear need exists, and there is not a high degree of IUU fishing **but** Fishery has characteristics of "ineffective" management for "management strategy and implementation" and/or "recovery of stocks of concern"	1
Critical	No management exists when a clear need for management exists in the fishery, including where catch regularly includes stocks of concern (overfished, depleted, endangered, threatened, etc.), **or** Substantial IUU fishing; 25% or more of the product is caught illegally.	0

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Factor 3.2	**Bycatch Management Strategy**

Goal: *Management strategy prevents negative population impacts on bycatch species, particularly species of concern.*

If the fishery has very low or no bycatch (due to highly selective gear, seasonal effort or other), score Factor 3.2 as N/A for bycatch management and the management score will be based solely on Factor 3.1.

Instructions
Step 1: Assign a ranking for each of the four management subfactors using the table below:

	Highly effective	**Moderately effective**	**Ineffective**
Management strategy and implementation	Fishery has highly effective or precautionary strategy and goals designed to understand and minimize the impacts of the fishery on bycatch species, **and** there is evidence that the strategy is being implemented successfully (e.g., there is a well-known track record of consistently setting conservative bycatch limits based on quality information and advice about bycatch, **or** bycatch is minimized to the greatest extent possible, especially for vulnerable species such as sharks, seabirds, turtles, marine mammals and some fish through mitigation measures (see Appendix 5 for guidance), area closures or other bycatch reduction techniques (Appendix 5) that have been shown to be highly effective)	Strategy or implementation effectiveness is under debate or uncertain (e.g., bycatch limits are imposed based on assumptions, but limits are disputed or unsure, or bycatch reduction techniques are used but are of unknown or uncertain effectiveness, or management has not been in place long enough to evaluate its effectiveness or is unknown)	Management measures such as bycatch limits or bycatch reduction techniques (Appendix 5) are in place but insufficient given the potential impacts of the fishery (e.g., a fishery that is heavily or fully exploited with no data collection or monitoring to ensure the health of bycatch populations), **or** No management if bycatch concerns are possible (based on region and gear type) but remain unknown
Scientific research and monitoring	Adequate observer coverage or effective video monitoring coverage, data collection and analysis are sufficient to determine that goals are being met	Collection of observer or effective video monitoring data exists, but coverage or analysis is limited	No regular collection or analysis of data, or no significant scientific research support
Scientific advice	As in Factor 3.1, but for bycatch	As in Factor 3.1, but	As in Factor 3.1, but for

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	species (set at score for Factor 3.1 if no other reason exists)	for bycatch species (set at score for Factor 3.1 if no other reason exists)	bycatch species (set at score for Factor 3.1 if no other reason exists)
Enforcement	As in Factor 3.1, but for bycatch species (set at score for Factor 3.1 if no other reason exists)	As in Factor 3.1, but for bycatch species (set at score for Factor 3.1 if no other reason exists)	As in Factor 3.1, but for bycatch species (set at score for Factor 3.1 if no other reason exists)

Step 2: Assign a ranking and a score for the fishery's management of impacts on bycatch species (Criterion 3.2 score) based on the four subfactors rated above.

Conservation Concern	Description	Score
Very Low	Meets or exceeds the standard of "highly effective" management for all four subfactors	5
Low	Meets or exceeds all the standard for "moderately effective " management for all four subfactors **and** Meets or exceeds the standard of "highly effective" management for, at a minimum, "management strategy and implementation" **but** Does not fully meet the standard for "very low concern" as defined above	4
Moderate	Meets or exceeds all the standards for "moderately effective" management for all four subfactors **but** Does not fully meet the standard for "low concern" as defined above	3
High	There is management in place where a clear need exists **and** Meets or exceeds the standard for "moderately effective" management for, at a minimum, "management strategy and implementation" **but** Does not fully meet the standards for "moderate concern" as defined above	2
Very High	There is management in place where a clear need exists **but** Fishery has characteristics of "ineffective" management for "management strategy and implementation"	1
Critical	No bycatch management even when overfished, depleted, endangered or threatened species are known to be regular components of bycatch and are substantially impacted by the fishery.	0

*Underlined terms have been defined in the glossary. Ctrl + Click to view.

Criterion 3 Score and Rank

Score = geometric mean (Factors 3.1, 3.2)

Rank is based on the Score as follows:

- **Green** if >3.2
- **Yellow** if >2.2 and <=3.2 **and** neither Factor 3.1 nor Factor 3.2 are Very High Concern or Critical
- **Red** if <=2.2 **or** either Factor 3.1 or Factor 3.2 is Very High Concern

Rank is **Critical** if either or both of Factors 3.1 and 3.2 are Critical.

*Underlined terms have been defined in the glossary. Ctrl + Click to view.

Criterion 4 – Impacts on Habitat and Ecosystem

Guiding principles

The fishery is conducted such that impacts on the seafloor are minimized and the ecological and functional roles of seafloor habitats are maintained.

Fishing activities should not seriously reduce ecosystem services provided by any fished species or result in harmful changes such as trophic cascades, phase shifts or reduction of genetic diversity.

Assessment instructions

Address Factor 4.1–4.2 for all fishing gears separately. Assess Factor 4.3 once per fishery.

Factor 4.1 Impact of Fishing Gear on the Substrate

Goal: *The fishery does not adversely impact the physical structure of the seafloor or associated biological communities.*

Instructions: Fishing gears that do **not** contact the seafloor score 5 for this criterion, and Factor 4.2 can be skipped. Use the table below to assign a score for gear impacts (Appendix 6 provides further guidance). If gear type is not listed in the table, use the score for the most similar gear type in terms of extent of bottom contact. Seafood Watch will not assess a fishery using destructive gear such as explosives or cyanide regardless of habitat type and management actions; therefore, those fishing methods are not included in the table. Where multiple habitat types are commonly encountered, and/or the habitat classification is uncertain, score conservatively according to the most sensitive plausible habitat type. See Appendix 6 for further guidance and the methods used in developing the table below.

Conservation Concern	Description	SFW score
None	Gear does not contact bottom	5
Very Low	Vertical line	4
Low	Gillnet, trap, bottom longline except on rocky reef/boulder and corals Bottom seine (on mud/sand only) Midwater trawl that is known to contact bottom *occasionally* (<25% of the time) or purse seine known to commonly contact bottom	3
Moderate	Scallop dredge on mud and sand Gillnet, trap, bottom longline on boulder or coral reef Bottom seine (except on mud/sand) Bottom trawl (mud and sand, or shallow gravel) (includes midwater trawl known to commonly contact bottom)	2
High	Hydraulic clam dredge Scallop dredge on gravel, cobble or boulder Trawl on cobble or boulder, or low energy (>60 m) gravel	1
Very High	Dredge or trawl on deep-sea corals or other biogenic habitat (such as eelgrass and maerl)	0

Factor 4.2	**Modifying Factor: Mitigation of Fishing Gear Impacts**

Goal: *Damage to the seafloor is mitigated through protection of sensitive or vulnerable seafloor habitats, and limits on the spatial footprint of fishing on fishing effort.*

Instructions: Assess Factor 4.2 only for fishing gear that contacts the bottom. Scores from Factor 4.2 can only improve the base score from 4.1. A high level of certainty is required to score a strong or moderate mitigation measure, e.g., good quality seafloor maps, VMS and/or observer coverage is required to document that spatial measures are effective and enforced. Further guidance can be found in Appendix 7.

Assess whether the fishery management's efforts to mitigate the fishery's impact on the benthic habitat fall into the categories strong, moderate, minimal or no effective mitigation, based on the table below. **Factor 4.2 allows the habitat score to increase, based on the strength of mitigation measures, by the number of bonus points specified in the table.**

Strong mitigation	At least 50% of the representative habitat is protected from the gear type used in the fishery under assessment (see Appendix 7). **or** Fishing intensity is sufficiently low and limited such that it can be scientifically demonstrated that at least 50% of the representative habitat is in a recovered state, based on knowledge of the resilience of the habitat and the frequency of fishing impacts from the gear type used in the fishery under assessment (see Appendix 7), **or** Gear is specifically designed to reduce impacts on the seafloor **and** there is scientific evidence that these modifications are effective in this regard **and** modifications are used on the majority of vessels, **or** Other measures are in place that have been demonstrated to be highly effective in reducing the impact of the fishing gear, which may include an effective combination of two or more "moderate" measures described below, e.g., gear modifications + spatial protection.	+1
Moderate mitigation	Ongoing, effective measures are reducing fishing effort, intensity or spatial footprint, **or** A substantial proportion of all representative habitats are protected from all bottom contact **and** expansion of the fishery's footprint is prohibited **and** vulnerable habitats are strongly protected, **or** Gear modifications or other measures are in use that are reasonably expected to be effective.	+0.5
Minimal mitigation	Fishing effort or intensity is effectively controlled, but is not actively being reduced, **or**	+0.25

*Underlined terms have been defined in the glossary. Ctrl + Click to view.

	Vulnerable habitats are strongly protected (e.g., in HAPCs) but other habitats are not strongly protected, **or** Modifications or measures anticipated to be effective are being tested or developed.	
No effective mitigation	No controls on fishing intensity are in place, **or** No or few efforts exist to limit the spatial extent of fishing, **or** No modifications anticipated to be effective are in use, **or** Modifications are in use but are not effective.	+0
Not applicable	Not applicable because gear used is benign.	**+0**

Factor 4.3 Impacts on the Ecosystem and Food Web

Goal: *All stocks are maintained at levels that allow them to fulfill their ecological role and to maintain a functioning ecosystem and food web.* Fishing activities should not seriously reduce ecosystem services provided by any retained species or result in harmful changes such as trophic cascades, phase shifts or reduction of genetic diversity.

Instructions: Assign an ecosystem-based management score for the fishery, taking into consideration the ecosystem role of the main species in the fishery, and whether they are "species of exceptional importance." Species of exceptional importance play a disproportionately important role relative to their biomass. These may include habitat-forming species, forage species, top predators, keystone species, ecosystem engineers, etc. A species should not be considered of "exceptional importance" unless it clearly fits in one of these categories or there is clear evidence that it plays a keystone role in the ecosystem.

*Underlined terms have been defined in the glossary. Ctrl + Click to view.

Conservation Concern	Description	Score
Very Low	There are policies in place designed to protect ecosystem functioning (e.g., a substantial proportion of the fishery area is protected in no-take marine reserves, which are designed and/or demonstrated to be effective for protecting ecosystem function, or there is a maximum catch or a minimum biomass based on ecosystem considerations), or an ecosystem study has been conducted and it has been scientifically proven that the fishery has no negative ecological and/or genetic impacts, **and** If the fishery catches "exceptional species" (see definition above), the ecological and food web impacts have been scientifically assessed **and** the management scheme protects enough biomass to allow these exceptional species to fulfill their ecological role (e.g., through the harvest control rule), **and** For fisheries with hatchery supplementation and/or use of Fish Aggregating Devices (FADs), these practices are demonstrated not to have negative ecological and/or genetic impacts.	5
Low	Scientific assessment and management efforts to account for ecological role are underway, **and** If the fishery catches "exceptional species", policies are in place to protect ecosystem functioning (e.g., a substantial proportion of the fishery area is protected in no-take marine reserves, or there is a maximum catch or a minimum biomass based on ecosystem considerations), though these may not be explicit or based on scientific assessment, **and** For fisheries with hatchery supplementation, and/or use of FADs, practices are designed to minimize or mitigate any potential negative ecological and/or genetic impacts, where applicable.	4
Moderate	The fishery does not catch "exceptional species" and scientific assessment and management of ecosystem impacts are not yet underway, though they may be in planning stages **or** The fishery catches "exceptional species" and lacks policies to protect the ecosystem role of these species, but scientific assessment to account for these species' ecological roles is underway, **or** For fisheries with hatchery supplementation, and/or use of FADs, negative ecological and/or genetic impacts from these practices are possible and management is not designed to minimize these impacts.	3
High	The fishery catches "exceptional species" and there are no explicit efforts to	2

*Underlined terms have been defined in the glossary. Ctrl + Click to view.

	incorporate ecological role into management.	
Very High	For fisheries with hatchery supplementation, and/or use of FADs, practices are in use that have been demonstrated or believed to have serious negative ecological and/or genetic impacts, **or** Scientifically demonstrated trophic cascades, alternate stable states, or other detrimental food web impacts are resulting from the fishery.	1

Criterion 4 Score and Rank

Score = geometric mean (Factors 4.1+4.2, 4.3)

Rank is based on the Score as follows:

- >3.2 = **Green**
- >2.2 and <3.2 = **Yellow**
- <=2.2 = **Red**

Rank cannot be Critical for Criterion 4.

*Underlined terms have been defined in the glossary. Ctrl + Click to view.

Overall Score and Final Recommendation

Final Score = geometric mean of the four Scores (Criterion 1, Criterion 2, Criterion 3, Criterion 4).

The overall recommendation is as follows:

- **Best Choice** = Final Score between 3.2 and 5, **and** no Red Criteria, **and** no Critical scores
- **Good Alternative** = Final score between 2.2 and 3.199, **and** neither Criterion 3.1 nor Criterion 3.2 is scored Poor (1) or below **and** no more than one Red Criterion, **and** no Critical scores
- **Red** = Final Score between 0 and 2.199, **or** either Criterion 3.1 or Criterion 3.2 is scored Very High Concern (1) or below, **or** two or more Red Criteria, **or** one or more Critical scores.

*Underlined terms have been defined in the glossary. Ctrl + Click to view.

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Glossary

Adequate observer coverage:

Observer coverage required for adequate monitoring depends on the rarity of the species caught, with fisheries that interact with rare species requiring higher coverage. Similarly, species that are "clumped" instead of being evenly distributed across the ocean also require higher levels of coverage. In addition, fisheries using many different gear types and fishing methods require higher levels of coverage. Bias may also be introduced if some areas, gear and seasons of a fishery are not well sampled. For these reasons, the exact level of coverage required for a particular fishery depends on the distribution of a species within the fishery as well as its associated discard and target species (Babcock and Pikitch 2003). The analyst will need to determine what level of observer coverage is adequate for the fishery of interest; coverage of 17–20% (or as high as 50% for rare species bycatch) may be required in some cases but may not be necessary in all cases.

Appropriate reference points:

Determination of the appropriateness of reference points depends on two questions:

1) *Is the goal appropriate?* Appropriate biomass reference points are designed with the goal of maintaining stock biomass at or above the point where yield is maximized (*target reference points*; *TRP*s) and safely above the point where recruitment is impaired (*limit reference points*; *LRP*s). Ideally, biomass reference points aim to maintain stock biomass at levels that allow the stock to fulfill its role in the ecosystem. Fishing mortality reference points should be designed with the goal of ensuring that catch does not exceed sustainable yield and has a very low likelihood of leading to depletion of the stock in the future.

2) *Is the calculation of the reference points credible?* There may be a concern if reference points have been lowered repeatedly or if there is scientific controversy regarding the reference points or the calculations of biomass and fishing mortality relative to reference points.
See the guidance for each type of reference point below and in Appendix 1.

Target reference point: Reference points need to be evaluated on a case-by-case basis, but in general: Biomass target reference points (TRPs) should generally not be lower than BMSY or approximately B35–B40%. TRPs below about B35% require strong scientific rationale. See Appendix 1 for more details.

Limit reference point: The point where recruitment would be impaired. Reference points need to be evaluated on a case-by-case basis, but in general: Biomass limit reference points (LRPs) should be no less than ½ BMSY, or ½ an appropriate target reference point such as B40%. LRPs below about B20% or ½ BMSY require strong scientific rationale.

Spawning potential ratio/fraction of lifetime egg production (SPR/FLEP) reference point: The SPR/FLEP limit reference point should either be derived through scientific analysis to be at or above replacement %SPR for the species (the threshold level of SPR necessary for replacement) based on its productivity and S-R relationship (viz., Mace and Sissenwine 1993), or should be set at about 35–40% of LEP. An exception can be made for species with very low inherent productivity (e.g., rockfish, sharks), in which case a reference point of 50–60% of LEP is more appropriate (Mace and Sissenwine 1993, Myers et al. 1999, Clark 2002, Botsford and Parma 2005).

Bycatch:

Refers to all fisheries-related injury or mortality other than in the retained catch. Examples include discards, endangered or threatened species catch, pre-catch mortality and ghost fishing. All discards, including those released alive, are considered bycatch unless there is both valid scientific evidence of high post-release survival **and** no documented evidence of negative impacts at the population level.

Critically endangered:

An IUCN category for listing endangered species. A taxon is considered "critically endangered" (CE) when it faces an extremely high risk of extinction in the wild in the immediate future, as defined by any of the relevant IUCN criteria for "critically endangered" (FAO Glossary; IUCN).

Data-moderate:

Reliable estimates of MSY-related quantities are either unavailable or not useful due to life history, a weak stock-recruit relationship, high recruitment variability, etc. Reliable estimates of current stock size, life history variables and fishery parameters exist. Stock assessments include some characterization of uncertainty (Restrepo and Powers 1998; Restrepo et al. 1998).

Data-poor:

Refers to fisheries for which there are no estimates of MSY, stock size, or certain life history traits. There may be minimal or no stock assessment data, and uncertainty measurements may be qualitative only (Restrepo and Powers 1998; Restrepo et al. 1998).

Data-rich:

Refers to fisheries with reliable estimates of MSY-related quantities and current stock size. Stock assessments are sophisticated and account for uncertainty (Restrepo and Powers 1998; Restrepo et al. 1998).

Depleted:

A stock at a very low level of abundance compared to historical levels, with dramatically reduced spawning biomass and reproductive capacity. Such stocks require particularly energetic rebuilding strategies. Recovery times depend on present conditions, levels of protection and environmental conditions. May refer also to marine mammals listed as "depleted" under the Marine Mammal Protection Act (FAO Glossary). Classifications of "overfished" or "depleted" are based on assessments by the management agency and/or FAO, but analysts can use judgment to override the classification, especially where the prior assessment may be out of date (also includes IUCN listings of "near threatened", "special concern" and "vulnerable"). Inclusion in this classification based on designations such as "stock of concern" is determined on a case-by-case basis, as such terms are not used consistently among management agencies. Stocks should be classified as "depleted" if the stock is believed to be at a low level of abundance such that reproduction is impaired or is likely to be below an appropriate limit reference point. Marine mammals classified as "depleted" under the Marine Mammal Protection Act fall into this category, if not listed as endangered or threatened. Also includes stocks most likely (>50% chance) below the level where recruitment or productivity is impaired. *Note:* Official IUCN listings should be overridden by more recent and/or more specific classifications, where available (e.g., NMFS stock assessment showing stock is above target levels).

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Ecological role:

The natural trophic role of a stock within the ecosystem under consideration in an assessment (MSC 2010).

Effective:

Management or mitigation strategies are defined as "effective" if a) the management goal is sufficient to maintain the structure and function of affected ecosystems in the long-term, **and** b) there is scientific evidence that they are meeting these goals.

Effective mitigation or gear modification:

A strategy that is "effective" as defined above, either in the fishery being assessed or as demonstrated in a very similar system (See Appendix 4 and Appendix 5 for a partial list of effective mitigations; this list will be continually developed).

Endangered/threatened:

Taxa in danger of extinction and whose survival is unlikely if causal factors continue operating. Included are taxa whose numbers have been drastically reduced to a critical level or whose habitats have been so drastically impaired that they are deemed to be in immediate danger of extinction (FAO Fisheries Glossary). This classification includes taxa listed as "endangered" or "critically endangered" by IUCN or "threatened", "endangered" or "critically endangered" by an international, national or state government body, as well as taxa listed under CITES Appendix I. This classification does not include species listed by the IUCN as "vulnerable" or "near threatened". Marine mammals listed as "strategic" under the Marine Mammal Protection Act are also considered as endangered/threatened if they are listed because "based on the best available scientific information, [the stock] is declining and is likely to be listed as a threatened species under the ESA within the foreseeable future." However, marine mammal stocks listed as "strategic" because "the level of direct human-caused mortality exceeds the potential biological removal level," or because they are listed as "depleted" under the Marine Mammal Protection Act, are instead classified as species of concern.

Exceptional importance to the ecosystem:

A species that plays a key role in the ecosystem that may be disrupted by typical levels of harvesting, including: keystone species (those that have been shown or are expected to have community-level effects disproportionate to their biomass), foundation species (habitat-forming species, e.g., oyster beds), basal prey species (including krill and small pelagic forage species such as anchovies and sardines), and top predators, where the removal of a small number of the species could have serious ecosystem effects. Species that do not fall into any of these categories but that have been demonstrated to have an important ecological role impeded by harvest (e.g., studies demonstrating trophic cascades or ecosystem phase shifts due to harvesting) shall also be considered species of exceptional importance to the ecosystem (Paine 1995; Foley et al. 2010).

FishBase vulnerability:

Cheung et al. (2005) used fuzzy logic theory to develop an index of the intrinsic vulnerability of marine fishes. Using certain life history parameters as input variables—maximum length, age at first maturity, longevity, von Bertalanffy growth parameter K, natural mortality rate, fecundity, strength of spatial behavior and geographic range—together with heuristic rules defined for the fuzzy logic functions, fish species were assigned to either a very high, high, moderate or low level of intrinsic vulnerability. In this framework, intrinsic vulnerability is also expressed with a numerical value from 1 to 100 with 100 being most vulnerable. This index of intrinsic vulnerability was then applied to over 1300 marine fish species to assess intrinsic vulnerability in the global fish catch (Cheung et al. 2007). FishBase, the online global database of fish, includes this numerical "vulnerability score" on the profiles of fish species for which this analysis has been conducted (Froese and Pauly 2010).

Fluctuating biomass:

- If a stock is trending upwards (based on the most recent assessment) and has just recently exceeded the target reference point (TRP), it can be ranked as **Very Low Concern**. If a stock is not trending but is truly fluctuating around the TRP (exceeding in some years and falling short in others, but with no clear trend), it can be ranked as **Very Low Concern.** However, if a stock is fluctuating around the limit reference point (LRP), it cannot be considered **Very Low Concern**.
- If a stock is trending downward and is currently below the TRP, the rank can be no better than **Low Concern.**
- If a stock is below the LRP, it is considered **a High Concern.**

Fluctuating fishing mortality:

- If F is trending downwards, or was previously above F_{MSY} (or a suitable proxy) but has recently gone below F_{MSY} (in the most recent assessment), fishing mortality should be ranked as **Low Concern.**
- If F is fluctuating around F_{MSY}, or if F has been consistently below F_{MSY} and has just recently (in the latest assessment) risen above F_{MSY} for just this one year (potentially due to management error or a new stock assessment and the consequent adjustment in reference points or estimates), fishing mortality should be ranked as **Moderate Concern**.
- If F is trending upwards and has just risen above F_{MSY}, fishing mortality should be ranked as **High Concern** unless there is a substantial plan to bring F back down. Such a plan would need to differ substantially from the existing harvest control rules (HCR), as those evidently did not keep F at a sufficiently low level.

Highly appropriate management strategy:

Management that is appropriate for the stock and harvest control rules takes into account major features of the species' biology and the nature of the fishery. Such a management strategy incorporates the precautionary approach while also taking uncertainty into account and evaluating stock status relative to reference points, as these measures have been shown to be robust (modified from MSC 2010). As an example, if management is based on Total Allowable Catch, these limits are set below MSY and/or scientifically advised levels, accounting for uncertainty, and lowered if $B<B_{MSY}$. However, alternatives to TAC-based management, such as area-based (closures), 3S (size, sex and/or season limitations) or other appropriate methods may also apply (Appendix 4).

Likelihood:

Highly likely: 70% chance or greater, when quantitative data are available; may also be determined by analogy from similar systems when supported by limited data from the fishery and no scientific controversy exists (modified from MSC 2010 and based on guidance from MSC FAM Principle 2). Examples of high likelihood for fishing mortality:

- All estimates of fishing mortality are within 70% or greater (e.g., 80% or 95%) confidence intervals, or all estimates of F from all scientifically feasible models and assumptions, are below F_{MSY} or equivalent.
- Estimate of F is at 75% of sustainable levels of F (such as F_{MSY}) or less, or estimates of catch are < 75% MSY if the fishery is at or above B_{MSY} (if F is fluctuating, see "fluctuating F" for more guidance).

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- Exploitation is very low compared to natural mortality, mortality from other sources or population size

Likely: 60% chance or greater, when quantitative data are available; may also be determined according to expert judgment and/or plausible argument (modified from MSC 2010 and based on guidance from MSC FAM Principle 2).

Probable: Greater than 50% chance; can be based on quantitative assessment, plausible evidence or expert judgment. Examples of "probable" occurrence for fishing mortality:

There may be some uncertainty or disagreement among various models; fishing mortality may be above 75% of a sustainable level and/or catch may be above 75% of a sustainable catch level (e.g., MSY) for stocks at B_{MSY}.

Historic high:

Refers to near-virgin biomass, or highest recorded biomass, if biomass estimates predate the start of intensive fishing. If a fishery has been historically depleted and then rebuilt, the rebuilt biomass is not considered a "historic high" even though it may be higher than historical levels.

Inherent vulnerability:

A stock's vulnerability to overfishing based on inherent life history attributes that affect the stock's productivity and may impede its ability to recover from fishing impacts. Marine finfish are considered highly vulnerable when their FishBase vulnerability score falls into the categories high "vulnerability", "high to very high vulnerability", or "very high vulnerability" (scores of 55 or above) based on the FishBase vulnerability score (derived from the formula in Cheung et al. 2005). All sea turtles, marine mammals, and seabirds are considered "highly vulnerable". Marine invertebrates' vulnerability is based on the average of several attributes of inherent productivity.

One of the first key papers on this subject (Musick 1999) summarizes the results of an American Fisheries Society (AFS) workshop on the topic and offers proposed low, medium and high "productivity index parameters" (for marine fish species) based on available life history information: the intrinsic rate of increase r, the von Bertalanffy growth function k, fecundity, age at maturity and maximum age. Notably, although a species' intrinsic rate of increase is identified as the most useful indicator, it is also difficult to estimate reliably and is often unavailable (Cheung et al. 2005). To enable more timely and less data-intensive and costly identification of vulnerable fish species, Cheung et al. (2005) used fuzzy logic theory to develop an index of the intrinsic vulnerability of marine fishes based on life history parameters: maximum length, age at first maturity, longevity, von Bertalanffy growth parameter K, natural mortality rate, fecundity, strength of spatial behavior and geographic range (input variables). The index also uses heuristic rules defined for the fuzzy logic functions to assign fish species to one the following groups: very high, high, moderate or low level of intrinsic vulnerability.

In this framework, intrinsic vulnerability is also expressed by a numerical value between 1 and 100 with 100 being most vulnerable. This index of intrinsic vulnerability was then applied to over 1300 marine fish species to assess intrinsic vulnerability in the global fish catch (Cheung et al. 2007). FishBase, the online global database of fish, uses the numerical value from this index as a "vulnerability score" on the profiles of fish species for which it has been evaluated (Froese and Pauly 2010).

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Large portion of the stock is protected:

At least 50% of the spawning stock is protected, for example through size/sex/season regulations or the inclusion of greater than 50% of the species' habitat in marine reserves. Future guidance will improve the integration of marine reserve science into the criteria, based on ongoing research.

Main species:

A species is included in the assessment as a main species if:

- The catch of the species in the fishery under assessment composes >5% of that fishery's catch, *or*
- The species is >1% of that fishery's catch *and* the fishery causes >5% of the species' total mortality across all fisheries, *or*
- The species is <1% of that fishery's catch *and* the fishery causes >20% of species' total mortality across all fisheries, *or*
- The species is overfished, depleted, a stock of concern, endangered, threatened, IUCN Near Threatened, US MMPA strategic species, and/or subject to overfishing *and* the fishery causes >1% of species' total mortality across all fisheries.
- If there are no other "main species" (based on the above guidance) besides the one assessed under criterion 1, but the total catch of other discarded and retained species is >5% (i.e. catch of criterion 1 species is <95% of total), assess the top 3 species by volume of catch (if there are only 1-2 other species caught, assess those species).

Managed appropriately:

Management uses best available science to implement policies that minimize the risk of overfishing or damaging the ecosystem, taking into account species vulnerability along with scientific and management uncertainty.

Negative genetic or ecological effects:

Hatchery supplementation of fisheries may have negative ecological effects, including competition between hatchery-raised and wild fish, as well as genetic effects, including reduced fitness of populations through genetic introgression and reduced genetic diversity (Kostow 2009; Araki and Schmid 2010). Other fishing practices may have additional detrimental genetic or ecological effects; for example, drifting Fish Aggregating Devices (FADs) may act as "ecological traps" that mislead fish into making maladaptive habitat choices that reduce their fitness (Hallier and Gaertner 2008). Unfortunately, these impacts are generally poorly understood for most fisheries, but where impacts are likely (i.e., where FADs are in use or where large-scale hatchery supplementation exists, as in most salmon fisheries), ecosystem-based management should include measures specifically designed, and in the best cases, proven to reduce these impacts.

No management:

A fishery with no rules or standards for regulating fishing catch, effort or methods. Management does not need to be enforced through government regulation or official management agencies but may also include voluntary action taken by the fishery, as long as there is general compliance.

Overfished:

A stock is considered "overfished" when exploited past an explicit limit where abundance is considered too low to ensure safe reproduction. In many fisheries, the term "overfished" is used when biomass has been estimated below a biological reference point used to signify an "overfished condition". The stock may remain overfished (i.e., with a biomass well below the agreed limit) for some time even though fishing mortality may have been reduced or suppressed (FAO Glossary). Classification as "overfished" or "depleted" (including IUCN listing as "near threatened", "special concern" and "vulnerable") is based on evaluation by the management agency and/or FAO, but an analyst can use judgment to override this classification, especially where the classification may be out of date as long as there is scientific justification for doing so. Inclusion in the "overfished" category based on designations such as "stock of concern" are determined on a case-by-case basis, as such terms are not used consistently among management agencies. Stocks should be classified as "overfished" if the stock is believed to be at such a low level of abundance that reproduction is impaired or is likely to be below an appropriate limit reference point. Marine mammals classified as "depleted" under the Marine Mammal Protection Act also fall into this category if not listed as endangered or threatened. Stocks that are most likely (>50% chance) below the level where recruitment or productivity is impaired are also considered "overfished". *Note:* Official IUCN listings should be overridden by more recent and/or more specific classifications where available (e.g., NMFS stock assessment showing that a stock is above target levels).

Overfishing:

A generic term used to refer to a level of fishing effort or fishing mortality such that a reduction of effort would, in the medium term, lead to an increase in the total catch; or, a rate or level of fishing mortality that jeopardizes the capacity of a fishery to produce the maximum sustainable yield on a continuing basis. For long-lived species, overfishing (i.e., using excessive effort) starts well before the stock becomes overfished. Overfishing, as used in the Seafood Watch® criteria, can encompass biological or recruitment overfishing (but not necessarily economic or growth overfishing).

- *Biological overfishing*: Catching such a high proportion of one or all age classes in a fishery as to reduce yields and drive stock biomass and spawning potential below safe levels. In a surplus production model, biological overfishing occurs when fishing levels are higher than those required for extracting the Maximum Sustainable Yield ($_{MSY}$) of a resource and recruitment starts to decrease.
- *Recruitment overfishing*: When the rate of fishing is (or has been) high enough to significant reduce the annual recruitment to the exploitable stock. This situation is characterized by a greatly reduced spawning stock, a decreasing proportion of older fish in the catch and generally very low recruitment year after year. If prolonged, recruitment overfishing can lead to stock collapse, particularly under unfavorable environmental conditions.
- *Growth overfishing:* Occurs when too many small fish are being harvested too early through excessive fishing effort and poor selectivity (e.g., excessively small mesh sizes), and the fish are not given enough time to grow to the size at which maximum yield-per-recruit would be obtained from the stock. Reduction of fishing mortality among juveniles, or their outright protection, would lead to an increase in yield from the fishery. Growth overfishing occurs when the fishing mortality rate is above F_{max} (in a yield-per-recruit model). This means that individual fish are caught before they have a chance to reach their maximum growth potential. Growth overfishing, by itself, does not affect the ability of a fish population to replace itself.
- *Economic overfishing*: Occurs when a fishery is generating no economic rent, primarily because an excessive level of fishing effort is applied in the fishery. This condition does not always imply biological overfishing.

(FAO Glossary; NOAA 1997)

Precautionary approach:

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The precautionary approach involves the application of prudent foresight. Taking account of the uncertainties in fisheries systems and considering the need to take action with incomplete knowledge, the precautionary approach requires, inter alia: (i) consideration of the needs of future generations and avoidance of changes that are not potentially reversible; (ii) prior identification of undesirable outcomes and measures to avoid or correct them promptly; (iii) initiation of any necessary corrective measures without delay and on a timescale appropriate for the species' biology; (iv) conservation of the productive capacity of the resource where the likely impact of resource use is uncertain; (v) maintenance of harvesting and processing capacities commensurate with estimated sustainable levels of the resource and containment of these capacities when resource productivity is highly uncertain; (vi) adherence to authorized management and periodic review practices for all fishing activities; (viii) establishment of legal and institutional frameworks for fishery management within which plans are implemented to address the above points for each fishery, and (ix) appropriate placement of the burden of proof by adhering to the requirements above (modified from FAO 1996).

Productivity is maintained/not impaired:

Fishing activity does not impact the stock, either through reduced abundance, changes in size, sex or age distribution, or reduction of reproductive capacity at age, to a degree that would diminish the growth and/or reproduction of the population over the long-term (multiple generations).

Productivity–susceptibility analysis (PSA):

Productivity-susceptibility analysis was originally developed to assess the sustainability of bycatch levels in Australia's Northern Prawn fishery (Patrick et al. 2009), and has since been widely applied to assess vulnerability to fishing mortality for as number of fisheries worldwide. Productivity-susceptibility analysis is used by NOAA and the Australian Commonwealth Scientific Industrial Research Organization (CSIRO) to inform fisheries management. It also constitutes the basis of the risk-based framework used to evaluate data-poor fisheries under the Marine Stewardship Council Fishery Assessment Methodology (MSC FAM). The PSA approach allows the risk of overfishing to be assessed for any species based on predetermined attributes, even in the most data-poor situations.

The exact sets of productivity and susceptibility attributes vary between PSA methodologies, and different weighting of attributes can be employed based on relative contextual importance. Additionally, scoring thresholds can vary depending on the context in which PSA is employed. In the US methodology, productivity is defined as the capacity for a stock to recover once depleted, which is largely a function of the life history characteristics of the species. Generally, productivity attributes are similar to the life history parameters used for the above index of intrinsic vulnerability.

While PSA analysis is a widely accepted approach for evaluating risk of overexploitation of a fished species, for the purposes of Seafood Watch assessments it is useful to separate the productivity attributes—which are intrinsic to a species and neither dependent on nor influenced by fishery practices—from the susceptibility attributes. Fisheries may influence the susceptibility of impacted stocks through the choice of gear, bait species, hook design, mesh size, area or seasonal closures, and other management measures. In addition, where detailed information on fishing mortality (e.g., estimates of F or harvest rates) is available, these data provide a more complete picture of the fishery impact that the susceptibility attributes are designed to predict. Therefore, under the revised Seafood Watch® criteria, the "inherent vulnerability" score will be derived from the FishBase vulnerability score, which address only those characteristics intrinsic to the species and equivalent to the productivity attributes considered under PSA. Susceptibility attributes will be separately considered as part of the evaluation of fishing mortality when more specific data are not available.

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Because the FishBase vulnerability index has not been evaluated for application to marine invertebrates (Cheung, pers comm., 2011), we propose the use of "productivity" attributes from the PSA methodology used by the MSC, with adjustments to account for particular aspects of marine invertebrate life history (see Criterion Factors 1.1 and 2.1 for guidance).

Changes to PSA resilience attributes made to increase applicability to invertebrates include:

- Removal of "average maximum size" and "average size at maturity" attributes, as body size has been demonstrated not to correlate with extinction risk for marine invertebrates (McKinney 1997, Finnegan et al. 2009).
- Incorporation of fecundity in the average only if fecundity is low, as strong evidence suggests that high fecundity does not necessarily correlate with low vulnerability; however, low fecundity does seem to correspond with high vulnerability (Dulvy et al. 2003, Cheung et al. 2005).
- Removal of the "trophic level" attribute. Anecdotally, trophic level does not appear to be a strong predictor of extinction risk for marine invertebrates. Some of the most vulnerable marine invertebrates are at the lowest trophic level (e.g., abalone). Additionally, in a review of Canadian fishes, trophic level was not found to be a strong predictor of extinction risk in marine fishes (O'Malley 2010; Pinsky et al. 2011).
- Incorporation of density dependence, particularly the existence of depensatory dynamics, or Allee effects, for small populations. Allee effects may have a profound effect on the resilience of marine invertebrates to fishing mortality (Hobday et al. 2001, Caddy 2004).

Reasonable timeframe (for rebuilding):

Dependent on the species' biology and degree of depletion, but generally within 10 years, except in cases where the stock could not rebuild within 10 years even in the absence of fishing. In such cases, a reasonable timeframe is within the number of years it would take the stock to rebuild without fishing, plus one generation, as described in Restrepo et al. (1998).

Recruitment is impaired:

Fishing activity impacts the stock—either through reduced abundance, changes in size, sex or age distribution, or reduction of reproductive capacity at age—to a degree that will diminish the growth and/or reproduction of the population over the long-term (multiple generations); or, the stock is below an appropriate limit reference point, if one is defined.

Regularly monitored:

Fishery-independent surveys of stocks, or other reliable assessments of abundance, are conducted at least every three years.

Reliable data:

Data produced or verified by an independent third party. Reliable data may include government reports, peer-reviewed science, audit reports, etc. Data are not considered reliable if significant scientific controversy exists over the data, or if data are old or otherwise unlikely to represent current conditions (e.g., survey data is several years old and fishing mortality has increased since the last survey).

Species of concern:

Species about which management has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species as endangered. In the U.S., this may include species for which NMFS has determined, following a biological status review, that listing under the ESA is "not warranted," pursuant to ESA section 4(b)(3)(B)(i), but for which significant concerns or uncertainties remain regarding their status and/or threats. Species can qualify as both "species of concern" and "candidate species" (http://www.nmfs.noaa.gov/pr/glossary.htm#s). In addition, marine mammal stocks listed as “strategic” because “the level of direct human-caused mortality exceeds the potential biological removal level” are classified as species of concern. The terms “species of concern” or “stock of concern” are used similarly by other federal and state management bodies.

Stakeholder input:

A stakeholder is an individual, group or organization that has an interest in, or could be affected by, the management of a fishery (modified from MSC 2010). Stakeholder input may include: involvement in all key aspects of fisheries management from stock assessment and setting research priorities to enforcement and decision-making. In addition, stakeholders may take ownership of decisions and greater responsibility for the wellbeing of individual fisheries (Smith et al 1999). Effective stakeholder engagement requires that the management system has a consultation processes open to interested and affected parties and that roles and responsibilities of the stakeholders are clear and understood by all relevant parties (modified from MSC 2010).

Stock:

A self-sustaining population that is not strongly linked to other populations through interbreeding, immigration or emigration. A single fishery may capture multiple stocks of one or multiple species. Stocks can be targeted or non-targeted, retained or discarded, or some combination thereof (e.g., juveniles are discarded and adults are retained).

Ideally, the management unit of “stock” should correspond to the biological unit. However, often the fisheries management unit of “stock” may not be the same as the biological unit. If multiple biological stocks are managed as one, and there is insufficient information to assess the stock status of each biological stock, the management unit is assessed. This situation detracts from the fishery’s “quality of information” score, as it makes it impossible to assess individual stocks’ health. If management occurs on a finer scale than biological stocks so that multiple management unit stocks compose one interbreeding population, the health and abundance of the biological stock should be assessed as a whole based on information aggregated across the management units. The effectiveness of management can be assessed at the finest scale for which meaningful and verifiable differences in management practice exist.

Substantial contributor:

A fishery is a substantial contributor to impacts affecting a population, ecosystem or habitat if the fishery is a main contributor, or one of multiple contributors of a similar magnitude, to cumulative fishing mortality. Examples of a fishery that is **not** a substantial contributor include: (a) catch of the species is a rare or minor component of the catch in this fishery **and** the fishery is a small contributor to cumulative mortality, relative to other fisheries. However, if there has been a jeopardy determination for that stock in the fishery being assessed it should be considered a substantial contributor regardless of this definition.

Substantial proportion of habitat:

Refers to a condition when at least 20% of each representative habitat (where representative habitats can be delineated by substrate, bathymetry, and/or community assemblages), within both the range of the targeted stock(s) and the regulatory boundaries of the fishery under consideration (i.e., within the national EEZ for the fishery under consideration), is completely protected from fishing with gear types that impact the habitat in that fishery.

Susceptibility (low/moderate/high)

A stock's capacity to be impacted by the fishery under consideration, depending on factors such as the stock's likelihood to be captured by the fishing gear. The susceptibility score is based on tables from MSC's Productivity-Susceptibility Analysis framework (see Appendix 2). Examples of low susceptibility include: low overlap between the geographic or depth range of species and the location of the fishery; the species' preferred habitat is not targeted by fishery; the species is smaller than the net mesh size as an adult, is not attracted to the bait used, or is otherwise not selected by fishing gear; or strong spatial protection or other measures in place specifically to avoid catch of the species.

Sustainable level (of fishing mortality):

A level of fishing mortality that will not reduce stock below the point where recruitment is impaired, i.e., above F reference points, where defined. The F limit reference points should be around either F_{MSY} or F35–40% for moderately productive stocks; low productivity stocks like rockfish and sharks require F in the range of F50–60% or lower. Higher F values require a strong scientific rationale. The F reference points are limit reference points, so buffers should be used to ensure that fishing mortality does not exceed these levels. Where F is unknown but MSY is estimated, fishing mortality at least 25% below MSY is considered a sustainable level (for fisheries that are at or above B_{MSY}).

Up-to-date data/stock assessment:

Complete stock assessments are not required every 1–3 years, but stocks should be regularly monitored at least every 1–3 years, and stock assessments should be based on abundance and fishing mortality data not more than three years old. Data may be collected by industry, but analysis should be independent.

Very limited area:

Fishing (with damaging gear, when assessing Criterion D) is limited to no more than 50% of each representative habitat (where representative habitats can be delineated by substrate, bathymetry, and/or community assemblages) within both the range of the targeted stock(s) and the regulatory boundaries of the fishery under consideration (e.g., the national EEZ for the fishery under consideration).

Very low levels of exploitation (e.g., experimental fishery):

Fishery is under-exploited or is being conducted experimentally to collect data or gauge viability, such that exploitation rates are far below sustainable yields (e.g., 20% or less of sustainable take). Alternatively, when no other information is available, exploitation levels may be considered very low if a fishery falls into the "low" category for all "susceptibility" questions under Productivity-Susceptibility Analysis (see Appendix 2 for more details on scoring susceptibility).

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Appendices

Appendix 1 – Further guidance on interpreting the health of stocks and fishing mortality

The tremendous variability among fisheries makes it impossible to define specific appropriate reference points that would be applicable to all assessed fisheries. Instead, criteria are based on the commonly accepted management goal that target biomass should be at or above the point where yield is maximized, and management should ensure a high probability that biomass is at or above a limit reference point (where recruitment or productivity of the stock would be impaired). Three common types of reference points are *MSY-based, SPR-based,* and *ICES reference points.* However, other reference points may be used in some fisheries, and should be evaluated in accordance with the management goal articulated above.

MSY-based reference points

While the concept of MSY is far from perfect, MSY-based biomass and fishing mortality reference points are commonly used in some of the most well managed fisheries around the world. When applied appropriately, these reference points are an important tool for maintaining stock productivity in the long term. However, without properly accounting for scientific and management uncertainty, maintaining a stock at B_{MSY} (the biomass corresponding to MSY) and harvesting at MSY runs a high risk of unknowingly either overshooting MSY or allowing biomass to drop below B_{MSY} without reducing harvest rates and thus inadvertently overharvesting (Roughgarden and Smith 1996; Froese et al. 2010). The risk of impacts from inadvertent overharvesting increases with increased uncertainty and with increased inherent vulnerability of the targeted stock. To account for these interactions, the guidance provided for assessing stock health and fishing mortality is based on MSY reference points but requires high scientific confidence that biomass is above target levels and that fishing mortality is below MSY.

Proxies for B_{MSY} are acceptable if shown to be conservative relative to B_{MSY} for that stock, or if they fit within the guidelines for appropriate target level*. Where B_{MSY} or proxy reference points are not known or are not applicable, the stock/population health criteria can be interpreted using relevant indicators that are appropriate as targets and safe limits for abundance of the species (e.g., escapement relative to escapement goals can be evaluated in lieu of biomass relative to limit reference points).

SPR-based reference points

In the absence of stock assessments and MSY-based reference points, the stock health can be evaluated based on CPUE, trends in abundance and size structure, and/or simple, easy to calculate reference points such as Fraction of Lifetime Egg Production (FLEP) (equivalent to Spawning Potential Ratio, SPR). Other data-poor or alternative assessment techniques that provide evidence that stocks are healthy (i.e., productivity and reproduction are not impaired) may be used in place of reference points. Guidelines may be added on a continuing basis, but they must be demonstrated to be accurate indicators of stock health. Guidance for assessing stock health and fishing mortality for data-poor stocks is based on O'Farrell and Botsford (2005) and Honey et al. (2010) but can be addressed on a case-by-case basis with a goal of ensuring that data-poor fisheries are held to the same standard of likelihood as data-rich fisheries when stocks are above a level where recruitment would be impaired and fishing mortality is at or below a sustainable level of harvest.

*Underlined terms have been defined in the glossary. Ctrl + Click to view.

- Examples of evidence that a stock is above the point where recruitment or productivity is impaired. i.e. an appropriate limit reference point, include:
    - o the current lifetime egg production (LEP) or spawning per recruit (SPR) is above an appropriate SPR or Fraction of Lifetime Egg Production (FLEP)-related reference point;
    - o spawning potential is well protected (e.g., females are not subject to mortality, and it can be shown or inferred that fertilization is not reduced);
    - o quantitative analyses conducted by fishery scientists under transparent guidelines indicate sufficient stock
- Strong, quantitative scientific evidence from the fishery under consideration is required to consider a stock a "very low concern". When limited data are available from the fishery, analogy with similar systems, qualitative expert judgments and/or plausible arguments may be used to consider the stock "low concern".
- Use of CPUE requires the absence of hyperselectivity, that CPUE is proportional to abundance (or adjusted), and that there have been no major changes in technology.
- If relying on CPUE rather than a LEP-based reference point, trends in size structure are also needed to ensure the fishery is not reducing stock productivity by depleting the relative proportion of large individuals.
- The LEP can be estimated from length frequency data from both unfished (or marine reserve) and current populations, and does not require catch-at-age data. Reference points based on FLEP should be considered limit reference points.

For "very low concern" rankings, there must be no evidence that productivity has been reduced through fisheries-induced changes in size or age structure, size or age at maturity, sex distribution, etc. SPR-based and MSY-based reference points should account for these changes as they are based on productivity of the stock rather than simple abundance. If the metric considers abundance only, or if there is evidence that productivity has been reduced through shifts in age, size or sex distributions, the stock cannot be ranked higher than "low concern".

ICES reference points

The ICES reference points Fpa, Flim, Bpa, and Blim are not equivalent to MSY-based reference points. In fact, comparisons have demonstrated that Fpa is typically above F_{MSY} and Bpa is typically below B_{MSY}, such that MSY-based reference points are generally more conservative (ICES 2010). In many cases, Bpa is well below B_{MSY} and even below $1/2B_{MSY}$ (Kell et al. 2005). Therefore, guidance for evaluating stock health using Bpa and fishing mortality using Fpa is conservative, accounting for the difference between these reference points and MSY-based reference points. ICES plans to transition to an MSY-based approach by 2015 (ICES 2010). If B>Bpa or F<Fpa, the stock should score as a moderate concern, unless a good reason exists to justify a "low concern" score (i.e., either the reference points have been shown to be conservative **or** the biomass is well above reference points).

Proxies

For many fisheries, F_{MSY} and B_{MSY} are unknown, and proxies are often used. Most commonly, biomass proxies are based on the percent of unfished or virgin biomass (B_0). Fishing mortality proxies are often based on spawning potential ratio (SPR).

Commonly used and acceptable biomass reference points are typically 35–40% of B_0 for most stocks (Clark 1991; NZ Ministry of Fisheries 2008). This target may vary according to stock productivity;

however, justifications for lower target levels are often based on assumptions about "steepness[1]" that may be highly uncertain or poorly understood. It is now recognized that stock targets lower than approximately 30-40% of B_0 are increasingly difficult to justify (NZ Ministry of Fisheries 2008). For these targets to be considered appropriate reference points, solid scientific justification is required. In addition, stocks reduced to this target level or below (equivalent to removing more than 60–70% of the stock's biomass) would be unlikely to achieve the ecosystem-based management goal of allowing a stock to fulfill its ecological role and should be scored accordingly under ecosystem-based management.

Alternatively, when unfished biomass cannot be estimated, proxy biomass reference points may be based on the equilibrium biomass achieved using appropriate fishing mortality reference points, as described below.

A large body of scientific literature addresses appropriate fishing mortality reference points based on spawner biomass per recruit (SPR). Ideally, these should be shown through scientific analysis to be at or above replacement %SPR (the threshold level of SPR necessary for replacement) for the species, based on its productivity and S-R relationship (viz. Mace and Sissenwine 1993). However, for many species this analysis will not be available. In these cases, guidance is based on the conclusions of numerous analyses demonstrating that, in general, $F_{35\text{-}40\%}$ (the fishing mortality rate that reduces the SPR to 35–40% of unfished levels) is appropriate for species with moderate vulnerability, while a more conservative fishing mortality rate of about $F_{50\text{-}60\%}$ is needed for highly vulnerable species such as rockfish and sharks (Botsford and Parma 2005; Mace and Sissenwine 1993; Clark 2002; Myers et al. 1999; Goodman et al. 2002).

Evaluating Fishing Mortality

Evaluation of fishing mortality should reflect the mortality caused by the fishery, but in the context of whether cumulative impacts on the species (including mortality from other fisheries) are sustainable. When determining whether a fishery is a substantial contributor, err on the side of caution. Unknown or missing data are grounds for classification as a substantial contributor.

Reference points

Generally, species should be managed with reference points that fit the definition of a sustainable level of fishing mortality and/or an appropriate SPR or Fraction of Lifetime Egg Production (FLEP)-related reference point. Species that are not commercially fished or managed but make up non-target catch in the fishery will generally not have reference points defined. In lieu of reference points, these stocks should be evaluated relative to a level of mortality scientifically shown not to lead to depletion of the stock. For species with high vulnerability, the reference point must be demonstrated to be appropriate for that species' biology. As a rule of thumb, F40% is not precautionary enough for high vulnerability species; F50% or lower is more appropriate when using SPR-based proxies.

ICES reference points

Because analysis has shown that the ICES reference point Fpa is typically above F_{MSY}, ICES stocks using Fpa as a reference point must be rated more conservatively than stocks using F_{MSY}. If F > Fpa, rank the stock as "high concern". If F < Fpa, rank the stock as "moderate concern," unless there is additional evidence that F is below a sustainable level such as Fmsy.

[1] Steepness is a key parameter of the Beverton-Holt spawner-recruit model that is defined as the proportion of unfished recruitment produced by 20% of the unfished spawning biomass. Steepness is difficult to estimate, and the calculation of reference points is often very sensitive to estimates of steepness.

Data-poor stocks

When no reference points are available (i.e., in data-poor fisheries), fishing mortality can be evaluated based on the likelihood that management actions and characteristics of the fishery constrain fishing mortality to acceptable levels. For example, fishing mortality could be considered a low concern if the fishery has a low likelihood of interacting with a non-target species due to low overlap between the species range and the fishery, or due to low gear selectivity for the species (resulting in low susceptibility; see below). Fishing mortality on target or non-target species may be considered a low concern if there is a very low level of exploitation, as in an experimental emerging fishery, or if a large portion of the stock's key habitat is protected in no-take reserves that have been shown to effectively protect the species. We hope to incorporate the results of ongoing research to provide more specific guidance on the amount of habitat that should be protected in marine reserves. In the interim, however, in order to score fishing mortality as a very low concern in the absence of reference points or other information about fishing mortality rates, at least 50% of all representative habitats should be protected in Marine Protected Areas where the assessed stock experiences no fishery mortality.

Appendix 2 – Susceptibility attributes from the MSC FAM

Where no information on fishing mortality is available in a data-poor fishery, susceptibility may be used as a proxy (see Factor 1.3). The concept of susceptibility is based on the "Susceptibility" attributes from the Productivity-Susceptibility Analysis (PSA) used in the MSC Certification Requirements document (2012). The susceptibility attributes and scoring guide from the MSC are given below. "Selectivity" should be scored only once for the appropriate gear type; where no cut-offs for a particular gear type are provided, the analyst shall develop similar selectivity tables that are appropriate for the gear and shall include a justification for the factors used and cut-offs selected in these cases.

Instructions for use: for each species in each fishery, score each attribute of susceptibility below. The final susceptibility score is the arithmetic mean of each attribute, and is considered "low" susceptibility overall if the final score is <=1.5, moderate if between 1.5 and 2.5, and high if >=2.5

	Low susceptibility (low risk, score: 1)	Medium susceptibility (medium risk, score: 2)	High susceptibility (high risk, score: 3)
Areal overlap – Overlap of the fishing effort with a species distribution of the stock.	<10% overlap	10–30% overlap	>30% overlap
Vertical overlap – The position of the stock/species within the water column relative to the fishing gear.	Low overlap with fishing gear	Medium overlap with fishing gear	High overlap with fishing gear
Selectivity for set gillnets Selectivity is the potential of gear to capture or retain the species	Length at maturity < mesh size, or >5 m in length	Length at maturity is 1-2 times mesh size or 4-5 m in length	Length at maturity >2 times mesh size, to say, 4 m in length

Selectivity for hooks Defined by typical weights of the species caught relative to the breaking strain of the snood, the gaffing method used in the fishery, and by diet of potential species Scores for hook susceptibility may be assigned using the categories to the right. If there are conflicting answers, e.g. Low on point 1 but medium on point 2, the higher risk score shall be used.	a. Does not eat bait (e.g. diet specialist), filter feeder (e.g. basking shark), small mouth (e.g. sea horse). Most robust scoring attribute. b. Species with capacity to break line when hooked (e.g. large toothed whales, and sharks). c. Selectivity known to be low from selectivity analysis/experiment (e.g. <33% of fish encountering gear are selected)	a. Large species, with adults rarely caught, but juveniles captured by hooks. b. Species with capacity to break snood when being landed. c. Selectivity known to be medium from selectivity analysis/experiment (e.g. 33-66% of fish encountering gear are selected).	a. Bait used in the fishery is selected for this type of species, and is a known diet preference (e.g. squid bait used for swordfish), or important in wild diet. b. Species unable to break snood when being landed c. Selectivity known to be high from selectivity analysis/experiment (e.g. >66% of fish encountering gear are selected)
Selectivity for Traps/Pots Scores for trap susceptibility may be assigned using the categories to the right. If there are conflicting answers, e.g. Low on point 1 but medium on point 2, the higher risk score shall be used.	a. Cannot physically enter the trap (e.g. too big for openings, sessile species, wrong shape, etc.). b. Can enter and easily escape from the trap, and no incentive to enter the trap (does not eat bait, trap is not attractive as habitat, etc.)	a. Can enter and easily escape from the trap, but is attracted to the trap (e.g. does eat the bait, or trap is attractive as habitat) b. Can enter, but cannot easily escape from the trap, and no incentive to enter the trap (does not eat bait, trap is not attractive as habitat, etc.) c. Species occasionally found in the trap.	a. Can enter, but cannot easily escape from the trap, and is attracted to either the bait, or the habitat provided by the trap. b. Species regularly found in the trap
Post-capture mortality (scores vary by fishery) The chance that, if captured, a species would be released in condition that would permit subsequent survival	Evidence of post-capture release and survival	Released alive	Retained species, or majority dead when released

Appendix 3 – Matrix of bycatch impacts by gear type

The matrix shown in this appendix is used to determine the relative impact of a fishery on bycatch species of various taxa for fisheries where species and amounts of bycatch are not available or are incomplete. The matrix represents typical relative impacts of different fishing gear on various taxa based on the best available science. The values in the matrix were developed initially by averaging the findings of two studies that ranked the relative ecological impacts of fishing gear (Fuller et al. 2008; Chuenpagdee et al. 2003). Some values in the matrix have been updated based on a survey of scientific experts on bycatch from around the world to increase the global relevance of the matrix.

The findings of the studies used to construct this matrix were pulled from literature searches, fisheries data and expert opinion. In general, these studies ranked the severity of fishing gear impacts as shown in this table (in order of severity):

Chuenpagdee et al 2003	Fuller et al 2008
Bottom trawl	Bottom trawl
Bottom gillnet	Bottom gillnet
Dredge	Dredge
Midwater gillnet	Bottom longline
Pot and traps	Midwater trawl
Pelagic longline	Pot and trap
Bottom longline	Pelagic longline
Midwater trawl	Midwater gillnet
Purse seine	Purse seine
Hook and line	Hook and line
	Dive
	Harpoon

Because these studies were based on fisheries operating in Canadian and United States waters, we also conducted a review of literature and expert opinion on bycatch severity by gear type from different regions of the world. Some of the initial values from Fuller et al. (2008) and Chuenpagdee et al. (2003) were adjusted accordingly. These changes are intended to better reflect the array of bycatch issues that occur using the same gear types in different regions of the world. For example, we increased the potential severity of bycatch of seabirds for trawlers operating in regions where there is a high occurrence of albatross and petrel interaction based on studies that found (1) seabirds may collide with net monitoring (net sonde) cables and trawl warps, and (2) seabirds can become entangled in the net (while attempting to feed) when the trawl is at the surface during setting and hauling (Weimerskirch et al. 2000; Wienecke and Robertson 2002; Sullivan 2006; Bull 2007; Abraham et al. 2008).

In addition, we increased the potential severity of midwater trawl impacts on marine mammals based on the study of DuFresne et al. (2007), which found fishing depth (midwater) to be the most important predictor of common dolphin bycatch. Another study by Fertl and Leatherwood (1997) found more cetaceans caught in midwater than bottom trawls. Also, pinniped species have been shown to use trawl fisheries for food and may become trapped in nets and drown (Fertl & Leatherwood 1997; Morizur et al. 1999; Rowe 2007). For example, New Zealand fur seals are attracted to the physical presence of fishing vessels and are thought to become caught when the net is being shot or during hauling (Baird & Bradford 2000).

Bycatch severity for biogenic habitats (coral and sponges) by gear type was determined by averaging the values given in Fuller et al. (2008) and Chuenpagdee et al. (2003). In Chuenpagdee et al. (2003), this category was named "biological habitat" and in Fuller et al. (2008) it was called "coral and sponges." We did not change these values because it is likely that gear types that contact the bottom have the same potential for severe impacts throughout the world's oceans. Impacts from fishing on the benthos occur on virtually all continental shelves worldwide (Watling 2005).

We increased the number of trawl types from only bottom and midwater (used in both Fuller et al. (2008) and Chuenpagdee et al. (2003)) to also include bottom trawl categories for tropical/subtropical fish, tropical/subtropical shrimp, coldwater fish, and coldwater shrimp. Shrimp trawls are not designed to drag along the bottom and herd fish, so they receive a lower impact score in the matrix for finfish bycatch. The turtle bycatch score was increased for tropical trawls to account for the severe threats to turtles posed by bottom trawling in tropical waters worldwide.

Other changes to the findings of Fuller et al. (2008) and Chuenpagdee et al. (2003) include separating the different purse seine techniques into FAD/log sets, dolphin/whale sets and unassociated school sets based on the variable bycatch rates found in a study by Hall (1998). Hall (1998) found that log (FAD) sets have the overall greatest bycatch for some species, followed by school sets and dolphin sets. Turtle bycatch potential was derived from research by Wallace and Lewison (2010).

Bottom seines or demersal seines (including Danish seines, Scottish fly-dragging seines and pair seines) were not included in the Fuller et al. (2008) and Chuenpagdee et al. (2003) studies because these gear types are not commonly used in the U.S. or Canada. Like purse seines, these gear types are used to encircle a school of fish, but they are operated in contact with the seafloor. A study by Palsson (2003) compared haddock discards among three demersal gear types in Icelandic waters and found fish bycatch to be lowest in Danish seines when compared with demersal trawls and longline gear. Danish seines targeting benthic fish species can incidentally catch non-target species such as flatfish, cod, and haddock (Icelandic Ministry of Fisheries 2010). Alverson et al. (1996) found that Danish seines generally fell into a low-moderate bycatch group of gear, with lower bycatch ratios than the majority of gear types, including bottom trawls, longlines and pots, but with higher bycatch than pelagic trawls and purse seines. Based on these findings, the bycatch score of Danish seines was estimated from the score for purse seines with an increase in the effects on shellfish to account for Danish seines being operated on the seafloor, an increase in the effect on finfish to account for greater bycatch of benthic fish such as flatfish, cod and haddock, and a decrease in the effect on forage fish, which are typically pelagic.

Unknown bycatch matrix

Highest impacts receive a score of 1 and lowest impacts receive a score of 5. Key: B = Bottom, P = Pelagic, M = Mid-water, BTF = Bottom tropical fish, BTS = Bottom tropical shrimp, BCF = Bottom coldwater fish, BCS = Bottom coldwater shrimp, PF = Purse FAD/log (tuna), PD = Purse dolphin/whale (tuna), PU = Purse unassociated (tuna), Pot = Pot and trap, HD = Harpoon/diver, TP = Troll/pole and line

	Longline		Gillnet		Trawl						Dredge	Seine					Other		
	B	P	B	M	B	BTF	BTS	BCF	BCS	M		B	P	PF	PD	PU	Pot	HD	TP
Benthic Inverts	4.5	5	3	5	2	2	2	2	2	5	1	3	5	5	5	5	3.5	5	5
Finfish	2	2	2	1	2	1	2	2.5	2	1	3	2	4	2	3	2	3.5	5	3
Forage Fish	5	4	2	2	3	2	2	2	2	1	5	3	3	2	3	2	4	5	4
Sharks	3	2	2	2	2	2	2	2	2	2	5	3.5	3.5	2	5	3	5	5	3.5
Mammals	4	4	1	1	2	1	4	4	4	2	5	3.5	3.5	5	3	5	4	5	5
Seabirds (within albatross range)	1	1	1	1	2	2	2	2	2	1	5	4	4	4	4	4	4	5	4.5
Seabirds (outside albatross range)	5	3	3	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Turtles (within turtle range)	4	1	2	1	4	1	1	5	5	4	3	4	4	3	5	4	5	5	4
Corals and other biogenic habitats	3	5	2	5	1	1	1	1	1	5	1	1	5	5	5	5	3.5	5	4.5

Additional guidance for unknown bycatch species

***Sea turtles* – *all endangered/threatened*:** See Wallace et al. (2010) for global patterns of marine turtle bycatch. In addition, a global program, Mapping the World's Sea Turtles, created by the SWOT (State of the World's Sea Turtles) database is a comprehensive global database of sea turtle nesting sites around the world. The SWOT map is highly detailed and can be customized, allowing location filters and highlights of both species and colony size with variously colored and shaped icons. This map together with the paper by Wallace et al. (2010) can help to determine if the fishery being assessed has potential interactions with sea turtles.

Sharks, marine mammals and seabirds: Identify whether the fishery overlaps with any endangered/threatened or overfished species and err on the side of caution if species-specific and geographic information is inconclusive. For example, if shark populations are data deficient, err on the side of caution and rank as "overfished" or "depleted".

Sharks: Select "overfished" or "depleted", when data deficient or select "endangered/threatened" when data exist to support this (see Camhi et al. 2009). Globally, three-quarters (16 of 21) of oceanic pelagic sharks and rays have an elevated risk of extinction due to overfishing (Dulvy et al. 2008). See Camhi et al. (2009) for geographic areas, IUCN status and conservation concerns by shark species. Table 1 illustrates additional resolutions, recommendations and conservation and management measures by RFMO for sharks. Additional region and species-specific shark conservation information associated follows Table 1 in list format (Camhi 2009; Bradford 2010).

***Marine mammals*:** The global distribution marine mammals and their important conservation areas are given by Pompa et al. (2011), who also used geographic ranges to identify 20 key global conservation sites for all marine mammal species (123) and created range maps for them (Figure 1; Table 2; Pompa et al. 2011 and supplt.).

Seabirds: Figures 2 and 3 illustrate the distribution of threatened seabirds throughout the world (Birdlife International 2011). Also see Birdlife International (2010) to locate Marine Important Bird Areas (MIBA). Albatross are the most highly threatened family, with all 22 species either globally threatened or near threatened. The penguins and shearwaters/gadfly petrels also contain a high proportion of threatened species (Birdlife International 2010).

***Teleost fish species*: Unknown** (a Moderate Concern) unless data exist that would indicate an alternative ranking.

Table 1. Active resolutions, recommendations, and conservation and management measures by RFMO for sharks. Table from Camhi et al. (2009). [a] ICCAT = International Commission for the Conservation of Atlantic Tunas; NAFO = North Atlantic Fisheries Organization; GFCM = General Fisheries Commission for the Mediterranean; SEAFO = South East Atlantic Fisheries Organization; IATTC = Inter-American Tropical Tuna Commission; WCPFC = Western and Central Pacific Fisheries Commission; IOTC = Indian Ocean Tuna Commission; CCAMLR = Commission for the Conservation of Antarctic Marine Living Resources. [b] The weight of recommendations and resolutions varies by RFMO. For example, all ICCAT recommendations are binding, whereas resolutions are not.

Ocean/ RFMO[a]/Year	**Res/Rec No.[b]**	**Title**	**Main actions**
Atlantic, ICAAT			
1995	Res. 95-2	Resolution by ICCAT on cooperation with the Food and Agriculture Organization of the United Nations with regard to study on the status of stocks and by-catches of shark species	• Urges members to collect species-specific data on biology, bycatch and trade in shark species and provide these data to FAO
2003	Res. 03-10	Resolution by ICCAT on the shark fishery	• Requests all members to submit data on shark catch, effort by gear, landings and trade in shark products • Urges members to fully implement a NPOA
2004	Rec. 04-10	Recommendation by ICCAT concerning the conservation of sharks caught in association with fisheries managed by ICCAT	• Requires members to annually report shark catch and effort data • Requires full utilization • Bans finning • Encourages live release • Commits to reassess shortfin mako and blue sharks by 2007 • Promotes research on gear selectivity and identification of nursery areas
2005	Rec. 05-05	Recommendation by ICCAT to amend Recommendation 04-10 concerning the conservation of sharks caught in association with fisheries managed by ICCAT	• Requires annual reporting of progress made toward implementation of Rec. 04-10 by members • Urges member action to reduce North Atlantic shortfin mako mortality
2006	Rec. 06-10	Supplementary recommendation by ICCAT concerning the conservation of sharks caught in association with fisheries managed by ICCAT	• Acknowledges little progress in quantity and quality of shark catch statistics • Reiterates call for current and historical shark data in preparation for blue and shortfin mako assessments in 2008
2007	Rec. 07-06	Supplemental recommendation by ICCAT concerning sharks	• Reiterates mandatory data reporting for sharks • Urges measures to reduce mortality of targeted porbeagle and shortfin mako • Encourages research into nursery areas and possible time and area closures • Plans to conduct porbeagle assessment no later than 2009
2008	Rec. 08-07	Recommendation by ICCAT on the conservation of bigeye thresher sharks (*Alopias superciliosus*) caught in association with fisheries managed by ICCAT	• Urges live release of bigeye thresher sharks to the extent practicable • Requires bigeye shark catches and live releases be reported
Atlantic, NAFO			
2009	Mgt. Measure	Conservation and management of sharks	• Requires reporting of all current and historical shark catches • Promotes full utilization • Bans finning • Encourages live release • Promotes research on gear selectivity and

	Article 17		identification of nursery areas
Atlantic, SEAFO			
2006	Conservation measure 04/06	Conservation measure 04/06 on the conservation of sharks caught in association with fisheries managed by SEAFO	• Same provisions as ICCAT Rec. 04-10, except does not include stock assessments
Med., GFCM			
2005	GFCM/2005/3	Recommendation by ICCAT concerning the conservation of sharks caught in association with fisheries managed by ICCAT	• Same provisions as ICCAT Rec. 04-10
2006	GFCM/2006/8(B)	Recommendation by ICCAT to amend Recommendation [04-10] concerning the conservation of sharks caught in association with fisheries managed by ICCAT	• Same provisions as ICCAT Rec. 05-05
Indian, IOTC			
2005	Res. 05/05	Concerning the conservation of sharks caught in association with fisheries managed by IOTC	• Requires members to report shark catches annually, including historical data • Plans to provide preliminary advice on stock status by 2006 • Requires full utilization and live release • Bans finning • Promotes research on gear selectivity and to ID nursery areas
2008	Res. 08/01	Mandatory statistical requirements for IOTC members and cooperating non-contracting parties (CPCs)	• Requires members to submit timely catch and effort data for all species, including commonly caught shark species and less common sharks, where possible
2008	Res. 08/04	Concerning the recording of catch by longline fishing vessels in the IOTC area	• Mandates logbook reporting of catch by species per set, including for blue, porbeagle, mako and other sharks
Pacific, IATTC			
2005	Res. C-05-03	Resolution on the conservation of sharks caught in association with fisheries in the Eastern Pacific Ocean	• Promotes NPOA development among members • Work with WCPFC to conduct shark population assessments • Promotes full utilization • Bans finning • Encourages live release and gear-selectivity research • Requires species-specific reporting for sharks, including historical data
2006	Res. C-04-05 (REV 2)	Consolidated resolution on bycatch	• Requires prompt release of sharks, rays and other non-target species • Promotes research into methods to avoid bycatch (time-area analyses), survival rates of released bycatch and techniques to facilitate live release • Urges members to "provide the required bycatch information as soon as possible"
Pacific, WCFPC			
2008	Cons. & Mgt. Measure 2008-06 (replaces 2006-05)	Conservation and management measure for sharks in the Western and Central Pacific Ocean	• Urges members to implement the IPOA and report back on progress • Requires annual reporting of catches and effort • Encourages live release and full utilization • Bans finning for vessels of all sizes • Plans to provide preliminary advice on stock status of key sharks by 2010

Southern, CCAMLR			
2006	32-18	Conservation of sharks	• Prohibits directed fishing of sharks • Live release of bycatch sharks

Additional shark information and citations (Bradford 2010)

- In the Gulf of Mexico, Baum and Myers (2004) found that between the 1950s and the late-1990s, oceanic whitetip and silky sharks (formerly the most commonly caught shark species in the Gulf of Mexico) declined by over 99 and 90%, respectively.
- In the Northwest Atlantic, Baum et al. (2003) estimated that scalloped hammerhead, white, and thresher sharks had declined by over 75% between the mid 1980s and late 1990s. The study also found that all recorded shark species in the Northwest Atlantic, with the exception of mako sharks, declined by over 50% during the same time period.
- Myers et al. (2007) reported declines of 87% for sandbar sharks, 93% for blacktip sharks, 97% for tiger sharks, 98% for scalloped hammerheads, and 99% or more for bull, dusky, and smooth hammerhead sharks along the Eastern seaboard since surveys began along the coast of North Carolina in 1972.
- The International Union for the Conservation of Nature (IUCN) has declared that "32% of all pelagic sharks and rays are Threatened." The IUCN has declared another 6% to be Endangered, and 26% to be Vulnerable.
- In the Mediterranean Sea, Ferretti et al. (2008) found that hammerhead, blue, mackerel, and thresher sharks have declined between 96 and 99.99% relative to their former abundance levels.
- Ward and Myers (2005) report a 21% decline in abundance of large sharks and tunas in the tropical Pacific since the onset of commercial fishing in the 1950s.
- Meyers and Worm (2005) indicate a global depletion of large predatory fish communities of at least 90% over the past 50–100 years. The authors suggest that declines are "even higher for sensitive species such as sharks."
- Dulvy et al. (2008) state that "globally, three-quarters (16 of 21) of oceanic pelagic sharks and rays have an elevated risk of extinction due to overfishing."
- Graham et al. (2001) found an average decrease of 20% in the catch rate of sharks and rays off New South Wales, Australia, between 1976 and 1997.

Table 2. Marine mammal species in important conservation sites. "Irreplaceable areas" contain species found nowhere else. Figures from Pompa et al. (2011; supplt. material). [1]*Monachus schauinslandi*, [2]*Arctocephalus galapagoensis*, [3]*A. philippii*, [4]*Inia geoffrensis*, *Trichechus inunguis* (both freshwater) and *Sotalia fluviatilis*, [5]*Monachus monachus*, [6]*Platanista minor* (freshwater), [7]*Platanista gangetica* (freshwater), [8]*Lipotes vexillifer* (freshwater), [9]*Pusa sibirica* (freshwater), [10]*Pusa caspica*, [11]*Cephalorhynchus commersonii* and *A. gazella.* *VU = Vulnerable, EN = Endangered, CR = Critically Endangered, LR = Lesser Risk, EX = Extinct, CE = Critically Endangered; V = Vulnerable, RS = Relatively Stable or Intact. Data from Olson and Dinerstein (2002).

Key conservation sites	Number of species	Endemic/ small-range	Risk category for each ecoregion*	Number and name of the ecoregion*	Estimated conservation status of the ecoregion*
Highest richness					
South African	16	4	VU, EN	209: Benguela Current 211: Agulhas Current	V RS
Argentinean	15	4	VU, EN	205: Patagonian Southwest Atlantic	V
Australian	14	4	VU, EN	206: Southern Australian 222: Great Barrier	RS RS
Baja Californian	25	7	VU, EN, CR	214: Gulf of California	CE
Peruvian	19	5	VU, EN	210: Humboldt Current	V
Japanese	25	7	VU, EN, LR	217: Nansei Shoto	CE
New Zealand	13	2	VU, EN, LR	207: New Zealand	V
Northwestern African	25	7	VU, EN, LR	216: Canary Current	CE
Northeastern American	25	7	VU, EN, LR	202: Chesapeake Bay	V
Irreplaceable					
Hawaiian Islands	1[1]	1	EN	227: Hawaiian Marine	V
Galapagos Islands	1[2]	1	VU	215: Galapagos Marine	V
San Félix and Juan Fernández Islands	1[3]	1	VU	210: Humboldt Current	V
Amazon River	2[4]	1	VU	147: Amazon River/Flooded Forests	RS
Mediterranean Sea	1[5]	1	CR	199: Mediterranean Sea	CE
Indus River	1[6]	1	Not Listed	Not Listed	Not Listed
Ganges River	1[7]	1	EN	Not Listed	Not Listed
Yang-tse River	1[8]	1	EX	149: Yang-Tse River And Lakes	CE
Baikal Lake	1[9]	1	LR	184: Lake Baikal	V
Caspian Sea	1[10]	1	VU	Not Listed	Not Listed
Kerguelen Islands	1[11]	1	Not Listed	Not Listed	Not Listed

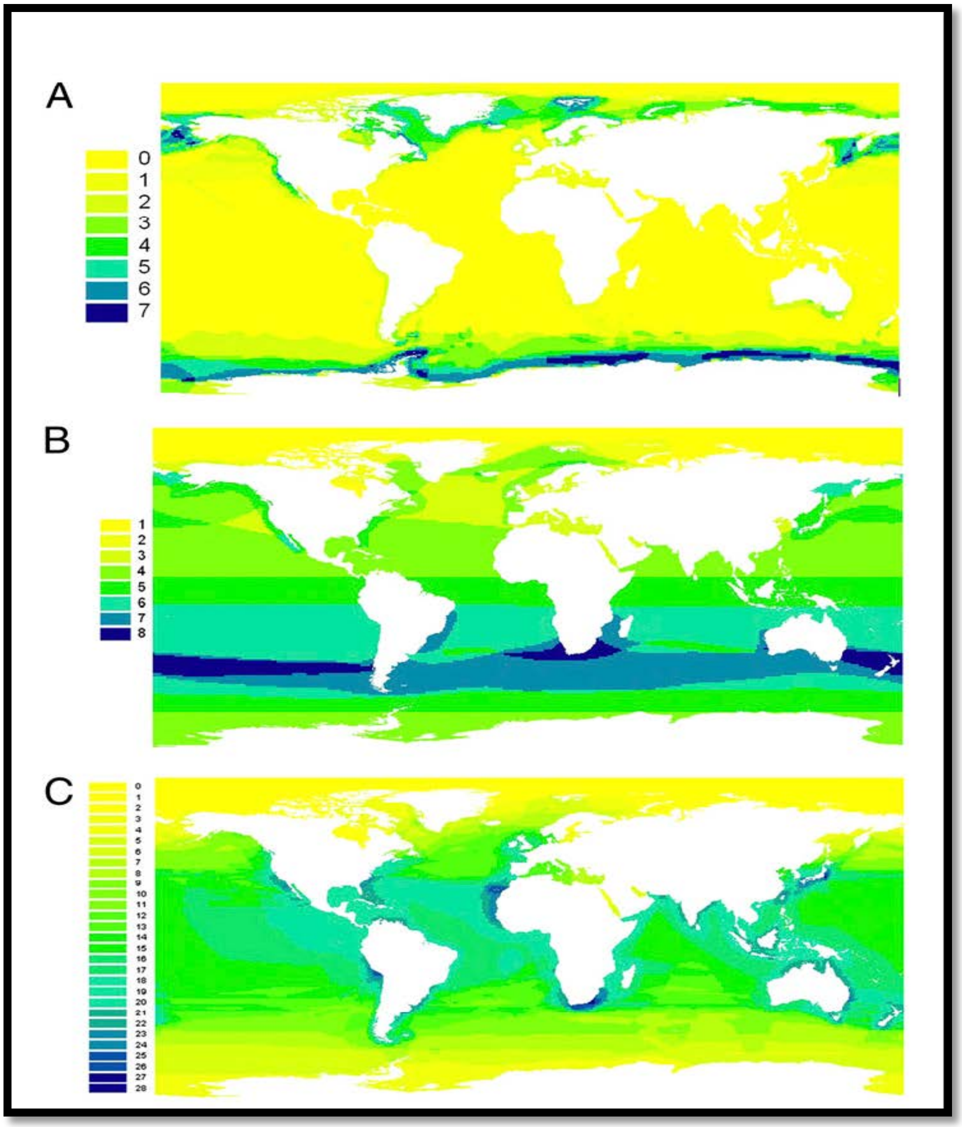

Figure 1. Geographic distribution of marine mammal species richness (left column) for **A**. Pinnipeds; **B**. Mysticetes; **C**. Odontocetes. Figure from Pompa et al. (2011).

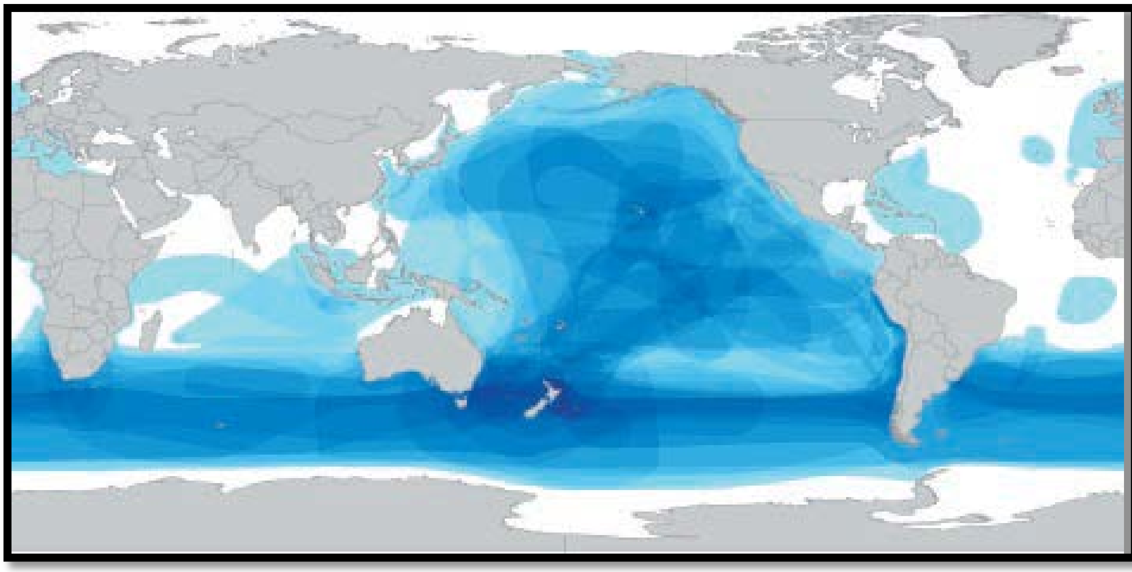

Figure 2. At-sea distribution of threatened seabirds around the globe. Each polygon represents the range map for one threatened species. Areas of darkest blue show the areas of the ocean where the ranges of the greatest number of threatened species overlap. Figure from Birdlife International (2011).

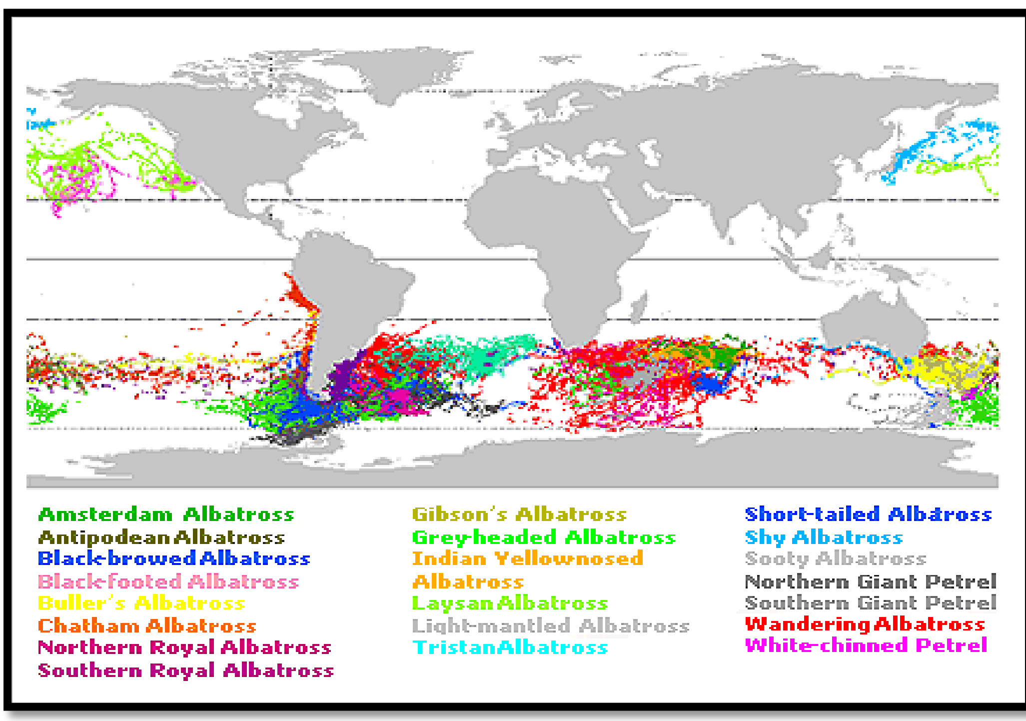

Figure 3. Worldwide distribution of albatross and petrels. Figure from Birdlife International (2011).

Appendix 4 – Appropriate management strategies

Appropriate management procedures may vary greatly between different fisheries, regulatory frameworks and species. To some extent, assessment of harvest control rules and other management strategies must therefore be addressed on a case-by-case basis. However, general guidelines for appropriate management are still relevant and useful. For fisheries managed using catch limits or TACs, these guidelines have been derived largely from the guidance provided for implementation of the Magnuson-Stevens Fishery Conservation and Management Act used for fishery management in the U.S. (Restrepo and Powers 1998; Restrepo et al. 1998). While other countries have different regulatory frameworks, similar strategies to those suggested in Restrepo et al. (1998) are used throughout the world where stock assessments are available and catch limits are employed (e.g., Australian Department of Agriculture, Fisheries and Forestry 2007; NZ Ministry of Fisheries 2008; DFO 2009). Commonly accepted strategies include setting fishing mortality rates safely below F_{MSY} (or equivalent) to account for uncertainty; reducing F when stocks fall below biomass target reference points (generally around B_{MSY} or 40% of unfished biomass); and reducing fishing mortality when stock falls below a critical level where recruitment is impaired. Management reference points are assumed to be valid unless scientific information exists to suggest otherwise, e.g., a scientific assessment or controversy that strongly suggests current reference points are not appropriate for the species under assessment.

In general, the minimal attributes of an appropriate management strategy include:

1. A process for monitoring and conducting "assessments" (not necessarily formal stock assessments). Monitoring should occur regularly, though the frequency of assessments needed may vary depending on the variability of the stock.
2. Rules that control the intensity of fishing activity or otherwise ensure the protection of stock productivity.
3. A process to modify rules according to assessment results, as needed.

Some effective management strategies

For data-rich or data-moderate stocks that have quota-based management, a "highly effective" management strategy is one that:

- Incorporates an up-to-date, scientific stock assessment that allows managers to determine if stocks are healthy and to set appropriate quotas;
- Uses appropriate limit and target reference points for stock and fishing mortality;
- Chooses risk-averse policies rather than risky, yield-maximizing policies;
- Includes buffers in the TAC to account for uncertainty in stock assessments
    - Set Allowable Biological Catch (ABC) and Annual Catch Limit (ACL) at less than the Over-Fishing Level (OFL = long term mean of MSY) to account for scientific uncertainty (survey data on stock size, etc. can reduce scientific uncertainty);
    - Set Total Allowable Catch (TAC) at less than ABC to account for management uncertainty (monitoring catch, etc. can reduce management uncertainty);
    - As a rule of thumb, TAC should have less than 30% p* (likelihood) of exceeding OFL; or TAC should be set such that F is 25% below the threshold fishing pressure, e.g. Fmsy (Restrepo et al. 1998)
    - Stocks with low biomass, high vulnerability, and high uncertainty warrant greater protection against overfishing (e.g., more conservative harvest control rules/ greater buffers in setting TAC and/or closer monitoring of stocks).

- Takes into account other sources of mortality (e.g., recreational fishery, bycatch of juveniles, etc.) and environmental factors that affect stock, such as oceanographic regime;
- Incorporates a strategy for maintaining or rebuilding stock productivity:
  - A no-fishing point when biomass is below the limit reference point;
  - A decrease in F when biomass is below the target reference point or is declining (whether declines are due to fishery or environmental factors).
- Employs an effective strategy to prevent overcapitalization;
- Has been demonstrated effective (e.g., stock productivity has been maintained over multiple generations), or if stock productivity has not been maintained or is declining, have adjusted management accordingly.

Effective management in data-poor fisheries
(more information on data-poor evaluation methods below)

Whether managed stocks are data-rich or data-poor, management must include a strategy to ensure that stock productivity is maintained in order to be considered effective. This strategy should include a process for monitoring and conducting "assessments" of some kind (not necessarily formal stock assessments), rules that control the intensity of fishing activity or otherwise ensure the protection of a portion of the spawning stock, and a system of adaptive management, such that rules are modified according to assessment results, as needed (Smith et al. 2009; Phipps et al. 2010).

There are some relatively reliable methods for setting catch limits in data-poor fisheries, including: An Index Method (AIM), which involves fitting a relationship between population abundance indices and catch; Depletion-Corrected Average Catch (DCAC), which allows managers to estimate a sustainable yield based on average catch over a set time period, adjusting for initial declines in abundance due to harvesting; and extrapolation methods, or relying on inferences from related or "sister" stocks, with the use of precautionary buffers in case the data-poor stocks are more vulnerable than the related data-rich stocks (Honey et al. 2010). Other techniques recommended for data-poor stocks include the use of productivity-susceptibility analysis (PSA) to highlight stocks that are particularly vulnerable to over-exploitation (Patrick et al. 2009; Honey et al. 2010) and setting catch limits based on historical catch from a period of no declines, with targets set at 75% of average catch if biomass is believed to be healthy, 50% of average catch if biomass is expected to be below target levels but above the point where recruitment would be impaired, and 25% of average catch if the stock is depleted (Restrepo and Powers 1998).

Other than constraining fishing mortality (e.g., through TACs), fisheries may be credited for employing alternative strategies that are widely believed to be help maintain stock productivity. Some examples of effective alternative strategies are spatial management, including protecting a large proportion of coastline in reserves and/or protecting known spawning aggregations with seasonal or spatial closures (e.g., Johannes 1998), or protecting females, which preserves the spawning per recruit of the population as long as fertilization does not decrease (e.g., Dungeness crab; Chaffee et al. 2010). Finally, stocks may be subject to low mortality in a data-poor fishery as a result of low susceptibility, e.g., if the species is small enough to fit between the mesh of the nets or is not attracted to the type of bait used (low susceptibility is generally more applicable as protection for non-target stocks).

Management of data-poor stocks – alternatives to MSY-based management

For data-poor stocks, management should:

- Include a process for monitoring and assessment, such as recording trends in CPUE and size structure, or estimating FLEP, or comparison of abundance index to historical high (see glossary), unfished, or marine reserve levels:
  - Trends in CPUE are appropriate only if technology has not changed, there is no hyperselectivity, and abundance is shown to be proportional to CPUE;
  - Trends in size structure must also be monitored to avoid depletion of large individuals.
- Include a strategy for protecting spawning stock, such as:
  - Estimate sustainable yield based on Depletion Corrected Average Catch (DCAC), An Index Method (AIM), or another accepted strategy;
  - Protect a large portion of spawning stock in marine reserves (at least 50%, including important spawning areas if applicable) or close hotspots to fishing (for bycatch species);
  - Enforce size, sex, and/or season limitations that are likely to be effective in protecting spawning stock productivity (e.g., Dungeness crab 3-S management);
  - Extrapolate based on data-rich related or "sister" stocks, with precautionary buffers in place to account for potential differences in the stocks' life histories;
  - Maintain exploitation rates at very low levels (e.g., experimental fishery) until more data can be collected, **or**
  - Base TAC on average historical catch during a period of time with no declines in abundance (TAC should be set at no more than 75% of average catch if stock is believed to be healthy, 50% if believed to be below target levels, and 25% if believed to be overfished. *Note:* as there is generally no data to assess whether a stock is healthy, TAC should not be more than 50% of historical catch unless there is a strong scientific reason to believe that stocks are above B_{MSY}).
- Allow for adaptive management so that fishing strategy is adjusted if assessment/monitoring indicates that stock is declining or below target levels;
- Have been demonstrated effective (e.g., stock productivity has been maintained over multiple generations) **or**, if stock productivity has not been maintained or is declining, management has been adjusted accordingly.

Procedures for monitoring/assessing stocks and procedures for protecting spawning stock must be in place, and be demonstrated effective, to qualify management strategy as "highly effective". If measures are expected to be effective, e.g., through analogy with similar systems, but have not been demonstrated effective in this fishery, management is "moderately effective". If measures are not expected to be effective, management strategy is "ineffective".

Appropriate management also depends on the conservation concern associated with the stock. In addition to the precautionary elements listed above, stocks that are endangered or threatened also require a recovery plan and/or best management practices designed and demonstrated to reduce mortality and allow the stock to recover. Overfished and depleted stocks require a rebuilding plan.

Data–poor fishery evaluation methods

Sequential trend analysis (index indicators)

Sequential analysis comprises a broad suite of techniques used to analyze time series data in order to detect trends in a variable (or in various indices) and infer changes in the stock or population. Sequential analyses can encompass a wide range of data types and requirements (Honey et al. 2010). Examples include: DCAC, time series of catch statistics, survey/weight/length-based reference points, trophic indices, and spawning potential ratio (SPR) analogues (Honey et al. 2010).

Depletion-corrected average catch (DCAC) uses only catch time-series data supplemented with educated guesses for a few supplementary parameters. Therefore, it is likely of practical use for many data-poor fisheries on long-lived species (e.g., natural mortality, $M < 0.2$) (Honey et al. 2010). The ability of this method to identify sustainable yields from simple data input makes DCAC useful as a first-step estimate for an allowable catch level along with other data-poor methods. See: http://nft.nefsc.noaa.gov/ for the NOAA toolbox to perform DCAC analysis (Honey et al. 2010).

Vulnerability analysis

Productivity and susceptibility analysis of vulnerability – The Productivity-Susceptibility Analysis of vulnerability (PSA) method is used to assess a stock's vulnerability to overfishing, based on relative scores derived from life-history characteristics. Productivity, which represents the potential for stock growth, is ranked semi-quantitatively from low to high on the basis of the stock's intrinsic rate of increase (r), von Bertalanffy growth coefficient (k), natural mortality rate (M), mean age at maturity, and other metrics (Patrick et al. 2009; Patrick et al. 2010; Field et al. 2010; Cope et al. 2011; Honey et al. 2010).

To assist regional fishery management councils in determining vulnerability, NMFS elected to use a modified version of a productivity and susceptibility analysis (PSA) because it can be based on qualitative data, has a history of use in other fisheries, and is recommended by several organizations as a reasonable approach for evaluating risk (Patrick et al. 2010). Patrick et al. (2010) evaluated six U.S. fisheries targeting 162 stocks that exhibited varying degrees of productivity and susceptibility, and for which data quality varied. Patrick et al. (2010) found that PSA was capable of differentiating the vulnerability of stocks along the gradient of susceptibility and productivity indices. The PSA can be used as a flexible tool capable of incorporating region-specific information on fishery and management activity. Similar work was conducted by Cope et al. (2011) who found that PSA is a simple and flexible approach to incorporating vulnerability measures into complex stock designations while also providing information helpful in prioritizing stock- and complex-specific management.

Extrapolation (Robin Hood Method)

When very limited or no data are available for a stock or specific species in a region, then managers may need to rely on extrapolation methods to inform decisions. Often, low-value stocks are data-poor (Honey et al. 2010). This method is termed the "Robin Hood" approach in Australia because it takes information and scientific understanding in data-rich fisheries and "gives" inferences to the data-poor fisheries (Smith et al. 2009). Data may include: (1) the local knowledge of the fishers and resource users; and/or (2) scientific research and ecosystem understanding from "sister" systems thought to be similar (Honey et al. 2010). Extrapolation from similar systems or related species may offer an informed starting point from which managers can build precautionary management (Honey et al. 2010). In these situations, life-history characteristics, potentially sustainable harvest levels, spawning behavior, and other information can be gleaned from nearby stocks, systems, or related species (Honey et al. 2010).

Decision-making methods

Decision trees

Decision trees provide systematic, hierarchical frameworks for decision-making that can scale to any spatial, temporal, or management context in order to address a specific question. A decision tree may be customized to meet any need (Honey et al. 2010). Trees may include: identification of reference points based on stock characteristics and vulnerability (Cope and Punt 2009); fostering of fine-scale, transparent, and local management (Prince 2010); and, estimation and refinement of an appropriate Total Allowable Catch (TAC) level (Wilson et al. 2010).

Management strategy evaluation

Management Strategy Evaluation (MSE) is a general modeling framework designed for the evaluation of performance of alternative management strategies for pursuing different objectives (Honey et al. 2010). This approach simulates the fishery's response to different management strategies (e.g., different TAC levels, seasonal closures, or other effort reductions) (Honey et al. 2010). Assuming sufficient quality data exist, MSE may be useful for assessing the effectiveness of different policy options (Honey et al. 2010).

In addition, a study by Dowling et al. (2008) developed harvest strategies for data-poor fisheries in Australia. Strategies included: (i) the development of sets of triggers with conservative response levels, with progressively higher data and analysis requirements at higher response levels, (ii) identification of data gathering protocols and subsequent simple analyses to better assess the fishery, (iii) the archiving of biological data for possible future analysis, and (iv) the use of spatial management, either as the main aspect of the harvest strategy or together with other measures (Honey et al. 2010).

Cooperative research and co-management to overcome data-poor situations

A recent study by Fujita et al. (2010) identified opportunities for cooperative research and co-management that would complement (but not replace) existing top-down fishery regulations. They conclude that management and data collection would improve for some small-scale fisheries if they started: collecting data at the appropriate spatial scales; collecting local information, improving the quality of data, and overcoming constraints on data; providing ecosystem insight from a small/local scale for new and different perspectives; reducing conflicts among fishermen, scientists, and regulators; and improving the responsiveness of fisheries management to local needs. Fujita et al. (2010) suggest that scientists and managers should further develop cooperative strategies (e.g., cooperative research and co-management) and include them in the management framework.

Appendix 5 – Bycatch reduction approaches

In general, fisheries should address bycatch with the following approaches:

- Monitor bycatch rates (using adequate observer coverage),
- Have some scientific assessment of impacts on bycatch populations
- Incorporate strategies that assure bycatch is minimized, such as:
    - Enforcing effective and appropriate bycatch caps,

- Closing hotspots or implementing seasonal closures,
- Promoting effective gear modifications such as BRDs, TEDs, etc.
- Adopting bycatch-reducing strategies such as night setting,
- Using the best available management techniques that have been demonstrated in this or a similar system to effectively constrain bycatch rates.

The effectiveness of various bycatch reduction approaches is synthesized from primary literature and reviewed below. To be considered "highly effective", all required measures and at least one primary measures should be in place.

Seabird sources are Løkkeborg (2008) (general conclusions and Table 3, including percent effectiveness of some modification/region strata) and SBWG 2010 (Annexes 3–8). *Secondary measures may be useful in conjunction with primary measures. Turtle sources are FAO 2009 (Tables 1 and page 79) and Gilman and Lundin (2008) (Table 3). Shrimp trawl modifications sources are Eayers 2007 and Gillet 2008 (Box 14). Sharks and marine mammals from Gilman and Lundin (2008) (Table 3). General information on fishing technologies can be found at http://www.fao.org/fishery/en, and a list of bycatch reduction literature can be found here: http://www.bycatch.org/articles.

Gear/taxon/modification	Primary/ secondary measure*	Effectiveness/notes
General strategies (good for all gears/taxa)		
Monitoring and compliance	Require-ment	Considerable difference between experimental and real-world effectiveness. "Three common themes to successful implementation of bycatch reduction measures are long-standing collaborations among the fishing industry, scientists, and resource managers; pre- and post-implementation monitoring; and compliance via enforcement and incentives" (Cox, Lewison et al. 2007).
Avoid bycatch hotspots	Primary	Area/time closures. Generally very effective, though more so when based on data such as tagging or bycatch data. Perhaps only a secondary mitigation measure for birds (Løkkeborg 2008). Alternatively, move when interaction rates are high. Effective for all fisheries, especially with fleet communication. Closures for one taxon without commensurate reduction in effort can increase bycatch of other taxa.
Bycatch caps	Primary	I.e., fishery closes when cap exceeded.
Bycatch fees, Compensatory Mitigation Strategies for Marine Bycatch (CMSMB)	Secondary, at best	Not effective. "We conclude that, overall, CMMB has little potential for benefit and a substantial potential for harm if implemented to solve most fisheries bycatch problems. In particular, CMMB is likely to be effective only when applied to short-lived and highly fecund species (not the characteristics of most bycatch-impacted species) and to fisheries that take few non-target species, and especially few non-seabird species (not the characteristics of most fisheries). Thus, CMMB appears to have limited application and should only be implemented after rigorous appraisal on a case-specific basis; otherwise it has the potential to accelerate declines of marine species currently threatened by fisheries bycatch" (Finkelstein, Bakker et al. 2008). May be useful, but only as a complementary measure (Žydelis, Wallace et al. 2009).
Pelagic longline		

Seabirds (albatrosses and petrels)	Best	No single solution to avoid incidental mortality of seabirds in pelagic longline fisheries. Most effective approach is streamer lines combined with branchline weighting and night setting. Best practices are followed for line setting and hauling (e.g., SRWG 2010).
Night setting	Primary	Proven effective in Southern Hemisphere. Streamer lines and weighted lines should also be used when interacting with nocturnal birds/fishing during bright moon.
Streamer/scarer lines	Primary	Proven to be effective in North Atlantic. Should be paired and/or weighted lines in North Pacific. Paired lines need more testing. Light configuration not recommended.
Weighted branch lines	Primary	Must be combined with other measures.
Offal discharge management	Secondary	Not yet established but is thought to assist.
Sidesetting	Secondary	Insufficiently researched; there have been operational difficulties on some vessels. Effective in Hawaii in conjunction with bird curtain and weighted branch lines. Japanese research conclusions must be combined with other measures. Untested in Southern Hemisphere.
Line shooter and mainline tension, bait caster, live bait, thawing bait	-	Not recommended.
Underwater setting chute, hook design, olfactory deterrents, blue-dyed bait	-	Insufficient research. Blue-dyed bait may be only effective with squid bait. Results inconsistent across studies.
Turtles		
Replacement of J and tuna hooks with circle hooks	Primary	Wide circle hook with </= 10 degree offset.
Bait change	Primary	Use of fish instead of squid.
Deep setting	Primary	Set gear deeper than turtle abundant depths (40–100m).
Fish bait hooking	Primary	Single hooking fish bait instead of threading hook through bait multiple times.
Temporal changes	Primary	Reduce soak time and haul during daylight.
Lights on gear	Secondary	Use of intermittent flashing light sticks instead of continuous use non-luminous gear.
Handling and release practices	Primary	To reduce mortality of caught turtles.
Sharks		
Bait change	Primary	Fish instead of squid.
Prohibit wire leaders	Primary	
Deeper setting	Primary	Avoid surface waters.
Shark repellants	-	Insufficient research.
Circle hooks		
Marine mammals		
Weak hooks, deterrents, echolocation disruption	-	Insufficient research.
Other finfish (including juvenile targets)		
Circle hooks		May help reduce mortality of billfish and tunas.
Shellfish		

Not problematic		
Bottom longline (Many measures similar to pelagic longline)		
Seabirds (albatrosses and petrels)	Best	No single solution to avoid incidental mortality of seabirds in demersal longline fisheries. No combination specified: assume streamers, weighted and night setting, or Chilean longline method (vertical line with very fast sink rates—considered effective even without other measures; widely used in South American waters and SW Atlantic). Best practices are followed for line setting and hauling (e.g., SRWG 2010).
Streamer/scarer lines	Primary	Effective, but must be used properly (streamers are positioned over sinking hooks). Better when combined with, e.g., night setting, weighting, or offal control.
Weighted lines	Primary	Must be combined with other measures, especially streamers, offal control and/or night setting.
Night setting	Primary	Same as pelagic.
Haul curtain (reduce bird access when line is being hauled)	Secondary	Can be effective, but must use strategically as some birds become habituated. Must be used with other measures.
Offal discharge control (discharge homogenized offal at time of setting)	Secondary	Must be used in a combo, e.g., with streamers, weighting, or night setting.
Side setting	Secondary	Insufficiently researched; there have been operational difficulties on some vessels.
Hook design, olfactory deterrents, underwater setting chutes, blue-dyed bait, thawed bait, use of line setter	-	Insufficiently researched. Blue-dyed bait, thawed bait, and use of line setter not relevant in demersal gear.
Turtles, sharks, mammals, other finfish, shellfish		
See pelagic longlines		
Trawl		
Seabirds (albatrosses and petrels)	Best	Little work has been done on seabird bycatch mitigation in trawl fisheries (pelagic and demersal). There is no single solution to avoid incidental mortality of seabirds in trawl fisheries. The most effective approach is offal discharge and discards control, through full retention of all waste or mealing (the conversion of waste into fish meal reducing discharge into sump water) plus streamer lines. Effectiveness of other offal control measures such as mincing and batching is not clear.
Limited waste control	Minimum requirement for + modifier	No discharge of offal or discards during shooting and hauling.
Reduce cable strike through bird scaring wires or snatch block	Primary	Scarers recommended even when offal/discard management is in place. Snatch block recommended on theory.
Reduce net entanglement through net binding, net weights, net cleaning		Recommended on theory.

Net jackets	-	Not recommended.
Reduced mesh size, acoustic scarers, warp scarers, bird bafflers, cones on warp cables	-	Effectiveness not yet established.
Turtles		
Turtle excluder device (TED)	Primary	Any modification to the trawl to reduce the capture of turtles, principally in tropical/subtropical shrimp trawls. Typically a grid or large-hole mesh designed to prevent turtles from entering the codend. The only designs approved for use in the US warm-water shrimp fisheries are hard TEDs (i.e., "hooped hard TEDs" such as NMFS, Coulon and Cameron TEDs, "single grid hard TEDs" such as the Matagorda, Georgia, or Super Shooter TED, and the Weedless TED) and the Parker Soft TED (the latter only in offshore and inshore waters in Georgia and South Carolina). Hard TEDs that are not approved for use in the shrimp fisheries are used in the Atlantic summer flounder bottom trawl fishery. TEDs must be used in conjunction with escape hatches, which also vary in size and design. More details on TED/hatch designs and US regulations can be found in Eayers (2007).
Sharks		
TED		TEDs generally allow large animals to escape, e.g., sharks (Belcher and Jennings 2010). Highly variable depending on net type and TED used. BRD made little difference (fisheye).
Marine mammals		
TED/BRD		Grids generally allow large animals to escape.
Other finfish		
Bycatch reduction device (BRD): Catch separators		A BRD is any modification designed principally to exclude fish bycatch from shrimp trawls. Catch separator designs include hard grids (e.g., Nordmore grid) and soft mesh panels attached at an angle inside the trawl net as well as the Juvenile and Trash Excluder Device (JTED), which has a grid/mesh design partially covering the inside of the trawl net. Hard grids are generally seen as more effective than soft panels. Effectiveness of JTED unknown.
BRD: Active swimmer escape hatches		Designed for strong-swimming fish to actively escape (shrimp are more passive swimmers). Most are located in the codend (e.g., fisheye and fishbox) although others can be in the body of the trawl (square mesh window, composite square mesh panel, radial escape section).
BRD: Square-mesh codend		Square mesh stays open under tow (unlike diamond mesh).
BRD assist		E.g., the cone. Stimulates fish to swim forward through escape hatches like the fisheye, square mesh window or radial escape section.
Coverless trawl		Inclusion of increased mesh sizes in the upper wings and upper netting panel immediately behind the headrope crown, coupled with reduced headline height, encourages the escape of fish species such as haddock and whiting in and around the mouth of the trawl.

Rigging modification		Triangular/diamond-shaped cut in the top of the codend (e.g., flapper), changes to ground chain settings, headline height reduction, a length of twine stretched between the otter boards to frighten fish, large mesh barrier across trawl mouth and large cuts in the top panel of the net ahead of the codend.
Semi-pelagic rigging		Avoid contact with seabed.
Trawl separator (Rhule trawl)		Reduces cod catch in haddock trawls by separating catch and releasing cod from the net.
Shellfish		
TED		TEDs generally allow large animals to escape (jellyfish). Downward facing TEDs may also allow benthic invertebrates to escape.
BRD e.g., Nordmore grid		Effective for jellyfish?
Rigging modification		Longer sweeps between the otter board and trawl can reduce invertebrate bycatch.
Semi-pelagic rigging		Avoid contact with seabed.
Other		
BRD		Seahorses, sea snakes in Australian prawn fisheries.
Gillnet		
Seabirds		Less research than for trawls.
Visual and acoustic alerts	-	Pingers may also reduce seabird bycatch (1 study in Lokkeborg 2008).
Turtles		
Use lower profile nets	Primary	Reduces entanglement as the net is stiffer. Good for both demersal and drift nets.
Use of tie-down ropes	Negative	Creates slack in the net, increasing chances of entanglement (rather than gilling).
Set nets perpendicular to shore	-	Insufficient research. May reduce interactions with nesting females.
Use deterrents	-	Insufficient research. Pingers, shark silhouettes, lights or chemicals.
Deep setting	-	Insufficient research. Avoid upper water column (above 40m).
Sharks		
Unknown		
Marine mammals		
Pingers		Acoustic devices to keep cetaceans (and possibly pinnipeds) away from nets. Effectiveness appears to vary considerably depending on fishery and cetacean species: http://cetaceanbycatch.org/pingers_effectiveness.cfm
Shellfish		
Weak buoy lines		
Mesh size		
Purse Seine		
Seabirds		
Not problematic		
Turtles		
Avoid turtles	Primary	Avoid encircling turtles. Restrict setting on FADs, logs and other debris.

Use of modified FAD designs	-	Insufficient research.
Sharks		
Avoid sharks	Primary	Avoid restrict setting on FADs, logs, other debris and whales. Avoid hotspots.
Shark repellants	-	For deployment on FADs. Insufficient research.
Marine mammals		
Backdown maneuver, Medina panel, deploy rescuers	Primary	
Avoid mammals		Restrict setting on mammals.
Other finfish		
Sorting grids	-	Insufficient research.
Avoid finfish		Restrict setting on FADs.
Shellfish		
Not problematic		
Pots and traps		
Turtles		
BRDs	Primary	E.g., Diamondback terrapins in Floridian blue crab pot fishery (Butler and Heinrich 2005).
Marine mammals		
Weak lines	Primary	E.g., northern right whales, NE lobster fishery.
Finfish, invertebrates		
BRDs	Primary	

Appendix 6 – Impact of fishing gear on the substrate

In order to assess fisheries for habitat impacts under the Seafood Watch ® criteria, we developed a matrix to help determine the potential impacts that different fishing gear may have on various habitat types. The matrix was developed based on similar work done by the New England Fisheries Management Council (NEFMC 2010) and the Pacific Fisheries Management Council (PFMC 2005).

The NEFMC (2010) created a “Swept Area Seabed (SASI) model” that assessed habitat susceptibility and recovery information. Susceptibility and recovery were scored (0–3) based on information found in the scientific literature and supplemented with professional judgment when research results were deficient or inconsistent.

“Vulnerability was defined as the combination of how susceptible the feature is to a gear effect and how quickly it can recover following the fishing impact. **Susceptibility** was defined as the percentage change in functional value of a habitat component due to a gear effect, and **recovery** was defined as the time in years that would be required for the functional value of that unit of habitat to be restored (ASFMC 2010).”

The PFMC (2005) created a similar habitat sensitivity scale (0–3) that represents the relative sensitivity of different habitats to different gear impacts. The sensitivity of habitats from the PFMC (2005) was based on actual impacts reported in the scientific literature.

The relative impacts by gear and habitat type used for the Seafood Watch® matrix were based on the sum of sensitivity and recovery values from tables developed by the NEFMC (2010) (substrates) and the PFMC (2005) (biogenic). The NEFMC (2010) excluded deep-sea corals with extreme recovery times. The values for deep-sea corals in this matrix are the sum of the sensitivity and recovery scores from PFMC (2005). Other biogenic habitats that were not included in the NEFMC (2010) data tables include: seagrass, sponge reefs (rather than individual sponges) and maerl beds. Due to the slow recovery and importance of these habitat types, they have been given the same value as coral and sponge habitats, all of which are listed as "biogenic".

Hall-Spencer and Moore (2000) examined the effects of fishing disturbance on maerl beds. Maerl beds are composed of a calcareous alga and form complex habitats with a high degree complexity. The associated species assemblages have high diversity (Hall-Spencer and Moore, 2000). Hall-Spencer and Moore (2000) showed that four years after an initial scallop-dredging disturbance had occurred, some fauna, such as the bivalve *Limaria hians,* had still not re-colonized the trawl tracks. Similarly, work by Sainsbury et al. (1998; in Kaiser et al. 2001) suggests that recovery rates may exceed fifteen years for sponge and coral habitats off the western coast of Australia.

Hydraulic clam dredges are ranked as a high concern according to Seafood Watch ®. There are very few studies on the impact of this gear type, so we have relied on expert opinion (NEFMC 2010). Hydraulic clam dredges are used primarily in sand and granule-pebble substrates because they cannot be operated in mud or in rocky habitats (NEFMC 2010). This gear type is effective at pulverizing and/or removing solids and flattening out seafloor topography (NEFMC 2010). In addition, the habitats where this gear type is used are very susceptible to hydraulic dredges; recovery is moderate on average (NEFMC 2010). This leads Seafood Watch® to rate hydraulic dredges as "high concern ." Hydraulic dredges do not operate on deep-sea coral or other biogenic habitats.

Neckles et al. (2005) found significant differences in eelgrass biomass between disturbed and reference sites up to seven years after dragging. The authors projected that it would require a mean of 10.6 years for eelgrass shoot density to recover in areas of intense dragging.

Demersal seines were not evaluated in the reports by Fuller et al. (2008), Chuenpagdee et al. (2003), NEFMC (2010) or PFMC (2005). Demersal seines include: Danish seines, Scottish fly-dragging seines and pair seines. These seines are similar to some bottom trawl gear in that they have a funnel shaped net with a groundrope. They are generally hauled by wires or ropes, and although they are lighter than some bottom trawl gear, they create habitat disturbance (Rose et al. 2000; Thrush et al. 1998; Valdemarason and Suuronen 2001). A review of trawling impacts by Jones (1992) grouped bottom trawling, dredges and Danish seines together as having similar impacts on the benthos when assessing the environmental effects of bottom trawling. However, studies have demonstrated Danish seines to have less impact on the substrate compared to bottom trawls (Gillet 2008). Therefore, in our matrix they are given an intermediate score as more damaging that bottom longlines and bottom gillnets, but less damaging than bottom trawls. Beam trawls were also not included in the reports, but were considered to be similar to otter trawls.

The matrix developed from the sources referenced above is shown on the next page. For use in evaluating the Fisheries Criteria, these data have been summarized into categories (low impact, moderate, moderate-severe, severe, and very severe) to simplify use of the table.

Habitat impacts matrix: Relative impacts by gear and habitat type.

	Mud		Sand		Granule-pebble		Cobble		Boulder		Deep-sea corals **
	low	high	low	high	low	high	low	high	low	high	
Line, Vertical (BL/2)	0.5	0.5	0.6	0.5	0.8	0.8	1.0	0.9	1.0	1.0	1.3
Longline, Bottom****	0.7	0.7	0.9	0.8	1.4	1.3	1.6	1.5	1.7	1.7	2.0
Trap (lobster and deep-sea red crab)	1.3	1.3	1.2	1.2	1.8	1.7	2.0	1.9	2.1	2.1	1.3
Gillnet, Bottom****	1.3	1.3	1.5	1.4	2.0	1.9	2.2	2.1	2.3	2.3	3.0
Bottom Longline, Gillnet	1.0	1.0	1.2	1.1	1.7	1.6	1.9	1.8	2.0	2.0	2.5
Seine, Bottom (BL,G+TBO/2)	1.8	1.7	2.0	1.9	2.5	2.3	2.7	2.5	2.6	2.6	3.6
Trawl, Shrimp (BS+TBO/2)	2.2	2.1	2.5	2.3	3.0	2.6	3.0	2.8	3.0	2.9	4.1
Trawl, Bottom Otter	2.6	2.4	2.9	2.7	3.4	2.9	3.4	3.1	3.3	3.2	4.6
Dredge, New Bedford Scallop	2.6	2.4	3.0	2.8	3.5	3.0	3.5	3.2	3.3	3.2	5.1
Dredge, Hydraulic Clam	n/a***		4.4	4.0	4.9	4.5	n/a***				
Explosives/Cyanide	6	6	6	6	6	6	6	6	6	6	6

* Shrimp trawls tend to be lighter than bottom otter trawls for fish and do not need to touch the seabed to be effective.

** Most biogenic habitats (macroalgae, cerianthid anemones, polychaetes, sea pens, sponges, mussel and oyster beds) are incorporated into the scores for each substrate/gear combination in the table. NEFMC 2010 specifially excluded deep-sea corals. The numbers for deep-sea corals in this matrix are the sum of the sensitivity and (standardized) recovery scores in PFMC 2005. Other biogenic habitats that were not included in the NEFMC data tables include seagrass meadows, sponge reefs (rather than individual sponges) and maerl beds. Use the 'deep-sea corals' column for these habitats.

*** Scores not determined for hydraulic dredges in these habitats as the gear is assumed to not operate in them (NEFMC 2010).

**** NEFMC 2010 groups bottom longlines and gillnets as 'fixed gear' (not shown in table). These scores have been disaggregated here for substrate habitats only by adding 0.4 to the aggregated score for gillnets and subtracting 0.4 for longlines, base don the relative impacts shown in PFMC 2005 (i.e. that gillnets are generally more damaging than longlines).

The values above are the sum of sensitivity and recovery values in tables from Section 5.2 in Part 1 of (NEFMC 2010) (substrates) and Tables 4 and 5 in Appendix C, Part 2 of (PFMC 2005) (biogenic). Gear types in black are from the Swept Area Seabed Impact (SASI) model used for the NEFMC EFH process (NEFMC 2010). Gear types in red are derived from those in black. Substrate types are self-explanatory except that mud includes clay-silt and muddy sand, and boulder includes rock. The energy regime is used here as a proxy for natural disturbance, with a cutoff between low and high stability at 60m depth. Most biogenic habitats (macroalgae, cerianthid anemones, polychaetes, sea pens, sponges, mussel and oyster beds) are incorporated into the scores for each substrate/gear combination in the table. NEFMC (2010) specifically excluded deep-sea corals with extreme recovery times. The numbers for deep-sea corals in this matrix are the sum of the sensitivity and (standardized) recovery scores from PFMC (2005). Other biogenic habitats that were not included in the NEFMC data tables include seagrass meadows, sponge reefs (rather than individual sponges) and maerl beds. Use the "deep-sea corals" column for these habitats

Appendix 7 – Gear modification table for bottom tending gears

Spatial protection

Reducing the footprint of fishing through spatial management can be one of the most effective ways to mitigate the ecological impact of fishing with habitat-damaging gears (Lindholm et al. 2001; Fujioka 2006). The relationship between gear impacts, the spatial footprint of fishing and fishing effort (i.e., frequency of impact) is complex (Fujioka 2006) and cannot be quantified precisely in Seafood Watch® assessments. Nevertheless, criteria should acknowledge the benefits of conservative habitat protection efforts by adjusting the habitat score. Thresholds for adjusting the habitat score due to habitat protection from the gear-type used in the fishery (50% protected to qualify as "strong mitigation" and 20% protected to qualify as "moderate mitigation") are based on recommendations for spatial management found in the scientific literature as noted in Auster (2001). Auster recommends use of the precautionary principle when a threshold level of 50% of the habitat management area is impacted by fishing, with a minimum of 20% of regions in representative assemblages and landscape features protected in MPAs in order to minimize impacts on vulnerable species and sensitive habitats.

The table below gives examples of gear modifications that are believed to be moderately effective at reducing habitat impacts based on scientific studies. This table will be continually revised as new scientific studies become available. The main sources for the current table are He (2007) and Valdemarsen, Jorgensen et al. (2007).

Gear	Modification
Otter Trawls	Semi-pelagic trawl rigging (trawl doors, sweeps and bridles off the bottom, also includes modifications such as short bridles and sweeps—most commonly used for shrimp, nephrops and other species that are not herded by sand clouds and bridles due to poor swimming ability)
	Quasi-pelagic trawl rigging/sweepless trawls (trawl doors remain in contact with the seafloor, remaining gear largely off the bottom, e.g., whiting in New England, flatfish in Alaska, red snapper in Australia)
	Lighter ground gear (e.g., fewer bobbins)
	Use of rollers instead of rockhoppers
	Trawl door modifications such as high aspect (smaller footprint), cambered (generally for fuel efficiency) or soft doors (e.g., self-spreading ground gear)

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