ARTESMAR® Fishery Improvement Program for Artisanal Small-Scale Fisheries

TECHNICAL ANNEX

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ARTESMAR® is a fishery engagement and improvement program focusing on artisanal small-scale inland and marine fisheries worldwide. High catch selectivity and low impacts on aquatic habitats are important merits of many small-scale fisheries, and ARTESMAR® aims to recognize these merits on international markets. ARTESMAR® offers a framework for fishery improvement by using market-incentivized processes and socioeconomic benefits as drivers for more sustainable business- and fishing-practices.

This technical annex defines all the relevant terms which are used in the ARTESMAR® criteria of fishery improvement of offers guidance to fishery stakeholders and auditing bodies.

Small-scale artisanal fishery
Different definitions might be applied to this term, e.g. definitions by the FAO[1], based on vessel size, engine power, and technological investment. The key is the distinction to its industrial counterparts for the same or similar species in the same region in the sense of having less impact on natural resources and by its interlink with coastal communities and the relatively high numbers of livelihoods that depend on it.

Food security
Food security depends on the availability, the accessibility and furthermore on the quality of food to ensure a healthy life, as according to the definitions of the FAO[2] or USDA[3]. This subject is especially relevant in coastal developing countries, where most of the total protein intake of the local population derives from fisheries.

IUU fisheries
Illegal, unregulated and unreported (IUU) fisheries, ,as defined by the European Commission's Council Regulation (EC) No. 1005/2008 of 29 September 2008[4] and/or by the United Nations Food and Aquaculture Organization (FAO) in the 2010 UN IPAO (International Plan of Action to Prevent, Deter, and Eliminate Illegal, Unreported and Unregulated Fishing)[5].

Stock
A self-sustaining population that is partially or totally reproductively isolated from other populations, although sometimes stocks can also be defined according to management convenience. 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.

Productivity susceptibility analysis (PSA) and **combined PSA-score**
A semi-quantitative approach to assess the risk of fishing impact on a population in data poor cases by combining scores of productivity and susceptibility attributes. Productivity attributes influence the intrinsic rate of population increase, while susceptibility attributes are reflected in the catch removal portion. The productivity and susceptibility attributes are scored as 1(low), 2 (medium) or 3 (high) risk, missing attributes are scored as a 3. These scores are then plotted for visualization on

[1] http://www.fao.org/fishery/topic/14753/en
[2] http://www.fao.org/docrep/005/y4671e/y4671e06.htm; http://www.fao.org/docrep/013/al936e/al936e00.pdf
[3] http://www.ers.usda.gov/topics/food-nutrition-assistance/food-security-in-the-us/measurement.aspx
[4] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:286:0001:0032:EN:PDF
[5] http://www.fao.org/fishery/ipoa-iuu/en

a PSA plot in the productivity-susceptibility space[6]. The Euclidean distance from the origin determines the combined PSA score from the productivity score *P* (x-axis) and the susceptibility score S (y-axis):

$$\text{combined PSA score} = \sqrt{(P - X_0)^2 + (S - Y_0)^2}$$

Productivity: The productivity score is determined by life history traits such as age and size at maturation, fecundity, growth rate, sexual reproduction strategy, maximum size and age, behavior of foraging, reproduction and migration etc. that make species differently "productive" and thus vulnerable to exploitation. By default, the vulnerability index (VI) available on Fishbase (ranging from 1 to 100) www.fishbase.org is used to assess the species productivity score (*P*) by linear transformation to a score of 1 to 3 (low to high risk):

$$P = \frac{97}{99} + \frac{2}{99} VI$$

Whenever a species is not assessed on Fishbase, or the Fishbase assessment is deemed unreliable, the productivity index is derived from Table A.1 (adopted from the SeafoodWatch methodology[7]). The Fishbase vulnerability index (VI) is deemed unreliable for marine invertebrates because its application to this species group has not been evaluated (Cheung, pers. comm., 2011). Productivity scores for invertebrates are therefore always assessed according to Table A.1.
Each productivity attribute (Table A.1) is scored 1, 2 or 3 and the productivity score *P* is then given by the arithmetic mean of all productivity attributes.

Productivity attribute	Vertebrates			Invertebrates		
	Score = 3	**Score = 2**	**Score = 1**	**Score = 3**	**Score = 2**	**Score = 1**
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	100-1000 eggs/yr	NA	100 eggs/yr	NA	NA
Average maximum size	>200cm	100 – 200cm	<100cm	NA	NA	NA
Average size at maturity (non-deep sea species)	>100cm	40-100cm	<40cm	NA	NA	NA
Average size at maturity (deep sea species)	> 60 cm	40-60 cm	< 40 cm			
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	NA	NA	NA
Density dependence	NA	NA	NA	Depensatory dynamics at low population sizes (Allee effects) demonstrated or likely	No depensatory or compensa-tory dynamics demonstrated or likely	Compensatory dynamics at low populations sizes likely or demonstrated

Table A.1: Attributes and scores to determine the productivity score

Susceptibility: Susceptibility of a stock to a fishery is the stock's capacity to be impacted by the fishery, depending on factors such as the stock's likelihood to be captured by the fishing gear. Where no information on fishing mortality is available in a data-poor fishery, susceptibility may be used as a proxy. 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. Each susceptibility attribute S_i (Table A.2) is scored 1, 2 or 3 and the productivity score *S* is then given by a linear transformation of the product of attributes (see Hobday et al. 2011[6]):

[6] Hobday, A.J. *et al*. 2011. Ecological risk assessment for the effects of fishing. Fisheries Research 108: 372-384, available at : http://www.daff.gov.au/__data/assets/pdf_file/0006/2219766/biological-risk-assessment-for-the-effects-of-fishing.pdf
[7] SeafoodWatch® , Criteria for fisheries, Monteray Bay Aquarium , available at: http://www.montereybayaquarium.org/cr/cr_seafoodwatch/content/media/MBA_SeafoodWatch_CaptureFisheriesMethodology.pdf

$$S = \frac{39}{40} + \frac{1}{40}\prod_{i=1}^{4} S_i$$

	Low susceptibility (low risk, score: 1)	Medium susceptibility (medium risk, score: 2)	High susceptibility (high risk, score: 3)
Availability – overlap of stock range with fishery	<10% overlap	10–30% overlap	>30% overlap
Encounterability – habitat and depth check (scores vary by fishery)	Low overlap with fishing gear	Medium overlap with fishing gear	High overlap with fishing gear
Selectivity (scores vary by gear type, this example is for set gillnets. Selectivity for hooks is in following table)	Less than mesh size, or >5 m in length	1–2 times mesh size, 4–5 m in length	More than 2x mesh size, 4 m in length
Post-capture mortality (scores vary by fishery)	Evidence of post-capture release and survival	Released alive	Retained species, or majority dead when released

Table A2: Determination of susceptibility scores, adopted from Hobday et al. (2011)[6].

The selectivity attribute scores depend on gear type. Selectivity tables will need to be developed by the assessment team that are appropriate for the gear being considered in the verification of criteria (see example for hooks in Table A.3). The documentation should include a justification for the factors and cut-offs selected.

	Low susceptibility	Medium susceptibility	High susceptibility
Selectivity for hooks: **Scores for hook susceptibility may be assigned using the categories to the right. If the answers conflict, e.g., low on Point 1 but medium on Point 2, the higher risk-score shall be used.**	1. Does not eat bait (e.g., diet specialist), filter feeder (e.g., basking shark), small mouth (e.g., sea horse). Most robust scoring attribute. 2. Species with capacity to break line when hooked (e.g., large toothed whales, and sharks). 3. Selectivity known to be low from selectivity analysis/experiment (e.g., <33% of fish encountering gear are selected).	1. Large species with adults rarely caught but juveniles captured by hooks. 2. Species with capacity to break snood when being landed. 3. Selectivity known to be medium from selectivity analysis/experiment (e.g., 33–66% of fish encountering gear are selected).	1. 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 is important in wild diet. 2. Species unable to break snood when being landed. 3. Selectivity known to be high from selectivity analysis/experiment (e.g., >66% of fish encountering gear are selected).

Table A.3: Final vulnerability classification

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. Susceptibility attributes are only separately considered as part of the evaluation of fishing mortality when more specific data are not available.

IUCN red list of species

The IUCN Red List of Threatened Species™ (www.iucnredlist.org), assesses the extinction risk of a species, ascribing it to several categories. Those with the highest extinction risk are (in increasing order): near threatened (NT), vulnerable (VU), endangered (EN) and critically endangered (CR). Although it is the most comprehensive science-based standard for evaluating the conservation status of species, it is strongly biased towards terrestrial species, and hence the Red List has only addressed a small fraction of all known aquatic species (and less than 5% of marine species known).

Reference points (target and limit)

MSY-based biomass and fishing mortality reference points are currently the most commonly used management tools and are deemed to be generally appropriate for maintaining stock productivity in the long term. The target reference point (TRP) determines the stock biomass B_{MSY} and the corresponding fishing mortality F_{MSY} resulting in the maximum sustainable yield, from an assessment model, iterated at equilibrium. The limit reference point (LRP) determines the stock biomass B_{lim} and the corresponding fishing mortality F_{lim} that should not be exceeded to ensure safe reproduction of the stock. The two reference points determine the language use of ‘overfished’/’overfishing’ and ‘depleted’.

- **Target reference points and 'overfished' / 'overfishing'**
  A population in this assessment methodology is called overfished if exploited to biomass levels that are too small to produce its maximum sustainable yield (MSY). When overfishing occurs, a reduction in fishing effort would therefore lead to an increase in the long-term total catch. In fisheries management, the population biomass (B_{MSY}) producing MSY and its corresponding fishing mortality rate at equilibrium (F_{MSY}) are the target reference points for biomass and fishing mortality rate, respectively. In this context, referring to a stock, 'overfished' means that population biomass is below B_{MSY}, and referring to the exploitation regime, 'overfishing' means that fishing mortality rate is above F_{MSY}. Keeping and managing the fishery at target reference points optimizes the long-term yield. However, due to the level of uncertainty in the estimation of these reference points, there is a substantial risk of overshooting the real reference point. Overfishing is diagnosed when there is a >50% probability that F is above F_{MSY} and/or there is a >50% probability that B (=stock biomass) is below B_{MSY}.

- **Limit reference points and 'depleted' / 'depletion'**
  A stock in this assessment methodology is called 'depleted' when exploited past an explicit limit where abundance is too low to ensure safe reproduction. Beyond that limit, recruitment decreases and the population risks extinction. In fisheries management the threshold is given by limit reference points in terms of population biomass (B_{lim}) and fishing mortality (F_{lim}). The fishery should be stopped before the threshold is reached. The threshold below which reproduction is hampered is derived from the relationship between recruits and total egg production, which is in practice approached by adult population biomass (spawning stock biomass or SSB). The relationship is usually represented by an asymptotic curve based on the carrying capacity of the environment; it can also be generalized to include depensatory effects. The limit reference points refer to the steepness of these curves. In order to take into account the uncertainty associated to the derivation of these reference points, a stock is considered likely depleted, when the probability of the biomass being below B_{lim} is >5%.

If it is not possible to derive these reference points, indicators and proxies for these should be used, for instance: CPUE, abundance and size structure, lifetime egg production (FLEP)/ spawning potential ratio (SPR), or proxies derived from the assumed virgin biomass B_0 (see section 5.9).

Reference point proxies
For many fisheries, F_{MSY} and B_{MSY} are unknown, and proxies are often used. 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[8]. Justifications for lower target levels are often based on assumptions about 'steepness'[10] that may be highly uncertain; hence, stock targets lower than 30-40% of B_0 are difficult to justify. 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 fulfill its ecological role.
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 based on spawner biomass per recruit (SPR). However, for many species this analysis will not be available; in these cases, studies show that $F_{35\text{-}40\%}$ (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 is needed for highly vulnerable species[9].
Proxies for B_{MSY} are acceptable if shown to be conservative relative to B_{MSY} for that stock, or if they fit within the following guidelines for appropriate target level:

- Target reference point: Reference points might need to be evaluated on a case-by-case basis, but in general, biomass target reference points (TRPs) should generally not be lower than B_{MSY} or approximately $B_{35\text{–}B40\%.}$
- 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 B_{MSY}, or ½ an appropriate target reference point such as $B_{40\%}$.
- Spawning potential ratio/fraction of lifetime egg production (SPR/FLEP) reference point: The SPR/FLEP limit reference point should either be derived to be at or above replacement %SPR for the species (the threshold level SPR necessary for replacement) based on its productivity and S-R relationship, or should be set at about 35–40% of LEP.

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. 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, F35-40% (the fishing mortality rate that reduces the SPR to 35–40% of unfished levels) is

[8] New Zealand Ministry of Fisheries. 2008. Harvest Strategy Standard for New Zealand Fisheries. 25 p. Available at: http://fs.fish.govt.nz/Doc/16543/harveststrategyfinal.pdf.ashx
[9] Botsford, L. W., and A. M. Parma. 2005. Uncertainty in Marine Management. Pages 375-392 in E. A. Norse and L. B. Crowder, editors. *Marine Conservation Biology: The Science of Maintaining the Sea's Biodiversity.* Island Press, Washington, DC.; Clark W. G. 2002. *F*35% revisited ten years later. *North American Journal of Fisheries Management* 22:251-257; Myers R. A., Bowen K. G., and Barrowman N. J. 1999. Maximum reproductive rate of fish at low population sizes. *Canadian Journal of Fisheries and Aquatic Sciences* 56:2404-2419

appropriate for species with moderate intrinsic vulnerability, while a more conservative fishing mortality rate of about F50-60% is needed for highly intrinsically vulnerable species such as deep-sea fish and elasmobranchs[10].

Data necessary for stock assessment

The two common types of reference points, *MSY-based* and indirect (*SPR-based*), used by default to assess stock status, always imply uncertainty around the estimators of the reference points. Without properly accounting for this scientific uncertainty, maintaining a stock at B_{MSY} and F_{MSY} risks to unknowingly allow biomass to drop below B_{MSY} without reducing fishing rates -and thus inadvertently overfishing[11]. The risk of unintended overfishing rises with increased uncertainty and increased vulnerability of the targeted stock. Therefore, 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 rate is below F_{MSY}.

Whenever *MSY-based* reference points are not available, the stock health can be evaluated based on CPUE, trends in abundance and size structure, and simple, easy to calculate reference points such as Fraction of Lifetime Egg Production (FLEP) (equivalent to Spawning Potential Ratio, SPR)[12] (see Reference points (RP) proxies above). Evidence that the stock's productivity is not impaired include:

- 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;
- spawning potential is well protected (e.g., mature females are not subject to mortality, and it can be shown or inferred that fertilization is not reduced);
- Quantitative analyses conducted by fishery scientists indicate sufficient stock

When limited data are available from the fishery, analogy with similar systems, qualitative expert judgments and/or plausible arguments may be used to consider a stock moderately abundant.

If relying on CPUE rather than a LEP-based reference points the following conditions are indispensable:

- Take into account trends in the technological efficiency of the fleet to ensure that the stock is not decreasing while the CPUE appears stable due to technological improvements in the capture gear
- Take into account trends in size structure to ensure that 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 and current populations, and does not require catch-at-age data. Reference points based on FLEP should be considered limit reference points.

Fishing effort

The fishing effort is a measure of the amount of fishing. Frequently some surrogate is used relating to a given combination of inputs into the fishing activity, such as the number of hours or days spent fishing, numbers of hooks used (in longline fishing), kilometres of nets used, etc. The European Union defines fishing effort as fleet capacity (tonnage and engine power) x days at sea (time)[13].

Target species

The target species is the species with either the highest weight-specific value or the highest proportion in weight in the catch, or both, hence the species driving the fishery operation (i.e. without the catch of this species the fishery would not operate). Species of similar physiological and behavioural traits might have similar capture probabilities by a certain gear. As long as criteria for target species are met, several species can be declared as targets. Target species can comprise more than one species given they meet the conditions for target species stock status and mortality. Target species also have different management requirements than bycatch species (D.4). All caught species other than target species are defined as bycatch in the ARTESMAR program.

Bycatch

Bycatch is usually defined as any other mortality caused through fishing on other natural resources other than the retained species (i.e. discards, and fishery-induced mortality to organisms that are not hauled). For the sake of simplicity bycatch under ARTESMAR is defined as any species affected by the fishery other than the target species (may these be retained or not). ARTESMAR seeks to minimize the loss of natural resources and therefore aims to source only from fisheries in which bycatch rates don't represent more than 10% of the landed catch. If this bycatch rate is *a priori* not available from fisheries-specific information, it is taken from global surveys estimating typical bycatch and discard rates by fishery, gear and area[14].

[10] Myers R. A., Bowen K. G., and Barrowman N. J. 1999. Maximum reproductive rate of fish at low population sizes. *Canadian Journal of Fisheries and Aquatic Sciences* 56:2404-2419; Clark W. G. 2002. *F*35% revisited ten years later. *North American Journal of Fisheries Management* 22: 251-257.

[11] Froese, R., T.A. Branch, A. Proelß, M. Quaas, K. Sainsbury, and C. Zimmermann. 2010. Generic harvest control rules for European fisheries. Fish and Fisheries: doi:10.1111/j.1467-2979.2010.00387.x

[12] O'Farrell, M.R. and L.W. Botsford. 2006. Estimation of change in lifetime egg production from length frequency data. Canadian Journal of Fisheries and Aquatic Sciences 62: 1626-1639; Honey, K.T. Moxeley, J.H., and Fujita, R. M. 2010. From rages to fishes. Managing Data-Poor Fisheries: Case Studies, Models & Solutions. California Sea Grant College Program. (1):159–184. ISBN number 978-1-888691-23-8.

[13] http://europa.eu/legislation_summaries/maritime_affairs_and_fisheries/fisheries_resources_and_environment/l66038_en.htm

[14] Kelleher, K., 2005. Discards in the world's marine fisheries. An update. FAO Fisheries Technical Paper. No. 470. Rome, FAO. 2005. 131p.

Gear selectivity

The impact of gear on bycatch species is given by its selectivity, as shown in Table A.4 (in order of increasing selectivity):

Dredge	**Unselective**
Beam trawl	
Bottom (otter) trawl	
Bottom gillnet	
Bottom seine	
Midwater trawl	
Midwater gillnet	
Trammel nets	
Bottom longline	
Purse seine (FAD-associated)	
Pelagic longline	**Moderately selective**
Purse seine (on free schools)	
Scottish seine	
Pots and traps	**Selective**
Hook and line (Pole and line, handline, trolling, jigging)	
Hand picking by divers	
Spear fishing and Harpoon	

Table A.4: Selectivity of gear with respect to its selectivity with increasing order

By default only fisheries of the category 'selective' are eligible for ARTESMAR. Strong evidence on low bycatch rates (<5% of total catch in weight) are needed approve any other gear which is not classified as selective in Table A.3. The bycatch of non-fish vertebrates, such as birds, marine mammals or reptiles is generally of high concern. For instance, seabirds are commonly bycaught by trawlers and pelagic longliners[15]. Midwater trawls have a high impact on marine mammals[16], whereas pelagic longlines and surface and midwater gillnets show high rates of sea turtles bycatch[17]. Regarding bycatch impact on biogenic species (e.g. coral and sponges, see Impact the physical structure of the seafloor and associated biological communities below) it is assumed that gear types that contact the seafloor have the same potential for severe impacts throughout the world's oceans. Impacts from fishing on the seafloor occur on virtually all continental shelves worldwide.

Unacceptable impact on the physical structure of the seafloor and associated biological communities

The habitat impact is given by the interaction of the destructiveness of the gear and the sensitivity of the habitat. Highly vulnerable habitats typically recover very slowly from structural damage by fishing gear. Table A.5 is used to determine the potential impacts that different fishing gear may have on various habitat types (adopted from the SeafoodWatch methodology[7]). For impact values <2 no or negligible impact of the physical structure of the seafloor or its associated biological communities is expected.

	mud		**sand**		**granule-pebble**		**cobble**		**boulder**		**Biogenic habitats*** **
Natural disturbance*	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	0.1	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
Traps	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
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 and Trawl, bottom beam	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	6	6	6	6	6	6	6	6	6	6	6
*The energy regime is used here as a proxy for natural disturbance, with a cutoff between low and high stability at 60m depth.											
**Shrimp trawls tend to be lighter than bottom otter trawls for fish											
***Refer to this column for biogenic habitats in general, also if not included in the list above.											
****Scores not determined for the hydraulic dredges in these habitats as the gear is assumed to not operate in them.											

Table A.5: Habitat impact matrix giving the relative impact by gear and habitat type.

The matrix was developed by assessing relative habitat sensitivity and recovery information against different gear impacts [18]. Biogenic habitats, such as e.g. *seagrass meadows, tropical coral reefs, deep-sea corals, sponge fields, maerl beds,*

[15] Wieneke, J. and G. Robertson. 2002. Seabird and seal—fisheries interactions in the Australian Patagonian toothfish, *Dissostichus eleginoides* trawl fishery, Fisheries Research 54 (2002). pp. 253–265; Sullivan, B.J., P. Brickle, T.A. Reid, D.G. Bone and D.A.J. Middleton. 2006. Mitigation of seabird mortality on factory trawlers: trials of three devices to reduce warp cable strikes, Polar Biology 29 (2006), pp. 745–753; Abraham, E., J. Pierre, et al. 2009. Effectiveness of fish waste management strategies in reducing seabird attendance at a trawl vessel. 95 (3): 210-219

[16] Morizur, Y.; Berrow, S.D.; Tregenza, N.J.C.; Couperus, A.S.; Pouvreau, S. 1999: Incidental catches of marine mammals in pelagic trawl fisheries of the northeast Atlantic. Fisheries Research 41: 297–307.

[17] Wallace, B.P. and others. 2010. Global patterns of marine turtle bycatch. Conservation Letters. 1-21.

[18] NEFMC. 2010. Essential fish habitat (EFH) omnibus amendment. The swept area seabed impact (SASI) model: A tool for analyzing the effects of fishing on essential fish habitat. Part 1: literature review and vulnerability assessment. Newburyport, MA. 160 pp. http://www.nefmc.org/habitat/index.html

gorgonian colonies, cerianthid colonies, sea pen colonies (Pennatulacea), Sabellidae reefs, bivalve reefs, hydrothermal vents, cold seeps, etc., are the most vulnerable habitats and recovery time after disturbance is in the order of decades to centuries[19].

Species of 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), top predators and endangered species, where the removal of a small number of the species would have serious or irreversible 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[20].

Monitoring and conducting assessments and harvest control rules based on assessment results and control fishing activity

Monitoring, conducting assessments and on this basis control fishing activity, provides the basis for an effective management strategy. In general, the minimal attributes of an appropriate management strategy include:

- A process for regularly monitoring and conducting 'assessments' (not necessarily formal stock assessments).
- Rules that control the intensity of fishing activity or otherwise ensure the protection of stock productivity.
- A process to modify rules according to assessment results, as needed.

Management can be effective for data-rich as well as for data poor fisheries. The following provides guidance for each of the two cases.

Data-rich fisheries:

For data-rich or data-moderate stocks that have quota-based management, the following requirements are desirable:

- Incorporate an up-to-date, scientific stock assessment that allows managers to determine if stocks are healthy and to set appropriate quotas;
- Use appropriate limit and target reference points for stock and fishing mortality;
- Comply with scientific recommendations;
- Choose risk-averse policies rather than risky, yield-maximizing policies;
- Include buffers in the TAC to account for uncertainty in stock assessments (TACs should be at least 25% below MSY).
- Take into account other sources of mortality (e.g., recreational fishery, bycatch of juveniles, etc.) and environmental factors that affect stock, such as oceanographic regime;
- Incorporate 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).
- Enforce effective limits on effort and prevent overcapitalization;
- 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, have adjusted management accordingly.

Data-poor fisheries:

Even when managed stocks are data-poor, any effective management must include a strategy to ensure that stock productivity is maintained. This strategy should include a process for monitoring and conducting 'assessments', rules that control the intensity of fishing activity or 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.

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

[19] Sainsbury, K.J., Campbell, R.A., Lindholm, R., Whitlaw, A.W. (1998) Experimental management of an Australian multispecies fishery: examining the possibility of trawl-induced habitat modification. Global Trends: Fisheries Management *(eds* E. K.Pikitch, D. D.Huppert & *M. P. Sissenwine), pp.* 107 112. *American Fisheries Society, Bethesda, Maryland;* Hall-Spencer, J.M., and P.G. Moore, 2000. Scallop dredging has profound, long-term impacts on maerl habitats. ICES Journal of Marine Science 57: (5) 1407-1415; Neckles, H., F.T. Short, S. Barker , B.S. Kopp 2005. Disturbance of eelgrass *Zostera marina* by commercial mussel *Mytilus edulis* harvesting in Maine: dragging impacts and habitat recovery. Marine Ecology Progress Series. 285: 57–73

[20] Paine, R.T. 1995. "A Conversation on Refining the Concept of Keystone Species". *Conservation Biology* 9 (4): 962–964 Foley, M.M., Halpern, B.S., Micheli, F. et al. 2010. Guiding ecological principles for marine spatial planning. *Marine Policy* 34: 955-966.

initial declines in abundance due to harvesting; and extrapolation methods, or relying on inferences from related or 'sister' stocks[21].

Other than constraining fishing mortality (e.g., through TACs), fishery managers may employ alternative strategies, for instance spatial management (including protecting a large proportion of habitat in reserves, or protecting spawning aggregations with seasonal or spatial closures), or protecting females, which preserves the spawning per recruit of the population. For data-poor stocks, management should:

- Include a process for monitoring and assessment, such as recording trends in CPUE and size structure.
- 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%) 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;
  - 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 until more data can be collected, or
  - Base TAC on average historical catch (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).

Fishing and closed season
A closed season might be legally imposed by the local authority. The closed season should either be set such as to minimize the capture of juvenile individuals or to avoid disturbance of reproducing females. If there is no legally imposed closed season, the fishing season generally refers to the time window during which fishermen go fishing to capture the target species as their main motivation.

Minimal size limit
There should always be a minimal size limit to minimize the capture of juvenile individuals, be it through legislation or as consequence of the supply chain requirement.

Quality grade
For certain species quality grades are assigned (e.g. tuna), which are mainly a result of the catch method (time of struggling), post-capture handling and freshness. The quality requirements depend on the final market and quality grades have thus to be defined specifically for each supply chain. In any case a metric system has to be defined with quantifiable indicators (e.g. texture consistency, transparency, color, oily shine) to determine the quality grade, such that the grading is reproducible.

[21] Honey, K.T. Moxeley, J.H., and Fujita, R. M. 2010. From rages to fishes. Managing Data-Poor Fisheries: Case Studies, Models & Solutions. California Sea Grant College Program. (1):159–184. ISBN number 978-1-888691-23-8