

EFFECTS OF FISHING ON BIODIVERSITY

Based on WGECO Work

- Review of IMPACT II (2000)
- Advice on Ecological Quality Objectives (2001)
- Consensus of diverse experts:
 - Fisheries Scientists, Community Ecologists, Modelers, Benthic Ecologists, Gear Technologists, Seabird & Marine Mammal Experts, Ecological Policy Advisors

Approach of WG

- List the possible effects (Sp., Comm., Habitats)
- Examine the strength of support from
 - Direct causes of mortality / change
 - Comparative Experiments (Design challenges)
 - Long-term Studies (Causal attribution challenges)
- If impact is serious, what can be done about it
- WG focused on bottom gears & benthic impacts (worst case for many effects)
- Generalizations to other cases are largely my own

Standards of Evidence

- Critical review of experiment design & analysis.
- Needed SOUND demonstration of effect, and STRONG weight of evidence (IMPACT & others)
- “No evidence” NOT = “No effect”
- List is conservative; basis for advice on ACTION, expecting challenge.
- 2nd-order effects on food webs, community stability, life histories dealt with separately from 1st order effects.

Complications

- Effects of FISHING or of OVER-fishing?
 - Likely U-shaped relationship of cumulative fishing to incremental impact
 - “Depth” of U varies with gear & substrate
- Not all gears equal (static / mobile).
- Not all USES of a gear are equal (Code).
- Catch NOT = effort; Small NOT = benign

Impacts on Habitats

- Much greater consideration for mobile bottom gears
 - Pelagic “Habitat” are ocean process features
 - Static gears NOT always benign to habitats
- Bottom gear weight & tow speed interact in compensatory way.
- Fine scale distribution of fishing aggregated even over several years (Kulka, Rijnsdorf)

Bottom trawling can remove some physical features

- Comparative Studies - YES
- Long-Term Studies - YES
- Effects ALWAYS PERMANENT (rocks can't heal or rebuild)
- 2ndary effects on species using the features
 - Few quantified, but information growing (SARA work, Natura 2000, etc)

Reduction in structural biota (biogenic features)

- Comparative - YES
- Long-Term - YES
- Effects MAY be quasi-permanent, may be largely undetectable after 18 months.
- 2ndary effects on species using the biogenic features for habitat structure
- Tied to fine-scale distribution of fishing

Reduction in fine-scale complexity of the sea floor

- Comparative Studies - YES
- Long-term Studies - NO
- Generally restricted to < 8 cm in soft sediments
- Effects last 36 hours to 18 months, depending how dynamic the habitat is
- May lead to decreased patchiness

Populations, Species & Communities

- Fisheries are PARTIALLY selective by
 - **Species Size Place**
- Hence Null Hypothesis is trivial - what forms and how strong are the effects.
- Selectivity HIGHLY fishery specific
- “Unaccounted mortality” also a factor

Reduction in the geographic range of species

- Comparative Studies - NO
- Long-Term Studies - YES (generally weak)
- Other causes of change usually a consideration
- Effects may last several years
- Ultimate range reduction is extinction.
 - NEVER documented for fish/invertebrates in marine ecosystems. (Yes for Seabirds & Marine Mammals)
 - In freshwater, only in association with habitat change, introductions, etc.

Decrease in populations which have low rates of turn-over

- Comparative Studies - YES (occasional)
- Long-term Studies - YES (occasional)
- Theory more convincing than empirical results
 - Evidence from Elasmobranchs fairly strong,
 - Evidence from fish communities spotty
- **Big problem with circularity of assigning species to place on continuum**
- Effect may last multiple generations

Fishing is patchy and can cause fragmentation of populations

- Comparative Studies - YES (esp. sessile)
- Long-term Studies - NO
- When documented, effect is generally weak and localized.
- Not lasting even for sessile species, if recruitment products distributed widely
- IF effect were strong, could have population genetics consequences.

Fragile species are more affected by bottom trawling than robust species

- Comparative Studies - YES
- Long-term Studies - NO
- Effect best documented for sessile invertebrates.
- Effect can be buffered by robust life history stages and wide distribution of spawn
- Effect likely reversed when fishing stops
- Problem again with circularity in many studies

Relative abundance of species is altered by fishing.

- Comparative Studies - YES (strong)
- Long-Term Studies - YES
 - Often problem attributing causality to fishing
- CHANGE is not necessarily decrease: North Sea -
 - Decrease 19 Possibly Decrease 3 (21)
 - Increase 16 Possibly Increase 11 (27)
 - No change 10 Couldn't be Determined 11
- Effect starts reversal after cessation of fishing

Δ Rel. Abundance on Diversity

- Impact of fishing on bioDIVERSITY depends on how “diversity” is measured
- Diversity indices are products of richness and evenness, by various weightings
 - Little impact on richness,
 - INCREASE in evenness
- Thus - Moderate fishing INCREASES most biodiversity indices.

Surface living species are more affected than deep burrowing species

- Comparative Studies - Weak
- Long-term Studies - NO
- Effect seems to be short-term
- May be an important effect where major impacts are on the leading edge of the U

Fishing can have sub-lethal effects on individuals

- Comparative Studies - YES
Long-term Studies - YES
- Injuries well documented for fish & benthos (and birds & mammals)
- Medium-term consequences of injury rarely can be documented
- Allocation of percent of predation mortality that is incremental also very difficult
- Effect not lasting after fishing ceases

Increase in populations which have high rates of turn-over

- Comparative Studies - NO
- Long-term Studied - YES
- Some direct effect (differential F/Z ratio) on both TARGET species and BYCATCH
- Some indirect effect of changing size & species of predator community
- Effect begins reversal with cessation of fishing
- Problem of circularity of assignment to continuum

Fishing favours populations of scavenging species

- Comparative Studies - YES
Long-term Studies - YES
- Strong documentation for seabirds, some for fish and benthic invertebrates (usually weaker)
- Widespread effect short-term
- Long-term effects documented but less common. However, can deter recovery of other impacts when fishing pressure reduced (seabirds)

Food Web Effects

- **ADDED AN EFFICIENT APEX PREDATOR**
- Reduce abundance of larger predators
 - Within targeted species - strong evidence (“Pauly” effect)
 - Within whole community - variable results
- Background variation huge so measurable effect must be very large.
- Reticulate webs make effects diffuse (and indeterminant)
 - Similar paths; different species - FAIRLY COMMON
 - Different paths - Rare and result of severe OVER-fishing
- “Bottom up” enrichment by mixing - evidence weak

Life History Effects

- Some basic to Fish. Pop. Dynamics theory
 - Mortality, fecundity, maturation schedules
- Speculation that effects go further
 - Stocks & community move on r/K continuum.
 - genotypic changes to life history schedules
- Many studies contaminated by circularity of placing species on r/K continuum

Predictions about Species

- Species with large ultimate body length (L_{\max} or L_{inf}) should decline;
- Species with slow growth rates (e.g. k from the von Bertalanffy equation) should decline;
- Species with older age at maturity (A_{mat}) should decline;
- Species with longer length at maturity (L_{mat}) should decline;
- Species with a low fecundity and lower life-time reproductive output should decline;

Predictions about Communities

- Community abundance-weighted characters move:
 - L_{\max} Decrease
 - L_{\inf} Decrease
 - Growth Rate Increase
 - Fecundity Increase
 - Life-time reproductive out-put Increase
 - A_{mat} Decrease
 - L_{mat} Decrease

Quantified life history effects

- North Sea (IBTS & SE), NW of Scotland, Iberian Shelf
- *A priori* assignment of species to continuum
- * **SOME** support for all predictions tests
- * **For EVERY** prediction with several tests, results were inconsistent (some accords, some neutral, some *opposite*)
- Can *talk* results into reconciling with predictions
 - Makes Null Hypothesis into a Postulate - No longer science
- Much further study planned.

POSSIBLE MITIGATION MEASURES

- **SIGNIFICANTLY AND PERMANENTLY REDUCE FISHING EFFORT**
- Gear Substitution (Often static for mobile)
- Gear Modifications (Bycatch reduction devices & improve selectivity; lighten & lessen contact; novel attractants)
- Spatial Closures
- Real-time closures (bycatch / size etc)
- Habitat improvements
- Species adjustment (enhancement?? Culling???)
- Bycatch quotas

Effects (see section 6.4)	Mitigation proportional to extent of implementation						Mitigation with inherent spatial dimension			
	Reduce effort ¹	Gear substitution ²	Gear usage ³	Gear mod. (light/novel) ⁴	Gear mod. (select) ⁵	Bycatch quota ⁶	Spatial closure	Real time closures	Improve habitat	Species adjustment
Ai) physical *	-	C	-	-	-	-	C	-	C	-
Aii) biogenic	-	C	-	-	-	-	C	-	E	M
Aiii) complex	E	C	-	M	-	-	C	-	M	-
Aiv) structure	E	C	-	M	-	-	C	-	-	-
Bi) range	E	E	M	M	M	M	M	-	M	M
Bi) low turnover	E	E	M	M	M	M	M	-	M	M
Bi) fragment	M	E	M	M	M	M	-	-	M	-
Bii) relative	M/E	E	-	E	E	-	M/E	M	-	-
Biii) fragile	E	C	-	M/E	-	M	M/E	M	M	-
Biii) surface	E	C	M	M/E	-	-	M/E	M	-	-
Biv) sub-lethal	E	C	M	M/E	E	-	M/E	M	-	-
Bv) small Spp.	M/E	E	-	M/E	M	-	E	-	-	-
Bv) scavenger	E	C	M	M/E	E	E	M	M	-	-

RECOMMENDED ACTIONS

- Restrict the use of each bottom trawl gear presently in use to those areas where it is presently employed.
- Prevent expansion of the numbers of vessels, and allow license transfer ONLY to lesser impact gears.
- Strengthen interactions with groups working on conservation of these ecosystems
- Improve ability to detect and measure impacts and consequences of remedial measures via better instrumentation and monitoring programs.

SUMMARY

- There are effects on target species, non-target species and communities
- Documentation often weak or absent, and advocates may be exaggerating in some cases
- Evidence for species >> communities
- Biggest effects are INITIAL fishing acts and severe OVER-fishing
- Mitigation measures ARE practical