THE BASIS FOR CHANGE 2: ESTIMATING TOTAL FISHERY EXTRACTIONS FROM MARINE ECOSYSTEMS OF THE NORTH ATLANTIC

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Abstract

The reason for estimating total extractions of fish is to able to account for their impacts on marine ecosystems. Such an evaluation has not been attempted before, since ecosystem modelling techniques suitable for this purpose have only recently become available. Putting a figure on total extractions entails the difficult task of estimating, in addition to reported landings, discards, illegal, and unmandated catches, including disreported catches. These unreported extractions cast various types of shadows, many of which may be tracked and estimated quantitatively. Official figures often have an implicit assumption that such categories are zero, an unacceptable option for an ecosystem-based project. Some examples of adjustments for unrecorded catches are reported. We describe an innovative, well-funded NGO that tracks and publicizes illegal catch in the Southern Ocean and which may provide a model for other areas of the world such as the North Atlantic. We present an adjustment procedure based on a simple spreadsheet, divided into categories of unreported annual catch. Adjustment factors are based on reports from observers, confidential correspondents and on information published in a variety of sources. Over time the adjustment factors respond to changes in regulatory regime and hence the incentives and disincentives to mis-report. Once in place, this method provides preliminary estimates that may be refined without disruption. Preliminary estimates, set up as a 'straw man' for Atlantic Canada, suggest average figures since 1960 of around 30% for unreported extractions of cod and over 100% for herring. Although at first sight an adjustment procedure for illegal catch may appear controversial, we argue that such transparency is not only an essential part of a new fisheries regime that mimimizes deleterious impacts to marine ecosystems, but is also in conformity with the treatment of other kinds of fraud in contemporary society.

"Shame to him that speaks not forth: for never was the time so good as now"

Robert le Coq, Bishop of Laon, 1356, denouncing the anarchy that prevailed under misrule by the Dauphin of France.

INTRODUCTION

In order to evaluate the impacts of fisheries on North Atlantic ecosystems, the total annual amount of fish killed, from all species and by each fishery, has to be estimated. Obtaining these figures is not a trivial exercise because some items are not recorded, for a variety of reasons, in published catch statistics. In this paper we aim to present a methodology for making such estimates of unreported catch, following on from the database methodology presented in *The Basis for Change 1* (Watson et al. 2000). Our analyses will touch on controversial topics, and can be expected, in some cases, to be at variance with conventional assessments or official positions.

CATEGORIES OF UNREPORTED CATCH

Fisheries catches may be separated into three components:

1) nominal catch, that reported to a monitoring agency, generally to national body that itself reports to the FAO (Food and Agriculture Organization of the United Nations);
2) discarded by-catch, the non-targeted part of a catch, often consisting of the juveniles of targeted or other species, caught due to the unselective nature of the gear used, and usually thrown overboard rather than landed and generally. At least in recent years, in North Atlantic fisheries, this is estimated by some sort of observer program;
3) unreported catch, consisting of categories not covered by the reporting system in question

Category 3, unreported catch, as illustrated in Figure 1, may be composed of:

1) unreported discards: fish of species or sizes not wanted by the fishing vessel. Discards may be in excess of quota, high grading, and may or may not be illegal, but are amounts not reported by observers.
2) unmandated catches: catches that a given agency is not mandated to report, either on account of the small size of the vessel (catch is not recorded from small inshore vessels in the UK), or the nature of the species (a by-

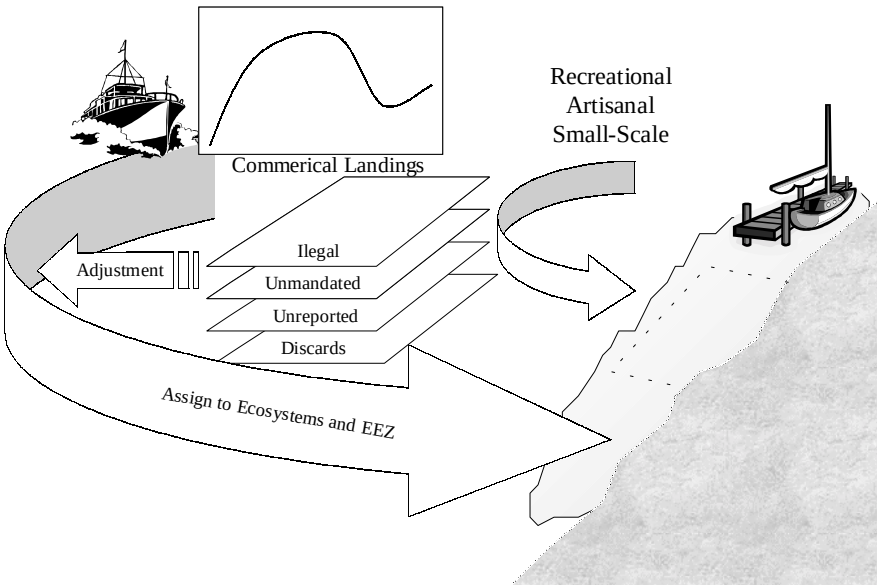

Figure 1. Illustrating how various categories of unreported catches maybe used to adjust reported landings and discards to estimate total extractions from a marine ecosystem.

catch of dogfish sharks often goes unreported). It may include discards of species not considered important enough to record, such as pelagic species like herring in some groundfish fisheries. A further example is catch from sport fisheries, which is often unmandated (it is not included in the FAO database) but can have significant impacts (see Walters 1995).

3) illegal catch: catches that contravene a regulation from the regulatory body. May be unreported by being landed away from the home port, or trans-shipped to foreign flagged vessels at sea. Includes disreported catches: catches whose identity (by species or size) may be deliberately misreported and concealed. Disreporting usually conceals quota violations, such as haddock reported as cod, or salmon concealed under surface layers of hake.

In the developed countries of the North Atlantic, the catch of fish of each commercially important species is routinely estimated by sampling at the ports of landing (Shepherd 1988), but this can be a difficult task, especially with scattered small-scale artisanal fisheries. Most of the above categories are missed by official fisheries catch statistics gathered in many countries, whose statistical systems were generally set up to track landings for economic purposes rather than the amount of fish killed by fisheries. Log books and sales figures kept by fishing captains or owners provide an alternative system, which has the advantage of also giving data on fish discarded at sea before landing, and on fishing effort. Interviews with fishers may provide historical information (Pauly 1998). But even the most plausibly diligent fishers can make mistakes under difficult conditions, and data from poorly-paid officials or observers employed to record landings can be less than accurate.

An assumption of zero is unacceptable

Where landing or catch data does not provide amounts of discards, or estimate unreported catches such as llegal and unreported catch, transshipments, or unmandated catches, it is important to realize that an implicit assumption has been made that such categories are zero. It is not our purpose to comment on the effect that such assumptions may have on conventional stock assessments, and in fact estimates of some catches, sometimes called 'unassigned', are often made and used in both the ICES and NAFO arenas at closed stock assessment workshops. Presumably for fear of embarrassing state governments, these figures generally remain confidential, or lie concealed in semi-private stock assessment working papers. In any event, they are not attributed to nations or locations but only to the fish stocks under examination. But leaving these figures at zero, as databases in the public domain tend to do, is unacceptable when trying to examine the impact of fisheries on marine ecosystems where total extractions must be estimated. Political pressures maybe such that even FAO's own, well-founded study of discards (Alverson et al. 1994) are omitted from the published FAO catch database.

Hence, the assumption of a zero adjustment to reported landings should not be used (Pauly 1998). Any percentage estimate of unreported catch by category, based on validated information, will be closer to the truth, and so should be used as a default in estimating the total catch figure for North Atlantic ecosystems modelled in Sea Around Us project. It is hoped

that improvements to our default figures may well be stimulated by its publication.

As well as unreported and illegal catches, the total mortality experienced by a stock also includes ghost ('cryptic') fishing mortality and other unaccounted sources of mortality. This topic is comprehensively reviewed by Alverson et al. (2000), building on the work of ICES (1995), and is not considered in detail here.

EXAMPLES OF HOW UNREPORTED CATCH HAS BEEN DEALT WITH

Lake Malawi

- In Lake Malawi, usipa, a small, streamlined, silvery pelagic zooplanktivore belonging to the carp family, is the subject of a considerable artisanal seine net fishery. The fish are caught at dusk and through the night with the aid of lights. There are small local markets for the fresh fish, but the bulk of the catch is sun-dried and exported from the lake shore, the local variety of a traditional and important food commodity known in central Africa as 'kapenta'. Official FAO statistics record a total catch of 3,000 to 5,000 tonnes of usipa per year, but this figure seemed low according to the suspicions of experienced fishery biologists.

  For eight months in 1985/6, Lewis and Tweddle (1990) stationed observers on the only two roads leading out of the Nankumba peninsula, situated in the heart of the usipa fishery, who censused all trucks and their sacks of dried usipa. Local consumption and usipa exported by lake steamer was also estimated. The catch from the peninsula, which represents only 5% of the lake shoreline, was calculated as five times greater than the official catch for the whole lake. Scaling up the Nankumba catch to an estimate for the whole lake involved a number of assumptions, but the total catch in 1985/6 was probably between 50,000 and 100,000 tonnes, contrasting with the official figures of 5,573 tonnes from beach recorders.

Ecuador

- In the late 1980s the tropical chub mackerel fishery in Ecuador landed over 500,000 tonnes per year, caught by a fleet of small vessels of 20 to 350 tonnes, most of which sell their fish directly to fishmeal factories at three ports along the coast. Official landing figures were suspect and a log book system had proved unreliable. Since catches and catch-per-unit-effort for this economically important fishery have been declining markedly, an accurate assessment of the fishery using reliable catch data was urgent (Patterson 1990, Pitcher and Stokes 1990) and indeed the stock collapsed soon afterwards (Patterson et al. 1993). The catch was cleverly estimated from the numbers of sacks of fishmeal output from the fishmeal factories (Patterson et al. 1990). The weight of fish input to the fishmeal process was back-calculated from the conversion ratios at each stage of the industrial process. The number of fishing vessels in each month was estimated from official permits issued each day ('zarpes'). Knowledge of the fleet structure allowed an estimate of the catch which did not go through this route (approximately 15%). Not only were the final catch estimates about double the official catch statistics, but disconcertingly there was poor correlation between the two sets of figures.

Peru

- During the heyday of the Peruvian anchovy fishery, in the late 1960s and early 1970s, it was realized that official statistics massively underestimated true catches, and that fishmeal plants were operating at much less than their mandated conversion efficiency. While the official figures were never revised (and are still cited, D. Pauly, pers. comm.), structured interviews of 40 former participants in the industry by one of the former participants pointed out the need to revise the official catch figure from 12 million tonnes in 1970 to 16 million tonnes, the actual value. Indeed, only the corrected catches are compatible with the true conversion efficiency of the reduction plants, and with fishmeal exports (Castillo and Mendo 1987).

North Atlantic

- In 1997 it is estimated that more than 75 % of the reported Spanish catch of 37,000 tonnes of swordfish was illegal. ICCAT's own records show that Spain exceeded its catch limit in both the North and South Atlantic in every year from 1996 when the ICCAT quotas were introduced. For Bluefin tuna, Spain exceeded the catch limits of about 8000 tonnes by 19% in 1995, 58% in 1996 and 51% in 1997. Moreover, France, Italy, Japan and Morocco

are reported as having illegal catches for Bluefin tuna and swordfish as large as those of Spain (Raymakers and Lynham 1998).

- Patterson (1998) used an "adapt" type of nonlinear-least-squares tuned VPA model in comparison with standard ICES VPA in order to estimate unreported catch. The Patterson model is able to provide good estimates of stock size and therefore catch, even when catches are under-reported. The method was used with three gadoid fisheries, North Sea cod and west Scotland cod and whiting. Patterson concluded that the West Scotland stocks, but not those in the North Sea, had been substantially under-reported since 1991 by a factor of 30-60%.

- In Scotland and France, large quantities of 25-30 cm cod are illegally landed as "blue greens", and under a different name, in France [2 correspondents].

- In western Ireland, the catch of large midwater trawlers targeting herring and mackerel is estimated to be at least 100% of the reported catch, with the consequence that the true catch was likely double the quota of 50,000 tonnes [1 correspondent].

- At least 50% of the catch of Scottish purse seiners is said to be illegal [1 correspondent].

- Unreported catch is said to equal reported catch for Humberside fisheries, and higher figures applied to historical periods of distant water fleets before the EEZs. [1 correspondent].

- In Denmark, cod landings are often disreported as dogfish shark. [1 correspondent].

- In Canada, the arrest of a Spanish trawler (the *Estai*) in 1995, revealed a secret specially-constructed hold that concealed unreported, illegal and undersized catch. There were two sets of log books, each reporting different catch figures. From the skipper's secret logbook, total catch was found to be 100% underreported [Harris 1998]. Moreover, 98% of the catch was undersized (and hence illegal).

- A significant amount of catch from the *Estai* was recorded in the logbook of another Spanish vessel, the *Patricia Nores* [Harris 1998]

- 45% of all Spanish catches of flounder are said to be discarded at sea and not reported [Harris 1998].

- In the late 1980s, every haul of the trawl by Russian vessels was estimated to be under-reported by at least 10 tonnes [Internal DFO document, quoted by Harris 1998].

Harris (1998), who appears to have had access to a considerable amount of privileged information, reports many instances of discards and disreported catch. His book can therefore be used to provide preliminary figures for Canadian waters. We are preparing a corrigenda from his book that may be used to tune estimates of discards and illegal catch for his region. We realize that it is easy to journalists' reports, but we would hope for better figures from those who have better knowledge.

An NGO tracking illegal fish catch

The 1996/7 annual quota for Patagonian toothfish (*Dissostichus eleginoides*), served as 'Chilean Sea Bass' in expensive seafood restaurants world-wide, was set at 17,000 tonnes by CCAMLR *(Commission for the Conservation of Antarctic Living Marine Resources)*, illegal catches taken around Heard and McDonald Island (Australia), Kerguelen Island (France) and Prince Edwards and Marion Island (South Africa), appear to have exceeded the legal quota by a factor of 500%. These illegal catches and sales of toothfish have been traced by an NGO, ISOFISH *(International Southern Oceans Longline Fisheries Information Clearing House)*.

Based in Hobart, Tasmania, and associated with CCAMLR, ISOFISH is funded by the Australian fishing industry. ISOFISH aims to track and report the unlicensed fishing activities of toothfish longliners and monitor the trade in illegally caught fish in cooperation with national authorities and the international regulatory body, CCAMLR.

The ISOFISH web site lists over 90 named individual boats and their owners, many with detailed records of their illegal activities. A newsletter dated March 1999 examines the Chilean fishing industry and names the 'pirate king' of the industry, (Roberto Verdugo, former Under-Secretary of State for Fisheries in a Chilean government) worth US$100 million in exports (80% to Japan) from Chile in 1997. Along with seven other Chilean companies, over 50 fishing vessels sell illegal toothfish catches. A

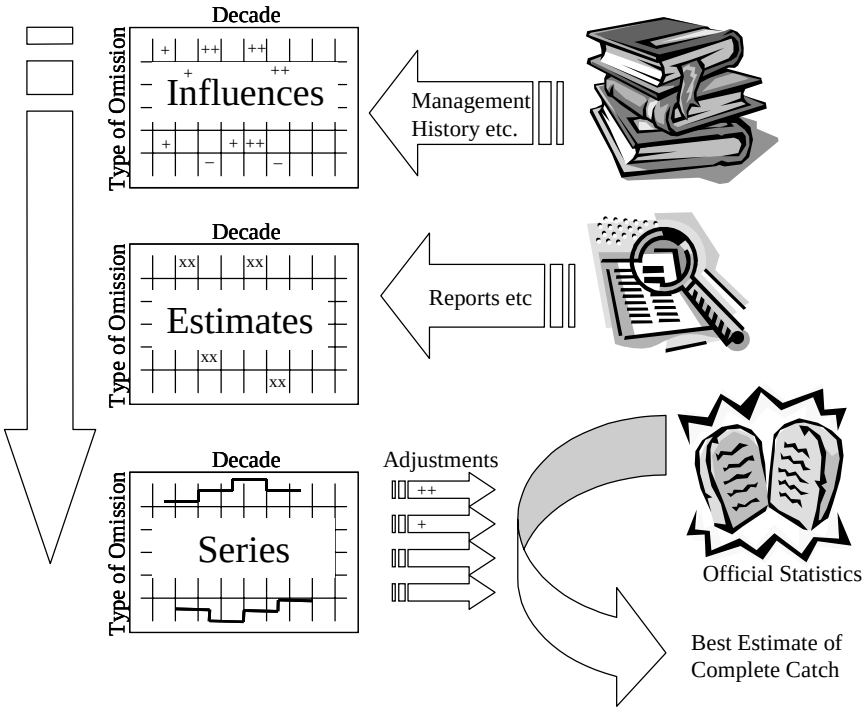

Figure 2. Illustrating adjustments to landings data to construct total fishery extractions from a marine ecosystem. A shifting climate of influences and point estimates at top lead to adjustment factor matrix at bottom of diagram.

1999 report states, "ISOFISH has enough evidence to publicly identify these companies as knowingly and persistently involved in and benefiting from toothfish poaching." By 1998, to its credit, government counter-measures in Chile were aimed at exposing the trade. However, a consequence was the re-flagging of many of these vessels in Belize, Panama, and Honduras. Moreover, port and trade authorities in Uruguay, Mauritius, Mozambique, Namibia and the French island of Réunion are identified as "providing unquestioning support" to the poachers, and being involved in trans-shipments of illegally caught fish.

ISOFISH is a good model of what may achieved, with adequate funding, in identifying specific illegal fishing and tracking the trade in illegally-caught fish that drives such activities.

Proposed Method for the SAU Project

Basis of the adjustment method

We present an adjustment procedure based on a simple spreadsheet, divided into categories of unreported annual catch (Figure 2). Adjustment factors are based on reports from observers, confidential correspondents and on information published in a variety of sources. Over time, the adjustment factors respond to changes in regulatory regime and hence the incentives and disincentives to mis-report. Once in place, this method provides preliminary estimates that may be refined without disruption, and offers a basis for collaboration and discussion. Figure 2 illustrates the general principles of the procedure. In Table 1 (a to f) we show a hypothetical example of the adjustment process. In each case we show five sections of catch adjustment: discards that are reported by observers (or in some other fashion); discards that are unreported (for example in the absence of observers); unmandated catches (defined as above); disreported catches and illegal landings (fish ultimately landed and sold somewhere in the world).

For each species these categories are shown for domestic and for foreign fleets. Table 1a lists a set of influences on misreporting, mapping the 'incentive climate' as it were, tabulated in 5-year periods. Table 1b contains some estimates used as anchor points that have some reasonable validation, obtained from surveillance, informants or other sources. Each anchor point is documented as to its source (as far as is possible). Table 1c shows adjustment factors interpolated between the point estimates of 1b using influences from 1a. Interpolations here are simply performed linearly between the points with information – obviously more sophisticated statistical methods could be used.

Total officially reported landings are listed in Table 1d: this data is extracted from official databases. Missing catches in Table 1e are estimated by multiplying the factors from1c by the landings in 1d. Hence Table 1f provides estimates of total extractions.

The most difficult part of the work is developing Tables 1a and 1b. It is important to emphasize that all anchor points at stage b are explicitly footnoted, even if exact sources cannot be revealed in some cases. Beyond this point the method flows fairly automatically and in such a way that most criticism is forced by the scheme to

Table 1. Illustrating the catch adjustment process. (a) climate of factors influencing misreporting; (b) documented point estimates (anchor points) of misreporting from informants or others; (c) interpolated adjustment factors; (d) landings (and recorded discards) data; (e) missing catch data; (f) estimated total fishery extractions from ecosystem.

Species	Jurisdiction	Type	Period						
(a) INFLUENCE FACTORS			**1960s**	**1970-74**	**1975-79**	**1980-84**	**1985-89**	**1990-94**	**1995-99**
Species A	Domestic	Obs discards	None	Some	Lots	Heaps	?	Lots	Some
		Obs effect discards	None	Some	Lots	Heaps	?	Lots	Some
		Unmandated	?	Some	Lots	Heaps	?	Lots	Some
		Disreported	None	Some	Lots	Heaps	Lots	Lots	Some
		Illegal	None	Some	Lots	Heaps	Lots	Lots	Some
	Foreign	Obs discards	None	?	Lots	Heaps	Lots	?	?
		Obs effect discards	None	Some	Lots	Heaps	Lots	Lots	?
		Unmandated	None	?	Lots	Heaps	Lots	?	?
		Disreported	None	Some	Lots	Heaps	Lots	Lots	?
		Illegal	None	Some	Lots	Heaps	Lots	Lots	?
Species B	Domestic	Obs discards	None	Some	Lots	Heaps	?	Lots	Some
		Obs effect discards	None	Some	Lots	Heaps	?	Lots	Some
		Unmandated	?	Some	Lots	Heaps	?	Lots	Some
		Disreported	None	Some	Lots	Heaps	Lots	Lots	Some
		Illegal	None	Some	Lots	Heaps	Lots	Lots	Some
	Foreign	Obs discards	None	?	Lots	Heaps	Lots	?	?
		Obs effect discards	None	Some	Lots	Heaps	Lots	Lots	?
		Unmandated	None	?	Lots	Heaps	Lots	?	?
		Disreported	None	Some	Lots	Heaps	Lots	Lots	?
		Illegal	None	Some	Lots	Heaps	Lots	Lots	Some
(b) ANCHOR POINTS (%)									
Species A	Domestic	Obs discards[L]							7[A]
		Obs effect discards							10[B]
		Unmandated		10[C]					
		Disreported	0[D]			100[E]			25[F]
		Illegal			30[G]				
	Foreign	Obs discards[L]							
		Obs effect discards							
		Unmandated							
		Disreported							
		Illegal						40[H]	
Species B	Domestic	Obs discards[L]							
		Obs effect discards							
		Unmandated			25[I]				
		Disreported							
		Illegal							
	Foreign	Obs discards[L]							
		Obs effect discards							
		Unmandated	0[J]						
		Disreported				80[K]			
		Illegal							

Notes on sources for Anchor Points (examples)

(A) Informant A. (B) DFO surveillance reports. (C) Harris (1998). (D) Harris (1998). (E) Informant B. (F) Informant A. (G) DFO estimate, Anon. (H) Harris (1998). (I) Word Bank Study 1990. (J) Informant A. (K) Informant A. (L) This is the portion of the observer discards that are discarded when no observer is present.

c) INTERPOLATIONS

Species A	Domestic	Obs discards	0.07	0.07	0.07	0.07	0.07	0.07	0.07
		Obs effect discards	0.10	0.10	0.10	0.10	0.10	0.10	0.10
		Unmandated	0.00	0.10	0.30	1.00	0.30	0.40	0.25
		Disreported	0.00	0.10	0.30	1.00	0.30	0.40	0.25
		Illegal	0.00	0.10	0.30	1.00	0.30	0.40	0.25
	Foreign	Obs discards	0.07	0.07	0.07	0.07	0.07	0.07	0.07
		Obs effect discards	0.10	0.10	0.10	0.10	0.10	0.10	0.10
		Unmandated	0.00	0.10	0.30	1.00	0.30	0.40	0.25
		Disreported	0.00	0.10	0.30	1.00	0.30	0.40	0.25
		Illegal	0.00	0.10	0.30	1.00	0.30	0.40	0.25
Species B	Domestic	Obs discards	0.07	0.07	0.07	0.07	0.07	0.07	0.07
		Obs effect discards	0.10	0.10	0.10	0.10	0.10	0.10	0.10
		Unmandated	0.00	0.10	0.25	1.00	0.30	0.40	0.25
		Disreported	0.00	0.10	0.25	1.00	0.30	0.40	0.25
		Illegal	0.00	0.10	0.25	1.00	0.30	0.40	0.25
	Foreign	Obs discards	0.07	0.07	0.07	0.07	0.07	0.07	0.07
		Obs effect discards	0.10	0.10	0.10	0.10	0.10	0.10	0.10
		Unmandated	0.00	0.10	0.25	1.00	0.30	0.40	0.25
		Disreported	0.00	0.10	0.25	0.80	0.30	0.40	0.25
		Illegal	0.00	0.10	0.25	0.80	0.30	0.40	0.25

(d) LANDINGS

Species A	Domestic	Landings	12000	12000	12000	12000	12000	12000	12000
	Foreign	Landings	8000	8000	8000	8000	8000	8000	8000
Species B	Domestic	Landings	11500	11500	11500	11500	11500	11500	11500
	non-CDN	Landings	400	400	400	400	400	400	400

(e) MISSING CATCH

Species A	Domestic	Obs discards	840	840	840	840	840	840	840
		Obs effect discards	84	84	84	84	84	84	84
		Unmandated	0	1200	3600	12000	3600	4800	3000
		Disreported	0	1200	3600	12000	3600	4800	3000
		Illegal	0	1200	3600	12000	3600	4800	3000
	Foreign	Obs discards	560	560	560	560	560	560	560
		Obs effect discards	56	56	56	56	56	56	56
		Unmandated	0	800	2400	8000	2400	3200	2000
		Disreported	0	800	2400	8000	2400	3200	2000
		Illegal	0	800	2400	8000	2400	3200	2000
Species B	Domestic	Obs discards	805	805	805	805	805	805	805
		Obs effect discards	80	80	80	80	80	80	80
		Unmandated	0	1150	2875	11500	3450	4600	2875
		Disreported	0	1150	2875	11500	3450	4600	2875
		Illegal	0	1150	2875	11500	3450	4600	2875
	Foreign	Obs discards	28	28	28	28	28	28	28
		Obs effect discards	3	3	3	3	3	3	3
		Unmandated	0	40	100	400	120	160	100
		Disreported	0	40	100	320	120	160	100
		Illegal	0	40	100	320	120	160	100

(f) ESTIMATED TOTAL EXTRACTIONS

Species A	Total	**21540**	**27540**	**39540**	**81540**	**39540**	**45540**	**36540**
	Percentage Unreported	*7.70*	*37.70*	*97.70*	*307.70*	*97.70*	*127.70*	*82.70*
Species B	Total	**12816**	**16386**	**21741**	**48356**	**23526**	**27096**	**21741**
	Percentage Unreported	*7.70*	*37.70*	*82.70*	*306.35*	*97.70*	*127.70*	*82.70*

be constructive by way of improving the interpolations. Moreover, the revised total extractions are not so controversial because they are no longer identified by country of origin, rather, they are articulated upon the ecosystem in question

A preliminary example: Atlantic Canada

A preliminary influence table for fishery catches in Atlantic Canada is shown in Table 2. This table is an example: a more complete table has to be assembled with more information for a wider range of species. Similar tables will be drawn up for each major area of marine ecosystems in the North Atlantic.

Table 2. Summary of influences on the incentives to misreport fishery catches from Atlantic Canada from 1960 to present day (with thanks to Sylvie Guénette).

	1960s	1970-74	1975-79	1980-84	1985-89	1990-94	1995-99
Regulatory regimes		ICNAF quotas overestimated	EEZs	NAFO quotas		1992 cod moratorium	cod fishery still closed
Non-Canadian catch	No incentive to misreport. Slight discarding of juveniles. Discarding high for some unused species[1]	Higher misreporting				100% unreported turbot catch outside EEZ (from arrested Spanish vessel *Estai*)	
Canadian unreported catch[2]	Moderate discarding by inshore fishery when plant capacity exceeded. Discarding may be high for some unused species[1]			Offshore vessels: strong incentive to discard after enterprise allocations put in place. Inshore: moderate cod discards at wharf[3]	Offshore: high incentive to discard; Inshore: Gill nets in water too long, increased soak times decreased proportion of marketable fish. Large discards at wharf- but decrease in minimum fish size accepted by buyers[3].	Illegal catch of cod during moratorium Low discards	Illegal catch of cod during moratorium (lower after 'sentinel' and food fishery opened)
unmandated catch			lanternfish and monkfish in scallop fishery				
disreported catch						Disreported catch of cod	High for Canadian and non-Canadian (outside the EEZ) for groundfish sector

Notes:
1. Skates for example, on Georges Bank in 1951, the average capture rate for Barndoor skates was as high as 21 per tonne of cod trawled (Bigelow, H.B., Schroeder, W.C., in Casey and Myers, 1998 (this has decreased now as their abundance has decreased)
2. Unreported catch defined as: fish in bad condition, for gill nets the catch is retained for household use, for traps, the fish are too small or are dumped when the processing plant's capacity is exceeded.
3. From Hutchings and Ferguson (ms submitted).

Table 3 presents our first attempt to quantify the effects of the factors presented in general terms in Table 2 for two species caught in the Scotian Shelf fishery, cod and herring. In Table 3b it is important to try to have at least one anchor point in each row of the table. In this example, unmandated cod and herring catches do not exist, so all the values, and the anchor point, are zero.

Note that herring are targeted by the pelagic purse seine fishery but are also caught as largely unreported bycatch in the demersal trawl fishery. Our percentage figure refers here to the target herring fishery, not the trawl fishery in which herring are a bycatch. This is different to

Table 3**. Estimations of total extractions of cod (*Gadus morhua*) and herring (*Clupea harengus*) from the 4VW region of Atlantic Canada from 1960 to present day.**

Species	Jursidiction	Type	Period						
(a) INFLUENCE FACTORS			**1960s**	**1970-74**	**1975-79**	**1980-84**	**1985-89**	**1990-94**	**1995-99**
Cod	Domestic	Obs discards	Low	Low	Medium	High	Medium	Low	Low
		Obs effect discards	High	High	High	High	High	High	High
		Unmandated	None	None	None	None	None	None	None
		Disreported	None	None	None	None	None	Low	Low
		Illegal	Lots	Lots	Some	Low	Low	More	More
	Foreign	Obs discards	Medium	Medium	Medium	High	Medium	Low	Low
		Obs effect discards	High	High	High	High	High	High	High
		Unmandated	None	None	None	None	None	None	None
		Disreported	None	None	Low	Low	Low	Medium	Medium
		Illegal	Some	Lots	Huge	huge	Lots	Some	Some
Herring	Domestic	Obs discards	Lots	Lots	Lots	Lots	Lots	Lots	Lots
		Obs effect discards	High	High	High	High	High	High	High
		Unmandated	None	None	None	None	None	None	None
		Disreported	None	None	None	None	None	None	None
		Illegal	Low	Low	Low	Low	Low	Low	Low
	Foreign	Obs discards	Lots	Lots	Lots	Lots	Lots	Lots	Lots
		Obs effect discards	High	High	High	High	High	High	High
		Unmandated	None	None	None	None	None	None	None
		Disreported	None	None	None	None	None	None	None
		Illegal	Low	Low	Low	Low	Low	Low	Low

(b) ANCHOR POINTS (%)									
Cod	Domestic	Obs discards					2[A]		
		Obs effect discards					1000B[B]		
		Unmandated	0[C]						
		Disreported							0.5[D]
		Illegal					0.5[E]	1[E]	1.5[E]
	Foreign	Obs discards					2[E]		
		Obs effect discards					1000[F]		
		Unmandated	0[C]						
		Disreported						0.5[E]	
		Illegal							5.0[E]
Herring	Domestic	Obs discards						7G	
		Obs effect discards						10H	
		Unmandated	0[C]						
		Disreported	0[C]						
		Illegal						1[E]	
	Foreign	Obs discards						5[E]	
		Obs effect discards						50[E]	
		Unmandated	0[C]						
		Disreported	0[I]						
		Illegal						5[E]	

Notes on sources for anchor points (examples)
(A) Informant A. (B) DFO surveillance reports. (C) Unmandated category not applicable to cod in this region. (D) Informant B. (E) Harris (1998). (F) Informant A. (G) DFO estimate, Anon. (H) estimate based on similar fisheries reported elsewhere. (I) Disreporting for herring from Informant C.

c) INTERPOLATIONS

Cod	Domestic	Obs discards	0.005	0.005	0.02	0.05	0.02	0.005	0.005
		Obs effect discards	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		Unmandated	0.0	0	0	0	0	0	0
		Disreported	0	0	0	0	0	0.005	0.005
		Illegal	0.04	0.04	0.01	0.005	0.005	0.001	0.015
	Foreign	Obs discards	0.02	0.02	0.02	0.05	0.02	0.01	0.01
		Obs effect discards	10	10	10	10	10.0	10	10
		Unmandated	0.0	0	0	0	0	0	0
		Disreported	0	0	0.01	0.01	0.01	0.05	0.05
		Illegal	0.05	0.1	0.3	0.3	0.1	0.05	0.05
Herring	Domestic	Obs discards	0.07	0.07	0.07	0.07	0.07	0.07	0.07
		Obs effect discards	10.0	10.0	10.0	10.0	10.0	10.0	10.0
		Unmandated	0.0	0	0	0	0	0	0
		Disreported	0	0	0	0	0	0	0
		Illegal	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	Foreign	Obs discards	0.05	0.05	0.05	0.05	0.05	0.05	0.05
		Obs effect discards	50.0	50.0	50.0	50.0	50.0	50.0	50.0
		Unmandated	0.0	0	0	0	0	0	0
		Disreported	0	0	0	0	0	0	0
		Illegal	0.05	0.05	0.05	0.05	0.05	0.05	0.05

(d) LANDINGS (1000 tonnes per annum)

Cod	Domestic	225	144	164	269	261	110	8
	Foreign	51	126	76	19	13	18	23
Herring	Domestic	1144	759	320	384	217	65	2
	Foreign	214	281	121	180	72	28	0

(e) MISSING CATCH (1000 tonnes per annum)

Cod	Domestic	Obs discards	1	1	3	13	5	1	0
		Obs effect discards	11	7	33	134	52	5	0
		Unmandated	0	0	0	0	0	0	0
		Disreported	0	0	0	0	0	1	0
		Illegal	9	6	2	1	1	0	0
	Foreign	Obs discards	1	3	2	1	0	0	0
		Obs effect discards	10	25	15	9	3	2	2
		Unmandated	0	0	0	0	0	0	0
		Disreported	0	0	1	0	0	1	1
		Illegal	3	13	23	6	1	1	1
Herring	Domestic	Obs discards	80	53	22	27	15	5	0
		Obs effect discards	801	531	224	269	152	45	2
		Unmandated	0	0	0	0	0	0	0
		Disreported	0	0	0	0	0	0	0
		Illegal	1	1	0	0	0	0	0
	Foreign	Obs discards	11	14	6	9	4	1	0
		Obs effect discards	536	702	302	451	180	69	0
		Unmandated	0	0	0	0	0	0	0
		Disreported	0	0	0	0	0	0	0
		Illegal	11	14	6	9	4	1	0

(f) ESTIMATED TOTAL EXTRACTIONS (1000 tonnes per annum)

Cod	Total	**312**	**324**	**318**	**453**	**338**	**139**	**37**
	Percentage unreported	*12.8*	*20.0*	*32.5*	*57.5*	*23.0*	*8.2*	*17.4*
Herring	Total	**2797**	**2356**	**1001**	**1330**	**643**	**214**	**4**
	Percentage unreported	*106.0*	*126.5*	*127.2*	*135.6*	*122.7*	*132.1*	*77.1*

conventional fishery work where there could be no percentage discard estimate as there is no catch reported by that particular fishery. The percentage figure here refers to the percentage of unreported by-catch of herring extracted from the ecosystem, by whatever gear may catch it.

The final results show an average of 30% and for cod and 157% for herring over the whole time period, although in the most recent half-decade with data reports these figures are 17% and 77% respectively. We emphasize again that these values are intended here only as 'straw men' to be refined and improved by those more knowledgeable about these fisheries than us.

Conclusions

Unreported extractions cast various kinds of shadows on fisheries and their associated activities. These shadows can help us track them. Patterson (1998) tracked the numerical shadows of illegal catch using a VPA technique. Illegal catch generates profits that may be revealed with suitable financial scrutiny. Transshipments may be observed directly by aerial surveillance or may create unexpected landings at ports complicit in such dealings (like the deep-sea Antarctic toothfish landings in tropical Mauritius). Without VMS or human observer schemes, the shadow of discards at sea may be more difficult to track, as often the only direct observers are seabirds and marine mammals. But even here, over time, mass-balance ecosystem models may reveal shadows of extractions that need to be explained.

As set out in this paper, our method of attempting to quantify unreported catches has some advantages. When setting the anchor points, for example, informants may be asked to rank the severity of unreported catches. In fact humans are quite good at ranking things presented in pairs, asking the question "which is the better and which is the worse?" A series of paired questions might be developed for a more formal protocols here.

The method has its difficulties, for example, in that we use a percentage of the reported catch. How do we deal with the problem where no catch is reported, yet discards and illegal catch are known to occur? Patterson (1998) considers it easier to estimate catch 'reporting efficiency' (i.e., accuracy) than to make absolute estimates of unreported catch. But the key here is that we are interested in an annual value for whole ecosystems. And this in itself makes some of the issues raised by identifying the sources of anchor point estimates less controversial. Therefore figures in tonnes can be raised to annual values and compared with the annual catch of the species over the whole system.

Publicizing or covering up illegal catches in the North Atlantic?

Creating an organization similar to ISOFISH in the North Atlantic would be of great value. Keeping illegal catch under wraps is what governments tend to want to do for fear, it seems, of causing political embarrassment to allies. Even Canada, famous for the 1995 arrest, instigated by the fisheries minister Brian Tobin, of a Spanish trawler, whose secret, specially constructed hold concealed 100% unreported, illegal and undersized catch, is coy about revealing illegal fishing activities. When asked, Australia rapidly provided lists of other vessels arrested for illegal fishing such information, but this information is difficult to obtain. One study on illegal catch in Scotland (data summaries reported in Beddington et al. 1997) is a confidential document, and not obtainable by the public or other scientists.

Murawski (1996) has looked at factors influencing discards in data from the US and Canada. General linear models were fitted to discard rates, total catch, species richness, species diversity evenness, together with operational variables associated with the fishing process (codend mesh, vessel size, tow duration, total catch, target species, year, month, depth and statistical area). Variances were high, but fisheries managed by mesh and fish size generally had higher discard rates. Year classes with high abundance influenced discard rates disproportionately. Murawski worked with observer estimates of discards, whereas the focus of this paper is to suggest a method to use when such data is not available.

In the ICES area, estimates of illegal fishing are routinely made by the stock assessment working

parties that regularly perform single-specie stock assessment. Yet, it is an unwritten but strictly imposed tradition that the basis of such adjustments are not made public, even when officials have direct knowledge of specific events. Such a policy of secrecy would likely be news for the public of the countries involved. Covering up for illegal fishing would be unthinkable if this were illegal drug running in North Atlantic countries. Bank staff who defraud the public of millions of dollars are not protected by a shield of anonymity – so why should this protection be afforded to illegal fishers?

Evaluation by FAO of IUU fishing

While our work was in progress, and following a series of discussions in international fora such as the International Maritime Organization (IMO), FAO convened a working group with mandate to evaluate, 'illegal, unreported and unregulated' catch (IUU: Bray 2000). Leading this initiative, Bray reviews IUU experience world wide, and points the finger at flag states for not providing adequate human and financial resources to tackle the problem.

Unfortunately, the three FAO categories do not map easily into the operational categories we use in our algorithm. Illegal catch includes both a reported element (disreported), an estimated element (e.g. observer and other estimates of discards) and an unreported component. Moreover the unregulated catch category seems ill-defined, and overlaps with our unmandated category. The term 'unauthorized' fishing is also used, but also does not easily link to our categories, except as an overarching term for all unreported and misreported catches.

In this work, however, FAO has published a very strong message concerning the critical importance of IUU fishing to the sustainability of benefits from capture fisheries. For example, Evans (2000) considers that IUU fishing distorts and devalues information from compliant fisheries, lowers allowable catches set using the precautionary approach, and increases uncertainty and the risk of overexploitation. Evans considers that, at national scales, there is often complacency about the intractability of the problem, echoing our concerns expressed above. Evans considers some fisheries, where new technology has recently made deepwater or marginal stocks vulnerable, to be underreported by as much as 75% , and in the case of stocks on the high seas, over 100%. Evans sees compliance with FAO Code of Conduct for Responsible Fisheries (see Doulman 1998; Edeson 1996) as an essential first step in improving the situation.

Doulman (2000) also considers IUU to be major flaw in present fisheries management, leading to a loss of economic and social benefits, and, in extreme cases, to the collapse of stocks. Doulman calls for a protocol that can operate regionally, sub-regionally and nationally, and be applicable to different types of fisheries and stock distributions. Hence we offer the method set out in draft here as candidate.

Finally, Edeson (2000) reviews the legal remedies available to combat IUU fishing. In particular, the possible role of the FAO Code of Conduct as an instrument of international law and a part of an International Plan of Action. Within the EEZs of nations, although some national laws might be improved, the problem is more a lack of implementation of existing regulations. Edeson considers this situation might be improved by explicit adoption of the FAO Code of Conduct. The possibility of enforcement by the flag state of the vessel is also under discussion

Benefits from a transparent new method

Obtaining estimates of the total extractions from an ecosystem as essential for a rational evaluation of the impact of fisheries When total extractions from an ecosystem are estimated, ECOPATH and ECOSIM modelling can reveal anomalies when models fail to balance, or simulated hindcasts do not fit biomass survey data. These methods can suggest alternative values for stock biomass. In some cases existing catch and biomass figures may be mutually incompatible where trophic webs cannot support them. We anticipate a number of anomalies of this kind arising from our total catch estimations.

Transparency is the only way that the many difficulties this new method will face can be reduced to a minimum. The database for SAU, together with its assumptions and modifiers used to infer total catches will be available on the World Wide Web, in order to allow the retracing of each step involved in arriving at certain conclusions. In so doing, the SAU team makes its conclusions not only reproducible in principle, as scientists always should, but also in practice. The only exception to this would be to protect the anonymity of certain informants, e.g., concerning illegal catches.

Cheating is widespread in fisheries, and the penalties are low, and the risk of detection is

often low as the participants are well aware. Unfortunately, political disincentives lead many concerned with fisheries to downplay their knowledge of this cheating. Where government and official sources have strong links, and even funding, from industry, we may expect these disincentives to be stronger. Fraud on this scale has not only contributed to the depletion of North Atlantic ecosystems and contributed to disastrous stock collapses, but has foreclosed options for the future generation of wealth and sustainable benefits from marine resources. Like any other criminal act, we need to estimate its true magnitude and encourage its disclosure.

CONCLUSION

Our method stands or falls by the explicitness and quality of the anchor points. These need to be defendable scientifically and to withstand scrutiny by scientists, fisheries, regional and government agencies, managers and informants. Ideally, in the public interest, an analysis would obtain the support of all of these constituents

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