The sound management of a fishery as a social engineering: applying Karl Popper's demarcation criterion to an Area 2 stock of Pacific halibut.

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Abstract

The Newfoundland fishery for Atlantic cod was once the largest cod fishery in the world. In the early 1990s this fishery formed part of an Atlantic Canadian groundfish fishery collapse that has become one of the world's most prominent case studies of failure in fisheries management. The proposition to be advanced in this paper is that this fishery collapse is attributable to the use of unsound inductive arguments that were over-reliant on 'facts' or data. Under Karl Popper's non-inductive theory of method the ability to understand and avoid a fishery collapse is not dependent on the certainty of the 'facts' or data, it is dependent of the soundness of the decisions that are taken. What is, or is not, a sound decision or sound argument is not a distinction discoverable 'naturalistically' by empirical science; rather, the distinction is based in logic. Sound management decisions require a critical or falsifiable view of science that has to be 'demarcated' from a verifiable and inductive view, two views illustrated in this paper by a singular 47 year data set of Pacific halibut. It is my prescriptive thesis that if the World's commercial fisheries are to realize a long-term sustainability they will need to be managed under a critical or falsifiable view of fishery science in which a trial and error management is guided by rules of thumb with prior improbability. After all, Canada's inshore Maritime lobster fishery has been managed in this way for well over a century without collapse.

Key words: social engineering; Pacific halibut; demarcation criterion; fisheries collapse; prior improbability

Introduction

The Newfoundland fishery for Atlantic cod was once the largest cod fishery in the world (McGrath, 1911). In the early 1990s this fishery formed part of an Atlantic Canadian groundfish fishery collapse that has become one of the most prominent case studies of failure in fishery management (Charles, 1997). Myers *et al*. (1997) looked to explain the collapse of the Newfoundland cod fishery by analysing the quality and quantity of the data used in its stock assessment. This was done by comparing abundance trends for six cod populations as determined by research surveys and as reconstructed from commercial catch at age data in a virtual population analysis (VPA). On the basis of this comparison it was suggested that the six cod populations had collapsed in part because of an overreliance on commercially collected catch at age data, data that were not proportional to the true abundance. Under Karl Popper's non-inductive theory of method the ability to avoid a fishery collapse is not dependent on the reliability or certainty of the 'facts' or data. It is dependent on the making of sound decisions: what is, or is not a sound decision or sound argument cannot be discovered 'naturalistically' by empirical study; [i] rather, it is a distinction based in logic. It is my prescriptive thesis that the prejudicial nature of a verifiable view of fisheries science with its emphasis on the unsound inductive argument is to be held responsible for the overfishing and collapse of Newfoundland's Atlantic cod stocks. If the World's commercial fisheries are to realize a long-term sustainability they will need to be managed under a critical and falsifiable view of science in which deduction forms the Organon of criticism.

1. Analytic method and the falsifiability criterion

The philosopher of science John Losee distinguishes between a descriptive approach to the philosophy of science and a prescriptive approach where the latter 'seeks to formulate evaluative standards by which scientific theories and explanatory arguments *ought* to be evaluated' (Losee, 2005, p. 2, emphasis added)[ii]. A prescriptive approach aims to answer such questions as:

What are the permissible types of scientific explanation?

In its methodological or heuristic aspect Karl Popper's falsifiability criterion forms an 'evaluative standard' that demarcates between

(a) A critical or falsifiable view of science as a permissible non-inductive method in which deduction forms the Organon of criticism, and

(b) A verifiable and inductive view of science as a non-permissible method.

From a logical point of view, the criterion of falsifiability is based on a fundamental logical asymmetry in which a (unilaterally falsifiable) universal statement (e.g. *all swans are white*) is logically much stronger than the corresponding (unilaterally verifiable) existential statement (*at least one white swan exists*). This 'demarcation' is based on a 'well-known logical rule' and is fully explained by Karl Popper in his 'Postscript to the Logic of Scientific Discovery' (Popper, 1983, p. 184).

2. The logically stronger critical or falsifiable approach

2.1. Fisheries management as a social engineering

Natural laws such as the laws of physics can be compared to 'proscriptions' or 'prohibitions.' For example: the law of the conservation of energy can be expressed as 'There is no perpetual motion machine.' And it is precisely because of this negative formulation that natural laws are falsifiable. If we accept for the sake of argument the occurrence of an event or the existence of a 'thing' excluded by the law then the law is falsified (Popper, 2002, p. 48). In terms of a fisheries management, the notion of 'non-existence' or 'proscription' takes the form of a rule of thumb that guides the trial and error management of a fishery by stating what cannot be achieved and should not therefore be attempted. Corkett (2011) gives several examples including:

> One cannot obtain a sustainable fishery (normative goal) while at the same time providing unlimited jobs for fishermen (social objective).

Natural laws such as Newton's theory of gravitation or the economic law of diminishing returns have to be clearly distinguished from normative laws or norms such as goals, standards and regulatory policies. In a social engineering this distinction between norms and natural laws is upheld in the form of a dual premised schema (Table 1) in which norms (given as goals and standards in Table 1) form the conclusion and rules of thumb (RT in Table 1) represent natural laws in the form of a universal premise. Consider the task of managing a fishery: from a logical point of view what are provided by the proponents are the norms to be attained (such as the requirement for a sustainable fishery) (N in Table 1). What remains to be found by the fisheries manager as 'social engineer' are the regulatory policies that have to be realised by trial and error in such a way that the normative goals and standards are deductively implied by the dual premises. Corkett (2011) represents a trial and error managing (M in Table 1) in the form of a problem solving schema, as:

$$P_1 \rightarrow TD \rightarrow EE \rightarrow P_2 \rightarrow TD \rightarrow EE \ldots \text{etc.} \quad (1)$$

where P_1 = the initial problem including the goal to be pursued (how do we obtain a sustainable fishery? How do we obtain further employment for our fish processors?); TD = tentative decision, a tentative policy that reflects the chosen goal; [iii] EE = error-elimination by critical feedback by which the effectiveness of the regulatory policy is assessed; and P_2 = the new problems and consequences that arise as the result of the decision taken. [iv] While uncertainty remains ubiquitous in the fisheries (Charles, 1998) we are still able to guide management decisions (TD in schema (1)) with the theory or rule of thumb that best survives a critical discussion (Corkett, 2002).

Table1. Schema for the management of a fishery

	Dualism [a]		Monism [b]
Universal premise	RT	Rules of thumb	
Singular premise [c]	M	Managing by trial & error	Data or 'facts'
Conclusion	N	Goals and standards	MSY or MEY

[a] Fisheries management as a dual premised social engineering (from Corkett, 1997, after Popper, 1979a).

[b] Managing a fishery at the maximum sustainable yield (MSY) or maximum equilibrium yield (MEY) as a single premised verification or monism (after Ricker, 1975).

[c] In Popper's (1979a) original schema the singular premise forms the initial conditions.

2.2. The early catch management of an Area 2 stock of Pacific halibut.

In the years following the original establishment of the International Pacific Halibut Commission (IPHC) in 1923, the catch management of the Pacific halibut fishery involved the setting of catch limits and a closing of the fishery when these limits were reached. The management of this fishery can be represented as a version of schema (1) that involves error-elimination (*EE*) from a catch per unit of effort or catch per unit (CPU), as:

$$P_1 \rightarrow TP \rightarrow EE\ by\ \mathrm{CPU} \rightarrow P_2 \qquad (2)$$

where P_1, represents the problem requiring solution, such as: should we decrease the catch limit?; *TP* = tentative policy in the form of regulatory catch limits (see Appendix A, column 2); *EE by* CPU = error-elimination by critical feedback from a CPU. For example: prior to regulation by the IPHC in 1932 the actual catch (Appendix A, column 3) continued on a downward trend indicating that abundance was declining (black CPU points from 1910 to 1931 in Figure 1 (a)). After the introduction of output controls in the form of catch limits in 1932 the abundance of the stock gradually increased as indicated by the white CPU points from 1932 to 1953 (Figure 1(a)). During this period an actual catch of 22-25 x 10^6 lb (Appendix A, column 3) was being maintained; that is: catch controls were effectively controlling effort levels and the fishery was being returned to sustainability. The sudden decline in abundance and increase in the variability shown by the CPU index for the period 1953 to 1957 indicates that catch controls were becoming ineffective. In 1954 for example the catch limit of 26.5 x10^6 lb was exceeded by an actual catch of 36.7 x10^6 lb (Appendix A, columns 2 and 3 for 1954). While the 47 year historical trend of Figure 1(a) can never be used to predict future performance, the trial and error management of a fishery (M in Table 1) can still be guided by simple rules of thumb (RT in Table 1) that explain what cannot be achieved and should not therefore be attempted.

3. The logically weaker verifiable and inductive approach

While a falsifiable view of fisheries science emphasises a critical attitude involving trial and error-elimination, a verifiable view of fisheries science emphasises verification by induction, by, for example estimating a maximum sustainable yield (MSY) or maximum equilibrium yield (MEY) from data by complex modelling (Table 1). W. E. Ricker (1975)

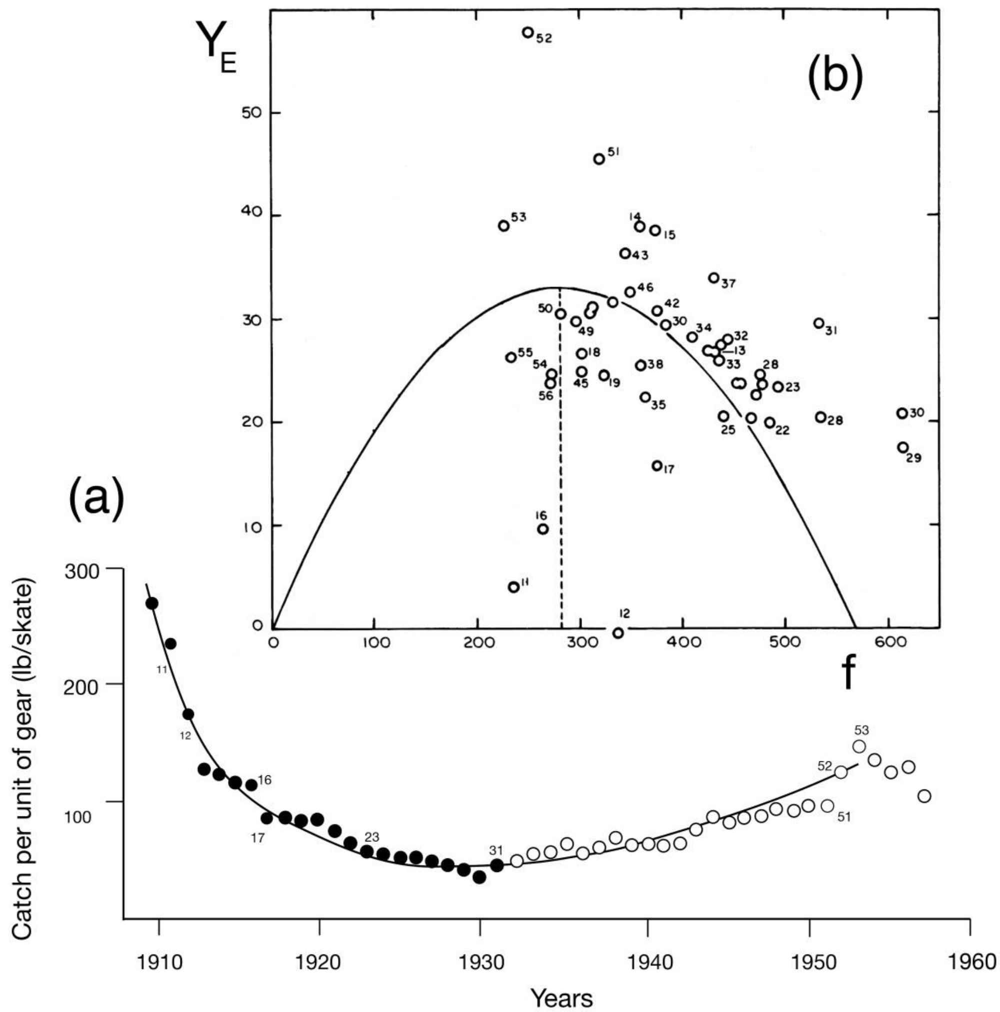

Figure 1 Two views of an Area 2 stock of Pacific halibut (a) A falsifiable view involving a catch per unit (CPU, lb/skate); black points indicate yearly CPU before management in 1932; white points indicate yearly CPU for the period when the fishery was being managed by the IPHC; 11, 12, 52 represent years 1911, 1912, 1952 etc; line fitted by eye; data in Appendix A. (b) A verifiable view involving a plot of yield (Y_E, 10^6 lb) against the gear fished (f, 10^6 skates) (from Ricker, 1975, his Figure 13.2B).

used a complex model to derive a quantified estimate for the MEY of 30 x 10^6 lb (Figure 1 (b)) for the same Area 2 stock of Pacific halibut referred to in section 2.2. From a logical point of view Ricker's estimate takes the form of a unilaterally verifiable existential hypothesis (see section 1), as:

> There is a MEY for an Area 2 stock of Pacific halibut of about 30 x 10^6 lb.

Why this hypothesis cannot be falsified can be illustrated in a simple way; any future deviation from the original estimate of 30 x10^6 lb could not falsify this original estimate, for it remains logically possible (or we can always believe) that in the long-run deviations in the opposite direction will return the MEY to its original value of 30 x10^6 lb (Corkett, 2002). This example of arguing inductively from 'data to MEY' is only one of many ways verifications are carried out by fishery scientists. The point to be made here is that no verifying argument or verification can belong to a critical or falsifiable view of science since verifications cannot be falsified. This non-falsifiability can be illustrated by a generalised single premised verification or monism (Table 1) of the following form:

> There is a verifying procedure involving: 'induction, complex modelling, expert opinion, statistics, biomass limits, reference points, fishing mortality, etc.' whose exact application to fisheries' observations or data is able to identify: 'population abundance, stock biomass, the greatest long-term sustainable yield, the precautionary approach, scientific advice, etc.' If a repeated carrying out of this application to observations or data fails to achieve the same result, it would not be a falsification, for perhaps an unnoticed yet essential aspect of the correct procedure had been omitted.

The reason why it is deceptively easy to find verifications of a theory is that observations are always interpretations of the 'facts' observed; that is observations and data are interpreted in the light of theory (Popper, 2002, p. 90, note *3). This is why a critical attitude to fisheries science is called for if we are not to argue in circles and thus prejudice management decisions guided in this way.

4. Discussion

4.1. Epistemology without the subjectivity of a mind

Karl Popper's objective view of epistemology takes an anti-naturalistic position (see note 1) in which human knowledge is interpreted as the product of intellectual activity. It consists of a series of statements or propositions that can be subjected to a critical discussion. There is of course another way of looking at knowledge: we can regard it as a subjective state of mind involving 'belief.' Karl Popper distinguished between these two forms of knowledge by assigning them to separate universes or worlds of discourse.

> **World 3** The objective products of the mind including works of art and ethical values such as goals and standards. This is the linguistically formulated world of problems, theories and critical arguments given here as problem-solving schemata (1) and (2).
>
> **World 2** The world of subjective thought processes involving 'beliefs' that play such an important part in religion. To these two universes of discourse must be added the physical world.
>
> **World 1** The world of 'things' of rocks and planets and physical fields of forces. Also are included are the worlds of chemistry and biology including organisms such as trees, crows and swans (Popper, 1979b). [v]

Only the statements of a World 3 are able to stand in timeless logical relationship such as compatibility or contradictoriness. [vi] Subjective thought processes on the other hand, can only stand in psychological relationship to one another.

4.2. Empirical content as falsifiability, testability and refutability

It is a well-established fact of elementary logic that a universal categorical proposition has no 'existential import.' That is: a universal law with the logical form of *all swans are white* does not assert the existence of any observable object such as a swan. It makes non-observable assertions such as: black, red and green swans do not exist. Since nothing observable follows from a universal law, Karl Popper makes use of possible falsifications as a World 3 measure of information content or empirical content. For example: consider the following three assertions:

1. *There are no black swans* is falsifiable by observing black swans.
2. *All swans are white* is falsifiable by observing black swans [vii] but also by observing red and green swans as well.
3. *At least one white swan exists* cannot be falsified by observation since an existential statement can only be falsified by a universal law. In this example *at least one swan is white* is falsifiable only by *all swans are black*.

We can say *all swans are white* has a greater falsifiability and testability than *there are no black swans* and *at least one swan is white*. That is assertion 2 is logically stronger than assertions 1 and 3; and assertion 1 is logically stronger than assertion 3 which has no empirical content or falsifiability. Empirical content in the form of high falsifiability and testability is equated with simplicity by Popper (2002, p. 128) in the following schema:

testability = high prior im*probability = paucity of parameters = simplicity*

For example rules of thumb (RT in Table 1) are associated with prior improbability or falsifiability allowing for the prior guidance of a social engineering by explaining what cannot be achieved, as:

> You cannot achieve a long-term sustainability (normative goal) for a catch or quota managed fishery if the CPU index is continuously declining.

By contrast the models used in guiding the decision-making of a fisheries stock assessment are complex. A good example of this kind of complex modelling is provided by the methods used to evaluate the six Eastern Canadian stocks of Atlantic cod (Myers *et al*., 1997, their Table 1) (see Introduction). That is: the prior use of research surveys and VPA to estimate cod population abundances are both examples of a complex modelling with prior probability or verifiability (not prior improbability or falsifiability).

Conclusion

(i) The early trial and error management of an Area 2 stock of a Pacific halibut (schema (2)) serves as a paradigm for the sound management of a fishery (M in Table 1) guided by simple rules of thumb (RT in Table 1) with prior improbability. This 'social engineering' paradigm includes Canada's effort managed inshore lobster fishery, a fishery that has been managed for well over a century without collapse (Corkett, 2011).

(ii) William E. Ricker's quantified estimate of a MEY for an Area 2 stock of a Pacific halibut (Figure 1(b)) serves as a paradigm for the identification of a fisheries' greatest long term sustainable yield as an existential hypothesis that cannot be falsified.

(iii) In my view the non-falsifiable verifications of a fisheries stock assessment with their emphasis on the unsound inductive argument (see note vii) are to be held responsible for the overfishing and collapse of Newfoundland's Atlantic cod stocks.

(iv) It is my prescriptive thesis that if the World's commercial fisheries are to realize a long-term sustainability they need to be managed under a critical or falsifiable view of science in which a dualism (Table 1) forms the Organon of criticism.

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Appendix A

The data set used in the construction of Figures 1(a) and (b) is reproduced below and is taken from the early catch management of an Area 2 stock of Pacific halibut by the IPHC (Anon, 1962, Tables V and VII). The data is reproduced in 5 columns: column 1= year; 2= Catch limit (10^6 lb); 3= Actual catch (10^6 lb); 4= Gear fished (f, 10^3 skates) and 5= Catch per unit (CPU, lb/skate) where column 2 is from Anon (1962, Table V) and columns 1, 3, 4 and 5 are from Table VII. This original data set is also reproduced in Ricker (1975, his Table 13.1) with the exception of the catch limit. Ricker replaces the IPHC's catch limit with a derived statistic (Y_E, 10^6 lb) reproduced as the ordinate Y_E in Figure 1(b) and as column 6 in the Appendix.

1 Year	2 Catch limit (10^6 lb)	3 Actual catch (10^6 lb)	4 Gear fished (f) (10^3 skates)	5 Catch per unit (lb/skate)	6 Yield (Y_E) (10^6 lb)
1910		51.0	188.7	271	...
1911		56.1	237.3	237	4.1
1912		59.6	339.5	176	-0.4
1913		55.4	431.7	128	26.9
1914		44.5	359.8	124	39.0
1915		44.0	374.7	118	38.7
1916		30.3	265.4	114	9.8

1917		30.8	378.8	81	15.8
1918		26.3	301.9	87	26.8
1919		26.6	325.2	82	24.6
1920		32.4	387.1	84	29.4
1921		36.6	478.7	76	24.6
1922		30.5	488.5	62	20.0
1923		28.0	494.0	57	23.5
1924		26.2	473.0	55	22.7
1925		22.6	441.3	51	20.6
1926		24.7	478.0	52	23.7
1927		22.9	469.0	49	20.4
1928		25.4	537.3	47	20.4
1929		24.6	617.2	40	17.6
1930		21.4	616.3	35	21.9
1931		21.6	534.0	41	29.6
1932	21.7	22.0	445.1	49	28.0
1933	21.7	22.5	437.5	52	26.0
1934	21.7	22.6	410.9	55	28.1
1935	21.7	22.8	365.6	62	22.3
1936	21.7	24.9	458.8	54	23.9
1937	21.7	26.0	430.9	60	34.0
1938	22.7	25.0	363.0	69	25.5
1939	22.7	27.4	452.1	61	23.9
1940	22.7	27.6	440.4	63	27.6
1941	22.7	26.0	425.6	61	27.0
1942	22.7	24.3	378.2	64	30.8
1943	23.0	25.3	345.8	73	36.3
1944	23.5	26.5	314.2	84	31.0
1945	24.5	24.4	302.8	81	24.9
1946	24.5	29.7	351.2	85	32.7

1947	24.5	28.7	333.6	86	31.7
1948	25.5	28.4	312.2	91	30.4
1949	25.5	26.9	299.0	90	29.9
1950	25.5	27.0	281.7	96	30.5
1951	25.5	30.6	320.8	96	45.6
1952	25.5	30.8	251.8	123	57.8
1953	25.5	33.0	228.6	145	39.0
1954	26.5	36.7	274.0	134	24.7
1955	26.5	28.7	233.5	123	26.2

End Notes

[i] The view according to which the method of science is an empirical science in its turn – a study of the behaviour of scientists, or of the actual procedure of 'science' – may be described as 'naturalistic' (Popper, 2002, p. 30).

[ii] This quote is used by permission of the University of Pittsburgh Press.

[iii] Normative goals are typically contradictory; for example we cannot expect to obtain a long-term sustainable fishery while at the same time providing unlimited employment. Deciding on a balance between two or more possible goals is one of the main challenges presented by the problem situation (P_1, P_2 …) of schema (1).

[iv] Schema (1) is a managerial trial and error version of Karl Popper's (1979b) problem solving schema. Starting from some theoretical or practical problem P_1, a tentative solution in the form of a tentative theory *TT* is proposed, which may be partly or wholly mistaken; in any case it is subjected to error-elimination *EE* in the form of critical feedback that may consist of experimental tests, as:

$$P_1 \rightarrow TT \rightarrow EE \rightarrow P_2$$

New problems P_2 arise from this error-elimination or 'critical discussion' and the process repeats itself.

[v] These crows and swans belong to a World 1 and are not to be confused with the 'white crows' and 'black swans' that represent premises in a World 3 falsifying inference or falsification.

[vi] A falsification exhibits both compatibility and contradiction, as: *all swans are white* is compatible with *black swans do not exist* which in turn is falsified (contradicted) by the observation of a black swan. That is: the universal law *all swans are white* excludes the existence of black swans and the observation of a black swan falsifies the law. In general terms: the negation of a strictly universal statement (not *all swans are white*) is always equivalent to a strictly existential statement (*there are non-white swans*) and vice versa, as: *there are* no *non-white swans* is equivalent to *all swans are white* (Popper, 2002, p. 47).

[vii] While the acceptance of a black swan (premise) is a totally sufficient guarantee that *all swans are white* (conclusion) has been falsified. The acceptance of any number of white swans (premise) can never be a totally sufficient guarantee that *all swans are white* (conclusion) has been confirmed; that is: from a World 3 perspective observing 50,000 white swans can make for no sounder an argument than observing one white swan. In both cases the argument remains an unsound inductive one.