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Reflections on the failure of traditional fisheries management

Christopher John Corkett

e-mail: chris.corkett@dal.ca

A science is not a God. While Jesus can turn water into wine, the fisheries scientist cannot turn data into advice.

Abstract: A traditional fisheries management or fish stock assessment takes a Lamarckian-like instructive view of fisheries science. Its invalid inductive arguments have no problem solving capacity and are responsible for the collapse of some of the World's largest Gadoid fisheries including Newfoundland's 'northern cod' in the early 1990s. If we are to solve our management problems; an instructive view of fisheries science will need to be replaced with a problem-solving critical dualism in which (i) norms are chosen by the participants and not predicted as MSYs and MEYs and (ii) a fishery is managed by the method of selection by critical elimination guided by 'there-is-not' rules such as the Universal Law of Sustainability. Like me, the ecologist Tony Underwood has developed a popperian program of research; but here the logical technical term 'falsification' has been viewed from a distance as the word 'false.' This linguistic mistake has had drastic consequences; the discipline of ecology has been turned into a pseudoscience, a non-falsifiable science incapable of guiding the management of a commercial fishery. The absurdity that a traditional management should seek instruction from the environment in the form of 'facts' or data instead of subjecting bold tentative policies to a Darwinian-like selection by error elimination, results in a monism of 'scientific' ethics. That is: an ethics in which norms (values) are not chosen by the participants, but are viewed as scientifically achievable predictions.

Keywords: fisheries; selection; Lamarckian; instruction; induction; deduction; corroboration; refutation; falsification; falsifiability; verification; pseudoscience

Introduction

Ray Hilborn and Daniel Ovando (2014) have recently reviewed the status of global fish stocks by reanalysing databases from three sources: (i) the RAM Legacy Stock Assessment Database (represented by Worm *et al*., 2009 and Ricard *et al*., 2012), (ii) the FAO evaluation of 395 stocks (FAO, 2011) and (iii) Costello *et al*. 2012. This review is similar to the data-based methods used in managing a commercial fishery in that both approaches involve interpretation of fisheries data. We can summarise a traditional fisheries management or fish stock assessment (DFO, 2015) by an *a priori* methodological scheme involving a 'decision-making.'

the 'facts' or data → theory or advice → 'decision-making' *a priori* scheme (1)

A painting is an interpretation of the 'facts' and in Figure 1 I have reproduced a still life painting in which the 'facts' are represented by a number of objects including a wine bottle. The bottle contains a label and the question arises how detailed should this label be in the final rendition of the painting. If the label was to be given in microscopic detail so that every word could be read it would be out of place with the rest of the painting. The detail in the label has to remain in context with the rest of the painting. That is: the label has to 'be convincing' as my old Art Master would have said. From a common sense point of view it would appear that theories and advice should be based on 'facts' in the form of data (as in the *a priori* scheme). However, just as reproducing the label on the wine bottle in microscopic detail for its own sake does not make for a better painting, so collecting and analysing data in a way that is accurate and certain does not make for a better theory or advice. Problems are solved by bold imaginative theories and policies; problems are not solved by basing advice on data that is accurate and certain! That is; theories in the form of expectations and interpretations are logically prior to the 'facts' as data. In obtaining knowledge about the external world we produce bold tentative theories; try them out and reject those that do not fit. This is the method of 'selection by critical elimination', referred to some 80 years ago by Popper (2002a) [i] as **corroboration**. [ii] From a distance this method of selection looks like instruction or as it is usually called **induction.**

Figure 1. A still life painting as a convincing interpretation of the external world; a representation created by the method of 'selection by critical elimination.' (from Corkett, 2015, his Figure 1).

The early management of the Pacific halibut

In the years following the establishment of the International Pacific Halibut Commission (IPHC) in 1923, managing an Area 2 stock of Pacific halibut involved the setting of catch limits and closing the fishery when these limits were reached. The management of this groundfish fishery can be represented as a selection by error elimination (EE) involving a catch-per-unit of effort or catch-per-unit (CPU), as:

$P_1 \rightarrow TP \rightarrow$ EE by CPU $\rightarrow P_2$ selection by EE, scheme (2)

where P_1, represents the problem requiring solution, such as: should we decrease or increase the catch limit?; TP = tentative policy in the form of regulatory catch limits; EE by CPU = error-elimination by critical feedback from a CPU. Figure 2 represents a yearly catch-per-unit (CPU, lb/skate) for an Area 2 stock of Pacific Halibut (Corkett 2014, his column 5, Appendix A). The black points indicate the decline in abundance that occurred before management by the IPHC. The period when the fishery was being managed by the IPHC (1932 to 1957) is given as white points in Figure 2(a) and forms a record of past performance in the form of a **corroborative index**. That is: the ability of management to solve problems effectively can be assessed by distinguishing between positive and negative trends in the index.

After the introduction of output controls in the form of catch limits in 1932 the abundance of the Area 2 stock gradually increased as indicated by a positive corroborative index given by white points from 1932 to 1953. During this period an actual catch of some 22-25 x 10^{6} lb (Corkett, 2014, his column 3, Appendix A) 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 negatively trending index for the period 1953 to 1957 indicated 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 (Corkett, 2014, his, columns 2 and 3 for 1954, Appendix A). While the corroborative index is a record of past performance and could never be used to predict the future performance of a fishery, the 'decision-taking' of a management by error elimination (EE in scheme (2)) can still be guided by simple 'there-is-not' rules, rules

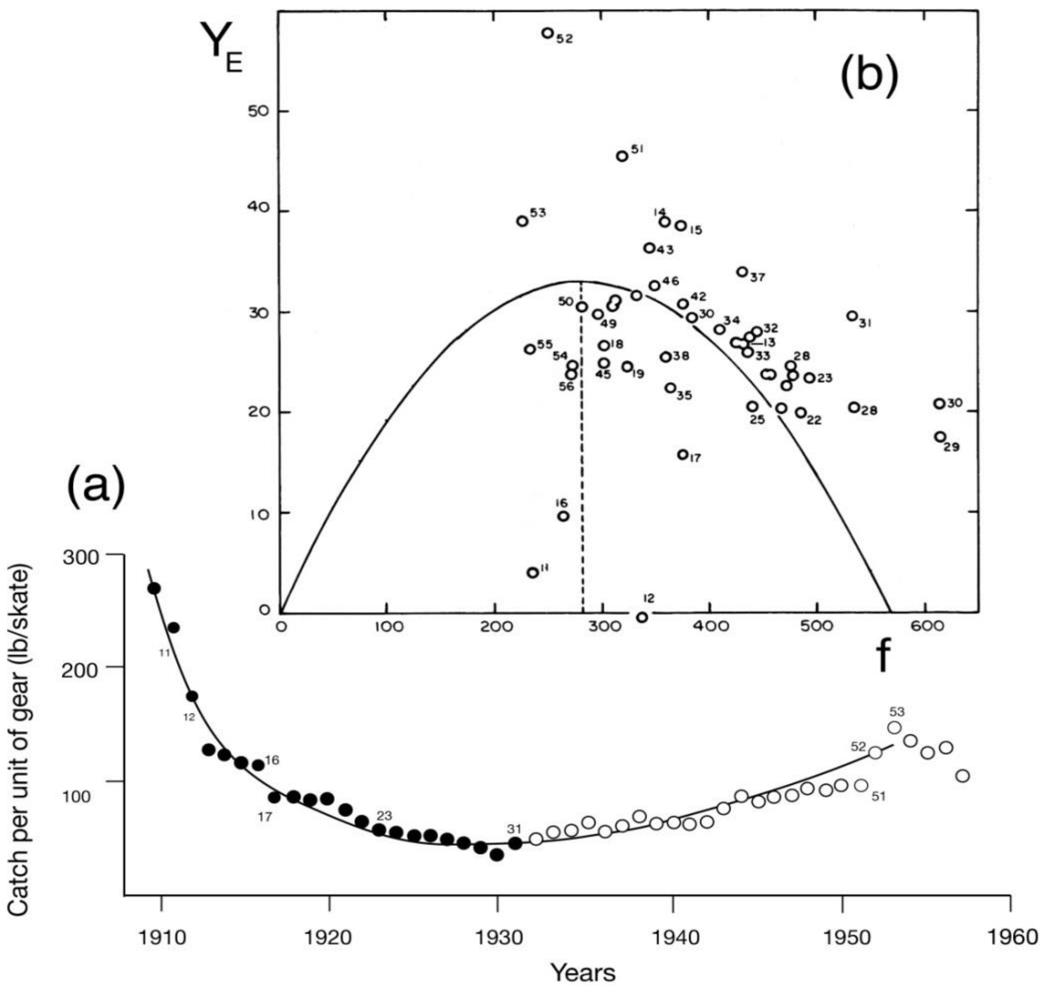

Figure 2. A yearly catch-per-unit (CPU, lb/skate) for an Area 2 stock of Pacific Halibut for1910 to 1957 (from Corkett 2014, his Figure 1). **(a)** A selective view of the fishery given as a corroborative index (white points) for the period 1932-1957 when the fishery was being managed by the IPHC; 11, 12, 52 represent years 1911, 1912, 1952 etc.; line fitted by eye (Corkett, 2014, his column 5, Appendix A). **(b)** A maximum economic yield (MEY) of 30 million lbs as a plot of yield (Y_E 10^6 lb; Corkett, 2014, his column 6, Appendix A) against the gear fished (f, 10^3 skates; Corkett, 2014, his column 4, Appendix A) formed by a downward causation in which Figure 2(a) is viewed from a distance as Figure 2(b).

that explain what cannot be achieved and should not therefore be attempted.

An example would be

> You cannot obtain a long term sustainable fishery (goal) while at the same time providing unlimited jobs for fishermen (social objective) (Corkett, 2011).

If we take sustainability as a universal goal then we can write the **Universal Law of Sustainability** in the form of a 'there-is-not' rule involving the corroborative index:

> You cannot obtain a long term sustainable fishery (goal) if the corroborative index is continuously declining.

As with any natural law these examples are applied universally. That is: 'there-is-not' rules apply to both finfish and shellfish. Under the **Precautionary Approach** to sustainability the participants would make every effort to problem-solve (P_1 in scheme (2)) by creating tentative policies (*TP* in scheme (2)) that avoid a declining index (as occurred in the period 1952 to 1957 in Figure 2(a)).

Method: demarcating between two views of science

The problem of demarcation (demarcating an empirical science from a pseudoscience especially metaphysics) [iii] was solved by Karl Popper some 80 years ago. His solution is based on the absence (and presence) of **existential import** (see Corkett, 2012, his section 3) and can be presented as a simple negated symmetry:

science = *'there-is-not' statement*

non-science = *'there-is' statement*

Under Popper's non-instructional theory of method [iv] a criterion of falsifiability or testability or refutability is used to distinguish or demarcate between:

(i) a selective view of science involving selection by error elimination (EE, scheme (2)) a view associated with the stronger 'all' notion [v] (*all swans are white*; *black swans do not exist*; *'there-is-not' statement*) and

(ii) an instructive view of science - or if you like a pseudoscience – a view associated with the weaker 'some' notion [vi] (*some swans are white; at least one white swan exists; 'there-is' statement*).

Metaphysical assertions

In my view a traditional fisheries management or fish stock assessment (DFO, 2015) is a logically weak pseudoscience that has more to do with magic and the magician than a testable natural law such as a law of physics.[vii] The metaphysical nature of a traditional fisheries management can be demonstrated by providing examples of metaphysical assertions that take the logical form of a *'there-is' statement* (see method, version (ii)) assertions that cannot be falsified. I will give four such examples.

1. There is an advanced statistical procedure whose exact application to fisheries data is able to turn it into advice (DFO, 2015). If a repetition of this procedure fails to achieve the same result that would be no falsification, for perhaps an unnoticed yet essential aspect of the correct procedure had been omitted.

2. There are 'primitive magic spells' (Corkett. 1997, p. 166) that are able to turn pumpkins into golden carriages. If repeated use of these spells failed to achieve the same result that would be no falsification, for perhaps an unnoticed yet essential aspect of the casting of spells had been omitted. While magic spells cannot be falsified, they are in principle verifiable: [viii] it is logically possible to find a magic spell that when applied to a pumpkin turns it into a golden carriage.

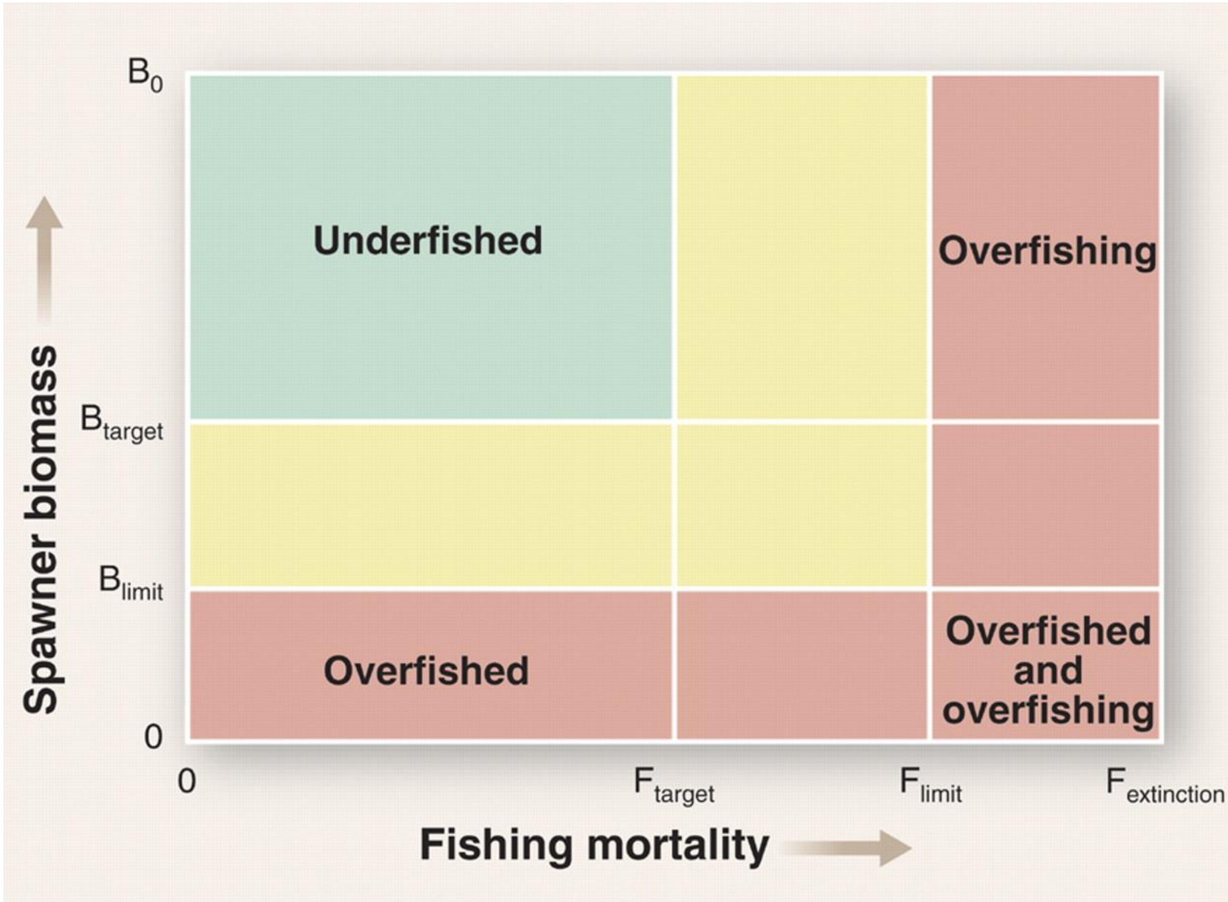

Figure 3. An instructive view of norms (values) in the form of 'reference points', a view that is essentially Lamarckian. That is: instruction by the environment is stressed (method, view (ii)) rather than selection by the environment (method, view (i)) as in managing a fishery by error elimination (EE in scheme (2))(Diagram from Beddington *et al.*, 2007, their Figure 1).

3. There is an interpretation of a 47 year database that gives an estimate for the maximum economic yield (MEY) of 30 million pounds for a stock of Pacific halibut (Figure 2(b)). If further collection of data changed this estimate and gave, say, an

MEY of 45 million pounds this would be no falsification, for it remains logically possible (or we can always hope) that in the long run deviations in the opposite direction will set matters right again by returning the MEY to 30 million pounds.

4. There is a target reference point (B_{MSY}) (Beddington *et al*., 2007) that when applied to observation or data is able to identify a maximum sustainable yield (MSY) (Figure 3). If further use of this reference point failed to achieve the same result that would be no falsification, for perhaps an unnoticed yet essential aspect of the application of reference points had been omitted. While target reference points cannot be falsified, they are in principle verifiable: it is logically possible to find a B_{MSY} that is able to identify a MSY.

Discussion

Downward causation

We may speak of downward causation whenever a logically strong structure (represented by Figure 2(a) and Table 1(A)) operates causally upon its logically weaker sub-structure (represented by Figure 2(b) and Table 1(B)). Under the logically stronger selective view of science (method, view (i)) natural laws such as the laws of physics and the economic law of diminishing returns (see Corkett, 2002, his Figure 1(a); parameter β in equation 1) are distinguished from values in the form of norms such as the goal of sustainability. From a logical point of view this distinction is upheld by a critical dualistic scheme (Table 1A) in which norms form the conclusion and 'there-is-not' rules such as the Universal Law of Sustainability guide management by error elimination (EE) by explaining what cannot be achieved and should not therefore be attempted. Consider the task of managing a fishery; the norms

Table 1 (after Corkett, 2014, his Table 1)

	A Critical dualism [a]	**B Instructive monism** [b]
Universal premise	'there-is-not' rule	
Singular premise	$P_1 \rightarrow TP \rightarrow EE \rightarrow P_2$	observations or data
Conclusion	norms such as goals and objectives	MSYs and MEYs

a Critical dualism as a dual premised deductive scheme (see note v) in which a distinction is made between (i) natural laws as 'there-is-not' rules (universal premise) and (ii) norms that are chosen by the participants (conclusion).

b Instructive monism as a single premised inductive scheme (see note vi) in which no distinction is made between normative laws or norms and natural laws

chosen by the proponents form the conclusion: what remains to be found by the fisheries manager as 'social engineer' (Corkett, 1997) are the regulatory policies (*TP* in scheme (2)) that have to be realised by error elimination (EE) in such a way that the conclusion is deductively implied by the dual premises.

Under a downward causation the dualistic and deductive scheme of Table 1A is viewed from a distance as an instructive monism (Table 1B) in which selection by the environment in the form of error elimination (EE) is replaced by instruction by the environment in the form of 'facts' or data (*a priori* scheme (1)) . That is: a traditional fisheries management or fish stock assessment treats norms (values) as 'data-based' scientifically achievable predictions (MSYs and MEYs in Table 1B), a downward causation that results in a monism of 'scientific' ethics (Corkett, 2005).

Darwinism as a metaphysical research program

Under the method of 'selection by critical elimination' (method, view (i)), natural laws such as the laws of physics remain conjectures, even if they have been well corroborated by vigorous testing (see note ii). However Darwin's theory of natural selection is difficult to test and this has led some to claim it is a tautology. A tautology such as 'All tables are tables' or 'It will or will not rain here tomorrow' is not of course testable or refutable; nor does it have any explanatory power. Since testability and refutability are criteria used to distinguish a testable science from an untestable metaphysics Darwin's theory of natural selection – in its widest sense a selection by critical elimination – has been characterised by Popper (2002b) as a *metaphysical research program* rather than a testable scientific theory such as a law of physics. Later Popper (1987) recanted this position, as he explains:

> In its most daring and sweeping form, the theory of natural selection would assert that *all* organisms, and especially *all* those highly complex organs whose existence might be interpreted as evidence of design and, in addition, *all* forms of animal behaviour, have evolved as the result of natural selection; that is, as the result of chance-like inheritable variations, of which the useless ones are weeded out, so that only the useful ones remain. If formulated in this sweeping way, the theory is not only refutable, but actually refuted. For *not all* organs serve a *useful* purpose; as Darwin himself points out, there are organs like the tail of the peacock, and behavioural programs like the peacock's display of his tail, which cannot be explained by their *utility*, and therefore not by natural selection. Darwin explained them by the preference of

> the other sex, that is, by sexual selection. Of course one can get round this refutation by some verbal maneuver; one can get round any refutation of any theory.

Darwin's contribution to the theory of evolution takes the form of his theory of natural selection. It is of considerable interest to illustrate how the method of 'selection by critical elimination' can be interpreted as a generalized version of Darwin's theory. While the theory of natural selection is *selective*, the theistic theory of Paley is *instructive*. Paley argued that just as a watch is designed by a watchmaker so a higher organism with its complex organs such as eyes must have been instructed (designed) by an intelligent Creator. Thus Darwin's theory of natural selection can be regarded as a theory that explains by selection something that looks like instruction (Popper, 1987). In similar vein the method of selection by error elimination (EE in scheme (2)) can be regarded as a method that explains by selection (Figure 2(a) and Table 1A) something that looks like instruction (Figure 2(b) and Table 1B).

Upward causation as a metaphysical research program

The opposite of downward causation is upward causation (Popper, 1987). In 1993 I started a new research program in which Karl Popper's selective (non-instructive) theory of method is being applied to the management of a commercial fishery. Much of this research has been published as working papers obtainable from DalSpace of Dalhousie University (see Appendix A1). Whereas in my original *empirical research program* on marine copepods (1963 to 1992) I learnt 'more and more about less and less', in my new *metaphysical research program* on the management of a commercial fishery (1993 to present) I am learning 'less and less about more and more.' That is: in my second research program upward causation has been used to apply Karl Popper's selective theory of method to the management of a commercial fishery.

Consider the following paired terms:

Lamarckian **instruction** vs Darwinian **selection** induction vs corroboration [ix]

boldness vs **falsifiability** [x]

false vs **falsification** [xi]

There is an important asymmetry in this pairing. Terms on the left are associated with a Lamarckian substructure; terms on the right are associated with a Darwinian structure. That is: theories of method that stress selection by refutation or 'falsification' (rather than **verification** [see note viii]) are essentially Darwinian. By contrast theories of method that stress instruction or 'verification' (rather than falsification) are essentially Lamarckian: they stress *instruction* by the environment rather than *selection* by the environment.

I suggest a lot can be learnt by comparing my research program on the application of Popper's theory of method to fisheries management, with the research program of the ecologist Tony Underwood (see Underwood, 1997). While both our research programs share an interest and debt to Karl Popper, Underwood's program of research has moved causally downward by, for example viewing the logical technical term 'falsification' from a distance as the word 'false.' It should come as no surprise that command of a rich structural language is required if a theory of method that stresses selection by refutation or 'falsification' (rather than verification) is to be applied to a discipline such as ecology or fisheries management. Examples of attempts to understand and apply Popper's theory of method with a language too weak for the task include my early work and a downward causation involving the key phrase 'Falsification of hypotheses' (Hilborn and Mangel, 1997, their Table 2.1. Four philosophies of science).

Conclusion

1. In my *empirical research program* on the biology of marine copepods (1963 to 1992) I learnt 'more and more about less and less' whereas in my *metaphysical research program* on the application of the method of 'selection by critical

elimination' to a fisheries management (1993 to present) I am learning 'less and less about more and more.'

2. A traditional fisheries management or fish stock assessment takes a Lamarckian-like instructive view of science that involves downward causation. Its invalid inductive arguments have no problem solving capacity and are responsible for the collapse of some of the World's Gadoid fisheries including Newfoundland's 'northern cod' in the early 1990s.

3. If we are to solve our management problems (P_1, P_2 in scheme (2)), a downward causation involving an *instructive monism* will have to be replaced with an upward causation involving a *critical dualism* in which (i) norms are chosen by the participants and not predicted as MSYs and MEYs and (ii) a fishery is managed by the method of selection by error elimination (EE) guided by 'there-is-not' rules such as the Universal law of Sustainability.

4. An example of selection by error elimination (EE) for an input [xii] managed fishery would be the use of lobster landings (LL) as a negative feedback index by the 120+ year old inshore Maritime lobster fishery.

5. An example of selection by error elimination (EE) for an output [xiii] managed fishery would be the use of a catch-per-unit (CPU) as a negative feedback index by the early management (1932-1957) of the Pacific halibut fishery.

6. The absurdity that we should seek Lamarckian-like instruction from the environment in the form of 'facts' or data (*a priori* scheme (1)) instead of subjecting bold tentative policies (*TP* in scheme (2)) to Darwinian-like selection by error elimination (EE in scheme (2)), results in a monism of 'scientific' ethics. That is: an ethics in which norms (values) are not chosen by the participants but are viewed as scientifically achievable predictions.

7. The ecologist Tony Underwood has also developed a popperian program of research, but here the logical technical term' falsification' has been viewed from a distance as the word 'false.' This has had disastrous consequences. The discipline of ecology has been turned into a pseudoscience, a non-falsifiable science incapable of guiding the management of a commercial fishery

Recommendation: The formation of databases (such as the RAM Legacy Database) involving *instruction* from the environment, should be replaced with the creation of corroborative indices (such as a lobster landings (LL) index) involving *selection* from the environment.

Acknowledgements

This work is dedicated to the memory of Dr Kraft von Maltzhan, Professor Emeritus of Biology at Dalhousie University.

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Appendix A1. Christopher Corkett: research program (1993 to present).

List of working papers available from DalSpace: an institutional depository of Dalhousie University

Corkett, C. J. 2016. Present working paper.

Corkett, C. J. 2015. What is a fish stock assessment? Is it a sound method? Can it be used to manage a commercial fishery? DalSpace. http://hdl.handle.net/10222/62094

Corkett, C. J. 2014. The sound management of a fishery as a social engineering: applying Karl Popper's demarcation criterion to an Area 2 stock of Pacific halibut. DalSpace. http://hdl.handle.net/10222/55954

Corkett, C. J. 2014. Critical thinking through the eyes of Richard Paul and Karl Popper. This 1993 workshop marks the beginning of my research program on the application of Karl Popper's non-inductive/instructive theory of method to the management of the World's commercial fisheries. DalSpace. http://hdl.handle.net/10222/54567

Corkett, C. J. 2013. Distinguishing input controls from output controls in Atlantic Canada's fisheries: explaining the decline and collapse of Newfoundland's Atlantic cod stocks. DalSpace. http://hdl.handle.net/10222/21402.

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Corkett, C. J. 2008. Scientific parameterization and its validation: comparing the universal models of fisheries economics with the invalid modelling of stock assessment. DalSpace. http://hdl.handle/10222/12426

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Corkett, C. J. 2006. Why Iceland has a cod fishery and Newfoundland does not. DalSpace. http://handle.net/10222/12424

Corkett, C. J. 2006. Why an ecosystem approach is the wrong paradigm for the next stage of fisheries management. DalSpace. http://handle.net/10222/12426

End Notes

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[i] *The Logic of Scientific Discovery* (*L. of Sc. D.*) was first published in 1934 in German. The first English edition was published in 1959. The *L. of Sc. D.* was first published in Routledge Classics in 2002, given here as Popper (2002a).

[ii] Following Corkett (2012, his section 6) we can illustrate the corroboration of a natural theory (such as Einstein's theory of gravitation) by a crucial testing involving two universal laws. Since a **universal categorical proposition** or universal law has no existential import (see Corkett, 2012, his section 3) the universal laws *all swans are black* and *all swans are white* do not contradict each other; taken together they merely imply that there are no swans. By contrast Einstein's and Newton's theories of gravitation possess testability since they lead to incompatible results for strong gravitational fields and fast moving bodies. In order for universal laws to possess a similar testability an additional singular statement is required such as 'at least one swan exists.'

If *all swans are white* entails 'at least one swan exists' then it asserts the existence of a white swan and excludes the existence of black, red and green swans. The failure to realise a falsification by finding a black swan corroborates *all swans are white*.

If *all swans are black* entails 'at least one swan exists' then it asserts the existence of a black swan and excludes the existence of white, red and green swans. The failure to realise a falsification by finding a white swan corroborates *all swans are black*.

Which of the two laws would be corroborated by a failure to realise a falsification can only be determined after conducting a thorough search for a black or white swan, always bearing in mind the unsuccessful attempt to find a red or green swan cannot constitute a crucial test since this failure would corroborate both universal laws (Popper, 2002a, p. 387, note 13). Under Karl Popper's non-instructive theory of method arguments are never carried 'positively' (given here as *a priori* scheme (1)). In this example of corroboration the nearest one gets to arguing 'positively' is as a 'failure to realise a falsification.'

[iii] Jon Schnute (1987, p. 159) has expressed the problem of demarcation in terms of resource modelling. 'Are resource modellers true scientists, or are their pronouncements more akin to those of witch doctors and readers of tea leaves?' That is: is resource modelling a 'true science' or 'metaphysics?'

[iv] In the early 1970s I held a National Environment research Council (NERC) Fellowship at the Marine Biological Association, Plymouth where I produced a paper in the ephemeral disciple of physiological ecology (Corkett, 1972). This work made use of instruction and the difficulty I experienced in handling this argument led me to take an interest in Karl Popper's non-instructive theory of method.

[v] Following Corkett (2012, his section 2) we can illustrate the logical strength of an 'all' notion by a **deductive argument** of the form:

All Senators are old (premise);
All octogenarians are Senators (premise);
Therefore, all octogenarians are old (conclusion)

This is a valid deductive argument since the premises form a complete and sufficient guarantee of the conclusion. That is: if the premises are accepted, there can be no choice but to accept the conclusion as well.

[vi] Following Corkett (2012, his section 2) we can illustrate the logical weakness of a 'some' notion by an **inductive argument** of the form:

Some Senators are old (premise);
Some octogenarians are Senators (premise);
Therefore, some octogenarians are old (conclusion)

In contrast to a deductive argument an inductive argument simply provides some grounds for the conclusion. That is: if the premises are accepted, there is still a choice involved in accepting the conclusion as well.

The distinction between the deductive and inductive argument is one of the most fundamental and important ideas in logic Since the premises of a deductive argument must provide a complete guarantee of the conclusion, the adequacy of an argument is a 'yes-or-no' matter: either the premises are sufficient to establish the conclusion and the argument is said to be **valid**; or they are not, and the argument is **invalid** (Rescher, 1964, p. 63).

[vii] Natural laws such as the laws of physics can be compared to '*there-is-not' statements*. For example the law of the conservation of energy can be expressed as 'There is no perpetual motion machine.' It is precisely because of this negative formulation that natural laws are falsifiable by **refutation** since if we accept the existence of the event or thing that has been excluded the law is refuted. In terms of a universal law such as *all swans are white* the law can be expressed as: 'There is no black swan.' If we accept that a black swan has been observed then we are committed to conceding the law has been falsified.

[viii] While a natural law and a universal law take the logical form of a *'there-is-not' statement* a metaphysical assertion takes the logical form of a '*there-is' statement* such as *at least one white swan exists* (see method, version (ii)). Since a white swan exists it can in principle always be found. That is: a '*there-is' statement* can always be **verified**.

[ix] Martin Gardner (2001) sates 'Popper's critics insist that 'corroboration' is a form of induction, and Popper has simply sneaked induction in through the back door by giving it a new name.' Seen from the perspective of downward causation, 'corroboration' can indeed be viewed as a form of 'induction.' But: at what cost? Changing the term 'corroboration' into the term 'induction' might seem like a sensible strategy for those who are accustomed to thinking along inductive or instructive lines; but this verbal maneuver changes a valid scientific method in which deduction forms the organon of criticism, into an invalid inductive one (see notes ii and vi).

[x] The relationship between 'boldness' and falsifiability can be demonstrated in a simple way.

> The *'there-is' statement: at least one white swan exists* has no 'boldness' or falsifiability since it cannot be falsified.
>
> The *'there-is-not' statement: a black swan does not exist* has some 'boldness' and falsifiability since it is falsified by a black swan.
>
> The universal law *all swans are white* has much 'boldness' and falsifiability since it is not only falsified by black swans but by red and green swans as well.

[xi] The consequence of a universal law such as *all swans are white* is a *'there-is-not' statement* such as *black swans do not exist* or *there are no black swans*. I used this deductive relationship of consequence to illustrate a falsifying inference or falsification involving the contradictoriness or falsifiability between two statements both of which cannot be true:

(i) *There are no black swans*
(ii) *Here is a black swan*

If we take (i) as representing a bold tentative theory; (ii) as representing the empirical evidence as a test statement and if

> for the sake of argument we accept (ii) as true, then we are committed to conceding (i) is false. As with any valid inference, the acceptance of (ii) as true does not guarantee (i) is false. It only guarantees that *if* (ii) were true then (i) would be false. Of course we may have made a mistake in accepting the test proposition [test statement] as true, but in no way does this mistake detract from the validity of the inference (Corkett, 2009).

[xii] Input controls are restrictions put on the intensity of the use of gear used to catch fish (including shellfish) such as controls on the number of fishing traps deployed.

[xiii] Output controls are direct limits put on the amount or fish or shellfish coming out of a fishery such as a Total Allowable Catch (TAC).