Capital Theory and the Economics of Fisheries: Implications for Policy

Colin Clark and Gordon Munro

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Introduction

- In our presentation/paper, we hope to do the following:
  - review in brief what we think we accomplished over the past 40 years, and ask: has it been worth it for policy purposes?
  - recognize some limitations to our earlier analysis, and ask how the limitations can be addressed
  - look forward to interlinked future areas of research, which we believe to be important

- First, let us Set the Stage by asking the all important question : MSY, MEY or WHAT?

Maximum Sustained Yield: The largest catch rate that can be sustained indefinitely.

Maximum Economic Yield: The sustainable yield having the largest possible *sustainable* profits (resource rent).

FACT: In most cases the MEY stock level is higher than the MSY level.

What is the optimal management target?

Fisheries Biologist: MSY -- obviously

Fishery Economist (old school): MEY -- obviously

Fisherman: …. ?

Government: …. ?

Example:

Name	Stock	Sustainable Yield	Sustainable Profit	Recovery time*
BE	100,000 t	10,000 t/yr	0 £/yr	---
MSY	150,000 t	14,000 t/yr	1.0 million £/yr	5 yr
MEY	180,000 t	13,000 t/yr	1.2 million £/yr	7 yr

* Assuming a complete moratorium

What is the optimal strategy?

Question: What kind of Economic problem is this?

It's an INVESTMENT problem!

-- The fish stock is a NATURAL CAPITAL ASSET
-- which can provide an ECONOMIC BENEFIT over time

-- Rebuilding the stock is an INVESTMENT (PAIN)
-- which yields a BENEFIT (GAIN)

How do Economists handle investment problems?

They DISCOUNT FUTURE BENEFITS at some specified rate –

just like everyone does in real life!

Optimal Economic Yield (OEY): The sustainable yield that provides the highest possible discounted present and future profits.

FACT: In most cases the OEY stock level is lower than the MEY level.

Conclusions:

(1) MEY is not economically optimal unless the discount rate is zero.

(2) The Optimal Economic Yield (OEY) stock level may be highly sensitive to the discount rate.

(3) A fishery moratorium is not economically optimal unless human and produced capital are perfectly malleable.

These are vitally important facts about the real world of fisheries management. THEY ARE STILL WIDELY MISUNDERSTOOD BY MANY (although not all).

Capital Theory and All That

- Now that we have Set the Stage, let us turn to some details.

- First, the idea that a fishery resource should be seen as a capital asset (natural capital) goes back more than 60 years to the work of IIFET Fellow Anthony Scott.
  - fisheries management – an asset management problem - manage fisheries natural capital assets through time.

- Nonetheless, fishery economics dominated by the static models of Warming/Gordon-Schaefer for two more decades after Scott's pioneering work- still have powerful influence.
  - reason given by H. Scott Gordon (1956) – capital theoretic approach should definitely be taken, but the approach is very difficult to apply to resources as complex as fisheries. A Problem, a challenge, for economists.

More on Capital Theory

- As indicated by our "Setting the Stage", the capital theory approach, the Gordon Problem, has two parts:
  - determine the optimal stock of capital – theory of capital (where do we want to go?).
  - determine how quickly we want to approach the optimal stock, if we are not there already – theory of investment (how do we get to where we want to go?).

- Our modest claim is that we were the first to come up with a tractable solution to the two part Problem – came forth with reasonable capital investment decision rules for fisheries.
    - had mathematical tools available, not dreamt of in Gordon's day.

- We cheerfully acknowledge the immense contributions of those who followed and enhanced (or corrected) our earlier work.

Investment Decision Rules

- Our investment decision rules
  - simplest version – 1975/76

$$F'(x^*) - \frac{c'(x^*)F(x^*)}{\left(p - c(x^*)\right)} = \delta \qquad (1)$$

$$h^*(t) = \begin{cases} h_{\max}, \text{ if } x(t) > x^* \\ F(x^*), \text{ if } x(t) = x^* \\ 0, \text{ if } x(t) < x^* \end{cases} \qquad (2)$$

where x* is the optimal biomass, the target, F(x) resource net natural growth rate, c(x) unit harvesting costs, **p** price of harvested fish and δ the social rate of discount (interest), h(t) the harvest rate.

- Eq.(1) – theory of capital (LHS - the "own rate of interest" of x – yield on marginal investment in x);
  - Eq.(2) – theory of investment

Are the Complexities Really Worth It?

- The "Setting the Stage" should have answered this question of whether the complexities of a capital theoretic approach are worth it. But for those in doubt the answer is: Yes.
  - example: one of the current major policy issues is that of rebuilding of world capture fishery resources overexploited in the past – OECD; World Bank/FAO. *The Sunken Billions* calls for a doubling of these resources. OECD reinforces this call. What is being called for is surely a program of massive investment in fisheries natural capital.
  - also note that taking this approach forces us to take time into account explicitly, which, among other things, compels us to confront head on the inescapable problem of uncertainty in fisheries management.

Investment Decision Rules: Limitations

- If the capital theoretic approach is worth it, then we next have to admit to some limitations of our 1975/76 decisions rules. Begin first with Eq.(1), theory of capital equation.

$$F'(x^*) - \frac{c'(x^*)F(x^*)}{\left(p - c(x^*)\right)} = d$$

I. unduly complicated- the LHS of the equation the "own rate of interest" is, quite honestly, a bit of a mess

II. intrinsic growth rate of the resource is hidden

III. hazy about our definition of the social rate of discount

Undue Complications

- The underlying model used by us leads to the cost of harvesting being a function of the size of the resource, x. This is what gives rise to the messy "own rate of interest". Suppose that the cost of harvesting is independent of the size of the resource (which is close to being true for many fisheries).Eq.(1) would then become:

$$\frac{(p-c)F'(x^*)}{(p-c)} = d \qquad (3)$$

or

$$F'(x^*) = d \qquad (3a)$$

what could be simpler?

Intrinsic Growth Rate

- The intrinsic growth rate, the maximum rate of growth of the resource, which we shall denote by **r**, is used by marine biologists to gauge whether a fishery resource is fast or slow growing.
    - e.g. bigeye scad- **r** = 0.75; orange roughy- **r** = 0.025
- The intrinsic growth rate is in Eq.(1), but is hidden – most unfortunate. It can be shown that we could re-write Eq. (1) as:

$$r\left(q(x^*)\right) = d$$

  – the "own rate of interest" of the resource is ***proportional*** to **r!**

Implications of Intrinsic Growth Rates

- To illustrate the implications of large vs. low intrinsic growth rates (**r**), consider the following example. We have two fisheries, A and B identical in all respects, except that in A, r =0.60, while in B, r =0.03.

- Now suppose that in A, the "own rate of interest" of the resource, evaluated at the MSY level, is equal to: 0.50 (50%)- terrific. The "own rate of interest" of the resource in the B fishery, evaluated at the MSY level, would prove to be: 0.025 (2.5%) -miserable.

- A low **r** does not just mean that it will take a long time for the resource to build up to a desired level. It means miserable rates of return on investments in the resource – common sense, when you think about it.
  - all of which serves to re-emphasize the vulnerability of slow growing fishery resources.
    - by the way, another implication is that, if **r** is low, the OEY is highly sensitive to the size of δ.

Social Rate of Discount

- The rate of discount used is "social", because we think of the fishery resources as being public resources.
  - for UK fishery resources, we would think of the rate of discount used by the UK Treasury for public investments as being appropriate – 3.5%

- Beyond this, we put forward the proposition that the social rate of discount, δ, is properly seen as a measure of opportunity cost.
  - this rests upon an argument made by Anthony Scott, over 60 years ago, about natural resources in general. Investments in natural resources constitute a small part of investment opportunities open to society.
  - given that in any time period society's savings are finite and scarce in relation to society's investment opportunities, devoting part of society's savings to investment in natural resources comes with an opportunity cost –some other investment opportunities will have to be forgone.

Implications of the Scott Argument

- To continue with the Scott argument and δ, we think of society managing a large portfolio of real capital assets, a small component of which consist of fishery resources.
  - how to manage this portfolio? We invoke the rule for portfolio equilibrium that assets of a common risk class must be found to be earning the same rate of return, which in our case we can think of loosely as being the social rate of discount.

- This in turn has consequences for the static model and the static MEY. We need to repeat what was put forth in "Setting the Stage". The static economic model of the fishery implies that the social rate of discount is: **δ= 0% !!**

- Unless the alternative investment opportunities open to society are offering a return of 0% (nonsense), using the static MEY as our fishery resource investment goal carries with it the promise of a misallocation of society's scarce savings.
  - as we can now surmise, the misallocation would be particularly great in the case of fishery resources with low intrinsic growth rates.

Investment Theory - Limitations

- Now go back to Eq. (2), our investment theory equation

$$h^*(t) = \begin{cases} h_{\max}, \text{ if } x(t) > x^* \\ F(x^*), \text{ if } x(t) = x^* \\ 0, \text{ if } x(t) < x^* \end{cases}$$

- The policy implications are striking. If the biomass level, x, is below the target, x*, declare a harvest moratorium, and maintain it in force, until the target is reached – if this takes 30 years that is just too bad!
- This equation has caused much difficulty, right up to the present time. It is not wrong, but its policy prescription is, in fact, valid only under very special and very restrictive conditions. We have tried to make this point, but with very limited success –we try again.

Harvest Moratoria and Economically Sensible Policy

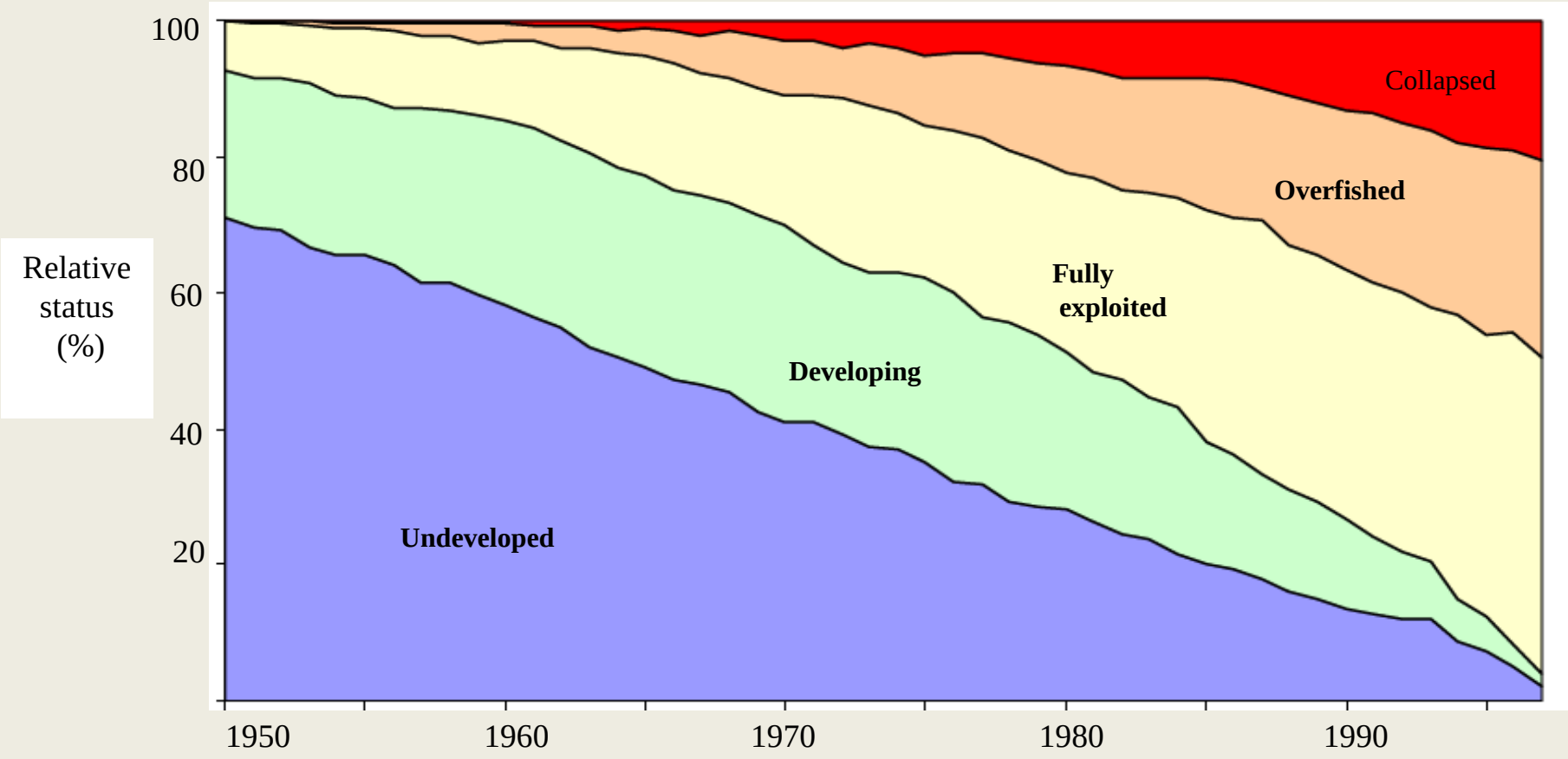
- Several conditions have to be met for a harvest moratorium to make economic sense in a fish stock rebuilding program – the most important of which is that the produced(physical) capital, e.g. fleet, and human capital used in the fishery be **perfectly** "malleable".
  - which means that such capital can be shifted into/out of the fishery easily and at negligible cost –opposite – "stranded" capital
- If this condition is not met, the economically optimal rebuilding program is a ***slow*** one (except in extreme cases) – reasons for ; harvest moratorium in this case – **bad economics**.
- Proposition: fisheries in which produced and human capital are both perfectly "malleable" are the exception, not the rule.

Possible Areas of Future Research - I

- Turn at last to our suggestions for future research. The first jumps off from our discussion of investment theory- need for ongoing research on the economics of re-building fishery resources.
  - the following slide, while admittedly dated, indicates the magnitude of the issue.
- BUT, in 2012 the OECD completed a major project on rebuilding fisheries and sponsored a substantial amount of research –so who says we need more? The OECD that is who. We quote:
  - **"---more work is needed---regarding the economic theory of rebuilding fisheries, the most important being the design of optimal harvesting rules --- taking into account the time aspect; the non-malleability of human and physical capital; and how uncertainty --- should be taken into account"** (OECD, 2012).
- Our call – respond to the OECD admonition.

Global trend in the status of marine fisheries resources based on FAO statistics

(Daniel Pauly and R. Froese, 2003)



Economics of Rebuilding Fisheries

- The research undertaking is daunting, because sweeping generalizations become suspect.
- Consider the consequences of non-malleable produced (physical) capital **alone**. The degree of non-malleability of such capital is certain to vary significantly from fishery to fishery.
- From this it follows that economics of rebuilding fisheries will have to proceed on a case, by case, by case basis.
  - OECD commissioned case studies a good start, but only a start

Non-Malleable Human Capital

- The economics of the consequences of non-malleable capital for fisheries rebuilding programs was set forth in an article several decades ago. That article, however, focussed entirely on non-malleable produced (physical) capital.
  - the implicit assumption in the article is that human capital in the fishery is perfectly malleable.
- Maybe the economics of non-malleable produced capital applies, without qualification to non-malleable human capital. But then maybe not. Human capital is, after all, not produced capital.

More on Non-Malleable Human Capital

- Unless we are missing something, we have been unable to find any significant research on the economic implications of non-malleable human capital for optimal fishery resource investment programs.
- We would urge that research be undertaken on this topic. The importance of non-malleable human capital to the rebuilding of capture fisheries to developing fishing states in particular should be obvious.

Possible Areas for Future Research II

- The second area of research that we would like to put forward is an area that one of us has been pressing for some time. This involves intra-EEZ fisheries management and the application of the theory of strategic interaction (game theory).
- The argument is that there are an increasing number of cases involving fishers –industry members- engaging in what amounts to cooperative resource management.
- What does this possibly have to do with capital theory?
  - simple: the ideal fisheries management regime is to be seen as one that does more than encourage the fishers to achieve static efficiency. It does as well cause them to regard the fishery resources as assets, in which it is their interests to invest.

Research Areas I and II -Linkages

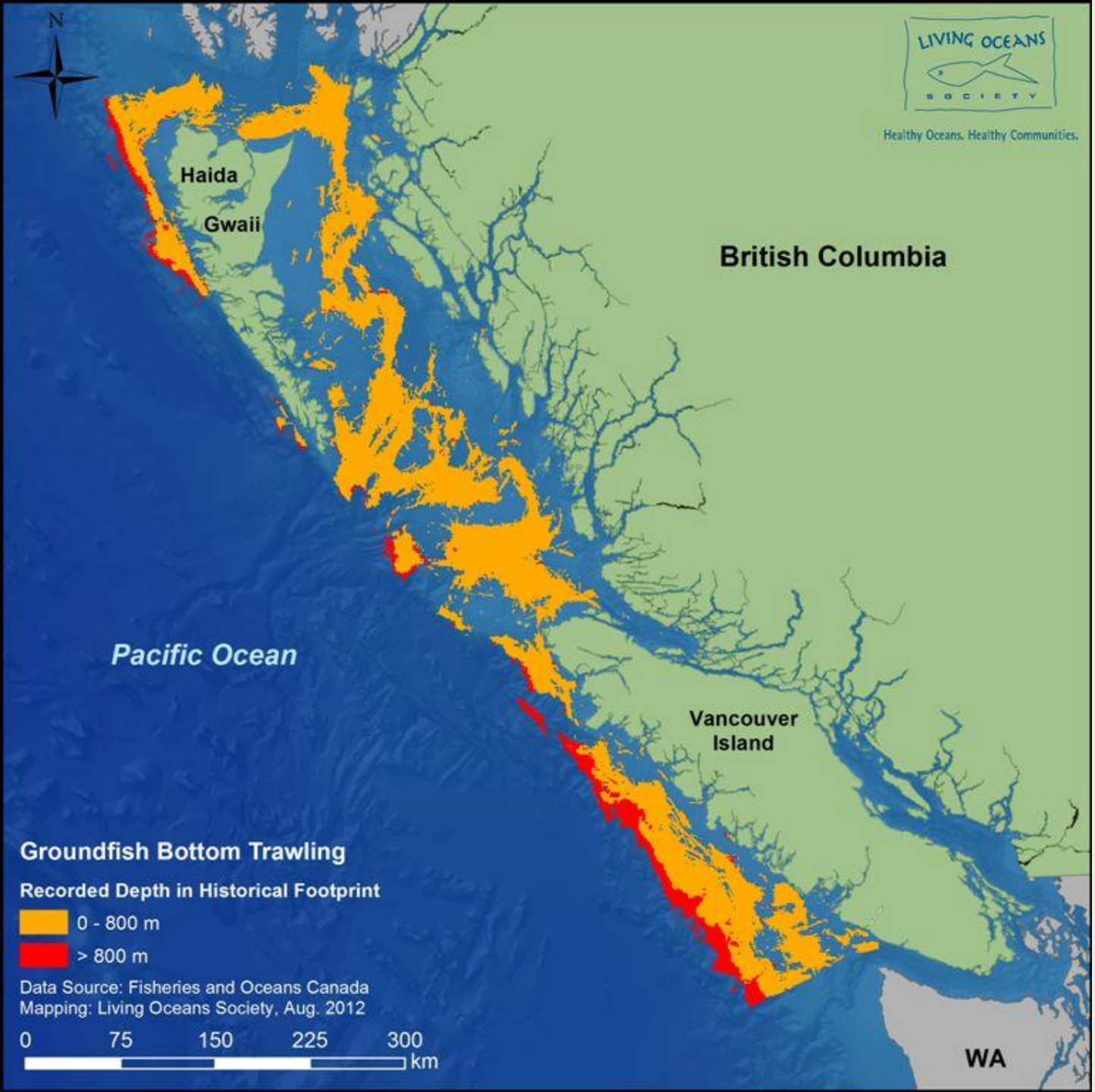
- The two areas are linked. OECD in its report on rebuilding fisheries stresses the importance of having an effective management regime in place.
  - reason straightforward: ineffective management regime could result in the yield on the resource investment being negligible, or even negative.
  - if fishers have an incentive to invest in the resources, this will strengthen the rebuilding program for obvious reasons.

Theory of Strategic Interaction (Game Theory)

- We argue that to examine this intra-EEZ cooperative development fully, we need to bring to bear, more than we have in the past, game theory. For the doubters ,we have this 2005 citation for Nobel Prize Laureates Aumann and Schelling:
  - "---why do some groups, organizations and countries succeed in promoting cooperation, while other suffer from conflict? The work of Robert Aumann and Thomas Schelling has established game theory---as the dominant approach to this age old question"
  - this "age old question" is precisely the one needing to be addressed in the context of intra-EEZ fisheries.

A Case Study

- To motivate the discussion, we put forward a case study from Canada, which has gained considerable prominence over the past year.
- The case study is the British Columbia (B.C.) groundfish trawl fishery, involving 50 species, 55 active vessels operating along the length and breadth of the B.C. coastline.
    - if British Columbia were an independent country, its coastline would be the eighth longest in the world.



Bottom area trawled between 1997-2011

~41,000 km^2

An ITQed Fishery and A Received View of ITQs

- The B.C. fishery has operated under an ITQ scheme, along with onboard observer coverage and dockside monitoring, since 1997.
- What we term as the "received view" sees ITQs enhancing efficiency, but, since they are by definition issued to individuals, sees them as having very limited scope for fostering cooperation among ITQ holders, unless the holders are few in number, or unless the holders are prepared to surrender some of their individual powers, e.g. to the board of a formal cooperative.
- The "received view" seems entirely reasonable, indeed common sense. The one problem is that the B.C. fishery in question provides a powerful counter example.

The Counter Example

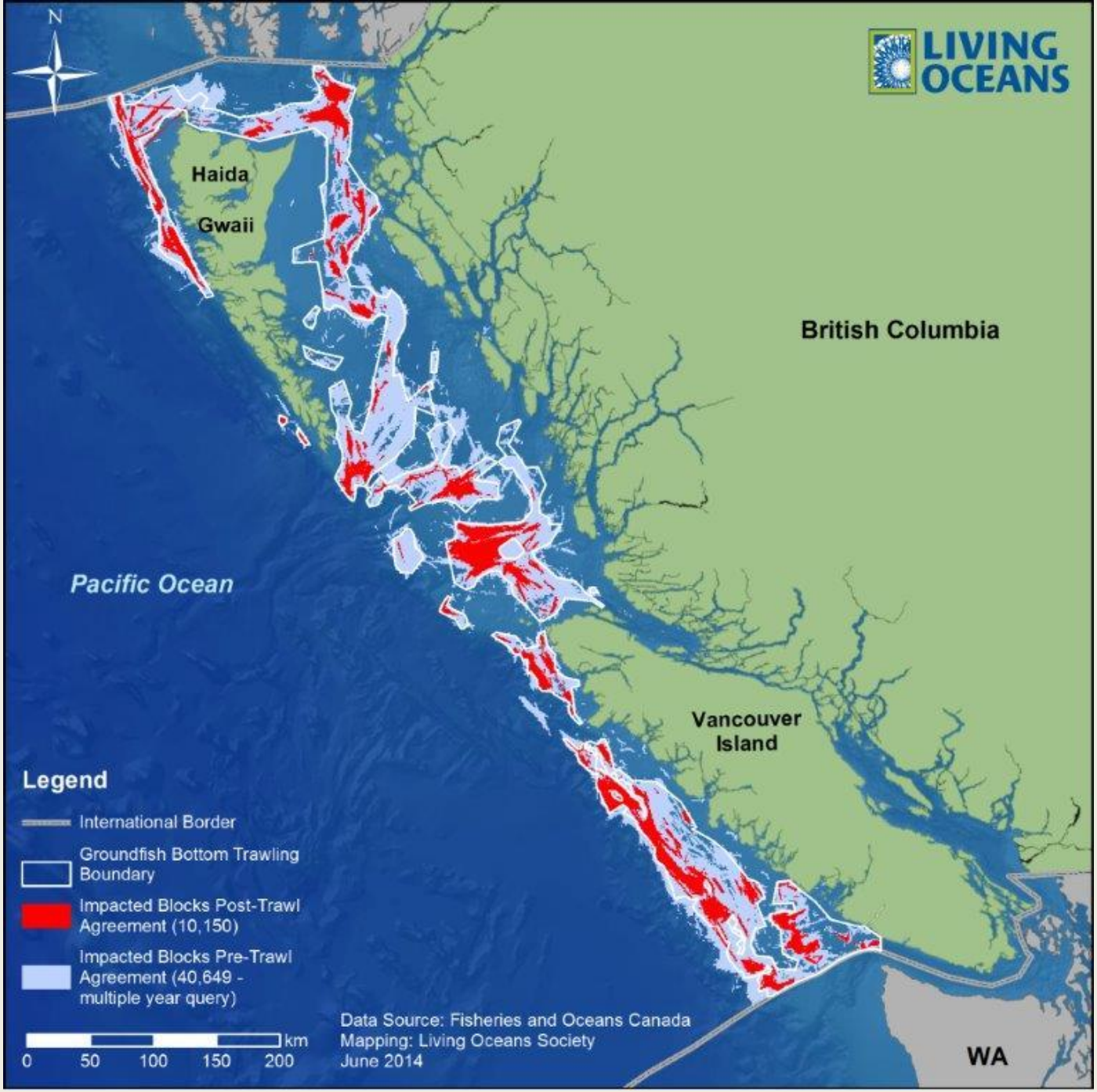
- The B.C. groundfish trawl fishery has 55 active vessels under complex ownership arrangements .It is estimated that there are not fewer than 30 independent "agents" in the fishery, well in excess of anyone's definition of "few". The industry does have an association –Canadian Groundfish Research and Conservation Society (CGRCS) – but the association has no power over individual members.
- Through industry initiative, a **world first** habitat bycatch limitation scheme was developed. This could not have happened, unless the industry was acting as a cohesive whole – constituting a stable cooperative game. In terms of the "received view" of ITQs, all of this should have been impossible.

Origins of the Agreement

- About a decade ago, the B.C. groundfish industry came under attack from environmental NGOs (ENGOs) for destroying sponge and coral through bottom trawling.
  - the attacks had teeth, because they could have resulted in the industry being shut out of the California market – of key importance.
- The resource manager – Canadian Department of Fisheries and Oceans(DFO)- lacked the legal wherewithall to address the problem. The industry was on its own.
- The industry approached a consortium of ENGOs to see if an agreement could be worked out. The response was positive.
    - DFO's approval and support were vital, but DFO's role was essentially a passive one.

The Agreement Negotiated

- The Agreement was negotiated over several years, and came into force in April, 2012.
- The negotiations involved extensive mapping, location of "hot spots", and led to a 20%+ reduction of the trawling area.
- In addition, a global annual sponge/coral quota of 4,500 kg. (**4.5 tonnes**) was agreed upon. The ITQ scheme was used to allocate the quota among the 55 vessels.
- Any vessel exceeding its very modest sponge/coral quota, and unable to buy/lease quota to cover the excess, has to cease fishing for the season.
  - sponge/coral as the ultimate "choke species".



Post agreement area trawled (red) is ~30%of allowable area (inside white line)

The Agreement in Force

- The B.C. groundfish trawl season is year round, but has an official close date of February 20th (next season starts the following day). February 20, 2013 was awaited anxiously to see if the industry could keep within the 4,500 kg. limit. The actual industry sponge/coral catch for 2012/13 – **500 kg**.
- The 4th year of the Agreement ended in February 2016. The actual industry sponge/coral catch for the 2nd, 3rd and 4th years were all below 500 kg. Fourth year catch: **280 kg**.
    - average of **5+ kg.** per vessel

Publicizing the Agreement

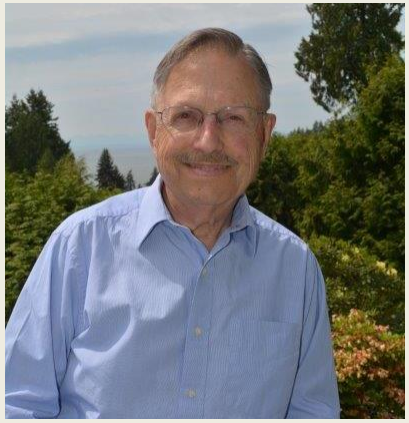
- The details of the Agreement and its progress were published in an a six authored article in *Marine Policy*, in October 2015.
- The six, shown on the following slide, are:
  - Karin Bodtker and Jon Driscoll, both of the ENGO, Living Oceans Society
  - Scott Wallace of the ENGO, the David Suzuki Foundation, and lead negotiator for the ENGOs
  - Bruce Turris, Executive Manager, Canadian Groundfish Research and Conservation Society, and lead negotiator for the industry
  - Brian Mose, President of the B.C. Deep Sea Trawlers Association, aptly referred to as "Mr. Bottom Trawler" for British Columbia
  - an academic

Karin Bodtker

Brian Mose

John Driscoll

Bruce Turris



Gordon Munro

Scott Wallace

A Conservation Action Award

- The Vancouver Aquarium, along with its associated Coastal Ocean Research Institute, are deeply concerned with aquatic conservation. Each year, they present awards for such conservation, with one of their top awards being a Conservation Action Award. The 2016 Conservation Action Award was given jointly to the six authors of the *Marine Policy* article.

- As we are all aware, to marine biologists/ecologists, bottom trawling is seen as the ***worst of the worst***. At the Vancouver Aquarium awards ceremony, the Award was accepted on behalf of the six by Scott Wallace, lead ENGO negotiator, accompanied by Brian Mose, "Mr. Bottom Trawler".
  - a decade ago, Scott Wallace and Brian Mose were bitter adversaries; today they are working together in close partnership.

De Facto Co-management

- Along with the Agreement, there have been several instances in which the industry has pushed DFO to reduce TACs in specific fisheries. In so doing, the industry has contracted scientists, at its expense, to collaborate with DFO scientists. The industry has become a resource investor.

- As well as effective cooperation within the industry, there is effective cooperation between the industry and DFO. What has emerged through a process of evolution, and most definitely not through design, is **de facto co-management**. The industry, along with the official resource manager DFO, have become co-asset managers.

Explaining the Developments

- How do we explain the cooperative developments, and how do we answer the question as to the applicability of the B.C. experience to fisheries in other parts of the world? The response is that, at this time, we cannot do so adequately. We have conjectures, but nothing concrete
- Go back to the Nobel citation. It is obvious that we have to bring the theory of strategic interaction - game theory - to bear.
  - there is a wealth of game theory tools applied in the analysis of international fisheries. Will these tools be adequate for the task at hand, or will new ones have to be developed? This is to be seen.

A Few Conclusions

- We began by asking whether the capital theory approach for fisheries economics has policy relevance. We hope now that the answer is self evident, because the approach really means taking time into account explicitly. How can rational policy makers possibly do otherwise?
- We offered up two areas for ongoing research, which we believe to be important: (i) responding to the OECD admonition to do more on the economics of rebuilding fisheries–with particular emphasis on the consequences of non-malleable human capital; (ii) cooperative management of intra-EEZ fisheries - cooperation among fishers, and between fishers and resource managers.
- The opportunities for future research in fisheries economics we see as immense, and predict with confidence that the future holds promise of full employment for fisheries economists for decades to come.

Thank you for your attention